CONFERENCE PROGRAM

THE UNIFIED INTERNATIONAL TECHNICAL CONFERENCE ON REFRACTORIES

17th Biennial Worldwide Congress on Refractories

March 15-18, 2022
Hilton Chicago
Chicago, Ill., USA

17TH BIENNIAL WORLDWIDE CONGRESS ON REFRACTORIES
UNITECR 2022
March 15-18, 2022 | Chicago, Ill. USA

CELEBRATING THE INTERNATIONAL REFRACTORIES COMMUNITY

Organized by The North American Members of the UNITECR International Executive Board
Under the auspices of the UNITECR International Executive Board | Hosted by The American Ceramic Society

HOSTED BY:

The American Ceramic Society
www.ceramics.org

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THE REFRACTORIES INSTITUTE (TRI), is a manufacturers trade association established in 1951 to promote the interests of refractories industry. The value of membership in TRI includes:

- Assistance with response to government regulatory initiatives.
- Targeted information in the form of educational seminars, strategic business planning documents and industry best practices.
- Alerts on emerging regulatory issues.
- Ability to provide input on benchmark one's practices and performance against the industry.
- The opportunity to network, exchange technical information, and collaborate with leaders and decision makers in the refractory industry.

TRI®

THE REFRACTORIES INSTITUTE

TRI contact information is:

Craig Addington | caddington@thomasamc.com | www.refractoriesinstitute.org | (P): 216-241-7333

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THE UNIFIED INTERNATIONAL TECHNICAL CONFERENCE ON REFRACTORIES

17th Biennial Worldwide Congress on Refractories

March 15–18, 2022
UNITECR2022.org
Hilton Chicago, Chicago, Ill., USA

UNITECR ORGANIZATION

UNITECR 2022 Officers

Tom Vert, President
James Hemrick, Technical Program Chair
North American IEB, Treasurer
Matt Lambert, **Josh Pelletier**, **Nancy Bunt**, Social Program Chairs

North American IEB

Duane Debastiani, Vesuvius
Jose Martin, Allied Mineral Products, LLC
James Hemrick, Oak Ridge National Laboratory
Ashley Hampton, Allied Mineral Products, LLC

Founding Members

– The American Ceramic Society (ACerS)
– The German Refractories Association (GRA)
– Association Latinoamericana de Fabricantes de Refractarios (ALAFAR)
– The Technical Association of Refractories, Japan (TARJ)

Principal Members

– Chinese Ceramic Society (CCS)
– Indian Refractory Makers Association (IRMA)
– Fédération Européenne des Fabricants de Produits Réfractaires (PRE)

Secretariat

The American Ceramic Society, 550 Polaris Parkway,
Suite 510, Westerville, OH 43082 U.S.A.
unitecr@ceramics.org | Phone: +1-614-890-4700

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WELCOME FROM UNITECR '22 PRESIDENT

On behalf of the UNITECR 2022 organizers, welcome and we are pleased that you are attending this conference in Chicago, USA, despite a six month delay from the original date in 2021.

I would like to personally thank Duane, Jose, James, Ashley, Andrea, Matt, Josh, Nancy, Dana, Eileen, Marilyn, Greg and the entire ACerS and Unitecr teams for persevering during this incredibly fluid, and ever changing period of time, and still organizing a great conference for us to attend and enjoy!

The past 2 ½ years since our last conference in Yokohama, Japan has been one of the most challenging in the past century as a worldwide pandemic struck and has affected every town, city, country and continent around the world!

However, the properties of refractories are embedded in those who are involved in them…resilience and strength under extreme stresses and strains. The industry rose to the challenge and people around the world have come to know what we already know in our hearts and minds…refractories are truly essential!

We are the unsung, unrecognized, "behind the scenes" industry that ensures that even during a global pandemic, worldwide manufacturing of steel, cement, aluminum, petrochemicals, lime, copper, etc., continued to produce due to our products and technology.

I am so proud at a moment like this to be a part of a great industry of humble people who give 110% to make the world a safer and better place by our research, technology, manufacturing and skills.

While the technical exchange of information at UNITECR is the highlight, focus, and purpose of the meeting, it has always been the social interaction and the exchange of stories and experiences that cements the bonds and relationships and allows progress to go forward.

The refractory industry and its end users are becoming key resources in the climate change discussion as new technologies and efficiencies are required, and each step demands new and improved refractory technology. We, as always, will be part of the solution to local and global issues and our sharing of testing methods, measurement techniques, and application technologies will be key to these desired improvements.

To all of you in the worldwide refractories community, I encourage you to participate fully in UNITECR 2022. This is truly the premier congress of refractory manufacturers, users, technologists, and scientists from around the globe, exchanging information in the field of refractories on which the industry of our world depends.

I look forward to seeing you this week.

Tom Vert, President UNITECR 2022
Strategic Refractory Consulting Inc.,
Hamilton, ON, Canada

Technical Program Chair

James Hemrick, Oak Ridge National Laboratory

Program Co-organizers

Steven Ashlock, Virginia Kyanite
Rakesh Dhaka, U.S. Steel
Scot Graddick, Imerys
Ashley Hampton, Allied Mineral Products, LLC
Bill Headrick, RHI Magnesita
Dawn Hill, Exertech LLC
Matt Lambert, Allied Mineral Products, LLC
Manoj Mahapatra, University of Alabama, Birmingham
Angela Rodrigues-Schroer, Wahl Refractories
Kelley Wilkerson, Missouri S&T

WELCOME FROM UNITECR22 CHAIRS

The theme of UNITECR 2022 is "Refractories as an Essential Global Industry". This was chosen to highlight that the refractory industry plays a vital role in the world's manufacturing sector. Refractories are a critical component for the iron, steel, aluminum, glass, cement, power and many other industries. The UNITECR Congress plays a very important role in the refractory industry by providing a broad technology forum to discuss and present scientific advancements, new processes and trends in our field.

Despite the ongoing global challenges associated with the COVID pandemic, 142 proceeding submissions have been submitted and approved for the 17th biennial worldwide refractories congress recognized as the Unified International Technical Conference on Refractories (UNITECR), held March 15-18, 2022 in Chicago, Illinois USA. The Executive Board and organizing committee of UNITECR is comprised of Duane DeBastiani, Jose Martin, James Hemrick and Ashley Hampton. The UNITECR Officers are Tom Vert (President), James Hemrick (Technical Chair) and the Social Program Chairs are Nancy Bunt, Matthew Lambert and Josh Pelletier. We would like to thank the entire ACerS team for the organization and continued support to deliver the premier worldwide congress on refractory technology.

For UNITECR22, the authors of submitted papers were offered the opportunity for their manuscripts to be peer reviewed and published in IJCES (International Journal of Ceramic Engineering and Science). The IJCES is an interdisciplinary digital journal that is indexed on the Directory of Open Access Journals. Fifteen author submissions were peer reviewed and will be published in IJCES. Also, UNITECR22 continues the history of promoting education through the Refractory Education symposium. The UNITECR organizing committee would also like to thank the RCD St. Louis Section (Refractory Ceramics Division of ACERS) for sponsoring the Refractory and Young Professionals Symposium. Refractory education and the attraction of students into our field are critical to the growth and future of refractory science.

The organizing committee want to thank the symposia organizers listed below, the authors for their contributions, the manuscript reviewers and the publication staff at ACerS.

Advances in Installation Techniques, Manufacturing, & Equipment – **Bill Headrick**, RHI Magnesita, USA

Advances in Monolithic Technology – **Scot Graddick**, Imerys, USA; **Bill Headrick**, RHI Magnesita, USA

Iron & Steel Making Refractories – **Rakesh Dhaka**, U.S. Steel, USA; **Scot Graddick**, Imerys, USA; **Ashley Hampton**, Allied Mineral Products, LLC, USA; **Angela Rodrigues-Schroer**, Wahl Refractories, USA; **Manoj Mahapatra**, University of Alabama, USA; **Matt Lambert,** Allied Mineral Products, LLC, USA

Modeling and Simulation of Refractories – **Bill Headrick**, RHI Magnesita, USA; **Rakesh Dhaka**,U.S. Steel, USA

New Developments in Refractory Formulation – **Ashley Hampton**, Allied Mineral Products, LLC, USA; **Angela Rodrigues-Schroer**, Wahl Refractories, USA

Nonoxide Refractory Systems – **Matt Lambert**, Allied Mineral Products, LLC, USA

Raw Materials – **Scot Graddick**, Imerys, USA; **Dawn Hill**, Xertech Specialties LLC, USA; **Steve Ashlock**, Kyanite Mining, USA

Refractories for Aluminum – **Ashley Hampton**, Allied Mineral Products, LLC, USA

Refractories for Cement & Lime – **Kelley Wilkerson**, Missouri S&T, USA

Refractories for Glass – **Angela Rodrigues-Schroer**, Wahl Refractories, USA

Refractories for Other Applications – **Dawn Hill**, Xertech Specialties LLC, USA; **Steve Ashlock**, Kyanite Mining, USA

Refractory Characterization and Testing – **Dawn Hill**, Xertech Specialties LLC, USA; **Rakesh Dhaka**, U.S. Steel, USA; **Kelley Wilkerson**, Missouri S&T, USA

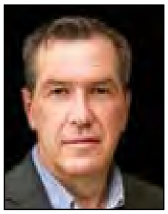
Refractory Education – **Kelley Wilkerson**, Missouri S&T, USA

Refractory Technology and Techniques for Energy Savings – **Steve Ashlock**, Kyanite Mining, USA; **Manoj Mahapatra**, University of Alabama, USA

Safety, Environmental Issues & Recycling – **Matt Lambert**, Allied Mineral Products, LLC, USA

Use of Artificial Intelligence, Machine Learning, and Big Data in Refractory Technology – **Manoj Mahapatra**, University of Alabama, USA

The organizing committee would also like to thank the Exhibitors and Sponsors to UNITECR22. It is hoped that this congress in Chicago will continue the tradition of promoting refractory science, technical exchange and the continued establishment of friendships within the international global refractory community.


DeBastiani

Duane DeBastiani

Chairman, North American UNITECR Executive Committee


Hemrick

James Hemrick

UNITECR 2022 Technical Program Chair

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SCHEDULE-AT-A-GLANCE

TUESDAY, MARCH 15, 2022		
Short Course and Exhibitor registration	7:30 a.m. – 12:00 p.m.	Coat Check & Foyer; 3rd Floor
UNITECR Founding members meeting (by invitation only)	8:30 a.m. – 9:30 a.m.	Lake Michigan; Eighth floor
UNITECR Founding & Principal Members meeting (by invitation only)	9:30 a.m. – 10:30 a.m.	Lake Michigan; Fourth Floor
Conference registration	12:00 p.m. – 6:30 p.m.	Coat Check & Foyer; 3rd Floor
Speaker presentation upload - for Wednesday talks	12:00 p.m. – 6:30 p.m.	Private Dining Rm #6; 3rd Floor
Refractory Optimization in Steelmaking short course (separate registration required)	12:30 p.m. – 4:30 p.m..	Room 4K; Fourth Floor
UNITECR DLM reception (by invitation only)	5:00 p.m. – 6:00 p.m.	Joliet; 3rd Floor
Welcome event at Museum of Science and Industry, Chicago sponsored by RHI Magnesita	6:00 p.m. – 10:00 p.m.	OFFSITE: Museum of Science and Industry, Chicago
WEDNESDAY, MARCH 16, 2022		
Conference registration	7:30 a.m. – 5:00 p.m.	Coat Check & Foyer; 3rd Floor
Speaker presentation upload - for Thursday talks	7:00 a.m. – 5:00 p.m.	Private Dining Rm #6; 3rd Floor
Refractory Ceramics Division annual meeting	7:00 a.m. – 8:30 a.m.	Lake Erie; Eighth Floor
Speaker's breakfast sponsored by Christy Minerals	7:30 a.m. – 8:30 a.m.	Salon D; Lower Level
Opening session and keynote: Carol Jackson, CEO, HarbisonWalker	8:40 a.m. – 9:30 a.m.	Williford A,B,C; 3rd Floor
Exhibits	9:30 a.m. – 7:00 p.m.	Salon D; Lower Level
Technical sessions	9:30 a.m. – 5:30 p.m.	
Refreshment break sponsored by TRI	10:00 a.m. – 10:40 a.m.	3rd Floor Foyer
Theodore J. Planje Award sessions and award presentation	10:40 a.m. – 12:20 p.m. 1:40 p.m. – 3:10 p.m	Marquette; 3rd Floor
Lunch sponsored by Vesuvius	12:20 p.m. – 1:40 p.m.	Salon D; Lower Level
Poster session setup - hang posters	1:40 p.m. – 4:00 p.m.	Salon D; Lower Level
Refreshment break sponsored by TRI	3:20 p.m. – 3:40 p.m.	3rd Floor Foyer
Posters session featuring St. Louis Section/RCD networking session	5:00 p.m. – 7:00 p.m.	Salon D; Lower Level
YPN Networking event sponsored by Imerys (invitation only)	7:00 p.m. – 10:00 p.m.	OFFSITE: Grant Park Bistro
THURSDAY, MARCH 17, 2022		
Conference registration	7:00 a.m. – 5:00 p.m.	Coat Check & Foyer; 3rd Floor
Speaker presentation upload - for Friday talks	7:00 a.m. – 5:00 p.m.	Private Dining Rm #6; 3rd Floor
Speaker's breakfast sponsored by TARJ	7:00 a.m. – 8:00 a.m.	Salon D; Lower Level
Plenary Session 1: Mike O'Driscoll, IMFORMED Industrial Mineral Forums & Research Ltd.	8:00 a.m. – 9:00 a.m.	Williford A,B,C; 3rd Floor
Refreshment break sponsored by Kyanite Mining	9:00 a.m. – 9:20 a.m.	3rd Floor Foyer
Technical sessions	9:20 a.m. – 5:00 p.m.	
Exhibits	9:30 a.m. – 4:30 p.m.	Salon D; Lower Level
Lunch	12:20 p.m. – 1:40 p.m.	Salon D; Lower Level
Refreshment break sponsored by Kyanite Mining	3:20 p.m. – 3:40 p.m.	3rd Floor Foyer
Women In Refractories Reception sponsored by Allied Mineral Products and Imerys	6:00 p.m. – 7:00 p.m.	Boulevard A; 2nd floor
UNITECR '22 Banquet sponsored by TRI	7:00 p.m. – 10:00 p.m.	Grand Ballroom
FRIDAY, MARCH 18, 2022		
Speaker's breakfast	7:00 a.m. – 8:00 a.m.	Private Dining Rm #2; 3rd Floor
Conference registration	7:30 a.m. – 12:00 p.m.	Coat Check & Foyer; 3rd Floor
Plenary II: Dana Goski, Allied Mineral Products, LLC	8:00 a.m. – 9:00 a.m.	Williford A,B,C; 3rd Floor
Technical sessions	9:20 a.m. – 12:00 p.m.	
Refreshment Break	9:20 a.m. – 10:40 a.m.	3rd Floor Foyer

KEYNOTE SPEAKER

Wednesday, March 16 | 8:40 a.m.

Carol R. Jackson, Chairman and Chief Executive Officer, HarbisonWalker International, USA

Title: ***Global refractories: Trends and opportunities***

Before joining HWI in 2014, Carol served as Vice President of the bar, wire, and strip business units of Carpenter Technology Corporation. She also progressed through numerous roles at PPG Industries, where she was ultimately Director of Global Raw Materials Purchasing.

In 2021, AZZ Inc. (NYSE: AZZ), a global provider of metal coating services, welding solutions, specialty electrical equipment, and highly engineered services, appointed Carol as an independent director. In 2019, Carol was elected to the Board of Directors of Sensient Technologies Corporation (NYSE: SXT), a leading global manufacturer and marketer of colors, flavors, and fragrances. She was also elected as President of the World Refractories Association and is serving a two-year term as its first North American leader. She has received numerous professional awards, including 2021 Director of the Year in Private Company Governance by the National Association of Corporate Directors (NACD), and Outstanding CEO and Top Executive by the Pittsburgh Business Times/American City Business Journals in 2019.

A licensed attorney in Pennsylvania, she holds a Juris Doctorate from the University of Pittsburgh, and a master's degree from Carnegie Mellon University, Tepper School of Business. She earned her undergraduate degree from Duquesne University. She is an alumnus and a Board member of Junior Achievement of Western Pennsylvania and is chairman of its BizTown Capital Campaign. She's also been involved with the Leukemia & Lymphoma Society, United Way, and numerous other local organizations.

PLENARY SPEAKERS

Thursday, March 17 | 8:00 a.m.

Mike O'Driscoll, IMFORMED Industrial Mineral Forums & Research Ltd., UK

Title: ***Riding the Tiger: Refractory raw material supply outlook***

Mike O'Driscoll is an independent consultant and freelance writer with over 30 years experience in the international mining and minerals industry, specializing in industrial minerals and markets. He is co-owner and director of IMFORMED Industrial Mineral Forums & Research Ltd – providing professional networking opportunities and market research expertise for the global non-metallic minerals industry, launched in January 2015.

Mike holds a BSc in Geography & Geology, and MSc in Mining Geology from the Camborne School of Mines. He was Associate Editor and contributing author to the "industry bible", 7th edition of Industrial Minerals & Rocks, published by the Society for Mining, Metallurgy & Exploration (SME) in 2006.

Mike has extensively researched, written, and devised editorial, event, and research report concepts on all aspects of the industrial minerals mine to market supply chain. He has visited a wide range of mineral supply and end user operations worldwide, meeting senior executives from all key sectors, and has regularly organized, chaired, and presented at many industry conferences.

Mike is a member of the SME, the Society of Petroleum Engineers, the Association of Mining Analysts, and is interviewed by media and investment consultants as an expert on industrial minerals.

Friday, March 18 | 8:00 a.m.

Dana Goski, Vice President, Research and Development, Allied Mineral Products, LLC, USA

Title: ***Frontiers in refractories***

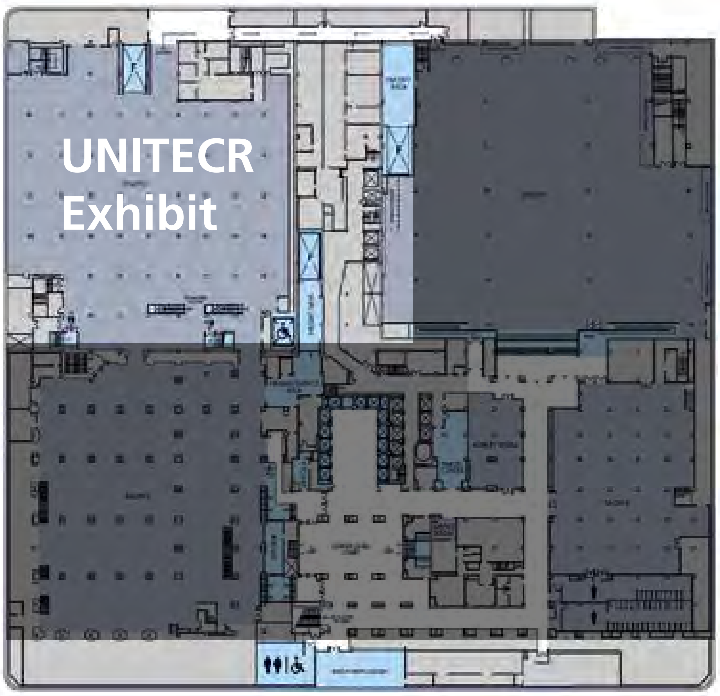
Dr. Dana Goski is currently Vice-President of Research & Development at Allied Mineral Products, LLC, where she guides global research initiatives and innovation in high temperature refractory ceramic materials. Dr. Goski is the immediate Past-President and a Fellow of the American Ceramic Society. Born, raised, and educated in Canada, she earned her undergraduate and graduate degrees in chemistry at Dalhousie University, Canada. Her PhD was completed through the Department of Mining & Metallurgical Engineering. Her profile can be found in, "Successful Women and Ceramic and Glass Scientists and Engineers, 100 Inspirational Profiles," Wiley & Sons, 2016. She is an advisor to the Edward Orton Jr. Ceramic Foundation Board of Trustees, and a member of the External Advisory Committee for the Department of Materials Science & Engineering at The Ohio State University. She is co-inventor to a number of international patents relating to engineered refractory materials and is an advocate of STEM initiatives for youth and adult learning opportunities in materials science.

SESSIONS BY DAY

SESSIONS	DATE	TIME	LOCATION
Opening Session and Keynote	**16-Mar-22**	**8:40 AM - 10:20 AM**	**Williford A, B, C**
Modeling and Simulation of Refractories I	16-Mar-22	10:40 AM - 12:20 PM	Williford A
Modeling and Simulation of Refractories II	16-Mar-22	1:40 PM - 5:40 PM	Williford A
Raw Materials I	16-Mar-22	10:40 AM - 12:20 PM	Williford B
Raw Materials II	16-Mar-22	1:40 PM - 5:00 PM	Williford B
Advances in Monolithic Technology I	16-Mar-22	10:40 AM - 12:20 PM	Williford C
Advances in Monolithic Technology II	16-Mar-22	1:40 PM - 4:20 PM	Williford C
Refractory Characterization and Testing I	16-Mar-22	10:40 AM - 12:20 PM	Joliet
Refractory Characterization and Testing II	16-Mar-22	1:40 PM - 5:00 PM	Joliet
Steel Making - Brick Development	16-Mar-22	10:40 AM - 12:20 PM	Waldorf
Steel Making - Monolithics Development	16-Mar-22	1:40 PM - 3:40 PM	Waldorf
Steel Making - Wear Mechanism & Prevention	16-Mar-22	3:40 PM - 5:40 PM	Waldorf
Theodore J. Planje Award Session I	16-Mar-22	10:40 AM - 12:20 PM	Marquette
Theodore J. Planje Award Session II	16-Mar-22	1:40 PM - 3:10 PM	Marquette
Refractory Student and Young Professionals I	16-Mar-22	3:40 PM - 5:40 PM	Marquette
Poster Session	16-Mar-22	5:00 PM - 7:00 PM	Salon D; Lower Level
Plenary I	**17-Mar-22**	**8:00 AM - 9:20 AM**	**Williford A, B, C**
Refractory Technology and Techniques for Energy Savings	17-Mar-22	9:20 AM - 12:30 PM	Williford A
Sustainability of Refractory Materials and Education	17-Mar-22	1:40 PM - 3:00 PM	Williford A
New Developments in Refractory Formulation I	17-Mar-22	9:20 AM - 12:20 PM	Williford B
New Developments in Refractory Formulation II	17-Mar-22	1:40 PM - 3:20 PM	Williford B
Refractories for Cement and Lime	17-Mar-22	9:20 AM - 11:40 AM	Williford C
Refractories for Aluminum	17-Mar-22	1:40 PM - 2:20 PM	Williford C
Advancements in Silicon Carbide-based and other Non-Oxide Refractory Materials	17-Mar-22	9:20 AM - 10:20 PM	Joliet
Advances in Installation Techniques, Manufacturing, and Equipment	17-Mar-22	11:00 AM - 12:40 PM	Joliet
Refractories for Other Applications I	17-Mar-22	1:40 PM - 3:40 PM	Joliet
Refractories for Other Applications II	17-Mar-22	3:40 PM - 4:40 PM	Joliet
Steel Making - Mag-Chrome Brick	17-Mar-22	9:20 AM - 11:00 AM	Waldorf
Steel Making - Dry-Vibe Ramming Mix	17-Mar-22	11:00 AM - 12:20 PM	Waldorf
Iron Making - Casthouse Monolithics	17-Mar-22	1:40 PM - 3:40 PM	Waldorf
Steel Making - Flow Control Shapes	17-Mar-22	3:40 PM - 5:40 PM	Waldorf
Refractory Characterization and Testing III	17-Mar-22	1:40 PM - 5:00 PM	Marquette
Refractory Student and Young Professionals II	17-Mar-22	9:20 AM - 11:50 AM	Marquette
Plenary II	**18-Mar-22**	**8:00 AM - 9:20 AM**	**Williford A, B, C**
Refractories for Glass	18-Mar-22	9:20 AM - 10:20 AM	Williford B
Use of Artificial Intelligence, Machine Learning, and Big Data in Refractory Technology	18-Mar-22	9:20 AM - 10:30 AM	Williford C
Iron Making - Shapes and Monolithics	18-Mar-22	9:20 AM - 11:00 AM	Joliet
Steel Making - Argon Plugs and Slidegate Plates	18-Mar-22	11:00 AM - 12:00 PM	Joliet
Iron Making - Taphole Clay Development	18-Mar-22	9:20 AM - 11:00 AM	Waldorf
Steel Making - Future Needs	18-Mar-22	11:00 AM - 12:00 PM	Waldorf

UNITECR MEETING SPACE FLOOR PLANS

Lower Level_Salon D – UNITECR Exhibit Hall
(exhibitor list on page 11)



2nd Floor_Grand Ballroom – UNITECR Conference Dinner

3rd Floor – UNITECR Registration and Technical Programming

SPECIAL EVENTS –

WELCOME RECEPTION

Sponsored by RHI Magnesita

Museum of Science and Industry, Chicago

Tuesday, March 15, 2022

6:00 p.m. – 10 p.m.

*Shuttles will run between the Hilton Chicago and Museum from 5:45 p.m. – 10:15 p.m. Shuttles will depart from the Hilton Chicago the main level of hotel at the 8th Street Entrance

UNITECR welcome receptions are events to be remembered. Since opening in 1933, the Museum of Science and Industry, Chicago (MSI) has been dedicated to inspiring the inventive genius in everyone with uniquely interactive experiences. Today, MSI is the largest science museum in the Western Hemisphere. UNITECR guests will get to experience the science and wonder of several exhibits including Science Storms, Genetics, Fast Forward, Out of the Vault, Extreme Ice, Earth Revealed, the Whispering Gallery, Numbers in Nature, Yesterday's Main Street, You! The Experience, Chemistry and the 727 Take Flight experience. Add in food and beverage and the companionship of your fellow UNITECR attendees and you have the makings of a truly memorable event. The reception includes food and beverage stations highlighting local cuisine. This event is included in full-conference, one-day, student, guest, and DLM registrations. All others must purchase a ticket. Thank you to RHI Magnesita for sponsoring this event.

POSTER SESSION FEATURING THE ST. LOUIS SECTION/RCD NETWORKING SESSION

Hilton Chicago; Salon D, Lower Level

Wednesday, March 16, 2022 | 5:00 p.m. – 7:00 p.m.

Featuring 17 presentations, meet with authors to discuss their research and network with your UNITECR peers over light refreshments. For our friends from ACerS' St. Louis Section and Refractory Ceramics Division, enjoy this networking opportunity with colleagues you've possibly not seen for an in-person meeting in two years!

While you're there, cast your vote for the Attendee's Choice Best Poster winner.

UNITECR YOUNG PROFESSIONAL NETWORKING RECEPTION

Sponsored by Imerys

Grant Park Bistro - 800 S Michigan Ave, Chicago, IL 60605

Wednesday, March 16, 2022

7:00 p.m. – 10:00 p.m.

*This event is within walking distance of the Hilton Chicago.

Join fellow students and young professionals for an off-site networking event. Light hors d'oeuvres and drinks will be provided. This reception is by invitation only, so stop by the UNITECR registration desk to ask about availability.

WOMEN IN REFRACTORIES RECEPTION

Sponsored by Allied Mineral Products and Imerys

Hilton Chicago; Boulevard A, 2nd Floor

Thursday, March 17, 2022 | 6:00 p.m. – 7:00 p.m.

Join women working in the industry for a short program, followed by networking. Light hors d'oeuvres and drinks will be provided. Allies are also welcome at this event.

UNITECR CONFERENCE DINNER

Sponsored by TRI

Hilton Chicago; Grand Ballroom

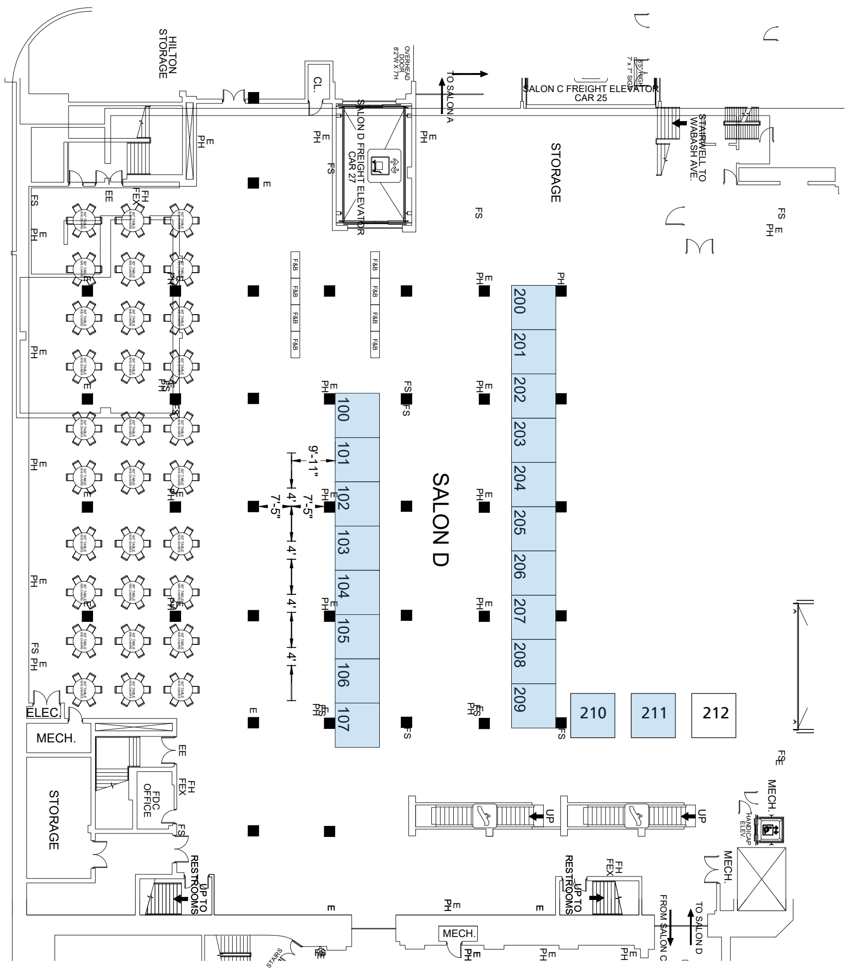
Thursday, March 17, 2022

7:00 p.m. – 10:00 p.m.

Celebrate St. Patrick's Day in Chicago with your UNITECR colleagues! Enjoy dinner and beverages with fellow UNITECR attendees. Wear your green. If you don't have any, we'll have some green for you! Sing along and even dance along to the Felix and Fingers Dueling Piano show. Celebrate awards and prizes plus see a sneak peek for the location of the next UNITECR event. This event is included in full-conference, one-day, student, guest, and DLM registrations. All others must purchase a ticket. Thank you to TRI for sponsoring this event!

EXHIBIT FLOOR PLAN

Wednesday, March 16, 2022	**9:30 a.m. – 7 p.m.**
Thursday, March 17, 2022	**9:30 a.m. – 4:30 p.m.**
Location:	**Lower Level – Salon D**



Reserved

Companies	Booth
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Washington Mills	200

EXHIBITOR COMPANY DIRECTORY

ALTEO
Booth #105
Worldwide leading producer of high-value specialty aluminas, Alteo offers a wide range of hydrated, calcined, reactive, low and very low soda aluminas for market leaders in the refractory and ceramics industries as well as LIB separators, thermal management, flame retardant industries, and much more…
Scott.Barnhouse@Alteo-Alumina.com
https://www.alteo-alumina.com

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Bass Tech International
Booth #208
BassTech International is the premier supplier of performance additives to the Refractory Industry which includes Phosphates binder/deflocculants, Sodium Silicates and Lithium chemistries. With over 30 years of experience, 4 regional offices and local stocking options, our experts can develop a customized solution for your refractory requirements.
info@basstechintl.com
https://www.basstechintl.com

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Bettersize Instruments
Booth #210
Bettersize Instruments is a world leader in the development of laser particle size and shape solutions. Our particle size and shape analyzers have been designed to be simple to use deliver fast and accurate results. The Bettersize ST is a compact and rugged particle size analyzer ideally suited for your QC requirements. While, the S3 integrates particle size & shape.
info@particle-size.com
https://www.bettersizeinstruments.com

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EIRICH
Booth #209
The EIRICH GROUP is a family-managed group of companies operating in the field of special mechanical engineering with its headquarters in Hardheim, Germany.
eirich@eirich.de | https://eirich.com

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Elkem Silicon Products
Booth #202
Elkem Silicon Products offers high quality microsilica, silicon powders and specialty products for advanced refractories and ceramic products globally. Our products are backed by a highly competent staff for customer service, technical assistance and product development.
We strive for sustainability in everything we do and Elkem's goal is net zero emissions by 2050.
refractories.materials@elkem.com
https://www.elkem.com/silicon-products/refractories/

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FIVEN
Booth #204
FIVEN is the result of a corporate carve-out of Saint-Gobain's Silicon Carbide business. Pioneer in development of SiC grains & powders not only for the technical ceramics industry, but also for refractory, metallurgical and abrasive applications.
robert.christensen@fiven.com
http://www.fiven.com

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German Refractory Association (GRA)
Booth #201
The business association "Deutschen Feuerfest-Industrie e. V." (DFFI) - German Refractory Association - represents the interests of the producing members and associated companies at national, European and international level. Host and organization of UNITECR 2023.
secretariat@unitecr2023.org
http://www.unitecr2023.org

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Grupo Curimbaba
Booth #104
All the companies in the Group work with differentiated products with high added value in the markets in which they operate: abrasive, refractory, ceramic, oil and gas, surface treatment, oil treatment, transportation sector, construction and agribusiness. This is a guideline of the Grupo Curimbaba, whose outset is the investment in technology and quality.
comercial@grupocurimbaba.com.br
https://www.grupocurimbaba.com.br

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Imerys
Booth #207
Imerys is the leading producer of some of the most trusted products in the industry including SECAR calcium aluminate binders, MULCOA aluminosilicate calcines and DAMREC andalusite. Imerys focus is on creating a sustainable future, via stewardship of resources and innovation to meet ever increasing demands and pressures of the refractory industry.
payton.wingate@imerys.com
https://imerys.com

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Laeis GmbH
Booth #100
LAEIS – Worldwide technology leader in the field of high performance hydraulic presses for all kind of applications in the refractories industry, with presses in the range of 500 to 4500 metric tons capacity. In cooperation with partner companies, LAEIS also supplies handling and automation equipment, marking systems, kilns & driers.
imfo@laeis.eu | http://www.laeis.eu

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Lancaster Products
Booth #106
Lancaster Products manufactures industrial mixers and material processing equipment for use in powder and powder to slurry applications. Lancaster Mixers excel in rapidly homogenizing, granulating, and pelletizing in a single machine with increased yields, uniform quality and improved mixing productivity. Process and material testing are available in our on-site facility.
info@lancasterproducts.com
https://www.lancasterproducts.com

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Possehl Erzkontor N.A.
Booth #107
Possehl Erzkontor is your team's first choice for all Raw Materials! Chemicals, Minerals, Ores and Metals and Plastics – we procure high-quality Raw Materials in the desired quantity and shape from all over the world. To the best possible purchasing and delivery conditions, on time and to the point. With flexible sales teams, proven suppliers and dynamic logisticians.
wsajjad@erzkontor-na.com
http://www.erzkontor.com

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Refra-Systems Kft
Booth #203
Refra-System Ltd is a Central European fused mineral manufacturer with a wide range of products to meet the needs of refractory manufacturers. Its products are mainly white corundum and fused mullite, but it also manufactures small batches of special compounds.
sales@refra-system.hu | www.refra-system.hu

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RHI Magnesita
Booth #205, 206
RHI Magnesita is the leading supplier of high-grade refractory products, systems, & solutions. Using its vertically integrated supply chain & global leadership position, RHI Magnesita intends to set the pace of innovation and sustainability in the industry and deliver the best for its customers.
William.headrickjr@rhimagnesita.com
www.rhimagnesita.com

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Riedhammer GmbH
Booth #101
Riedhammer - worldwide leading manufacturer of industrial kiln plants, offers reliable technological solutions for all thermal processes, including complete plant solutions, with installation. To produce refractories Riedhammer supplies a wide range of plants as tunnel-, shuttle- and tempering kilns for all types of fuel, for production at very low energy consumption.
markus.gerstner@riedhammer.de
https://www.riedhammer.de/

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The Refractories Institute
Booth #102
The Refractories Institute (TRI), is a manufacturers trade association established in 1951 to promote the interests of refractories industry. TRI holds two meetings each year, where industry decisions makers gather to learn, network and grow their business.
caddington@thomasamc.com
https://www.refractoriesinstitute.org

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Velco GmbH
Booth #103
VELCO GmbH is a medium-sized company based in Velbert / Germany. For 50 years we supply gunning machines for refractories. Moreover we supply solutions for automatic gunning repair of EAF, Ladles, RH-degassers. With our GUNMIX(R) nozzle system you can process dry mixes (ULC or NC grades) in dry gunite with low dust and low rebound, an alternative to shotcrete.
info@velco.de | https://www.velco.de

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Washington Mills
Booth #200
Washington Mills is one of the world's largest producers of abrasive grain and electro-fused mineral products for abrasive, refractory, ceramic, metallurgical, and a wide range of general industrial applications. We offer an exceptionally wide line of standard abrasive grain and specialty electro-fused minerals from our worldwide multi-plant locations.
tduquette@washingtonmills.com
https://www.washingtonmills.com

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Oral Presenters

Name	Date	Time	Room	Page Number
A				
Ali, M.	16-Mar	5:00PM	Williford A	6
Andreev, K.	16-Mar	2:40PM	Williford A	5
Angelkort, J.	17-Mar	10:00AM	Joliet	8
Asadi, F.	16-Mar	4:00PM	Williford A	6
Ashlock, S.	16-Mar	11:20AM	Williford B	6
B				
Baba, H.	18-Mar	11:40AM	Joliet	13
Bach, M.	17-Mar	1:40PM	Williford A	11
Borges de Melo, B.L.	17-Mar	9:20AM	Waldorf	10
Borges, O.H.	16-Mar	4:10PM	Marquette	4
Borges, O.H.	17-Mar	9:40AM	Williford B	12
Boris, R.	16-Mar	4:40PM	Williford B	7
Brochen, E.M.	17-Mar	2:20PM	Marquette	9
Brochen, E.M.	17-Mar	2:40PM	Marquette	9
Buhr, A.	17-Mar	2:20PM	Williford A	12
Bunt, N.E.	16-Mar	2:10PM	Marquette	4
C				
Cabalo, L.I.	16-Mar	12:00PM	Williford B	6
Camelli, S.H.	17-Mar	4:00PM	Marquette	10
Cameron, I.	18-Mar	9:40AM	Waldorf	14
Chandra, K.S.	17-Mar	1:40PM	Williford B	12
Chen, Y.	16-Mar	3:00PM	Waldorf	5
Chiartano, S.	17-Mar	2:40PM	Waldorf	10
Cristante, A.	16-Mar	4:40PM	Joliet	3
Cunha, T.M.	16-Mar	11:20AM	Williford A	5
D				
Das, S.	17-Mar	10:20AM	Waldorf	10
De Oliveira, T.M.	18-Mar	9:20AM	Williford B	14
Delobel, F.	18-Mar	10:20AM	Joliet	13
Doll, J.	17-Mar	2:40PM	Williford B	12
Dos Santos, M.F.	18-Mar	9:40AM	Williford C	14
dos Santos, T.	17-Mar	10:00AM	Williford A	11
Dünzen, C.	16-Mar	11:40AM	Williford B	6
Dvorak, S.	16-Mar	4:00PM	Williford C	7
E				
Engel, R.	16-Mar	11:20AM	Marquette	4
F				
Fallah-Mehrjardi, A.	17-Mar	3:40PM	Waldorf	11
Falsetti, L.Z.	16-Mar	11:40AM	Williford A	5
Falsetti, L.Z.	17-Mar	11:20AM	Marquette	9
Finhana, I.	17-Mar	10:20AM	Williford A	11
Fu, Q.	16-Mar	5:20PM	Williford A	6
Fujii, M.	16-Mar	2:20PM	Williford C	7
G				
Gajjar, P.N.	16-Mar	4:20PM	Williford A	6
Gehre, P.	16-Mar	4:40PM	Waldorf	5
Gehre, P.	17-Mar	9:40AM	Williford C	12
Gehre, P.	17-Mar	11:00AM	Joliet	8
Gehre, P.	17-Mar	11:40AM	Williford B	12
Geith, M.	17-Mar	11:20AM	Williford C	13
Ghosh, G.	16-Mar	5:00PM	Waldorf	5
Golestani-fard, F.	17-Mar	11:20PM	Williford B	12
Goski, D.G.	18-Mar	8:10AM	Williford A, B, C	13
Guo, Z.	16-Mar	2:00PM	Williford B	6
H				
Hahn, D.	16-Mar	3:40PM	Marquette	3
Haines, K.A.	17-Mar	9:20AM	Marquette	9
Halder, R.	17-Mar	1:40PM	Joliet	9
Han, J.	17-Mar	2:00PM	Williford A	11
Hazra, S.	17-Mar	10:00AM	Waldorf	10
Hemrick, J.G.	17-Mar	9:20AM	Williford A	11
Heuer, C.	17-Mar	1:40PM	Marquette	9
Hopp, V.	16-Mar	4:20PM	Joliet	3
Horn, S.	17-Mar	11:00AM	Waldorf	10

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J				
Jackson, C.	16-Mar	9:20PM	Williford A, B, C	3
Jahn, C.	17-Mar	4:20PM	Joliet	9
Jang, S.	17-Mar	12:00PM	Joliet	8
Jia, Q.	16-Mar	3:40PM	Williford C	7
K				
Kaczmarek, R.	17-Mar	3:00PM	Marquette	10
Karson, J.A.	16-Mar	1:40PM	Williford B	6
Kasper, J.	17-Mar	10:00AM	Williford B	12
Kasper, J.	17-Mar	10:20AM	Williford B	12
Kerber, F.	16-Mar	12:00PM	Waldorf	4
Kerr, J.	17-Mar	12:20PM	Joliet	8
Kieliba, I.P.	17-Mar	4:40PM	Marquette	10
Kim, J.	17-Mar	4:40PM	Waldorf	11
Kim, S.	16-Mar	2:00PM	Waldorf	4
Klischat, H.	17-Mar	10:20AM	Williford C	13
Koehler, A.	16-Mar	10:40AM	Williford A	5
Kovar, P.	17-Mar	2:40PM	Joliet	9
Kruk, A.	16-Mar	3:00PM	Joliet	3
Kuiper, S.	16-Mar	11:40AM	Williford C	7
Kushchenko, K.	17-Mar	2:00PM	Waldorf	10
L				
Li, X.	17-Mar	10:40AM	Williford B	12
Li, Z.	16-Mar	2:20PM	Williford B	6
Liu, G.	18-Mar	11:20AM	Joliet	13
Luz, A.	16-Mar	12:00PM	Williford C	7
M				
Madej, D.	16-Mar	11:20AM	Williford C	7
Maeda, T.	16-Mar	4:20PM	Williford B	6
Maeno, S.	16-Mar	1:40PM	Williford A	5
Mahapatra, M.	17-Mar	9:40AM	Waldorf	10
Mahata, T.	16-Mar	11:20AM	Waldorf	4
Maity, M.	17-Mar	2:00PM	Joliet	9
Maki, R.	16-Mar	4:00PM	Williford B	6
Mandal, S.	16-Mar	5:10PM	Marquette	4
Martynenko, V.	18-Mar	11:00AM	Joliet	13
Mathai, R.	17-Mar	11:20AM	Williford A	11
Melo, C.C.	16-Mar	3:40PM	Williford A	6
Moreira, M.H.	16-Mar	11:00AM	Williford A	5
Moreira, M.H.	16-Mar	3:40PM	Joliet	3
Moreira, M.H.	17-Mar	10:20AM	Marquette	9
Mouiya, M.	17-Mar	4:20PM	Marquette	10
N				
Nakano, J.	17-Mar	3:00PM	Joliet	9
Nayak, J.P.	17-Mar	2:00PM	Williford C	13
Neese, J.	16-Mar	11:00AM	Williford C	7
Niessen, J.	16-Mar	2:40PM	Joliet	3
O				
O'Driscoll, M.	17-Mar	8:10AM	Williford A, B, C	8
Ohno, M.	17-Mar	9:20AM	Williford C	12
Okuhara, Y.	17-Mar	2:20PM	Waldorf	10
Oliveira, R.L.	16-Mar	11:40AM	Joliet	3
Otroj, S.	16-Mar	5:20PM	Waldorf	5
P				
Pagliosa, C.	16-Mar	10:40AM	Waldorf	4
Pan, L.	17-Mar	5:20PM	Waldorf	11
Paul, J.	16-Mar	11:00AM	Joliet	3
Peng, H.	16-Mar	2:00PM	Williford C	7
Pilate, P.	16-Mar	10:40AM	Joliet	3
Poirier, J.	17-Mar	9:20AM	Williford B	12
Portilho, T.M.	17-Mar	11:00AM	Williford A	11
Pywell, N.	16-Mar	4:20PM	Waldorf	5
Q				
Qin, Y.	16-Mar	2:40PM	Waldorf	4

Presenting Author List

Oral Presenters

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R				
Ramos, V.P.	16-Mar	3:00PM	Williford C	7
Rath, M.	17-Mar	9:40AM	Williford A	11
Raughley, M.	16-Mar	11:20AM	Joliet	3
Reichert, W.R.	16-Mar	3:00PM	Williford A	5
Reynaud, V.	16-Mar	3:40PM	Williford B	6
Richards, T.	16-Mar	4:40PM	Marquette	4
Richards, T.	17-Mar	11:40AM	Waldorf	10
Richards, T.	17-Mar	4:00PM	Waldorf	11
Rigaud, M.	16-Mar	11:50AM	Marquette	4
Rigaud, M.	17-Mar	2:40PM	Williford A	12
S				
Sahu, B.S.	17-Mar	4:20PM	Waldorf	11
Sako, E.Y.	17-Mar	11:40AM	Williford A	11
Sako, E.Y.	18-Mar	9:20AM	Waldorf	13
Salvini, V.R.	17-Mar	10:40AM	Williford A	11
Samadi, S.	16-Mar	2:20PM	Williford A	5
Samanta, A.K.	17-Mar	11:20AM	Waldorf	10
Samanta, A.K.	17-Mar	3:00PM	Waldorf	10
Sardelli, J.	18-Mar	11:20AM	Waldorf	14
Sasatani, Y.	16-Mar	4:00PM	Joliet	3
Sayet, T.	16-Mar	12:00PM	Williford A	5
Sayre, J.	16-Mar	2:40PM	Williford C	7
Schantl, P.	16-Mar	12:00PM	Joliet	3
Scheer, A.D.	17-Mar	9:50AM	Marquette	9
Schemmel, T.	16-Mar	10:40AM	Williford C	7
Schemmel, T.	16-Mar	4:00PM	Waldorf	5
Shao, C.	18-Mar	10:00AM	Waldorf	14
Shimada, G.	16-Mar	11:00AM	Waldorf	4
Shiohama, M.	17-Mar	2:00PM	Marquette	9
Sliwinska, J.	16-Mar	2:00PM	Joliet	3
Soares, T.	16-Mar	4:40PM	Williford A	6
Souza, M.	17-Mar	1:40PM	Waldorf	10
Srinivasa Rao, P.	17-Mar	3:00PM	Williford B	12
Stein, A.	16-Mar	10:40AM	Williford B	6
Sun, H.	17-Mar	2:20PM	Joliet	9
Swain, R.	16-Mar	1:40PM	Waldorf	4
T				
Taniguchi, K.	18-Mar	9:20AM	Joliet	13
Teixeira, L.B.	16-Mar	2:00PM	Williford A	5
Teixeira, L.B.	17-Mar	3:40PM	Marquette	10
Tian, X.	16-Mar	2:40PM	Williford B	6
Tian, X.	16-Mar	3:00PM	Williford B	6
Tixier, A.	17-Mar	4:00PM	Joliet	9
Tokunaga, R.	16-Mar	1:40PM	Joliet	3
Tonnesen, T.	17-Mar	12:00PM	Williford A	11
Tonnesen, T.	17-Mar	1:40PM	Williford C	13
Touzo, B.	17-Mar	11:40AM	Joliet	8
Touzo, B.	18-Mar	11:00AM	Waldorf	14
Tripathi, H.S.	17-Mar	12:00PM	Waldorf	10
U				
Uwanyuze, S.	17-Mar	2:00PM	Williford B	12
V				
van Beurden, P.	18-Mar	9:20AM	Williford C	14
Veres, D.	16-Mar	11:40AM	Waldorf	4
Veres, D.	17-Mar	3:40PM	Joliet	9
Vert, T.	16-Mar	10:50AM	Marquette	4
Vert, T.	16-Mar	3:40PM	Waldorf	5
W				
Walls, P.	17-Mar	2:20PM	Williford B	12
Wang, H.	17-Mar	9:20AM	Joliet	8
Wang, J.	17-Mar	5:00PM	Waldorf	11
Wang, Y.	16-Mar	2:20PM	Waldorf	4
Wang, Y.	18-Mar	9:40AM	Joliet	13
Wang, Z.	16-Mar	1:40PM	Williford C	7
Waters, J.	17-Mar	10:50AM	Marquette	9
Weber, K.	17-Mar	11:00AM	Williford C	13
Willi, J.P.	16-Mar	1:40PM	Marquette	4
Wöhrmeyer, C.	17-Mar	11:00AM	Williford B	12
Wolf, C.	17-Mar	11:20AM	Joliet	8
Wu, Y.	18-Mar	9:40AM	Williford B	14
Wu, Y.	18-Mar	10:00AM	Williford B	14
Y				
Yan, W.	17-Mar	10:00AM	Williford C	13
Yin, K.	18-Mar	10:00AM	Joliet	13
Yuan, W.	16-Mar	11:00AM	Williford B	6
Z				
Zhang, S.	17-Mar	9:40AM	Joliet	8
Zhang, Y.	18-Mar	11:40AM	Waldorf	14
Zhang, Z.	16-Mar	2:20PM	Joliet	3
Zhu, H.	18-Mar	10:20AM	Waldorf	14

Poster Presenters

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Darban, S.	16-Mar	5:00PM	Lower Level Exhibit Area	7
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Gerz, A.	16-Mar	5:00PM	Lower Level Exhibit Area	8
K				
Kumar, A.	16-Mar	5:00PM	Lower Level Exhibit Area	7
Kushchenko, P.	16-Mar	5:00PM	Lower Level Exhibit Area	8
L				
Lang, C.	16-Mar	5:00PM	Lower Level Exhibit Area	8
Li, T.	16-Mar	5:00PM	Lower Level Exhibit Area	7
Ludwig, M.J.	16-Mar	5:00PM	Lower Level Exhibit Area	7
M				
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Malaiskiene, J.	16-Mar	5:00PM	Lower Level Exhibit Area	8
N				
Nakane, T.	16-Mar	5:00PM	Lower Level Exhibit Area	8
Q				
Qian, F.	16-Mar	5:00PM	Lower Level Exhibit Area	8
S				
Smith-Gray, N.J.	16-Mar	5:00PM	Lower Level Exhibit Area	8
V				
Van Ende, M.	16-Mar	5:00PM	Lower Level Exhibit Area	7
Y				
Yin, K.	16-Mar	5:00PM	Lower Level Exhibit Area	7
Z				
Zhang, Y.	16-Mar	5:00PM	Lower Level Exhibit Area	7

Wednesday, March 16, 2022

Opening Session and Keynote

Room: Williford A, B, C

Session Chair: James Hemrick, Oak Ridge National Laboratory

8:40 AM

Opening Remarks and Introduction of Keynote Speaker

9:20 AM

(UNITECR-KEY-2022) Global Refractories: Trends and Opportunities

C. Jackson*[1]

1. HarbisonWalker International, Inc., USA

10:20 AM

Break

Refractory Characterization and Testing I

Room: Joliet

Session Chairs: Dawn Hill, Exertech LLC; Bob Hunter, Special Shapes Refractory Co.

10:40 AM

(UNITECR-001-2022) Oxidation behaviour and thermomechanical characterization of silicon carbide containing castables

F. Delobel[1]; P. Dietrich[2]; F. Holleyn[3]; L. Erbar[3]; C. Dannert[2]; O. Krause[3]; P. Pilate*[1]

1. Belgian Ceramic Research Center, Belgium
2. Forschungsgemeinschaft Feuerfest e. V., Germany
3. Hochschule Koblenz, Germany

11:00 AM - WITHDRAW

(UNITECR-002-2022) The Impact of beta-alumina to spinel-formation in refractory castables

J. Paul*[1]; O. Krause[1]; L. Reichert[1]; F. Holleyn[1]

1. Hochschule Koblenz, Germany

11:20 AM

(UNITECR-003-2022) Investigation of Sintering Characteristics of a 70% Alumina Dry-Vibratable Refractory Material

M. Raughley*[1]

1. HarbisonWalker International, Research and Development, USA

11:40 AM

(UNITECR-004-2022) Thermomechanical behaviour of refractory dry-stacked masonry walls

R. L. Oliveira*[1]; J. C. Rodrigues[1]; J. M. Pereira[2]; P. Lourenço[2]; H. U. Marschall[3]; M. Ali[4]

1. University of Coimbra, Faculty of Sciences and Technology, Portugal
2. ISISE, Portugal
3. RHI Magnesita, Austria
4. Université d'Orléans, LaMé laboratory (EA 7494), France

12:00 PM

(UNITECR-005-2022) Reaction Textures in Al_2O_3-SiO_2 Bricks induced by gaseous SO_x Attack: New Insights from Mineralogy and Thermodynamic Modelling

P. Schantl*[1]; C. Majcenovic[1]

1. RHI Magnesita, Austria

Refractory Characterization and Testing II

Room: Joliet

Session Chairs: Dawn Hill, Exertech LLC; Bob Hunter, Special Shapes Refractory Co.

1:40 PM

(UNITECR-006-2022) Phase composition and microstructure of silica bricks characterized by micro-Raman spectroscopy

R. Tokunaga*[1]; K. Goto[1]; K. MORIKAWA[1]

1. KROSAKI HARIMA CORPORATION, Technical Reserch Laboratories, Japan

2:00 PM

(UNITECR-007-2022) Test Method for Purge Plug Corrosion Resistance and Metal Penetration

Q. Robinson[1]; P. Hunger[1]; J. Sliwinska*[1]

1. Vesuvius Research, USA

2:20 PM

(UNITECR-008-2022) SiO_2-CaO-Al_2O_3 slag viscosity measurement by aerodynamic levitation

Z. Zhang*[1]; E. de Bilbao[1]

1. CNRS, CEMHTI UPR3079, Univ. Orléans, F-45071 Orléans, France, France

2:40 PM

(UNITECR-009-2022) Examination of the Binary System Al_2O_3-ZrO_2 by Aero Acoustic Levitation Melting

J. Niessen*[1]; D. Muehmer[1]; T. Tonnesen[1]; R. Telle[1]; J. Gonzalez[1]

1. RWTH University, Germany

3:00 PM

(UNITECR-010-2022) Ab inito and electrochemical impedance spectroscopy (EIS) studies on the hydration behaviour of cement-bonded refractory composites

A. Kruk*[1]; J. Ramult[2]; K. Warmuz[2]; D. Madej[2]

1. Pedagogical University of Cracow, Institute of Technology, Poland
2. AGH University of Science and Technology, Faculty of Materials Science and Ceramics, Poland

3:20 PM

Break

3:40 PM

(UNITECR-011-2022) Direct Observation of Drying by Neutron and X-ray Tomography Analysis

M. H. Moreira*[3]; S. Dal Pont[2]; A. Tengattini[4]; A. Luz[3]; T. M. Cunha[3]; R. F. Ausas[1]; V. C. Pandolfelli[3]

1. University of São Paulo, Institute of Mathematical and Computer Sciences, Brazil
2. Université Grenoble Alpes, 3SR, France
3. Federal University of São Carlos, Graduate Program in Materials Science and Engineering (PPGCEM), Brazil
4. Institut Laue-Langevin, Large Scale Structures, France

4:00 PM

(UNITECR-012-2022) Effect of Internal Pores on Properties in Castable Refractories

Y. Sasatani*[1]; K. YAMADA[1]; T. OKADA[1]; K. MORIKAWA[1]

1. KROSAKI HARIMA CORPORATION, Japan

4:20 PM

(UNITECR-013-2022) Observation of the setting process of unshaped refractory materials by dynamic-mechanical analysis

V. Hopp*[1]; A. Masoudi Alavi[1]; A. Sax[1]; P. Quirmbach[1]

1. University of Koblenz-Landau, Institute for Integrated Natural Sciences, Technical Chemistry, Germany

4:40 PM

(UNITECR-014-2022) Study of the Addition of a Special Chemical Mix Additive and Curing Temperature on the Setting Time and Mechanical Properties of No-cement Castable

A. Cristante*[1]

1. Reno Refractories, Inc., USA

Refractory Student and Young Professionals I

Room: Marquette

Session Chair: Austin Scheer, Kyanite Mining Corportation

3:40 PM

(UNITECR-015-2022) Influence of $MgAl_2O_4$-spinel additions on the phosphate bonding in Al_2O_3-refractories

D. Hahn*[1]; P. Quirmbach[1]

1. University of Koblenz-Landau, Technical Chemistry and Corrosion Sciences, Germany

4:10 PM

(UNITECR-016-2022) Development of greener and more effective high-temperature thermal insulators

O. H. Borges*[1]; T. dos Santos[1]; V. R. Salvini[1]; V. C. Pandolfelli[1]

1. Federal University of São Carlos, Materials Engineering Department (DEMa), Brazil

4:40 PM

(UNITECR-017-2022) Impact of Olivine on Refractory Corrosion Resistance

T. Richards*[1]; J. Smith[1]; R. O'Malley[1]; T. Sander[1]

1. Missouri University of Science and Technology, Materials Science and Engineering, USA

5:10 PM

(UNITECR-018-2022) Use of Dilatometer to Screen Refractory Raw Materials (Invited)

S. Mandal*[1]; M. Mahapatra[1]

1. University of Alabama at Birmingham, Materials Science and Engineering, USA

Theodore J. Planje Award Session I

Room: Marquette

Session Chairs: James Hemrick, Oak Ridge National Laboratory; Jeffrey Smith, Missouri S&T

10:40 AM

Introduction

10:50 AM

(UNITECR-019-2022) How much and what type of refractory do steel plants really use? An Accurate Refractory Cost / Usage Model for the North American Steel Industry (Invited)

T. Vert*[1]

1. Independent Expert, Canada

11:20 AM

(UNITECR-020-2022) Metal Anchors: An Abreviated Review (Invited)

R. Engel*[1]

1. Refractory Consulting Services, USA

11:50 AM

(UNITECR-021-2022) Refractories from fire to FIRE (Invited)

M. Rigaud*[1]

1. École Polytechnique, U. of Montreal, Mechanical Engineering, Canada

Theodore J. Planje Award Session II

Room: Marquette

Session Chairs: James Hemrick, Oak Ridge National Laboratory; Jeffrey Smith, Missouri S&T

1:40 PM

(UNITECR-022-2022) What I have learned from 55 years in Refractories (and not from a book) (Invited)

J. P. Willi*[1]

1. Sunset Refractory Services, USA

2:10 PM

(UNITECR-023-2022) 'Through the looking glass' how the refractory industry will need to evolve towards a sustainable future - a personal perspective. (Invited)

N. E. Bunt*[1]

1. Imerys, USA

2:40 PM

Award Presentation

Steel Making - Brick Development

Room: Waldorf

Session Chairs: Ashley Hampton, Allied Mineral Products, LLC; Angela Rodrigues-Schroer, Wahl Refractories

10:40 AM

(UNITECR-024-2022) Ultra Low Carbon Bricks for Steel Ladles with Nanographite Technology

C. Pagliosa*[1]; B. L. Borges de Melo[1]; M. S. Borges[2]; R. Favalessa[2]

1. RHI Magnesita, R&D Center, Brazil
2. RHI Magnesita, Brazil

11:00 AM

(UNITECR-025-2022) Reduction of Gas Permeability of MgO-C Brick by Optimizing Particle Size Distribution

G. Shimada*[1]; E. ISHIHARA[1]; T. FURUKAWA[1]; A. IIDA[1]

1. SHINAGAWA REFRACTORIES CO., LTD., Japan

11:20 AM

(UNITECR-026-2022) Effect of different antioxidants on the properties of Steel Ladle Dolo-C refractories

T. Mahata[1], B. Ghosh*[1]

1. TRL Krosaki Refractories Limited, Technology, India

11:40 AM

(UNITECR-027-2022) Magnesia–carbon refractories from recycled MgO–C materials

K. Moritz*[1]; S. Dudczig[1]; G. Endres[2]; D. Herzog[2]; M. Schwarz[3]; L. Schöttler[3]; D. Veres[1]; C. Aneziris [1]

1. Technische Universität Bergakademie Freiberg, Institute of Ceramics, Refractories and Composite Materials, Germany
2. Horn & Co. Minerals Recovery GmbH & Co. KG, Germany
3. Deutsche Edelstahlwerke Specialty Steel GmbH & Co. KG, Germany

12:00 PM

(UNITECR-028-2022) Interactions of MgO-C refractory materials with Al-deoxidized steel

F. Kerber*[1]; V. Stein[2]; T. Schemmel[2]; H. Jansen[2]; C. Aneziris[1]

1. Institute of Ceramics, Refractories and Composite Materials, Germany
2. Refratechnik Steel GmbH, Germany

Steel Making - Monolithics Development

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Angela Rodrigues-Schroer, Wahl Refractories

1:40 PM

(UNITECR-029-2022) Development of Al_2O_3 – $MgAl_2O_4$ spinel castable for various applications

R. Swain[1], A. Sumanta*[1]

1. TRL KROSAKI REFRACTORIES LIMITED, Technology, India

2:00 PM

(UNITECR-030-2022) Effect of spinel on the properties of alumina-spinel magnesia refractory castables for steel-ladle bottom

S. Kim*[1]; C. Ha[1]; J. Huh[1]

1. KOREA REFRACTORIES CO., LTD., R&D Center, Republic of Korea

2:20 PM

(UNITECR-031-2022) Study on Fluidity of Magnesia Self-flowing Castable Used in Converter

Y. Wang*[1]; Y. Qin[1]; Y. Wang[1]; P. Zhang[1]

1. Puyang Refractories Group Co., Ltd., China

2:40 PM

(UNITECR-032-2022) Study and application of shotcreting for ladle lining

Y. Qin*[1]; Y. Wang[1]; Y. Wang[1]; P. Zhang[1]

1. Puyang Refractories Group Co., China

3:00 PM

(UNITECR-033-2022) Effect of curing agents on the fluidity and setting behavior of alumina-silica castables bonded with colloidal silica

Y. Chen*[1]

1. Puyang Refractories Group Co., Ltd., China

3:20 PM

Break

Steel Making - Wear Mechanism & Prevention

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Ashley Hampton, Allied Mineral Products, LLC

3:40 PM

(UNITECR-034-2022) How to Read Steel Ladle Wear - 30 Years of Experience (Good, Bad and Ugly)

T. Vert*[1]

1. Independent Expert, Canada

4:00 PM

(UNITECR-035-2022) A Unique Approach of Correlating the Zonal Wear of Steel Ladles with their Operational Parameters

T. Schemmel*[1]; U. Sengupta[1]; D. Chandra[1]; H. Jansen[1]

1. Refratechnik Steel GmbH, Germany

4:20 PM

(UNITECR-036-2022) Vertical cracks in steel ladles – new solutions to overcome a common issue

N. Pywell[1]; B. Buchberger*[1], A. Viertauer[1], J. Longley[1]

1. Mayerton Refractories Ltd., Group Technical, Austria

4:40 PM

(UNITECR-037-2022) Impact of calcium magnesium aluminate on liquid phase formation and high-temperature behaviour of MgO-CMA-C ladle refractories

P. Gehre*[1]; T. Preisker[1]; S. Guhl[1]; C. Wöhrmeyer[2]; C. Parr[2]; C. Aneziris[1]

1. TU Bergakademie Freiberg, Germany
2. Imerys Aluminates, France

5:00 PM

(UNITECR-038-2022) Correlation of air-permeability and slag corrosion resistance of advanced carbon-containing refractory materials for high-temperature applications

G. Ghosh*[1]

1. Tata Steel Limited, RTG, India

5:20 PM

(UNITECR-039-2022) Investigation of effective parameters on increasing the durability of pitch-bonded MgO-C bricks used in the trunnion area of the steel converter

S. Otroj*[1]; M. Knoll[1]; F. Stöckmann[1]

1. Intocast AG, Research and Development, Germany

Modeling and Simulation of Refractories I

Room: Williford A

Session Chair: Rakesh Dhaka, U.S. Steel

10:40 AM

(UNITECR-040-2022) Investigation of different curing temperatures on phase changes during drying of castables

A. Koehler*[2]; S. Kuiper[3]; S. Klaus[1]; F. Goetz-Neunhoeffer[2]

1. Almatis GmbH, Germany
2. University of Erlangen-Nuernberg, Germany
3. Almatis B.V., Netherlands

11:00 AM

(UNITECR-041-2022) Drying of Refractory Castables – How complex the modelling needs to be? A numerical and experimental study

M. H. Moreira*[2]; S. Dal Pont[3]; R. F. Ausas[1]; T. M. Cunha[2]; A. Luz[2]; V. C. Pandolfelli[2]

1. University of São Paulo, Institute of Mathematical and Computer Sciences, Brazil
2. Federal University of São Carlos, Graduate Program in Materials Science and Engineering (PPGCEM), Brazil
3. Université Grenoble Alpes, 3SR, France

11:20 AM

(UNITECR-042-2022) Drying behavior of refractory castables when using continuous heating-up curve: a numerical simulation analysis

T. M. Cunha*[1]; M. H. Moreira[1]; A. Luz[1]; V. C. Pandolfelli[1]

1. Federal University of Sao Carlos, Graduate Program in Materials Science and Engineering, Department of Materials Engineering, Brazil

11:40 AM

(UNITECR-043-2022) Advanced thoughts on the infiltration of ceramic porous plugs by liquid steel

L. Z. Falsetti*[1]; D. N. Muche[1]; V. C. Pandolfelli[1]

1. Federal University of São Carlos (UFSCar), Department of Materials Engineering, Brazil

12:00 PM

(UNITECR-044-2022) A novel method for the prediction of non-reactive impregnation in porous media

T. Sayet*[1]; C. Trang[1]; A. Batakis[2]; E. de Bilbao[3]; E. Blond[1]

1. University of Orléans, France, LaMé, France
2. Institut Denis Poisson, France
3. CEMTHI, France

Modeling and Simulation of Refractories II

Room: Williford A

Session Chairs: Manoj Mahapatra, University of Alabama at Birmingham; Somnath Mandal, University of California, Irvine

1:40 PM

(UNITECR-045-2022) Theory and fact of local corrosion of refractories containing non-oxide at the slag-metal interfaces under metal level fluctuation

S. Maeno*[1]; K. MORIKAWA[1]

1. Krosaki Harima, Japan

2:00 PM

(UNITECR-046-2022) Proposition of Two Asymmetric Constitutive Laws to Model the Creep Behavior of Refractory Materials at High Temperatures

L. B. Teixeira*[1]; E. Blond[1]; T. Sayet[1]; J. Gillibert[1]

1. Univ. Orléans, Univ. Tours, INSA-CVL, LaMé, France

2:20 PM - WITHDRAWN

(UNITECR-047-2022) Determination of secondary creep stage parameters of a shaped alumina spinel refractory with the aid of genetic algorithm

S. Samadi*[1]; S. jin[1]; D. Gruber[1]; H. Harmuth[1]

1. Montanuniversity of Leoben, Chair of Ceramics, Austria

2:40 PM

(UNITECR-048-2022) Flexible usage Ladle Shroud enabled by advanced thermo-mechanical analysis

K. Andreev[1]; S. Mazerat*[1]; S. Romero Bavier[1]; Y. Chen[1]; S. Gregoire[1]; V. Esteves de Almeida Filho[1]; T. Pereira[1]; E. Haeder[1]; V. Costa[1]

1. Vesuvius, Brazil

3:00 PM

(UNITECR-049-2022) Determination of temperature dependent static young's modulus of refractory ceramics using refractoriness under load tests

M. Henze[2]; W. R. Reichert*[1]; T. Tonnesen[1]; R. Telle[1]; G. Hirt[2]

1. RWTH Aachen, Chair of ceramics, Germany
2. RWTH Aachen, Institute of Metal Forming, Germany

3:20 PM

Break

3:40 PM

(UNITECR-050-2022) A thermomechanical model of a full 3D steel ladle using homogenization technique

C. C. Melo*[1]; L. B. Teixeira[1]; H. U. Marschall[1]; A. D. Resende[1]; G. Hackl[1]

1. RHI Magnesita, Simulation, Austria

4:00 PM

(UNITECR-051-2022) Modelling the elastic properties of bi-phase refractories by using periodic homogenization approach with Discrete Element Method (DEM)

F. Asadi*[1]; D. ANDRÉ[1]; S. EMAM[2]; P. DOUMALIN[3]; M. HUGER[1]

1. UMR CNRS 7315, Institute of Research for Ceramics (IRCER), France
2. Itasca Consultants S.A.S., France
3. Institut PPRIME, UPR CNRS 3346, France

4:20 PM - WITHDRAWN

(UNITECR-052-2022) The behaviour of dry-joints in mortarless refractory masonry at high temperatures

P. N. Gajjar*[1]; P. Put[2]; J. M. Pereira[1]; B. Luchini[2]; S. Sinnema[2]; P. Lourenço[1]

1. University of Minho, ISISE, Department of Civil Engineering, Portugal
2. TATA Steel, Ceramics Research Centre, Netherlands

4:40 PM - WITHDRAWN

(UNITECR-053-2022) Thermo-mechanical modeling of refractory masonry wall under variable thermo-mechanical history

T. Soares*[1]

1. University of Minho, Portugal, ISISE, Portugal

5:00 PM

(UNITECR-054-2022) Nonlinear Thermomechanical Modelling of Refractory Masonry Linings with Dry Joints

M. Ali*[1]; T. Sayet[1]; A. Gasser[1]; E. Blond[1]

1. University of Orléans, France

5:20 PM - WITHDRAWN

(UNITECR-055-2022) Research on Numerical Simulation Method of Tundish Flow Field Based on OpenFOAM CFD Toolkit

Q. Fu*[1]; W. Zhang[1]; Q. Fan[1]

1. Puyang Refractories Group Co., Ltd., China

Raw Materials I

Room: Williford B

Session Chair: Scot Graddick, Imerys

10:40 AM

(UNITECR-056-2022) Iron Leaching from Non-Refractory Grade Bauxite: Individual Process Optimization and Prediction by using DOE

A. Stein*[1]; A. Sax[1]; P. Quirmbach[1]

1. University of Koblenz-Landau, Department of Chemistry, Germany

11:00 AM - WITHDRAWN

(UNITECR-057-2022) The impact of reactive alumina powders on properties of corundum based refractory castables

H. Tang[1]; W. Yuan*[1]

1. Wuhan University of Science and Technology, China

11:20 AM

(UNITECR-058-2022) The Effect of Iron Oxide Impurities on the Hot Properties of Mullite

S. Ashlock*[1]; A. D. Scheer[1]

1. Kyanite Mining Corporation, Research and Development, USA

11:40 AM

(UNITECR-059-2022) Influence of Super Reactive Alumina on Rheological Behavior of Free Flowing Castables at Low and High Shear Rate

C. Dünzen*[1]; D. Janousch[1]; R. Dirscherl[1]

1. Nabaltec, Germany

12:00 PM - WITHDRAWN

(UNITECR-060-2022) Fabrication of Red Firing Clay Ceramic Water Filter Tempered with Iron Rich Oxide Material and Treated Mining Waste

L. I. Cabalo*[1]; E. Ibarra[1]

1. Mindanao State University-Iligan Institute of Technology, Department of Materials Resource and Technology, Philippines

Raw Materials II

Room: Williford B

Session Chairs: Steven Ashlock, Virginia Kyanite; Scot Graddick, Imerys

1:40 PM

(UNITECR-061-2022) High Grade Guyanese Bauxite Source in a Class of Its Own

J. A. Karson*[1]

1. First Bauxite LLC, Sales, USA

2:00 PM

(UNITECR-062-2022) Purification and Densification of High Purity Sintered Magnesia from Natural Magnesite in China

Z. Guo*[1]

1. Yingkou Jindai Technologies, China

2:20 PM

(UNITECR-063-2022) Study on Hydration Process of Preparing High Purity Magnesium Hydroxide from Microcrystalline Magnesite

Z. Li*[1]

1. Puyang Refractories Group Co. Ltd., China

2:40 PM

(UNITECR-064-2022) Preparation of Active MgO from Microcrystalline Magnesite and Its Application in the Hydrometallurgy

X. Tian*[1]

1. Puyang Refractories Group Co. Ltd., China

3:00 PM

(UNITECR-065-2022) Preparation of High-purity Low-activity MgO from Microcrystalline Magnesite and Its Application in the Production of Acetate Fiber

X. Tian*[1]

1. Puyang Refractories Group Co. Ltd., China

3:20 PM

Break

3:40 PM

(UNITECR-066-2022) Investigation of the passive-oxidation of SiC in the temperature range 1200 to 1500 °C

V. Reynaud*[1]; M. Dombrowski[2]; J. Poirier[3]; E. de Bilbao[3]

1. CNRS CEMHTI - Calderys, France
2. Calderys, France
3. University of Orleans, CEMHTI-CNRS, France

4:00 PM - WITHDRAWN

(UNITECR-067-2022) Synthesis and Characterization of Single-Phase Al_3BC_3

R. Maki*[1]; Y. Kusano[1]; T. Maeda[2]; H. Taira[2]

1. Okayama University of Science, Japan
2. Okayama Ceramics Research Foundation, Japan

4:20 PM

(UNITECR-068-2022) Thermal Decomposition of Al_3BC_3 in Various Atmosphere: a New Boride Additive for Carbon-Containing-Refractories

T. Maeda*[1]; H. Taira[1]; R. Maki[2]; Y. Kusano[2]

1. Okayama Ceramics Research Foundation, Institute, Japan
2. Department of Applied Chemistry and Biotechnology, Faculty and Engineering, Okayama University of Science, Japan

4:40 PM

(UNITECR-069-2022) The influence of curing and thermal treatment temperature on the microstructure of CAC binder with nano additives

R. Boris*[1]; V. Antonovič[1]; J. Malaiskiene[1]; R. Stonys[1]

1. Vilnius Gediminas Technical university, Lithuania

Advances in Monolithic Technology I

Room: Williford C

Session Chairs: William Headrick, RHI Magnesita; John Waters, RHI Magnesita

10:40 AM

(UNITECR-070-2022) Contribution to environmental sustainability

P. TASSOT[1]; T. Schemmel*[2]

1. REFRATECHNIK Steel GmbH, Technical Marketing, Germany
2. REFRATECHNIK Steel GmbH, R&D, Germany

11:00 AM

(UNITECR-071-2022) HYBRID - Innovative Bonding Technology for Refractory Concrete

J. Neese*[1]; B. Kesselheim[1]; S. Rollmann[1]; S. Scheffler[1]

1. REFRATECHNIK Steel GmbH, Germany

11:20 AM

(UNITECR-072-2022) Advanced refractory no-cement castables based on alumina and spinel with improved thermomechanical properties

D. Madej*[1]; J. Ramult[1]; K. Warmuz[1]; A. Kruk[2]

1. AGH University of Science and Technology, Faculty of Materials Science and Ceramics, Poland
2. Pedagogical University of Cracow, Institute of Technology, Poland

11:40 AM

(UNITECR-073-2022) New calcium aluminate cement for refractory pre-cast shape production

S. Kuiper*[1]; A. Buhr[1]; S. Klaus[1]; D. Schmidtmeier[1]; G. Wams[1]; A. Spies[1]

1. Almatis, Netherlands

12:00 PM - WITHDRAWN

(UNITECR-074-2022) Novel agents for refractory castables containing hydraulic binders

I. M. Milanezzi[1]; V. S. Pinto[1]; D. S. Fini[1]; B. P. Bezerra[1]; V. C. Pandolfelli[1]; A. Luz*[1]

1. Federal University of São Carlos, Materials Engineering Department, Brazil

Advances in Monolithic Technology II

Room: Williford C

Session Chairs: William Headrick, RHI Magnesita; John Waters, RHI Magnesita

1:40 PM

(UNITECR-075-2022) Effect of Particle Size Distribution on Explosion Resistance During Heating of Alumina Castable Bonded by Hydratable Alumina

Z. Wang*[1]; H. Wang[1]; H. Feng[1]; X. Cao[1]; Y. Cao[1]

1. Sinosteel LIRR, State Key Laboratory of Advanced Refractories, China

2:00 PM

(UNITECR-076-2022) Improvement in Explosion Resistance of Low Cement Refractory Castables Using Drying Agents

H. Peng*[1]; B. Myhre[1]

1. Elkem silica products, Norway, R&D, Norway

2:20 PM

(UNITECR-077-2022) Development of Highly Densified Precast Block for Impact Zone in Teeming Ladle

M. Fujii*[1]; M. Nishimura[1]

1. Shinagawa Refractories Co., Ltd., Research Center, Japan

2:40 PM

(UNITECR-078-2022) Thermal Shock Resistance of 60% Alumina Gunite with a Zircon Addition

J. Sayre*[1]

1. HarbisonWalker Internation, USA

3:00 PM

(UNITECR-079-2022) Innovative Profile Printing System for Steel Ladle Bottom to Improve Steel Flow and Metallic Yield

V. P. Ramos*[2]; A. Nascimento[2]; D. F. Galesi[2]; H. Guimarães[2]; H. A. Lima[2]; L. Souza[2]; L. H. Souza[2]; B. C. Andrade[1]; B. N. Stoco[1]; D. S. Orosimbo[1]; G. N. Souza[1]; L. Crivelari[1]; T. Silva[1]

1. Ternium Brasil, Brazil
2. Saint-Gobain do Brasil Ltda, Brazil

3:20 PM

Break

3:40 PM

(UNITECR-080-2022) Effect of ball pitch addition on the microstructure and properties of Al_2O_3-SiC-C castables

P. Zhou[1]; X. Liu[1]; Y. Zhang[2]; Q. Jia*[1]

1. Zhengzhou University, High Temperature Ceramics Institute, China
2. Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China

4:00 PM

(UNITECR-081-2022) Development and Production of High-density Silica Bricks for Coke Ovens

S. Dvorak*[1]

1. P-D Refractories CZ, Czechia

Poster Session

Room: Lower Level Exhibit Area

5:00 PM

(UNITECR-P001-2022) Cost Effective Model for Torpedo Ladle Refractory

A. Kumar*[1]; S. A. KHAN[2]; M. K. Singh[2]; M. Bag[2]; U. Singh[3]; P. Panigrahi[1]

1. Tata Steel, Refractory Technology Group, India
2. Tata Steel, Iron Making Refractory, India
3. Tata Steel, V.P (C.S.I), India

(UNITECR-P002-2022) Research and Development, Manufacturing and Application of Series of Andalusite bricks Used for Hot Blast stove

K. Yin*[1]

1. Zhengzhou Annec Industrial Co., Ltd, Refractory Technology, China

(UNITECR-P003-2022) Corroded alumina-spinel brick preparation in laboratory condition for thermomechanical investigations

S. Darban*[1]; R. Prorok[1]; J. Szczerba[1]

1. AGH University of Science and Technology, Department of Ceramics and Refractories, Poland

(UNITECR-P004-2022) Corrosion Mechanism of MgO-Al_2O_3-C Refractories Containing SiC with Different Particle Size

T. Li*[1]

1. Puyang Refractories Group Co., Ltd, Technial center, China

(UNITECR-P005-2022) Formation of MgO dense layer in MgO-C refractories by carbothermic reaction and its influence on refractory corrosion by high MnO slag - *WITHDRAWN*

D. Lee[1]; M. Van Ende*[1]; I. Jung[1]

1. Seoul National University, Department of Materials Science and Engineering, Republic of Korea

(UNITECR-P006-2022) Present situation and development trend of refractory raw materials in China - *WITHDRAWN*

Y. Zhang*[1]; Z. Xiaohui[1]; C. Qingxian[1]; P. Xigao[1]; W. Zhanmin[1]

1. Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China

(UNITECR-P007-2022) Investigation of recycled magnesia-carbon aggregate obtained with omitting carbon removal step

M. J. Ludwig*[1]; I. Jastrzebska[1]; R. Prorok[1]; M. Sulkowski[2]; C. Golawski[2]; J. Szczerba[1]

1. AGH University of Science and Technology, Department of Ceramics and Refractories, Poland
2. ArcelorMittal Refractories, Poland

(UNITECR-P008-2022) Study on Slag Corrosion of the Fused Magnesia with Ultra-low content of SiO_2 and Fe_2O_3 from Microcrystalline Magnesite

T. Li*[1]; Q. Zuo[1]; J. Gao[1]

1. Puyang Refractories Group Co., Ltd, Technial center, China

(UNITECR-P009-2022) Investigation on Corrosion Resistance of Chromic Oxide, AZS/Cr and High-Alumina Refractories to Aluminaboronsilicate Glasses and Basalt Melts

V. Martynenko[1]; P. Kushchenko*[1]; I. Shulik[1]; Y. Mishnyova[1]; K. Kushchenko[1]

1. Ukrainian Research Institute of Refractories named after A.S. Berezhnoy, Ukraine

(UNITECR-P010-2022) Analysis of Monofrax K-3 Refractory Corrosion Within a Research Scaled Melter

N. J. Smith-Gray*[1]; J. McCloy[1]

1. Washington State University, Materials Science and Engineering, USA

(UNITECR-P011-2022) Oxydation behavior of SiC refractory samples used in waste inceniration furnaces containing different antioxdizing compounds in the starting mixture

C. Lang*[1]; S. Abdelouhab[1]; F. Delobel[1]; P. Pilate[1]

1. BCRC, Research & Technological Support Department, Belgium

(UNITECR-P012-2022) The Analysis of the Change in the Structure and Properties of Refractory Castable Impregnated with SiO_2 Sol

J. Malaiskiene*[1]; V. Antonovič[1]; R. Boris[1]; R. Stonys[1]

1. Vilnius Gediminas technical university, Laboratory of Composite Materials, Lithuania

(UNITECR-P013-2022) Corrosion mechanism of Al2O3-MgO-SiO2 sagger by Li-ion cathode materials

F. Qian*[1]

1. Sinosteel Luoyang Institute of Refractorie Research, China

(UNITECR-P014-2022) Application of Ultra-Porous Ceramics Prepared by Gelation Freezing Method to Refractories

T. Nakane*[1]; P. JIA[1]; M. Fujii[1]; A. Matsuoka[1]; Y. Tanaka[1]; F. Ozeki[1]

1. MINO CERAMIC CO., LTD, Japan

(UNITECR-P015-2022) Study on preparation and properties of high temperature thermal insulating materials with microporous powders packed under vacuum

C. Ma*[1]

1. High temperature ceramic institute (HTCI), Zhengzhou University (ZZU), China

(UNITECR-P016-2022) Interactions between Calcium Aluminate Cement, reactive- and calcined alumina in a Low Cement Castable system

A. Gerz*[1]; M. Schmid[1]; G. Walenta[1]; C. Dünzen[3]; N. Noel[2]; A. Sax[2]; P. Quirmbach[2]

1. Calucem GmbH, Germany
2. Universität Koblenz-Landau, Germany
3. Nabaltec AG, Germany

(UNITECR-P017-2022) Research and development of perovskite-like refractory compounds

M. Bach*[1]; T. Schemmel[2]; M. Bühringer[3]; H. Jansen[2]; C. Aneziris[1]

1. Technische Universität Bergakademie Freiberg, Institute of Ceramics, Refractories and Composite Materials, Germany
2. Refratechnik Steel GmbH, Germany
3. Alexander Tutsek-Stiftung, Germany

Thursday, March 17, 2022

Plenary I

Room: Williford A, B, C

Session Chair: James Hemrick, Oak Ridge National Laboratory

8:00 AM

Introduction of Speaker

8:10 AM

(UNITECR-PLEN-001-2022) Riding the Tiger: Refractory raw material supply outlook

M. O'Driscoll*[1]

1. IMFORMED Industrial Mineral Forums & Research Ltd., United Kingdom

9:00 AM

Break

Advancements in Silicon Carbide-based and other Non-Oxide Refractory Materials

Room: Joliet

Session Chair: Matt Lambert, Allied Mineral Company

9:20 AM

(UNITECR-082-2022) Effect of Different Catalysts on Performance of Self-bonded SiC Refractories

H. Wang*[1]; H. Zhang[2]; Y. Bi[3]

1. Shanxi Institute of Technology, China
2. Wuhan University of Science and Technolog, China
3. Henan University of Science and Technology, China

9:40 AM

(UNITECR-083-2022) Catalytic Preparation of High Performance Refractory Materials

S. Zhang*[1]

1. University of Exeter, College of Engineering, Mathematics and Physical Sciences, United Kingdom

10:00 AM

(UNITECR-084-2022) Investigations on nitride-bonded SiC ceramics produced from thixotropic castables

J. Angelkort*[1]; N. Fröse[1]; M. Mix[1]; M. Knoll[1]; B. Epstein[2]; S. Fromm[2]; I. Hofmann[2]

1. Intocast AG, Germany
2. VGT-Dyko, Germany

Advances in Installation Techniques, Manufacturing, and Equipment

Room: Joliet

Session Chairs: William Headrick, RHI Magnesita; Somnath Mandal, University of California, Irvine

11:00 AM

(UNITECR-085-2022) The Use of Flame-Spray Technology to Manufacture Carbon-Free Alumina Molten Metal Filters

P. Gehre*[1]; B. Bock-Seefeld[1]; S. Dudczig[1]; J. Hubálková[1]; N. Child[2]; I. Delaney[2]; D. DeBastiani[3]; C. Aneziris[1]

1. TU Bergakademie Freiberg, Institute of Ceramics, Refractories and Composite Materials, Germany
2. Foseco International, United Kingdom
3. Vesuvius, USA

11:20 AM

(UNITECR-086-2022) Gunning manipulators for the hot repair

C. Wolf*[1]

1. Velco GmbH, Germany

11:40 AM

(UNITECR-087-2022) Optimisation of blast furnace iron trough by monitoring the wear with 3D scanner

B. Touzo[1]; M. Dombrowski*[2]

1. Imerys, Science and Technology, Belgium
2. Calderys, France

12:00 PM

(UNITECR-088-2022) Repair Process of Hot blast Outlet Part in Blast Furnace Hot Stove Combustion Chamber

S. Jang*[1]

1. Hyundai Steel company, Ironmaking Refractories Team, Republic of Korea

12:20 PM

(UNITECR-089-2022) Next Generation of Electric Furnace Bottom Technology

J. Kerr*[1]

1. RHI Magnesita, USA

Refractories for Other Applications I

Room: Joliet

Session Chair: Steven Ashlock, Virginia Kyanite

1:40 PM

(UNITECR-090-2022) Development of Phosphate bonded Plastic refractory

R. Halder*[1]

1. Calcutta University, Ceramic Engineering, India

2:00 PM

(UNITECR-091-2022) Refractory lining revamping and integrity management of aged furnaces and reactors in hydrocarbon process industries

M. Maity*[1]

1. Saudi Basic Industries Corporation, Saudi Arabia

2:20 PM - WITHDRAWN

(UNITECR-092-2022) Analysis of the damage process of high chromium refractories during the whole service life in coal-water slurry gasifier

H. Sun*[1]; H. Li[1]; K. Geng[1]; Y. Du[1]; H. Wang[1]

1. Sinosteel Luoyang Institute of Refractories Research Co., Ltd., State Key Laboratory of Advanced Refractories, China

2:40 PM

(UNITECR-093-2022) Refractory Materials for Thermal Processing of Biomass

P. Kovar*[1]; J. Vlček[2]; H. Ovčačíková[2]

1. P-D Refractories CZ a.s., Czechia
2. VSB - Technical University of Ostrava, Faculty of Materials Sciency and Technology, Department of Thermal Engineering, Czechia

3:00 PM

(UNITECR-094-2022) In-situ observations of alumina- and mullite-based refractory materials interacting with ash in coal-biomass gasification environments

K. Tippey*[1]; J. Nakano[1]; A. Nakano[1]; H. Thomas[1]; Ö. Doğan[1]; M. Lambert[2]; D. G. Goski[2]

1. US Department of Energy National Energy Technology Laboratory, USA
2. Allied Mineral Products, LLC, USA

3:20 PM

Break

Refractories for Other Applications II

Room: Joliet

Session Chair: Steven Ashlock, Virginia Kyanite

3:40 PM

(UNITECR-095-2022) Development of self-glazing carbon-bonded SiC castables

D. Veres*[1]; P. Gehre[1]; R. Tronstad[2]; K. R. Forwald[2]; L. Stephan[3]; C. Aneziris[1]

1. TU Bergakademie Freiberg, Germany
2. Elkem Technology, Norway
3. Elkem GmbH, Germany

4:00 PM

(UNITECR-096-2022) Corrosion of oxide-bonded SiC refractories by C-A-S slag

A. Tixier*[1]; J. Poirier[2]; E. de Bilbao[2]; C. Varona[3]; F. Valdivieso[1]; P. Ganster[1]; J. Brossard[4]; A. Villain[4]

1. Ecole des Mines de Saint-Etienne, France
2. CEMHTI, France
3. BONY SA, France
4. Veolia Recherche et Innovation, France

4:20 PM

(UNITECR-097-2022) $CaZrO_3$ Refractories for improved Melting and Casting Behaviour of Titanium Alloys

C. Jahn*[1]; T. Schemmel[1]; H. Jansen[1]; F. Bulling[2]; U. Klotz[2]; C. Aneziris[3]

1. Refratechnik Steel GmbH, Germany
2. fem Forschungsinstitut Edelmetalle + Metallchemie, Germany
3. TU Bergakademie Freiberg, IKFVW, Germany

Refractory Student and Young Professionals II

Room: Marquette

Session Chairs: Dawn Hill, Exertech LLC; Austin Scheer, Kyanite Mining Corportation

9:20 AM

(UNITECR-098-2022) Alkali resistance of the matrix of aluminosilicate refractories

K. A. Haines*[1]; D. Lankard[2]; D. G. Goski[1]; K. Byrd[1]; D. Loiacona[1]

1. Allied Mineral Products, USA
2. Lankard Materials Laboratory, Inc., USA

9:50 AM

(UNITECR-099-2022) Utilization of Virginia Kyanite™ and Virginia Mullite™ in Refractory Applications Worldwide

S. Ashlock[1]; A. D. Scheer*[1]

1. Kyanite Mining Corportation, Research and Development, USA

10:20 AM

(UNITECR-100-2022) Open-source tools for the refractory engineer of the present and the future

M. H. Moreira*[1]; M. F. Dos Santos[1]; V. C. Pandolfelli[1]

1. Federal University of São Carlos, Graduate Program in Materials Science and Engineering (PPGCEM), Brazil

10:50 AM

(UNITECR-101-2022) The Effect of Different Grades of Mulcoa Aggregate on the properties of Refractory Castables (Invited)

J. Waters*[1]; L. Lanna[1]; W. Headrick[1]; S. Graddick[2]; D. Tucker[2]

1. RHI Magnesita, USA
2. Imerys, USA

11:20 AM

(UNITECR-102-2022) The role of refractory ceramic plugs in the production of clean steels

L. Z. Falsetti*[1]; D. Ferreira Muche[1]; M. R. Andreeta[1]; M. H. Moreira[1]; V. C. Pandolfelli[1]

1. Federal University of Sao Carlos, Department of Materials Engineering (DEMa), Brazil

Refractory Characterization and Testing III

Room: Marquette

Session Chairs: Dawn Hill, Exertech LLC; Bob Hunter, Special Shapes Refractory Co.

1:40 PM

(UNITECR-103-2022) Influence of the stabilizer types and the phase composition on the thermal shock performance and corrosion resistance of zirconia ceramics

C. Heuer[1]; P. Gehre[1]; C. Aneziris[1]; A. Priese[2]; R. Soth[2]; C. Wöhrmeyer[2]; C. Parr[2], M. Bach *[1]

1. Technical University Bergakademie Freiberg, Germany
2. Imerys S.A., France

2:00 PM

(UNITECR-104-2022) Thermal shock resistance of MgO-C bricks under mechanical constraints

M. Shiohama*[1]; H. Kamio[1]; R. Hosogi[1]; K. Goto[1]; K. MORIKAWA[1]

1. Krosaki harima corporation, Technical research laboratories, Japan

2:20 PM

(UNITECR-105-2022) Thermal shock testing system able to adapt and depict the service conditions of refractory materials

E. M. Brochen*[1]; M. Kaminski[1]; C. Dannert[1]; J. Klose[2]; S. Esch[2]; P. Kohns[2]; G. Ankerhold[2]

1. Forschungsgemeinschaft Feuerfest e.V., Germany
2. Koblenz University of Applied Sciences, RheinAhrCampus, Germany

2:40 PM

(UNITECR-106-2022) Investigation of the fracture behaviour of refractory materials up to service temperatures: A tribute to Prof. R. C. Bradt

E. M. Brochen*[1]; C. Dannert[1]; J. Paul[2]; O. Krause[2]

1. Forschungsgemeinschaft Feuerfest e.V., Germany
2. Koblenz University of Applied Sciences, WesterWaldCampus, Germany

3:00 PM

(UNITECR-107-2022) In-situ monitoring of magnesia spinel refractories during thermal shock tests by an advanced experimental device (ATHORNA)

R. Kaczmarek*[1]; R. L. Oliveira[2]; J. Dupré[3]; P. DOUMALIN[3]; N. Tessier-Doyen[1]; I. Pop[4]; M. HUGER[1]
1. University of Limoges, UMR CNRS 7315 - IRCER, Centre Européen de la Céramique, France
2. University of Coimbra, ISISE Institute, Department of Civil Engineering, Portugal
3. University of Poitiers, Pprime Institute, UPR CNRS 3346, France
4. University of Limoges, GC2D, France

3:20 PM

Break

3:40 PM

(UNITECR-108-2022) Identification of Mechanical Properties of an Asymmetric Creep Law Applied to Refractories Using the Integrated Digital Image Correlation Technique

L. B. Teixeira*[1]; P. Leplay[2]; J. Gillibert[1]; E. Blond[1]; T. Sayet[1]
1. Univ. Orléans, Univ. Tours, INSA-CVL, LaMé, France
2. Saint-Gobain Research Provence, France

4:00 PM

(UNITECR-109-2022) Influence of Mineralogical Composition on Strength Deterioration by Thermal Cycling of High Alumina Bricks

S. H. Camelli*[1]; P. Marinelli[2]; M. Dignani[1]
1. Instituto Argentino de Siderurgia, Refractory Area, Argentina
2. Ternium Argentina, Refractory Area, Argentina

4:20 PM

(UNITECR-110-2022) Thermoelastic properties of microcracked aluminium titanate based materials at high temperature

M. Mouiya*[1]; Y. Tamraoui[2]; N. Tessier-Doyen[1]; H. Hannache[3]; J. Alami[2]; M. HUGER[1]
1. UMR CNRS 7315, Institute of Research for Ceramics (IRCER), Limoges, France., France
2. Mohammed VI polytechnic university, MSN, Morocco
3. Mohammed VI polytechnic university, MSN, Morocco

4:40 PM

(UNITECR-111-2022) Anelastic relaxation phenomena in alumina-spinel refractories

I. P. Kieliba*[1]; T. Tonnesen[1]; M. HUGER[2]; R. Telle[1]
1. RWTH Aachen University, GHI, Germany
2. IRCER - University of Limoges, France

Steel Making - Mag-Chrome Brick

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Scot Graddick, Imerys

9:20 AM

(UNITECR-112-2022) Zero Carbon Tempered MgO-Cr_2O_3 bricks for RH Degassers: Advances from Customers' Trials

B. L. Borges de Melo*[1]; C. Pagliosa[1]; M. S. Borges[1]; A. A. Campos[1]; V. G. Madalena[1]
1. RHI MAGNESITA, R&D, Brazil

9:40 AM - WITHDRAWN

(UNITECR-113-2022) Phase diagram and additive selection for chrome-free spinel refractories

M. Mahapatra*[1]; S. Mandal[1]
1. University of Alabama at Birmingham, USA

10:00 AM

(UNITECR-114-2022) Improvement in Properties and Performance of Re-bonded Magnesia Chrome Bricks for RH Snorkel

A. Mitra[1]; S. Hazra*[1]; S. Nagpal[1]
1. Dalmia Cement Bharat Limited, India

10:20 AM

(UNITECR-115-2022) New Generation Semi-Rebonded Magnesia Chrome Refractories for RH Degasser

S. Das[1], B. Ghosh*[1]
1. TRL Krosaki Refractories Ltd, R&D, India

Steel Making - Dry-Vibe Ramming Mix

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Scot Graddick, Imerys; Matt Lambert, Allied Mineral Company

11:00 AM

(UNITECR-116-2022) Resin free and environmentally friendly binder for dry vibratable tundish linings

S. Horn*[1]; K. Lippold[1]; S. Barlag[1]; C. Setzer[1]; C. Aneziris[2]; S. Dudczig[2]; D. Veres[2]
1. Chemische Fabrik Budenheim KG, Germany
2. TU Bergakademie Freiberg, Institute of Ceramics, Refractories and Composite Materials, Germany

11:20 AM - WITHDRAWN

(UNITECR-117-2022) Studies on the Properties and Performance of Dry Coating Mass for Tundish working Lining: Effect of raw materials and sintering additives

A. K. Samanta*[1]
1. TRL Krosaki Refractories Limited, Technology, India

11:40 AM

(UNITECR-118-2022) Comparison of Two Dry Vibratable Tundish Linings Through Laboratory Experiments

T. Richards*[1]; J. Smith[1]; R. O'Malley[1]; T. Sander[1]
1. Missouri University of Science and Technology, Materials Science and Engineering, USA

12:00 PM

(UNITECR-119-2022) Magnesia Based Dry Ramming Mass for Induction Furnace Suitable for Steel Refining

H. S. Tripathi*[1]; S. Sinhamahapatra[1]; V. P. Reddy[1]; K. Dana[1]; A. Ghosh[1]
1. CSIR-Central Glass & Ceramic Research Institute, Refractory & Traditional Ceramics Division, India

Iron Making - Casthouse Monolithics

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; William Headrick, RHI Magnesita; John Waters, RHI Magnesita

1:40 PM

(UNITECR-120-2022) Repair Methodology by Injection of Refractory Mass in Blast Furnaces

M. Souza*[1]; R. Couto[1]; R. G. Magalhães[3]; G. Silva[2]
1. Usiminas, Refractory maintenance, Brazil
2. Usiminas, Blast furnace ironmaking, Brazil
3. Vesuvius, R&D, Brazil

2:00 PM

(UNITECR-121-2022) Influence of Type and Grain Composition of High-alumina Coarse Batch Component on Blast Furnace Trough Castable Properties

P. Kushchenko[1]; L. Savina[1]; K. Kushchenko[1], V. Martynenko*[1]
1. Ukrainian Research Institute of Refractories named after A.S. Berezhnoy, Ukraine

2:20 PM - WITHDRAWN

(UNITECR-122-2022) Development of high toughness refractory for iron runner with metal fiber

Y. Okuhara*[1]
1. Nippon Crucible Co/.Ltd, Sourcing & Procurement, Japan

2:40 PM

(UNITECR-123-2022) Trends and Differences in Blast Furnace Main Iron Runner Design

S. Chiartano*[1]; Y. MONVILLE[1]; Y. PRUVOST[1]
1. TRB, France

3:00 PM

(UNITECR-124-2022) Design of improved Al_2O_3 – SiC – C Trough Castable suitable for high MnO in slag

A. K. Samanta*[1]
1. TRL KROSAKI REFRCTORIES LIMITED, Technology, India

3:20 PM

Break

Steel Making - Flow Control Shapes

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Manoj Mahapatra, University of Alabama at Birmingham; Matt Lambert, Allied Mineral Company

3:40 PM

(UNITECR-125-2022) Degradation mechanisms of zirconia-containing refractories in continuous casting nozzles of steelmaking

A. Fallah-Mehrjardi*[1]; J. Berton[1]; D. Dumont[1]

1. Vesuvius GH, Belgium

4:00 PM

(UNITECR-126-2022) Interactions Between Glazed Carbon-Bearing Refractories and Steel Melts

T. Richards*[2]; J. Smith[1]; R. O'Malley[1]; T. Sander[1]

1. Missouri University of Science and Technology, Materials Science and Engineering, USA
2. Missouri University of Science and Technology, Peaslee Steel Manufacturing Research Center, Department of Materials Science and Engineering, USA

4:20 PM

(UNITECR-127-2022) Study of Zirconia-Carbon Refractory containing Y/Ca stabilized zirconia for SEN Application

B. S. Sahu*[1]; A. ADHIKARY[1]; L. P. MALLA[1]; S. CHATTERJEE[1]

1. DALMIA CEMENT (BHARAT) LIMITED, India

4:40 PM

(UNITECR-128-2022) Development of aluminum oxynitride based anti-clogging lining material for submerged entry nozzle

J. Kim*[1]; C. PARK[1]; S. Lee[1]

1. Chosun Refractories Co., Ltd., Republic of Korea

5:00 PM - WITHDRAWN

(UNITECR-129-2022) Research and Application of Long Service Life ZrO_2-C Material Used in SEN

J. Wang*[1]; J. Chen[1]; Y. Liu[1]

1. Puyang Refractories Group Co., Ltd, China

5:20 PM

(UNITECR-130-2022) Application of the fused magnesia with high purity and large crystal size in ladle shroud for continuous casting

L. Pan*[1]

1. Puyang Refractories Group Co., Ltd., China

Refractory Technology and Techniques for Energy Savings

Room: Williford A

Session Chairs: Steven Ashlock, Virginia Kyanite; Manoj Mahapatra, University of Alabama

9:20 AM

(UNITECR-131-2022) Use of Novel Refractory Design and Installation Techniques for Improved Energy Efficiency in Iron and Steel and Other Energy Intensive Industries

J. G. Hemrick*[1]

1. Oak Ridge National Laboratory, USA

9:40 AM

(UNITECR-132-2022) Thermotechnical Properties of Macroporous Foam Ceramics

M. Rath*[1]; R. Stoettner[2]

1. spumix Daemmstoffe GmbH, Management Board, Austria
2. spumix Daemmstoffe GmbH, R&D, Austria

10:00 AM - WITHDRAWN

(UNITECR-133-2022) Macroporous refractory ceramics prepared with ultrastable foams stabilised with Al_2O_3 and calcite

T. dos Santos*[1]; O. H. Borges[1]; I. Finhana[1]; V. R. Salvini[2]; V. C. Pandolfelli[1]

1. Federal University of São Carlos, Materials Microstructure Engineering Group (GEMM), Materials Engineering Department, Brazil
2. College of Technology (FATEC), Sertãozinho, Brazil

10:20 AM - WITHDRAWN

(UNITECR-134-2022) Novel strategies to enhance the properties of macroporous thermal insulators produced with ultrastable Al_2O_3-stabilized foams

I. Finhana*[1]; O. H. Borges[1]; T. dos Santos[1]; V. R. Salvini[2]; V. C. Pandolfelli[1]

1. Federal University of São Carlos, Materials Microstructure Engineering Group (GEMM), Materials Engineering Department, Brazil
2. College of Technology (FATEC), Sertãozinho, Brazil

10:40 AM

(UNITECR-135-2022) Nb_2O_5 containing alumina foams for high temperature applications$_2$

V. R. Salvini*[1]; M. F. Dos Santos[2]; É. França[3]; D. P. Fridman[3]; R. A. Mesquita[3]; M. A. Stuart[4]; V. C. Pandolfelli[5]

1. Solve High Temperature Ceramics, Brazil
2. RED Lab, Brazil
3. CBMM, Sales & Applications Technology, Brazil
4. St3 Consulting, Brazil
5. UFSCar, DEMa - GEMM, Brazil

11:00 AM - WITHDRAWN

(UNITECR-136-2022) Analytical and Numerical Determination of the Volumetric Rate of Thermal Energy Generation in a Refractory Castable

T. M. Portilho*[2]; M. F. Dos Santos[2]; R. A. Angelico[1]; V. C. Pandolfelli[2]

1. Universidade de São Paulo, Aeronautical Engineering Department, Brazil
2. Universidade Federal de São Carlos, Materials Engineering Department, Brazil

11:20 AM

(UNITECR-137-2022) Two Case studies on energy saving refractory techniques in waste recovery coke ovens

R. Mathai*[1]

1. Jindal Saw Ltd., Coke Oven, India

11:40 AM - WITHDRAWN

(UNITECR-138-2022) Spinel and Titanate Structures as an Alternative Solution for High Emissivity Ceramic Coatings

E. Y. Sako*[1]; H. D. Orsolini[1]; M. Moreira[2]; V. C. Pandolfelli[2]

1. Saint-Gobain Performance Ceramics and Refractories, R&D, Brazil
2. Federal University of Sao Carlos, Sao Carlos, Department of Materials Engineering (DEMa), Brazil

12:00 PM

(UNITECR-139-2022) Hydrogen combustion in industrial furnaces and the impact on the corrosion of refractory materials

T. Tonnesen*[1]; T. Leber[1]; M. Kirschen[2]

1. RWTH Aachen University, Institute of Mineral Engineering, Germany
2. University of Bayreuth, Professorship Thermal Process Engineering, Germany

Sustainability of Refractory Materials and Education

Room: Williford A

Session Chair: Matt Lambert, Allied Mineral Company

1:40 PM

(UNITECR-140-2022) Recycled carbon fiber composites as carbon source in refractories

M. Bach*[1]; P. Gehre[1]; M. Bühringer[2]; H. Jansen[3]; C. Aneziris[1]

1. Technische Universität Bergakademie Freiberg, Institute of Ceramics, Refractories and Composite Materials, Germany
2. Alexander Tutsek-Stiftung, Germany
3. Refratechnik Steel GmbH, Germany

2:00 PM

(UNITECR-141-2022) Development of an optimal system to prevent waste refractory dust scattering in HYUNDAI STEEL

J. Han*[1]; J. Kim[1]; T. Woo[1]; M. Hwang[1]; S. Cho[2]; J. Kim[1]

1. Hyundai Steel Company, Republic of Korea
2. Allswell, Republic of Korea

2:20 PM

(UNITECR-142-2022) Steel meets Refractory – a new platform for technical exchange in Germany

A. Buhr*[1]; P. Quirmbach[2]; J. Pischke[3]; E. Steinle[4]

1. Almatis GmbH, Product & Market Development, Gibraltar
2. DIFK, Germany
3. Salzgitter AG, Germany
4. VDFFI, Germany

2:40 PM

(UNITECR-143-2022) How to Benefit from the CDIO Approach to Meet Refractory Education Needs for Innovations

M. Rigaud*[1]; J. Poirier[2]

1. Ecole Polytechnique, Mechanical Engineering, Canada
2. University of Orleans, France

New Developments in Refractory Formulation I

Room: Williford B

Session Chairs: Ashley Hampton, Allied Mineral Products, LLC; Angela Rodrigues-Schroer, Wahl Refractories

9:20 AM

(UNITECR-144-2022) Controlling the sintering process of mullite-zirconia bonded refractories made from zircon and andalusite

A. Villalba Weinberg[2]; J. Poirier*[1]; D. Goeuriot[3]; C. Varona[2]; X. Chaucherie[4]

1. University of Orleans, Fr, CEMHTI-CNRS, France
2. Bony SA, France
3. MINES Saint-Étienne, France
4. SARPI-VEOLIA, France

9:40 AM

(UNITECR-145-2022) ZnO induced spinel-like phase formation on alumina-based castables

O. H. Borges*[2]; J. Sardelli[1]; C. Pagliosa[1]; V. C. Pandolfelli[2]

1. RHI Magnesita, CPQD, Brazil
2. Federal University of São Carlos, Materials Microstructure Engineering Group (GEMM), Materials Engineering Department, Brazil

10:00 AM

(UNITECR-147-2022) Refractory castables dispersed by phosphates (Part 1): influence of chain length, concentration and citric acid on dispersion and stiffening

J. Kasper*[1]; A. Röser[1]; C. Dannert[1]

1. Forschungsgemeinschaft Feuerfest e. V. at the European Centre for Refractories, Germany

10:20 AM

(UNITECR-148-2022) Refractory castables dispersed by phosphates (Part 2): influence of chain length, concentration and citric acid on hardening and CA cement hydration

J. Kasper*[1]; A. Röser[1]; C. Dannert[1]

1. Forschungsgemeinschaft Feuerfest e. V. at the European Centre for Refractories, Germany

10:40 AM - WITHDRAWN

(UNITECR-149-2022) Preparation and Properties of Microcellular High-Strength Thermal Insulation Materials by High Temperature Micro-Foamed

X. Li*[1]; M. Pan[1]; X. Wu[1]; X. Zhan[1]; H. Ma[1]; C. Ma[1]

1. School of Materials Science and Engineering Zhengzhou University, Henan Key Laboratory of High Temperature Functional Ceramics, Zhengzhou 450052, China

11:00 AM

(UNITECR-150-2022) Designed porous aggregates – a new path towards more sustainable steel ladle refractories

C. Wöhrmeyer*[1]; J. Gao[1]; M. Szepizdyn[1]; S. Graddick[1]; C. Liu[1]

1. Imerys, France

11:20 PM - WITHDRAWN

(UNITECR-151-2022) The effect of Nano-Iron on microstructure and phase evolution of MgO-C refractory treated by iron nitrite

H. Rastegar[1]; m. bavand-vandchali[1]; F. Golestani-fard*[3]; A. Nemati[2]

1. Department of Materials Engineering, Saveh Branch, Islamic Azad University, Islamic Republic of Iran
2. Materials Science & engineering, Sharif University of Technology, Tehran, Iran, Tehran, Tehran, Iran (the Islamic Republic of)., Department of Materials Science and Engineering, Islamic Republic of Iran
3. Refracto-Ceramic Consultancy LTD, United Kingdom

11:40 AM

(UNITECR-146-2022) Design and production of coarse-grained aggregates for (Nb/Ta)-Al_2O_3 refractory composites

P. Gehre*[1]; T. Zienert[1]; D. Endler[1]; J. Hubálková[1]; C. Aneziris[1]

1. TU Bergakademie Freiberg, Germany

New Developments in Refractory Formulation II

Room: Williford B

Session Chair: Angela Rodrigues-Schroer, Wahl Refractories

1:40 PM

(UNITECR-152-2022) Dispersion-strengthened Al_2O_3-MgO-C refractories

K. S. Chandra*[1]; D. Sarkar[1]

1. National Institute of Technology (NIT), Ceramic Engineering, India

2:00 PM

(UNITECR-153-2022) Advanced strontium zirconate refractories for investment casting titanium alloys

S. Uwanyuze*[1]; S. Schaffoener[2]; P. Alpay[1]

1. University of Connecticut, Materials Science and Engineering, USA
2. University of Bayreuth, Ceramic Materials Engineering, Germany

2:20 PM - WITHDRAWN

(UNITECR-154-2022) Review of the Design Principles for Corrosion Resistant Refractories

P. Walls*[1]

1. Hitech Materials Pty Ltd, Australia

2:40 PM

(UNITECR-155-2022) Comparative analytical characterization of two carbonaceous binders used in refractory materials

P. Quirmbach[1]; J. Doll*[1]

1. University of Koblenz-Landau, Germany

3:00 PM

(UNITECR-183-2022) Challenges in characterization of Ferro silicon nitride and determining its suitability for use in taphole clays for Blast Furnaces

P. Srinivasa Rao*[1]

1. Vesuvius Refractory India Private Limited, India

Refractories for Cement and Lime

Room: Williford C

Session Chair: Kelley Wilkerson, Missouri S & T University

9:20 AM

(UNITECR-156-2022) Magnesia-Spinel Brick with Excellent Coating Adherence for Cement Rotary Kilns

M. Ohno*[1]; S. Takeuchi[1]; H. Toda[1]; Y. Yoshimi[1]

1. MINO CERAMIC CO., LTD., Technical Research Laboratory, Japan

9:40 AM

(UNITECR-159-2022) Development of alkali corrosion resistant high temperature materials

P. Gehre*[1]; C. Dietze[1]; T. Schemmel[2]; M. Bühringer[3]; H. Jansen[2]; C. Aneziris[1]

1. Technische Universität Bergakademie Freiberg, Institute of Ceramics, Refractories and Composite Materials, Germany
2. Refratechnik Steel GmbH, Germany
3. Alexander Tutsek-Stiftung, Germany

10:00 AM

(UNITECR-157-2022) Energy efficient periclase-magnesium aluminate spinel refractory for cement rotary kiln

W. Yan*[1]

1. Wuhan University of Science and Technology, The State Key Laboratory of Refractories and Metallurgy, China

10:20 AM

(UNITECR-158-2022) Sustainable Linings For Rotary Kilns

H. Klischat*[1]; P. Groger[2]; H. Wirsing[1]

1. Refratechnik Cement GmbH, Research & Development, Germany
2. Refratechnik Cement GmbH, Sales Department, Germany

10:40 AM

Break

11:00 AM

(UNITECR-160-2022) Effect of fuel composition on refractory linings in cement clinker production

K. Weber[1]; J. Södje[1]; S. Uhlendorf[1], H-J. Klischat*[1]

1. Refratechnik Cement GmbH, Research & Development, Germany

11:20 AM

(UNITECR-161-2022) Spinosphere Technology - an Innovative flexibilization technology

M. Geith*[2]; R. Krischanitz[1]; S. Jörg[2]

1. RHI Magnesita GmbH, Global Product Management, Austria
2. RHI Magnesita GmbH, Research & Development, Austria

Refractories for Aluminum

Room: Williford C

Session Chair: Ashley Hampton, Allied Mineral Products, LLC

1:40 PM

(UNITECR-162-2022) Influence of Modern Aluminum Alloys on the Reaction Behavior of Refractory Linings

T. Tonnesen*[1]; W. R. Reichert[1]; R. Telle[1]

1. RWTH Aachen University, Institute of Mineral Engineering, Germany

2:00 PM - WITHDRAWN

(UNITECR-163-2022) Development of New Generation Tie-rod Refractory Brick for Anode Baking Furnace Application

J. P. Nayak*[1]

1. TRL Krosaki Refractories Ltd, Technology (R&D), India

Friday, March 18, 2022

Plenary II

Room: Williford A, B, C

Session Chair: James Hemrick, Oak Ridge National Laboratory

8:00 AM

Introduction of Speaker

8:10 AM

(UNITECR-PLEN-002-2022) Frontiers in Refractories

D. G. Goski*[1]

1. Allied Mineral Products, LLC, USA

9:00 AM

Break

Iron Making - Shapes and Monolithics

Room: Joliet

Session Chairs: Scot Graddick, Imerys; William Headrick, RHI Magnesita

9:20 AM

(UNITECR-164-2022) Improvement in torpedo ladle refractory corrosion rate by mist cooling

K. Taniguchi*[1]; H. Matsunaga[1]; K. Takahashi[1]

1. JFE steel corporation, Japan

9:40 AM

(UNITECR-165-2022) Study and application of wet shotcrete castable sprayed on iron ladle working linings

Y. Wang*[1]; w. chen[1]; Y. Wang[1]; Y. Wang[1]; Y. Qin[1]

1. Puyang Refractories Group Co., Ltd., China

10:00 AM

(UNITECR-166-2022) Effect of Firing Temperature and Creep Rate Testing Temperature on Creep Resistance of Sillimanite-Based High Alumina Brick

F. LI[1]; K. Yin*[1]; T. Ge[2]; Y. Yang[1]

1. Zhengzhou Annec Industrial Co., Ltd, Refractory Technology, China
2. Zhengzhou University, China

10:20 AM

(UNITECR-167-2022) Innovative fused silica pre-shaped refractory for coke ovens

L. Roumigiuer[2]; F. Delobel*[1]; P. Pilate[1]

1. Belgian Ceramic Research Center, Belgium
2. Belref SA, Belgium

Steel Making - Argon Plugs and Slidegate Plates

Room: Joliet

Session Chairs: Manoj Mahapatra, University of Alabama at Birmingham; Scot Graddick, Imerys

11:00 AM

(UNITECR-168-2022) Improved Slag and Metal Resistance of Bottom Blowing Purging Plugs with Fused Magnesia-Alumina Spinel Doped by Chromic Oxide

V. Martynenko*[1]; P. Kushchenko[1]; I. Shulik[1]; L. Zolotukhina[1]

1. Ukrainian Research Institute of Refractories named after A.S. Berezhnoy, Ukraine

11:20 AM

(UNITECR-169-2022) Preparation of corundum-mullite castables for purging plug in ladle

G. Liu*[1]

1. Puyang Refractories Group Co., Ltd., China

11:40 AM

(UNITECR-170-2022) Development of Sliding Valve Plates Containing Metal Chromium

H. Baba*[1]; N. HAMAMOTO[1]; W. LIN[1]; T. MATSUNAGA[1]

1. Shinagawa refractories CO., LTD., Japan

Iron Making - Taphole Clay Development

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Matt Lambert, Allied Mineral Company; Ashley Hampton, Allied Mineral Products, LLC

9:20 AM - WITHDRAWN

(UNITECR-171-2022) Graphene-like structured tap hole clay for long lasting casting times and lower CO_2 emissions

E. Y. Sako*[1]; D. F. Galesi[1]; H. D. Orsolini[1]; D. Hespanhol[1]; N. Januario[1]; B. M. Silva[1]

1. Saint-Gobain Performance Ceramics and Refractories, R&D, Brazil

9:40 AM

(UNITECR-172-2022) Premature cross-linking in a resole resin and synthetic coal tar pitch binder system as cause of reduced workability of a blast furnace taphole clay

I. Cameron*[1]; S. Ramjee[1]; A. Garbers-Craig[1]

1. University of Pretoria, Materials Science & Metallurgical Engineering, South Africa

10:00 AM

(UNITECR-173-2022) Study on the thermal-pyrolysis kinetics of blast furnace THC with aging

C. Shao*[1]; C. LIU[1]

1. China Steel Corporation, Research and Development Department, Taiwan

10:20 AM

(UNITECR-174-2022) The Study and Application of MgO-C Based Tap Hole Clay for Submerged Arc Furnace

H. Zhu*[1]

1. Puyang Refractories Group Co., Ltd, China

Steel Making - Future Needs

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Ashley Hampton, Allied Mineral Products, LLC; Angela Rodrigues-Schroer, Wahl Refractories

11:00 AM

(UNITECR-175-2022) Evaluation of the possible changes of refractory linings for green steel processes

B. Touzo[1]; B. Hiot*[2]; N. Eliazord[3]

1. Imerys, Science and Technology, Belgium
2. Calderys, France
3. Calderys, France

11:20 AM

(UNITECR-176-2022) Zero Carbon Tempered Bricks for Safety Lining: Complete Energy Saving Solutions for Steel Ladle

J. Sardelli*[1]; C. Pagliosa[1]; M. S. Borges[2]

1. RHI Magnesita, R&D, Brazil
2. RHI Magnesita, TE&S, Brazil

11:40 AM - WITHDRAWN

(UNITECR-177-2022) The Development and Status of advanced Refractory Technologies for Converter

Y. Zhang*[1]

1. Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China

Refractories for Glass

Room: Williford B

Session Chair: Angela Rodrigues-Schroer, Wahl Refractories

9:20 AM

(UNITECR-178-2022) Stress elastic analysis of AZS fused cast blocks for glass furnaces

T. M. De Oliveira*[1]; M. F. Dos Santos[1]; R. A. Angelico[2]; V. C. Pandolfelli[1]

1. Federal University of Sao Carlos, Department of Materials Engineering, Brazil
2. University of São Paulo, Department of Aeronautical Engineering, Brazil

9:40 AM

(UNITECR-179-2022) Ultra-Low Exudation of Fused Cast Alumina-Zirconia-Silicate Refractory for Glass Melting Furnaces

F. Wei[2]; W. Zhu[2]; Y. Wu*[1]

1. ICEON Glasstech Limited Co., USA
2. Anhui Sino-Refractory Technology Co., Ltd., China

10:00 AM

(UNITECR-180-2022) New Yttria-Stabilized Fused Cast AZS for Glass Melting Furnaces

Y. Wu*[1]; F. Wei[2]

1. ICEON Glasstech Limited Co., USA
2. Anhui Sino-Refractory Technology Co., LtD, China

Use of Artificial Intelligence, Machine Learning, and Big Data in Refractory Technology

Room: Williford C

Session Chair: Manoj Mahapatra, University of Alabama at Birmingham

9:20 AM

(UNITECR-181-2022) Operational Refractory Management of Hot Metal Process Installations Using a FEM Based Digital Twin

P. van Beurden[1]; B. Luchini[1]; S. Sinnema*[1]

1. Tata Steel Netherlands, Research & Development, Netherlands

9:40 AM

(UNITECR-182-2022) Improving taphole clay performance by machine learning tools

M. F. Dos Santos*[1]; M. G. Campos[2]; E. Y. Sako[2]; D. Hespanhol[2]; B. G. Rangel[2]; V. C. Pandolfelli[1]

1. Federal University of Sao Carlos, Department of Materials Engineering, Brazil
2. Saint-Gobain Performance Ceramics & Refractories, Brazil

The American Ceramic Society

2022 Conference on Unified International Technical Conference on Refractories (UNITECR 2022)
17th Biennial Worldwide Congress on Refractories

ABSTRACT BOOK

March 16–18, 2022
Chicago, Illinois

Introduction

This volume contains abstracts for over 200 presentations during the 2022 Conference on Unified International Technical Conference on Refractories (UNITECR 2022) 17th Biennial Worldwide Congress on Refractories in Chicago, Illinois. The abstracts are reproduced as submitted by authors, a format that provides for longer, more detailed descriptions of papers. The American Ceramic Society accepts no responsibility for the content or quality of the abstract content. Abstracts are arranged by day, then by symposium and session title. An Author Index appears at the back of this book. The Meeting Guide contains locations of sessions with times, titles and authors of papers, but not presentation abstracts.

How to Use the Abstract Book

Refer to the Table of Contents to determine page numbers on which specific session abstracts begin. At the beginning of each session are headings that list session title, location and session chair. Starting times for presentations and paper numbers precede each paper title. The Author Index lists each author and the page number on which their abstract can be found.

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Wednesday, March 16, 2022

Refractory Characterization and Testing I

Room: Joliet
Session Chairs: Dawn Hill, Exertech LLC; Bob Hunter, Special Shapes Refractory Co.

10:40 AM

(UNITECR-001-2022) Oxidation behaviour and thermomechanical characterization of silicon carbide containing castables

F. Delobel[1]; P. Dietrich[2]; F. Holleyn[3]; L. Erbar[3]; C. Dannert[2]; O. Krause[3]; P. Pilate*[1]

1. Belgian Ceramic Research Center, Belgium
2. Forschungsgemeinschaft Feuerfest e. V., Germany
3. Hochschule Koblenz, Germany

SiC containing materials are currently used in incineration of waste. They have a high corrosion resistance against alkaline vapours and due to their high thermal conductivity, they are less sensitive to thermal stress. Castables could be used, but they suffer of a lack of strength in the temperature range of 800 to 1350°C. However, castables are inevitable as repair mixes and for building of complex structures, because they allow to reduce significantly downtimes for repair. With increasing SiC content, the resistance to corrosion, thermal shock and gradient are significantly improved. However, SiC is sensitive to oxidation and especially if water vapour is present. In this work, the oxidation behaviour of a lot of silicon carbide raw materials was tested and discussed versus the particle size and other parameters. Castable with different compositions and SiC content were also tested and their oxidation resistance was discussed versus their composition, SiC content and raw materials characteristics. Mechanical properties (Young modulus and strength) were also measured versus temperature to evaluate the effect of a first heating.

11:00 AM - WITHDRAWN

(UNITECR-002-2022) The Impact of beta-alumina to spinel-formation in refractory castables

J. Paul*[1]; O. Krause[1]; L. Reichert[1]; F. Holleyn[1]

1. Hochschule Koblenz, Germany

Spinel forming refractories are frequently used for refractory linings, because of their outstanding thermo-mechanical properties. In these refractories the volume expansion of the forming spinel counteracts the shrinkage of the refractory and densifies the monolithic structure. In addition, the {111} lattice translation as typical for spinel increases the thermal shock resistance. This presentation focuses on the implication of the typical impurity, β-alumina on the formation of spinel. It could be clearly figured out that the presence of β-alumina affects the spinel yield, because the chemical affinity of Mg is higher to be incorporated in β-alumina to form β″-alumina instead of spinel. However, the thermal stability even if it is higher for β″-alumina is limited to approximately 1500 °C under long-term use. In consequence when β″-alumina is thermally decomposed, and Mg is released ready to develop a second generation of spinel. The presentation will discuss how distinct additions of β-alumina to the refractory castable may contribute to the thermal stability in long term use. Therefore, the thermal behavior of spinel forming refractory castables with certain additions of β-alumina was focus on this study.

11:20 AM

(UNITECR-003-2022) Investigation of Sintering Characteristics of a 70% Alumina Dry-Vibratable Refractory Material

M. Raughley*[1]

1. HarbisonWalker International, Research and Development, USA

Dry vibratables are used in many applications including between working and backup linings of steel ladles to stop penetration and reduce shell temperatures and to help level ladle bottom bricks. The sintering characteristics of dry vibratables are very important because they can influence both performance and tearout. An investigation to characterize the sintering behavior of a 70% alumina material using borax as a sinering aid was done. A relationship between the percentage of sintering aid and the sintering temperature was developed. The relationship was established by measuring the degree of sintering in lab specimens. In addition, the FactSage analysis tool was used to assess the phase changes that occurred based on the sintering aid level and correlate these results to the lab measured data.

11:40 AM

(UNITECR-004-2022) Thermomechanical behaviour of refractory dry-stacked masonry walls

R. L. Oliveira*[1]; J. C. Rodrigues[1]; J. M. Pereira[2]; P. Lourenço[2]; H. U. Marschall[3]; M. Ali[4]

1. University of Coimbra, Faculty of Sciences and Technology, Portugal
2. ISISE, Portugal
3. RHI Magnesita, Austria
4. Université d'Orléans, LaMé laboratory (EA 7494), France

The vessels used in industrial high temperature processes of steel and cement production are protected by refractory linings built with dry-stacked masonry, which plays a crucial role on the overall behaviour of the vessels. This paper presents the results of an experimental and numerical research on dry-joint refractory masonry. Its main purpose is to fully characterize the masonry walls at different temperatures and different loading conditions. Several aspects that may influence the behaviour of these walls have been tested, namely the loadbearing capacity, the behaviour under cyclic loading and the restrained thermal elongation. The experimental results allowed to identify the effects of the stresses concentrations caused by brick's height imperfections in the mechanical behaviour of the bricks and in the loadbearing capacity of specimens, the evolution of the wall's Young's modulus with the load application, the developed crack patterns and the mechanical behaviour of the samples under room and elevated temperatures. Numerical models were also developed to simulate the behaviour of the walls under different testing conditions and a good agreement with the experimental results was obtained.

12:00 PM

(UNITECR-005-2022) Reaction Textures in Al_2O_3-SiO_2 Bricks induced by gaseous SO_x Attack: New Insights from Mineralogy and Thermodynamic Modelling

P. Schantl*[1]; C. Majcenovic[1]

1. RHI Magnesita, Austria

In the sulphate process, Al_2O_3-SiO_2 bricks are used as refractory lining in rotary kilns. During calcination of hydrated TiO_2, the bricks are subjected to highly corrosive SO_x gas attack. A mineralogical study on reaction textures and compositional zoning from the hot face towards the cold end of a used fireclay brick in combination with thermo-chemical modelling allows to reconstruct the modification of the brick microtexture and the acting wear mechanism. Gaseous SO_x supply results in alteration of the mullite dominated brick matrix up to a depth of ~28 mm through mullite decomposing and aluminium-sulphate + quartz forming reactions. Based on thermo-chemical calculations these reactions appear between 760 to 440 °C. In a second step, the newly formed aluminium-sulphate decomposes and transforms to flaky corundum. This can be only observed at the very hot face of the brick, up to depth of ~10 mm, where minimum temperatures of 720-780 °C are reached. This two-step corrosion texture development leads to a weakening of the brick bonding structure and enables consequent discontinuous material loss by abrasive wear during the feed material transport through the rotary kiln. The current post-mortem study further allows to recommend a special silica sol impregnation to improve the resistance of the brick matrix against volatile SO_x attack.

Refractory Characterization and Testing II

Room: Joliet
Session Chairs: Dawn Hill, Exertech LLC; Bob Hunter, Special Shapes Refractory Co.

1:40 PM

(UNITECR-006-2022) Phase composition and microstructure of silica bricks characterized by micro-Raman spectroscopy

R. Tokunaga*[1]; K. Goto[1]; K. MORIKAWA[1]

1. KROSAKI HARIMA CORPORATION, Technical Reserch Laboratories, Japan

Microstructure of polymorphous substance like silica has been conventionally characterized by polarizing microscope through identifying the difference in the optical property of the ingredient crystal phases. The composition of the phases in the substance, however, is not able to determine quantitatively by the polarizing microscope. Since a method using micro-Raman spectroscopy made possible the quantitative analysis through detecting the difference in the Raman spectrum for composed phases, variations of the phase composition and microstructure of the silica bricks during firing process were investigated. Quartz as main phase of the silica bricks starts to transform to cristobalite at the grain boundary area by heating up to the firing temperature of 1450 °C. After keeping at the temperature for 5 h, the main phase of the brick became to cristobalite and tridymite with small amount of retained quartz at the grain interior. For the prolonged firing time, both peak intensity and microstructure image in the micro-Raman spectroscopy clarified that the occupation of the tridymite phase increased with the firing time and in all the samples fired up to for 10 h, the quartz, cristobalite and tridymite phases were confirmed to exist in the state of the mix phase, then only two phases of the cristobalite and tridymite were confirmed for 30 h firing.

2:00 PM

(UNITECR-007-2022) Test Method for Purge Plug Corrosion Resistance and Metal Penetration

Q. Robinson[1]; P. Hunger[1]; J. Sliwinska*[1]

1. Vesuvius Research, USA

A novel test method was developed for evaluating the corrosion resistance of refractory ceramic materials used for argon purging in steel ladles. This new test uses a purge plug, mounted into the bottom of a 250kg capacity ladle. Potential mechanisms of erosion and steel penetration were investigated and correlated with testing parameters employed in the test. Differences in steel penetration between directional and random porosity refractory containing purge plugs were evaluated. A significantly improved erosion resistance was measured for the next generation porous purge plug compared to other commercially available porous purge plugs.

2:20 PM

(UNITECR-008-2022) SiO_2-CaO-Al_2O_3 slag viscosity measurement by aerodynamic levitation

Z. Zhang*[1]; E. de Bilbao[1]

1. CNRS, CEMHTI UPR3079, Univ. Orléans, F-45071 Orléans, France, France

Slag corrosion resistance understanding and modeling of refractory require accurate thermophysical properties such as density, surface tension and viscosity. However, measuring such properties at high temperatures with conventional methods is very difficult due to possible reactions between slag and crucible. On the contrary, the aerodynamic levitation technique which is a container-less method prevents container contamination and provides accurate data. The aerodynamic levitation with acoustic excitation was used to measure thermophysical properties for slag composed of CaO-Al_2O_3 in a wide range of temperature from 1650 to 2400 °C. CaO-Al_2O_3 melts corresponding to C3A, C12A7, CA and CA2 mixtures were tested. The density, surface tension and viscosity of melts all showed downtrends, especially, the exponential decline trends of viscosity. In the temperature range of 1650 to 2400 °C, the viscosity range of C3A, C12A7, CA and CA2 were 80.7-16.0 mPas, 135.5-23.6 mPas, 98.6-24.4 mPas, 67.7-23.0 mPas, respectively. The experimental results were compared with viscosity assessed with Urbain's model and FactSage® calculation. It was found that the decreasing trends of viscosity were basically consistent with the results calculated by Urbain's model and FactSage®. SiO_2-CaO-Al_2O_3 melts based on CaO/Al_2O_3 = 1 wt.% and SiO_2 content from 5 to 25 wt.% are being tested and results will also be presented at the conference.

2:40 PM

(UNITECR-009-2022) Examination of the Binary System Al_2O_3-ZrO_2 by Aero Acoustic Levitation Melting

J. Niessen*[1]; D. Muehmer[1]; T. Tonnesen[1]; R. Telle[1]; J. Gonzalez[1]

1. RWTH University, Germany

Al_2O_3-ZrO_2 composites exhibit excellent mechanical and high-temperature properties. The solidification of various hypo eutectic compositions has been studied by means of aero-acoustic levitation. A high-speed camera recorded the crystallization, to the correlation of the video stills with the observed microstructures. Solidification takes place by formation of several nuclei and subsequent growth. Nuclei are formed in the supercooled melt, entailing to a fine-grained, simultaneously solidified structure. The remaining melt between the growing nuclei is heated due to recalescence leading to primary precipitation of zirconia, followed by eutectic solidification. A consistent behavior is presented to explain the observed microstructures. Additionally, samples between 40-50 mol% ZrO_2 exhibit lamellar areas, which exceed the initial zirconia composition. The observed microstructure strongly indicates the existence of a liquid miscibility gap.

3:00 PM

(UNITECR-010-2022) Ab inito and electrochemical impedance spectroscopy (EIS) studies on the hydration behaviour of cement-bonded refractory composites

A. Kruk*[1]; J. Ramult[2]; K. Warmuz[2]; D. Madej[2]

1. Pedagogical University of Cracow, Institute of Technology, Poland
2. AGH University of Science and Technology, Faculty of Materials Science and Ceramics, Poland

New approach to equivalent circuit modelling of the CaO-SrO-Al_2O_3-H_2O-based cement-bonded refractory composites was implemented to interpret spectra obtained from EIS, assigning electrical responses to the hydration features such as hydration products types and microstructure. Properties of new refractory composites and progress of cement hydration were derived from the development of a high-frequency arc in the Nyquist plot with hydration time. Both, early and long-term kinetic investigations on the hydration of cement-bonded refractory composites were also traced by means of XRD, DSC-TG-EGA-MS and SEM-EDS. The time development of both compressive and flexural strength, including results of 1, 3 and 7-day testing were determined. This paper deals also with the ab inito calculations (WIEN2K code) of the structural, elastic, and thermodynamic properties for the tested materials. Especially, the theoretical electron density of states and theoretical value of the bulk modulus of the analysed materials were investigated in the present work. The experimental data were correlated with the ab inito calculations. Acknowledgements This study was partly supported by the statutory funding of Pedagogical University of Cracow (Recipient: AK) and the National Science Centre, Poland, project number 2017/26/D/ST8/00012 (Recipient: DM).

3:40 PM

(UNITECR-011-2022) Direct Observation of Drying by Neutron and X-ray Tomography Analysis

M. H. Moreira*[3]; S. Dal Pont[2]; A. Tengattini[4]; A. Luz[3]; T. M. Cunha[3]; R. F. Ausas[1]; V. C. Pandolfelli[3]

1. University of São Paulo, Institute of Mathematical and Computer Sciences, Brazil
2. Université Grenoble Alpes, 3SR, France
3. Federal University of São Carlos, Graduate Program in Materials Science and Engineering (PPGCEM), Brazil
4. Institut Laue-Langevin, Large Scale Structures, France

The drying of refractory monolithics is one of the main drawbacks of this class of materials due to its implication on the production halt of many industrial equipment. This is especially true for calcium aluminate cement (CAC)-bonded castables, where the vapor derived from the unreacted water and dehydration reactions can pressurize yielding cracks and explosions of the ceramic lining. Numerous advances on additives have been made to increase these materials' resistance to explosive spalling, however, the fundamentals of the physical phenomena that yields such a problem remain an open issue. For years, the techniques used to study this process were limited to indirect tests, such as the thermogravimetric analysis or the pressure and temperature measurements of samples being unidirectionally heated. Recently, direct techniques such as nuclear magnetic resonance and X-ray tomography were applied in the context of regular concrete on fire scenarios. The current work presents preliminary results of neutron tomography applied to monitoring the drying of refractory castables. The overall behavior of the castable was qualitatively similar to those observed for regular concrete, and the results provide information that can be successfully employed on numerical simulations of larger pieces with dimensions closer to the industrial ones, overcoming the main drawback of such techniques, their small sample dimensions.

4:00 PM

(UNITECR-012-2022) Effect of Internal Pores on Properties in Castable Refractories

Y. Sasatani*[1]; K. YAMADA[1]; T. OKADA[1]; K. MORIKAWA[1]

1. KROSAKI HARIMA CORPORATION, Japan

When water is added to the powder of castable refractories and kneaded with a mixer, air is entrained and remains as internal pores in the casted body after curing, which may affect the durability. Therefore, it is important to clarify the relationship between the pores inside the body and the physical properties. Recently, X-ray CT, which can visualize the internal structure three-dimensionally without destruction, has been actively applied to refractories. Therefore, in this report, we investigated the pores inside the body of alumina-silica castable refractories by X-ray CT and analyzed the relationship with various physical properties.

4:20 PM

(UNITECR-013-2022) Observation of the setting process of unshaped refractory materials by dynamic-mechanical analysis

V. Hopp*[1]; A. Masoudi Alavi[1]; A. Sax[1]; P. Quirmbach[1]

1. University of Koblenz-Landau, Institute for Integrated Natural Sciences, Technical Chemistry, Germany

The investigation of the stiffening behavior of unshaped refractories is essential for an adequate lining process. The most common method to monitor the stiffening is to observe the propagation of ultrasonic waves in the material over time. However, this method is not applicable for every refractory system. In some cases, it could be shown that the propagation of the ultrasonic waves does not directly correlate with the increase of the mechanical strength and thus the real hardening of the mixture. Therefore, an alternative measuring method is presented. The so-called Dynamic-Mechanical Analysis (DMA) provides a new approach for the observation of setting processes. Although originated in the plastics research area, this method can be adapted for inorganic systems as for example unshaped refractories. It allows monitoring the evaluation of the viscoelastic properties of a material as a function of time and temperature, thus representing a powerful tool for time-dependent tracking of the strength-development during setting processes. In addition, frequency-dependent measurements offer the possibility to determine characteristic points in the setting process as for example the gel and the glass point in sol-gel-bonded systems. The suitability of the Dynamic-Mechanical Analysis for the class of unshaped refractories is shown by means of hydraulic and chemically bonded materials.

4:40 PM

(UNITECR-014-2022) Study of the Addition of a Special Chemical Mix Additive and Curing Temperature on the Setting Time and Mechanical Properties of No-cement Castable

A. Cristante*[1]

1. Reno Refractories, Inc., USA

Tight installation schedules and economic pressures are potential drawbacks for castable installation and performance. Many factors influence the setting behavior and the properties of no-cement castable refractories including temperature and chemical composition. In this study, the setting behavior and the mechanical properties of a no-cement castable were analyzed varying the amount of a special chemical additive mix and curing temperature. The special chemical additive mix concentration was varied from 0wt% to 1wt%. The curing temperature was varied from low (4°C/40°F) to high (40°C/104°F). The mechanical properties were characterized by cold crushing strength (CCS). A variance in the pH level drastically increased the setting time of the castable. Mechanical properties on green samples showed lower strength for castables with higher concentration of the special mix. This difference in performance is the result of the lower pH preventing the formation of a chain mechanism in the no-cement castable bonded with colloidal silica.

Refractory Student and Young Professionals I

Room: Marquette

Session Chair: Austin Scheer, Kyanite Mining Corportation

3:40 PM

(UNITECR-015-2022) Influence of $MgAl_2O_4$-spinel additions on the phosphate bonding in Al_2O_3-refractories

D. Hahn*[1]; P. Quirmbach[1]

1. University of Koblenz-Landau, Technical Chemistry and Corrosion Sciences, Germany

Phosphates are used in high-temperature materials as bonding agents to increase the (early-)strength and resistances towards corrosive mediums. Although the initialisation of phosphate bonds has been elucidated in scientific literature, especially networking and cross-linking of phosphate spezies during firing as well as their interaction and compatibility with other ceramic components are still not clearly understood and insufficiently investigated. This research concerns how the addition of $MgAl_2O_4$ to an alumina-rich refractory changes its bonding mechanism and, consequently, affects key performance characteristics of the ceramic. The approach is based on a comprehensive structural analysis (solid-state NMR, XRD) which gives insight into structural changes of the bonding phase and, ultimately, allows structure-property-correlations to be drawn. Results demonstrate that the addition of $MgAl_2O_4$-spinel (1) leads to the formation of Magnesium hydrogen phosphates during initialisation, (2) influences the cross-linking of the aluminium phosphate bonding network (less polymerisation) and (3) results in Mg-containing high-temperature ortho phosphates, which significantly reduce the bonding capacity and high temperature properties of the refractory.

4:10 PM

(UNITECR-016-2022) Development of greener and more effective high-temperature thermal insulators

O. H. Borges*[1]; T. dos Santos[1]; V. R. Salvini[1]; V. C. Pandolfelli[1]

1. Federal University of São Carlos, Materials Engineering Department (DEMa), Brazil

Since mankind started to apply fire to make Earth more suited to their lifestyle, the use of energy became to be closely related to life quality. Nowadays, we are facing a high-demand energy scenario and the easiest pathway to supply such growing requirements is by increasing energy efficiency. In this context, high-temperature industries play a key role, accounting for 13% of all power consumed worldwide. Using a nontoxic direct foaming method, alumina, $CaCO_3$, and distinct mineralizing agents were applied to produce macroporous thermal insulators. In these systems, Al_2O_3 and CaO react to form calcium hexaluminate (CA_6), which is accompanied by a remarkable expansion. This feature was used to counterbalance the high shrinkage of the porous media, leading to a material with no dimensional changes after firing at 1600°C for 5h. Furthermore, lower strengthening and CA_6 formation temperature were observed and attributed to the use of $CaCO_3$ and the addition of ZnO or TiO_2 as mineralizing agents, respectively. The most promising composition gave rise to an insulator that presents high porosity (80%) and refractoriness (>1600°C), no shrinkage after firing, and low thermal conductivity (0.53W/mk at 1200°C). Therefore, an alternative to the fiber-based insulator was obtained and its application could increase the efficiency of energy-intensive industries, lowering environmental impacts and production costs.

4:40 PM

(UNITECR-017-2022) Impact of Olivine on Refractory Corrosion Resistance

T. Richards*[1]; J. Smith[1]; R. O'Malley[1]; T. Sander[1]

1. Missouri University of Science and Technology, Materials Science and Engineering, USA

The corrosion behavior of dry vibratable tundish lining materials was studied. Compositions were batched using periclase and increasing amounts of olivine. A corrosion cup test was employed to react the refractory material with a basic commercial tundish flux. Cathodoluminescence was employed to highlight the migration of silica within the refractory samples, and the chemistry of the resulting phases was determined using energy dispersive spectroscopy. FactSage was used to predict the phases present in the samples, and suggest possible reaction mechanisms that would result in the loss of olivine aggregates from tundish lining material.

5:10 PM

(UNITECR-018-2022) Use of Dilatometer to Screen Refractory Raw Materials (Invited)

S. Mandal*[1]; M. Mahapatra[1]

1. University of Alabama at Birmingham, Materials Science and Engineering, USA

Sudden shortage of a particular raw material due to freight disruptions, competitive market, and COVID restrictions have frequently forced the refractory industry to rapidly develop alternative formulations using available low-cost materials. Time-consuming trials are necessary as the potential candidate replacement ingredients just don't differ slightly in chemistry and particle size, the variation in impurities, mineral composition and powder tapped density greatly impact the liquid phase formed at high temperature (and thereby hot strength), firing shrinkage/ expansion that cause warpage, and high porosity that reduces both strength and corrosion resistance. Dilatometer studies on pressed or cast samples in a single test can identify reaction temperatures of spinel or mullite formation which expand during firing, the amount of expansion and exact times at which firing needs to be done. It can also compare relative shrinkage due to liquid phase formation among impure raw materials like recycled grogs or low-grade ores. Finally, dilatometric step scan is shown as a fast technique to prepare in-house, low-cost reactive spinel powder which can also work for mullite.

Theodore J. Planje Award Session I

Room: Marquette

Session Chairs: James Hemrick, Oak Ridge National Laboratory; Jeffrey Smith, Missouri S&T

10:50 AM

(UNITECR-019-2022) How much and what type of refractory do steel plants really use? An Accurate Refractory Cost / Usage Model for the North American Steel Industry (Invited)

T. Vert*[1]

1. Independent Expert, Canada

Steel plants use roughly 60% of all refractories worldwide, and yet, when trying to find accurate models of how much refractory is used it is very difficult. Currently public models available are extremely costly and based on import/export and financial data from public refractory companies and are inaccurate due to their top-down approach. A new model has been created using a "bottom-up" approach using 30 years of in plant refractory experience combined with actual operating North American AIST steel plant production data. The results are a very accurate model that shows usage of refractory in steel plants by type, by region, and by spend! This paper will give an overview summary of the current state of refractory usage in steel plants in North America and a forecast for 2030 based on the author's knowledge of both the steel and refractory industry.

11:20 AM

(UNITECR-020-2022) Metal Anchors: An Abreviated Review (Invited)

R. Engel*[1]

1. Refractory Consulting Services, USA

Anchors have been used to hold monolithic refractories in place for a long time. Notwithstanding this long history, it is estimated that anywhere from 40% to 60% of all lining failures are the result of a lack of proper anchor design and installation. Many decisions have to be made when designing a lining, installing it and bringing the unit to operating conditions and they require the proper interplay of anchor and refractory for success. Among the many areas that need to be considered are anchor installation method and density, effect of operating temperature, atmosphere, refractory type, panel size, joint position, and many others. In this review some of the above mentioned parameters will be discussed as they pertain to metal anchors with emphasis on the effect of the environment on anchor dimensions and metallurgy and, on their interaction with the refractory.

11:50 AM

(UNITECR-021-2022) Refractories from fire to FIRE (Invited)

M. Rigaud*[1]

1. École Polytechnique, U. of Montreal, Mechanical Engineering, Canada

A brief description of the evolution of the making and usagess of crucibles and heat containing linings to the development of today eco-designed refarctories materials is offered to illustratte the gigantic steps the refractory constituancy has accomplished. Eco for Ecological, Economical, Eco-Energetical. That is from fire to FIRE, To prolong Professor T. Plantje's vision, the research and education needs are to be secured. This will require unified efforts of all stakeholders of our community. A brief description of FIRE's roles for such a purpose is hence recalled.

Theodore J. Planje Award Session II

Room: Marquette
Session Chairs: James Hemrick, Oak Ridge National Laboratory; Jeffrey Smith, Missouri S&T

1:40 PM

(UNITECR-022-2022) What I have learned from 55 years in Refractories (and not from a book) (Invited)

J. P. Willi*[1]

1. Sunset Refractory Services, USA

For the past 55 years I have been involved in many different aspects of the refractories industries. Most of what I have learned has been from my mentors, bosses, co-workers, and from experience.

2:10 PM

(UNITECR-023-2022) 'Through the looking glass' how the refractory industry will need to evolve towards a sustainable future - a personal perspective. (Invited)

N. E. Bunt*[1]

1. Imerys, USA

Changing roles in the twilight of a 38-year career in the sales of minerals to the refractory industry has led this author to the newly-appointed role of Sustainability Coordinator in Imerys' Refractories Abrasives and Construction Business Area. This talk will discuss the historical evolution of refractory raw material selection and the global forces that continue to impact the decisions being made today by the biggest names in the industry. Imerys, as a trusted supplier of mineral-based solutions, is making significant contributions to meet these constantly-changing targets. This paper will discuss the author's personal perspective on the evolution of Sustainability as a theme in the Refractory Industry over the course of nearly four decades as well as providing insight into Imerys increasing commitments in this space.

Steel Making - Brick Development

Room: Waldorf
Session Chairs: Ashley Hampton, Allied Mineral Products, LLC; Angela Rodrigues-Schroer, Wahl Refractories

10:40 AM

(UNITECR-024-2022) Ultra Low Carbon Bricks for Steel Ladles with Nanographite Technology

C. Pagliosa*[1]; B. L. Borges de Melo[1]; M. S. Borges[2]; R. Favalessa[2]

1. RHI Magnesita, R&D Center, Brazil
2. RHI Magnesita, Brazil

Steel quality requirements have become increasingly strict with strong demand for high strength and toughness steel plates and a new refractory generation with ultra low carbon was developed to attend customers' needs. Besides the advantages of energy economy in steel process and higher clean steel, some additional benefits include less shell deformation and less CO_2 emissions. Ultra low carbon bricks mean less thermal conductivity products was achieved by replacing natural graphite by a synthetic nanographite. However, less carbon content bricks have several challenges to overcome: 1. higher thermal shock susceptibility, 2. higher wettability to the molten metal and slag and 3. lower oxidation resistance due to graphite particle reduction. Special nanographite was conceived to withstand same oxidation resistance than natural flake graphite to compensate the nano particle size and also to achieve the desired properties to match the requirements for steel industry trials. This work presents the nanographite approach to the magnesia-alumina-carbon (MAC) bricks with an expressive reduction in the amount of graphite from 5%wt to 1%wt. Properties and customer's trials with nanographite bricks in integrated steel ladle are also shown with improving carbon and energy.

11:00 AM

(UNITECR-025-2022) Reduction of Gas Permeability of MgO-C Brick by Optimizing Particle Size Distribution

G. Shimada*[1]; E. ISHIHARA[1]; T. FURUKAWA[1]; A. IIDA[1]

1. SHINAGAWA REFRACTORIES CO., LTD., Japan

MgO-C brick is a refractory material composed of magnesia grain and graphite flake, which is used as a refractory lining for a number of steel refining vessels because it shows excellent slag corrosion resistance and thermal spalling resistance. As is obvious, densification for shaping a mixture having a grain size distribution is crucial to bring out the potential, thus, high pressure-pressing has been being adopted. Based on the powder engineering theory, there is a close relationship between a denseness of a packed material and a gas permeability, which can be a comprehensive index showing the filling state. Further, in order to express particle size distribution, the distribution coefficient of Andreasen's equation, namely q-value, is employed so often. In this study, therefore, influence of q-value on gas permeability of MgO-C brick was examined experimentally. As a result, it was found out that gas permeability decreases as q-value decreases, i.e., fraction of fine particle increases. On the other hand, mixture with excessively low q-value showed the pressing pressure absorption that induces insufficient pressure transmission in packing structure, resulting in a significant deterioration in quality and productivity. Hence, from the view point of gas permeability and productivity, 0.30 to 0.32 was concluded to be optimum range of q-value.

11:20 AM

(UNITECR-026-2022) Effect of different antioxidants on the properties of Steel Ladle Dolo-C refractories

T. Mahata*[1]

1. TRL Krosaki Refractories Limited, Technology, India

Steel ladle refractory always plays a major role to produce cleaner steel. Significant amount of refractory material is consumed in this area. Generally magnesia carbon material is used for lining of steel ladle. In last few years uncertainty in the availability of high quality magnesia and price increase experienced by refractory manufacturer and end users. As dolomite is the potential alternative steel ladle refractory due to its high thermodynamic stability and good slag corrosion and erosion resistance, people are thinking to optimize its use in steel ladle. In this present investigation, behaviour of different antioxidants in Dolo-Carbon refractories has been studied. Purpose of this study is to find a suitable antioxidant of Dolo-C refractory for steel ladle application, which will provide optimum thermo-mechanical property along with best corrosion and erosion resistance. Two different metallic and carbide antioxidants is selected for this purpose. Addition of single antioxidant and combination of both in dolo-carbon refractory was studied. Variation of physical and thermo mechanical properties was studied along with oxidation resistance and slag corrosion resistance. Combination of two antioxidants was found to be more efficient compared to single antioxidant.

11:40 AM

(UNITECR-027-2022) Magnesia–carbon refractories from recycled MgO–C materials

K. Moritz*[1]; S. Dudczig[1]; G. Endres[2]; D. Herzog[2]; M. Schwarz[3]; L. Schöttler[3]; D. Veres[1]; C. Aneziris[1]

1. Technische Universität Bergakademie Freiberg, Institute of Ceramics, Refractories and Composite Materials, Germany
2. Horn & Co. Minerals Recovery GmbH & Co. KG, Germany
3. Deutsche Edelstahlwerke Specialty Steel GmbH & Co. KG, Germany

Recycling of used refractories – in particular closed-loop recycling – gains in importance because of both ecological and economic benefits, such as the conservation of natural resources, reduced landfilling, and the reduction of greenhouse gases and energy consumption. In the frame of a research project funded by the

German Research Foundation, the TU Bergakademie Freiberg and the industrial partners Horn and DEW investigate the influence of recycled magnesia–carbon raw materials on the properties of MgO–C refractories and on the steel purity after the contact of the melt with the refractory. Different formulations based on three fractions of fused magnesia and/or MgO–C recyclate (maximum grain size: 5 and 6 mm, resp.), fine-grained magnesia, graphite, and a carbon binder combination were tested. The weight ratio between fused MgO and MgO–C recyclate was varied in the following steps: 100 : 0, 50 : 50, 20 : 80, and 0 : 100. The carbon content was always adjusted to approx. 10 wt%. The investigated uniaxially pressed test bars (coked at 1000 °C) showed a tolerable increase in porosity and decrease in the cold modulus of rupture and dynamic Young's modulus with increasing recyclate content. The thermal shock resistance of the recyclate-containing samples was at least similar to that of the reference material or higher. In ongoing investigations, the MgO–C materials are tested in a steel casting simulator.

12:00 PM

(UNITECR-028-2022) Interactions of MgO-C refractory materials with Al-deoxidized steel

F. Kerber*[1]; V. Stein[2]; T. Schemmel[2]; H. Jansen[2]; C. Aneziris[1]

1. Institute of Ceramics, Refractories and Composite Materials, Germany
2. Refratechnik Steel GmbH, Germany

During steel making the formation of different inclusions is unavoidable, which results in a negative influence on the properties of the final steel product. Therefore, those harmful particles need to be reduced as much as possible. In this work the interactions of four different MgO-C refractory materials in contact with molten Al-deoxidized steel was investigated. Therefore, prisms of the refractory material were dipped into molten steel at 1600°C in a steel cast simulator. To characterize the inclusion population into the steel matrix after the dipping trial a new analyse method, called automatic feature analysis, was used, which detected particles automatically due to their geometry and chemistry. Huge differences could be detected with regards to the particle population for the four different batches. On the dipped prisms formed layers and structures could be observed, which were characterized by using light microscopy, scanning electron microscopy and energy dispersive X-ray spectroscopy for the surface and the cross-section. It could be determined, that those structured differ significantly in their shape, but also in their chemical composition. Those investigations showed very promising results for designing new MgO-C refractory materials, that can have a positive influence on the inclusion population in the final steel product.

Steel Making - Monolithics Development

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Angela Rodrigues-Schroer, Wahl Refractories

1:40 PM

(UNITECR-029-2022) Development of Al_2O_3 – $MgAl_2O_4$ spinel castable for various applications

R. Swain*[1]

1. TRL KROSAKI REFRACTORIES LIMITED, Technology, India

To fulfill the needs from automobile industry, ultra-low carbon (ULC) and interstitial-free (IF) grades of steel are getting more importance. The stringent specification of steel can be fulfilled not only by special secondary metallurgical process but also by the performance reliability of refractory lining in different equipment. The refractory performance depends on operational safety, life, specific refractory cost along with its contribution for achieving the high demanding metallurgical targets where interaction of steel and refractory plays a vital role. Al2O3 – MgAl2O4 castable is a special grade of castable used not only in steel ladle working lining but also in prefabricated refractory well block, seating block, porous plug, RH snorkel etc. The application areas being stringent, high temperature thermo-mechanical properties are very important along with slag corrosion resistance. In the present work, one special spinel is incorporated in the matrix which not only gives the excellent slag corrosion resistance but also better thermal spalling resistance, volume stability and high temperature thermo-mechanical properties like HMOR and RUL. In presence of special spinel there is enough formation of CA6 which enhance the volume stability and other properties. This castable is used to make seating block and well block for steel ladles and the performance is enhanced significantly.

2:00 PM

(UNITECR-030-2022) Effect of spinel on the properties of alumina-spinel magnesia refractory castables for steel-ladle bottom

S. Kim*[1]; C. Ha[1]; J. Huh[1]

1. KOREA REFRACTORIES CO., LTD., R&D Center, Republic of Korea

Al_2O_3-MgO castable and Al_2O_3-spinel castable are generally used for the bottom of steel-ladle, depending on the operating and facility environment. Al_2O_3-spinel castable has excellent thermal stability, while structural spalling by slag erosion can occur. Al_2O_3-MgO has good corrosion resistance, but has problems with thermal spalling due to spinel generation differences. In this study, the influence of spinel on the properties of Al_2O_3-spinel-MgO castables was investigated to compensate for the weakness of Al_2O_3-MgO and Al2O3-spinel castables. The most important thing in Al_2O_3-spinel-MgO castables is to control the rate of linear change, which is the key factor for the particle size and content control of spinel. In the case of spinel, the higher the fine particle ratio and the higher the overall content, the lower the expansion rate. Therefore, it was possible to compensate for the problems of the two castable types by controlling the rate of linear change with proper spinel particle size and content control. Field test results showed that there were no troublemakers due to spalling compared to Al_2O_3-spinel castable, and that the average lifespan was improved by about 10%.

2:20 PM

(UNITECR-031-2022) Study on Fluidity of Magnesia Self-flowing Castable Used in Converter

Y. Wang*[1]; Y. Qin[1]; Y. Wang[1]; P. Zhang[1]

1. Puyang Refractories Group Co., Ltd., China

The magnesia self-flowing castable can be used as environmentally friendly aqueous fettling material to prolong the service life of the converter. To guarantee the successful workability of the magnesia self-flowing castable, the effects of the type of water-reducing agent, particle size grading and retarder on the fluidity of castable were researched. The research results indicate that the polycarboxylate superplasticizer B and C have remarkable water-reducing effect, and the fluidity of the self-flowing castable with more 0.5-0mm magnesia is better. Moreover, although the addition of retarder can reduce the initial flow value of the castable, it can outstandingly decrease the attenuation of the flow value, and it should be added appropriately.

2:40 PM

(UNITECR-032-2022) Study and application of shotcreting for ladle lining

Y. Qin*[1]; Y. Wang[1]; Y. Wang[1]; P. Zhang[1]

1. Puyang Refractories Group Co., China

Corundum spinel shotcreting were prepared by using tabular comndum, active a- Al_2O_3 micropowde, calcium aluminate cement and spinel. The effect of spinel on shotcreting was studied on the rheology, the strength, etc. by Add 1-0 mm spinel, 320 mesh spinel powder and the micron grade spinel particles. The experimental results show that : Using the smaller particle size of the spinel, the better to improve the performance of pumping construction on the shotcreting, and more conducive to improve the sintering strength.

The shotcreting by developed with good construction performance, During construction, the pressure of pump is lower than 8 MPa. Micron grade spinel particles dispersed in the matrix, isolation low melting phase, and improve the ability of slag erosion resistance and thermal shock resistance. The used results of shotcreting on ladle show that it is beneficial to improve the service life of shotcreting by add the micron grade spinel particles. The material adhesion rate is more than 95% by manually constructed,When use of the mechanical arm automatic spraying construction, the material adhesion rate is more than 98%. The service life more than 50 furnaces when the thickness at 40mm of the shotcreting,and The service life of shotcreting ladle lining more than 5-10 furnaces longer with by mechanical arm spraying than by manual spraying construction.

3:00 PM

(UNITECR-033-2022) Effect of curing agents on the fluidity and setting behavior of alumina-silica castables bonded with colloidal silica

Y. Chen*[1]

1. Puyang Refractories Group Co., Ltd., China

Alumina-silica castables bonded by colloidal silica were prepared by using tabular corundum, white fused alumina, ultra-fine alumina and colloidal silica (pH = 9.0) as main raw materials, calcium aluminate cement, fused magnesia and NH_4Cl as curing agents. The influence of different curing agents on the fluidity and setting behavior of the castables were studied. The results indicated that calcium aluminate cement could improve the demoulding strength of the castable, but it's HMOR reduced significantly. Fused magnesia would reduce the fluidity of the castable rapidly and could not meet the requirements of setting time. As curing agent, NH_4Cl can meet the requirements about fluidity and demoulding strength of the castable bonded by colloidal silica. When the addition amount was 3c%, the castable had the good performance with fluidity, initial setting time and demoulding strength.

Steel Making - Wear Mechanism & Prevention

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Ashley Hampton, Allied Mineral Products, LLC

3:40 PM

(UNITECR-034-2022) How to Read Steel Ladle Wear - 30 Years of Experience (Good, Bad and Ugly)

T. Vert*[1]

1. Independent Expert, Canada

Steel ladle refractory wear can be boring and normal, or weird, inconsistent, and totally unpredictable. In addition to the variations of refractory material, installation, dry out, repairs, etc, there is a highly variable processing route! It can take many years to get a "keen eye" to spot ladle wear patterns and their causes (which a laser will not tell you). The author has over 30 years of experience in reading steel ladles, investigating ladle breakouts, and managing process routes, and will attempt to review key wear patterns and their potential cause(s). This paper will provide the practical tools and tips to achieve the goal of quick troubleshooting for effective wear resolution of steel ladle wear.

4:00 PM

(UNITECR-035-2022) A Unique Approach of Correlating the Zonal Wear of Steel Ladles with their Operational Parameters

T. Schemmel*[1]; U. Sengupta[1]; D. Chandra[1]; H. Jansen[1]

1. Refratechnik Steel GmbH, Germany

The Steel ladle holds a major share of specific consumption of refractories in steel melt shop which is controlled by selection of refractories with respect to operational practice. Establishment of relation between quality of refractory and operational parameters is the main task of Refractory Engineers to lower specific consumption by continuous improvement in performance. Steel ladle may be sub-divided into many micro-zones based on operational steel plant parameters to develop a tailor-made refractory design. An attempt has been made to develop database of major operational parameters for steel ladle as a function of erosion profile of different qualities of refractories in working lining for micro-zones by accumulating data from different steel plants. Such unique approach has been successfully used in different Indian steel plants having different manufacturing routes and end products to validate the concept. This paper deals in the development of database and it's thought process followed by design of ladle working lining to minimize specific consumption by performance improvement with minimum down time and better safety. Finally, the co-relation between operational parameters, performance and quality of working lining was established with respect to its design and chemical, physical and mineralogical properties.

4:20 PM

(UNITECR-036-2022) Vertical cracks in steel ladles – new solutions to overcome a common issue

N. Pywell*[1]; B. Buchberger[1], A. Viertauer[1], J. Longley[1]

1. Mayerton Refractories Ltd., Group Technical, Austria

Vertical cracks are a very common topic often limiting the service life of magnesia-carbon bricks in slag lines and barrels of steel treatment ladles. In most cases cracks start to occur early in the lining campaign and then increase in severity the longer the ladle stays in operation. According to experience the crack formation is caused by mechanical stresses in the lining and strongly related to brick shapes used. After extensive scientific investigations of several cold and hot physical properties of magnesia-carbon bricks, like the nominal notch tensile strength and specific fracture energy, the reason for crack formation has been identified and countermeasures to prevent the crack formation have been determined. Both technological changes in the production process and new material developments have led to different solutions to avoid cracking of bricks in ladle linings. Several trials at different steel plants showed the improvement of the newly developed materials. In some trials the crack formation disappeared completely, in all others it was significantly reduced.

4:40 PM

(UNITECR-037-2022) Impact of calcium magnesium aluminate on liquid phase formation and high-temperature behaviour of MgO-CMA-C ladle refractories

P. Gehre*[1]; T. Preisker[1]; S. Guhl[1]; C. Wöhrmeyer[2]; C. Parr[2]; C. Aneziris[1]

1. TU Bergakademie Freiberg, Germany
2. Imerys Aluminates, France

In a ladle furnace (LF), MgO-C bricks have to withstand high temperatures, thermal shock, and aggressive melts. Industrial applications in numerous steel plants have shown that the addition of calcium magnesium aluminate (CMA) increases the corrosion and penetration resistance of MgO-C ladle bricks by forming a protective slag coating on top of the hot face. However, there is concern that the addition of CMA promotes the formation of liquid phases lowering the high-temperature properties of the bricks. Hence, thermochemical equilibrium calculations using FactSage software were applied to describe the phase development in the range of 1200–1700 °C. By determining HMOR and RuL of MgO-CMA-C, the calculated portion of the liquid phase in the microstructure was linked with high-temperature properties. Based on the calculations, the addition of 5 wt.% CMA to MgO 98-grade retarded the liquid phase formation from 1400 °C to a temperature of 1460 °C. The calculated liquid phase was composed of Fe_xO_y, SiO_2, MgO, CaO, and Al_2O_3. Overall, the increase in the liquid phase portion by adding CMA was only marginal with +0.6 wt.% in MgO 98-grade batches with a total amount of 3.5 wt.%. Evaluating HMOR and RuL showed no distinctive negative effect of CMA addition on the thermo-mechanical properties of MgO-C, which confirms the results of the thermodynamic calculations.

5:00 PM

(UNITECR-038-2022) Correlation of air-permeability and slag corrosion resistance of advanced carbon-containing refractory materials for high-temperature applications

G. Ghosh*[1]

1. Tata Steel Limited, RTG, India

There is a steady demand for high-performance advanced carbon containing refractory to cope with increasing steel production. For accurate prediction of refractory performance in plant application, estimating the effect of corrosion by metal or slag on refractory is essential. Corrosion properties are mainly affected by apparent porosity, permeability, oxidation, and thermal spalling resistance. Air permeability has a substantial effect on the slag corrosion resistance of the materials. Magnesia carbon refractory materials with low, medium, and high permeability values were performed a finger corrosion test in an induction furnace at application temperature. Microstructural study of the samples was conducted along with thermo-mechanical, thermal spalling, and oxidation properties. This present work aims to achieve the correlation between permeability and slag corrosion resistance, which will bring forth the potential benefits of optimizing the refractory permeability property for better performance in our plant.

5:20 PM

(UNITECR-039-2022) Investigation of effective parameters on increasing the durability of pitch-bonded MgO-C bricks used in the trunnion area of the steel converter

S. Otroj*[1]; M. Knoll[1]; F. Stöckmann[1]

1. Intocast AG, Research and Development, Germany

In this paper, the effective parameters on increasing the durability of pitch-bonded MgO-C bricks used in the trunnion area of the steel converter has been studied. In this relation, the durability of the pitch-bonded MgO-C bricks containing B_4C and carbon fiber and different types of magnesite and graphite has been compared together. For this reason, the thickness measurement of remainder bricks by use of laser has been considered as durability of bricks and has been used to compare their wear rates. Besides, the physical and mechanical properties, thermo-mechanical properties and microstructure of these bricks has been investigated. The results showed that the purity and crystal size of magnesite grains, purity of graphite and B_4C addition have a great effect on the durability of pitch-bonded MgO-C bricks used in the trunnion area of the steel converter.

Modeling and Simulation of Refractories I

Room: Williford A

Session Chair: Rakesh Dhaka, U.S. Steel

10:40 AM

(UNITECR-040-2022) Investigation of different curing temperatures on phase changes during drying of castables

A. Koehler*[2]; S. Kuiper[3]; S. Klaus[1]; F. Goetz-Neunhoeffer[2]

1. Almatis GmbH, Germany
2. University of Erlangen-Nuernberg, Germany
3. Almatis B.V., Netherlands

Calcium aluminate cement (CAC) is the most important and most used binder for monolithic refractory castables. It is well known that the hydration of CAC clinker phases leads to different hydrate phases depending on the temperatures during hydration of the green bodies. In this study the influence of different curing conditions on the phase changes during the drying process of calcium aluminate cement bond castables is presented. A mixture of CAC and alumina was hydrated at different temperatures, which should represent extreme working conditions during casting. The quantitative phase composition after 48 hours of hydration was determined by Rietveld-analysis with G-factor quantification of the X-Ray diffraction data (XRD). Thermogravimetric analysis (TGA) was used to also characterize the weight loss. After curing, the samples were heated up and the resulted phase changes were again investigated by XRD. TGA results have shown that above 350 °C all hydrate phases are dehydrated, but that the differently cured samples lead to quite different dehydration processes and phase compositions. Therefore, the cured samples were heated up to 180 °C, as at this temperature the different curing conditions lead to a different dehydration progress. The different starting conditions before drying strongly affect the final phase composition, as well as a different way to get the water-free product.

11:00 AM

(UNITECR-041-2022) Drying of Refractory Castables – How complex the modelling needs to be? A numerical and experimental study

M. H. Moreira*[2]; S. Dal Pont[3]; R. F. Ausas[1]; T. M. Cunha[2]; A. Luz[2]; V. C. Pandolfelli[2]

1. University of São Paulo, Institute of Mathematical and Computer Sciences, Brazil
2. Federal University of São Carlos, Graduate Program in Materials Science and Engineering (PPGCEM), Brazil
3. Université Grenoble Alpes, 3SR, France

Calcium aluminate cement (CAC)-bonded castables present numerous benefits when compared to monolithic refractories. Their main drawback is its long initial heating when the physical and chemically-bonded water are released. If the mass flux of water to the external environment is lower than the vapor generation, the gas pressure can increase resulting in cracks and spalling of the ceramic lining. In order to avoid this, optimized heat up curves are needed, and modeling is a promising methodology for it. Most of these calculations are based on tools used for simulating Portland cement concrete structures under fire and vary both in complexity and their basic assumptions. Thus, the main question that remains is how complex such models need to be to fulfill the fundamental aspects of this phenomenon. In this sense, the present work aimed to implement multiple numerical tools reported in the literature with distinct complexity levels and fundamental assumptions and by also conducting neutron tomography tests on a CAC-bonded castable. Based on the results, it was possible to conclude that the pressure values predicted by such methodologies are equivalent and the calculated water content is qualitatively similar within the models and with the experimental values, indicating that the simplest approach might be used for the evaluation of the castables' drying.

11:20 AM

(UNITECR-042-2022) Drying behavior of refractory castables when using continuous heating-up curve: a numerical simulation analysis

T. M. Cunha*[1]; M. H. Moreira[1]; A. Luz[1]; V. C. Pandolfelli[1]

1. Federal University of Sao Carlos, Graduate Program in Materials Science and Engineering, Department of Materials Engineering, Brazil

The current trend to replace shaped refractories with monolithics is related to various reasons, as lack of joints, ease of installation and freedom on geometry of the latter. However, the main drawback of these non-shaped products is that they require a careful first heat-up, otherwise explosive spalling may follow due to the steam pressurization of the well packed consolidated structure. Thus, conservative yet secure drying schedules are commonly applied, which are not optimal in terms of energy consumption nor time wise. Considering the recent advances in numerical simulations, this work discusses the implications of different heating-up rates during the drying of a refractory castable's lining in a steel ladle. Also, a new methodology based on the correlation of the maximum vapor pressure with the mechanical strength of the material is also proposed. The simulation results indicated that higher vapor pressures and a displacement of the maximum pressure position could be achieved with the use of high heating rates and by changing the lining thickness. Such behavior seems to be related with the water migration to the inner regions of the structure. Moreover, by converting the measured flexural strength of the castable into triaxial traction resistance, it was possible to directly correlate the calculated steam pressures with the refractory's likelihood to explode.

11:40 AM

(UNITECR-043-2022) Advanced thoughts on the infiltration of ceramic porous plugs by liquid steel

L. Z. Falsetti*[1]; D. N. Muche[1]; V. C. Pandolfelli[1]

1. Federal University of São Carlos (UFSCar), Department of Materials Engineering, Brazil

Controlling of non-metallic inclusion content during the secondary metallurgy is a key feature to guarantee the quality of the steel. In a typical process, these particles are captured by bubbles generated by a porous plug located at the bottom of the ladle, which structure consists of open pores that allow gas injection into the molten bath. On the other hand, liquid steel may penetrate through this porous structure during the non-bubbling period and solidify, as the ladle cools down. In order to remove the infiltrated thickness, an oxygen lance (at approximately 2000°C) heats the surface of the porous plug, in a cleaning procedure pointed out as the leading wear mechanism in such refractory. A classical approach to understand the infiltration of a liquid in a porous structure is based on Washburn's equation, which defines the basic condition for liquid penetration. By applying the same Washburn's fundamentals to this matter, a criterion to avoid liquid steel infiltration into the plug was determined. Additionally, the influence of the pore diameter, the material composition and the gas counter-pressure on steel penetration was analysed. Based on these results, a feasible solution was proposed as an alternative to prevent the infiltration of porous plugs.

12:00 PM

(UNITECR-044-2022) A novel method for the prediction of non-reactive impregnation in porous media

T. Sayet*[1]; C. Trang[1]; A. Batakis[2]; E. de Bilbao[3]; E. Blond[1]

1. University of Orléans, France, LaMé, France
2. Institut Denis Poisson, France
3. CEMTHI, France

The issues connected with the impregnation phenomena particularly interest various industrialists in the sectors of refractories, composites, civil engineering and so on. The existing numerical tools require a high computational resource and are usually subjected to spurious oscillations affecting the accuracy of the results. The aim of the work is to propose a novel method for the simulation of non-reactive impregnation based on a probabilistic approach and called Self-Organised gradient percolation method. The evolution of the impregnation front is governed by a cluster evolution taking into account the physical aspects and the boundary conditions. Subsequently, the macroscopic saturation is interpolated from a sorption curve. Numerical simulation results are presented to compare Self-Organised Gradient Percolation method and classical finite element method in 1D and 2D. Good agreements are obtained. We emphasize a drastic reduction of the computational cost and a result free of spurious oscillations. The objective is now to add reaction kinetics to address reactive impregnation process.

Modeling and Simulation of Refractories II

Room: Williford A

Session Chairs: Manoj Mahapatra, University of Alabama at Birmingham; Somnath Mandal, University of California, Irvine

1:40 PM

(UNITECR-045-2022) Theory and fact of local corrosion of refractories containing non-oxide at the slag-metal interfaces under metal level fluctuation

S. Maeno*[1]; K. MORIKAWA[1]

1. Krosaki Harima, Japan

Conventionally, local corrosion of refractories at the slag-metal interface has been theorized and explained experimentally i.e. the wettability of the melt (slag or metal) to refractories determines the contact target, and the wettability depends on the carbon concentration in the metal. However, for the trough refractories exposed to pig iron containing more than 4mass% of carbon, we devised a new model that fits better than that derived from the theory mentioned above. The conventional theory does not consider the fluctuation of the molten metal level that should occur in the actual trough, but the equation derived from our new model that takes metal level fluctuation into consideration reproduce the local corrosion shape of the slag-metal interface. It was suggested that the essence of the local corrosion consistent with the actual trough is not the conventional theory considering only wetness but the alternative contact to the slag and the metal caused by the fluctuation of the molten metal level.

2:00 PM

(UNITECR-046-2022) Proposition of Two Asymmetric Constitutive Laws to Model the Creep Behavior of Refractory Materials at High Temperatures

L. B. Teixeira*[1]; E. Blond[1]; T. Sayet[1]; J. Gillibert[1]

1. Univ. Orléans, Univ. Tours, INSA-CVL, LaMé, France

The accurate description of the mechanical behavior of refractory materials using constitutive models, as well as the identification of their mechanical properties at high temperatures, have been a challenge for many years. In general, these materials present an asymmetric creep behavior, with the creep strain rate being considerably higher in tension than in compression. The creep behavior of materials can, in general, be divided into primary (decrease of the strain rate over time), secondary (constant strain rate) and tertiary (increase of the strain rate and subsequent failure). The current constitutive models available in commercial software lack in the features necessary to represent such behavior, and, in general, symmetric models are used to simulate refractories under working conditions, which leads to a reduction on the results accuracy. In this work, two new asymmetric creep models are proposed. The first model is able to represent primary or secondary creep under tension and compression. The second model can be used to simulate transient creep under compression, i.e., primary and secondary creep in sequence, and secondary creep under tension. Numerical simulation results are presented to compare the currently available symmetric models and the proposed asymmetric models.

2:20 PM - WITHDRAWN

(UNITECR-047-2022) Determination of secondary creep stage parameters of a shaped alumina spinel refractory with the aid of genetic algorithm

S. Samadi*[1]; S. jin[1]; D. Gruber[1]; H. Harmuth[1]

1. Montanuniversity of Leoben, Chair of Ceramics, Austria

Creep is one of the major causes of irreversible strains in refractory linings at high temperatures. The corresponding Norton-Bailey creep parameters of ordinary refractory ceramics can be inversely identified with the Levenberg-Marquardt algorithm. Nevertheless, in most cases, the experimental creep curves are rather fluctuant and diverse. For some cases, the inverse identification could fall into a local minimum if a good initial guess of creep parameters fails. In the current presentation, the genetic algorithm is introduced to overcome the local minima of inverse identification. A shaped alumina spinel refractory was used to manifest the benefits and disadvantages of the combination of the genetic algorithm and the Levenberg-Marquardt algorithm.

2:40 PM

(UNITECR-048-2022) Flexible usage Ladle Shroud enabled by advanced thermo-mechanical analysis

K. Andreev[1]; S. Mazerat*[1]; S. Romero Bavier[1]; Y. Chen[1]; S. Gregoire[1]; V. Esteves de Almeida Filho[1]; T. Pereira[1]; E. Haeder[1]; V. Costa[1]

1. Vesuvius, Brazil

Ladle shrouds are subjected to a cyclic use causing repeated thermal shocks. The inability for refractory to be cold restarted after an idle time preclude the life extension over one sequence. The paper illustrates an approach to analyse thermal shock applied to a specific customer design. The approach features Finite Element modelling accounting for the statistical nature of failure typical for refractories. The models utilise Bigoni-Piccolroaz criterion for multi-axial tensile, shear and compaction failure. The analysis of potentially instable crack is based on the ratios of the elastic and fracture energy. Necessary material properties were extracted from laboratory experiments, including Brazilian, wedge splitting set-ups and compressive tests with different hydrostatic pressure. The application of such an approach allowed developing the ladle shroud that was successfully tested at Gerdau Charqueadas. The ladle shroud sustained record number of heats and several cold restarts. The tested ladle shroud represents the family of Duraflex products of improved operational flexibility, which assumes the utilisation over an extended number of heats during several casting sequences. Such flexibility reduces logistical efforts, waste and HSE hazards due to hot piece handling.

3:00 PM

(UNITECR-049-2022) Determination of temperature dependent static young's modulus of refractory ceramics using refractoriness under load tests

M. Henze[2]; W. R. Reichert*[1]; T. Tonnesen[1]; R. Telle[1]; G. Hirt[2]

1. RWTH Aachen, Chair of ceramics, Germany
2. RWTH Aachen, Institute of Metal Forming, Germany

Refractory linings are, in addition to loads due to corrosion and creep processes, particularly affected by thermomechanical stresses caused by the restricted thermal expansion of the lining. These stresses can occur within individual components as well as in bricks and can lead to plastic deformation, cracks and material failure. Thus, comprehensive knowledge about thermomechanical behavior is mandatory for an accurate prediction of occurring stresses to design load optimized linings. This paper presents a method for utilizing refractoriness under load (RUL) tests to determine a temperature dependent static young's modulus for refractories. In a first step, RUL tests with a negligible load are carried out in order to determine the materials temperature dependent thermal expansion coefficient. Afterwards several RUL tests with higher loads are carried out. The measured data of change in temperature and length is then corrected by the thermal expansion and used to construct elastic lines for several temperatures, where the elastic slope is determined using the change in length and the respective load. Thus, young's modulus for several temperatures can be determined. The obtained values for the young's modulus are then compared to RFDA measurements and validated using a FE model of the RUL test.

3:40 PM

(UNITECR-050-2022) A thermomechanical model of a full 3D steel ladle using homogenization technique

C. C. Melo*[1]; L. B. Teixeira[1]; H. U. Marschall[1]; A. D. Resende[1]; G. Hackl[1]

1. RHI Magnesita, Simulation, Austria

A very common lining type in steel ladles is dry-joint refractory masonry. The presence of joints and their state (open or closed) affects the stiffness of the structure. Accordingly, the joint behavior needs to be accounted for implementing reliable thermomechanical models of mortarless refractory vessels. As these large-sized structures have many components, an approach that represents bricks as individual solids has a high computational cost and may lead to convergence problems. To work around this shortcoming, one may use an equivalent material model, replacing the bricks and joints of the structure. The present work uses this approach to model a full 3D solution of a steel ladle, including regions with different stiffness such as plug and well block. The numerical model also considers a detailed representation of steel shell. The evolution of joint state as a function of the thermal load applied and stresses are reported, bringing some insights for the design of steel-ladle masonry linings.

4:00 PM

(UNITECR-051-2022) Modelling the elastic properties of bi-phase refractories by using periodic homogenization approach with Discrete Element Method (DEM)

F. Asadi*[1]; D. ANDRÉ[1]; S. EMAM[2]; P. DOUMALIN[3]; M. HUGER[1]

1. UMR CNRS 7315, Institute of Research for Ceramics (IRCER), France
2. Itasca Consultants S.A.S., France
3. Institut PPRIME, UPR CNRS 3346, France

The ATHOR (Advanced THermomechanical multiscale mOdelling of Refractory linings) project is an innovative training network, supported by the European Commission. This study is a part of the ATHOR project and focuses on the numerical simulation of refractories by considering their microstructure and scale-related homogenization. Using Discrete Element Method (DEM) to model a multiphase continuum media, especially in the ceramics field, is a new modelling approach which can be of great interest to consider the multiple cracks propagation within a heterogeneous media. The objective of the present study is to accurately simulate the macroscopic elastic properties of bi-phase materials by using periodic homogenization at the boundaries of a 3D Representative Volume Elements (RVE) in order to work with a limited number of discrete elements to decrease calculation time. At this stage, without considering microcracks, the obtained results were successfully compared to experimental data of composites, and analytical bounds of Hashin and Shtrikman, and thus, validating the proposed numerical approach. This approach could later allow allocating computing resources to an essential point for refractories: considering the multiple cracks propagation within a heterogeneous microstructure during thermomechanical loadings.

4:20 PM - WITHDRAWN

(UNITECR-052-2022) The behaviour of dry-joints in mortarless refractory masonry at high temperatures

P. N. Gajjar*[1]; P. Put[2]; J. M. Pereira[1]; B. Luchini[2]; S. Sinnema[2]; P. Lourenço[1]

1. University of Minho, ISISE, Department of Civil Engineering, Portugal
2. TATA Steel, Ceramics Research Centre, Netherlands

Refractory linings are commonly employed in Industrial vessels to protect against extreme working environments. Mortarless refractory masonry are frequently used in the working lining of steel ladles to contain the molten steel and limit the heat losses. During operation, such masonry lining undergoes high thermo-mechanical loads, primarily due to the complex thermal and mechanical boundary conditions. Dry-joints, present as a physical breaks in the continuum,

can partially reduce the stress levels in the lining. Therefore, developing numerical constitutive models at micro and macro scale considering their effects is extremely relevant. This work aims to experimentally investigate the normal compressive behaviour of dry joints in refractory masonry. For this purpose, various refractory specimens were tested from ambient temperature to 1400 °C under cyclic loading. The results obtained from these experiments were used to identify critical joint parameters with a non-linear numerical constitutive model for the interface. The outcome described exponential joint closure and opening behaviour with respect to the force applied. It was observed that the pressure required to close a joint significantly reduces with an increase in temperature.

4:40 PM - WITHDRAWN

(UNITECR-053-2022) Thermo-mechanical modeling of refractory masonry wall under variable thermo-mechanical history

T. Soares*[1]

1. University of Minho, Portugal, ISISE, Portugal

Refractories constituting the steel ladle used in steel industries have deformation at high temperatures as one of their mechanisms of failure, since commonly, the load-induced compressive mechanical stresses in the structure are low when compared to both tensile and compressive transient stresses induced by the high temperatures. Moreover, the ladle's environment and the chemical reactions between its contents often affect its deformation. Thus, to estimate the mechanical response of the ladle lining, numerical models able to simulate the particularities of refractory masonry become crucial. In this work, a finite element (FE) based micro-modeling framework will be applied to simulate a refractory masonry wall response to thermo-mechanical load cycles and produce a thorough sensitivity study of the impact of stress-strain history on the structural response when considering the effects of creep/relaxation. The FE framework considers geometric and material nonlinearities in conjunction with temperature-dependent material properties. The nonlinearities within the FE model are considered by the nonlinear behavior of the joints interfaces and by the effects of creep/relaxation on the refractory units. The investigation is specially focused on the effect of creep and stress relaxation on the development of stresses and strains within the wall.

5:00 PM

(UNITECR-054-2022) Nonlinear Thermomechanical Modelling of Refractory Masonry Linings with Dry Joints

M. Ali*[1]; T. Sayet[1]; A. Gasser[1]; E. Blond[1]

1. University of Orléans, France

Refractory masonry with dry joints is extensively used for lining many large-scale industrial components such as steel ladles and furnaces. The design and optimization of these linings are still an engineering challenge due to the coupled interactions between thermal, mechanical and chemical fields. Thus, advanced simulation techniques are necessary especially when experimental work is still a challenging task due to the harsh working conditions. Conventional simple macro models are in many cases not sufficient to predict the appropriate mechanical response. Micro modelling approaches must be resorted to, but these are known to be computationally expensive. In this regard, we propose an efficient multiscale model for the design and optimization of these linings. The bricks and joints are replaced by a homogeneous equivalent material, whose mechanical behavior is obtained using nonlinear FE based homogenization technique. Nonlinear effects caused by progressive closure of joints are accurately captured. Comparisons between experimental and numerical results of refractory masonry subjected to uniaxial and biaxial compression at different temperatures are reported. The present model considers the orthotropic, nonlinear, elastic-viscoplastic behavior of refractory masonry at high temperature and can be used to predict the mechanical response and optimize many high temperature industrial components.

5:20 PM - WITHDRAWN

(UNITECR-055-2022) Research on Numerical Simulation Method of Tundish Flow Field Based on OpenFOAM CFD Toolkit

Q. Fu*[1]; W. Zhang[1]; Q. Fan[1]

1. Puyang Refractories Group Co., Ltd., China

In order to study the simulation method of tundish flow field based on open source software, a mathematical model was established based on the stable incompressible turbulence solver simpleFoam in the open source CFD toolkit OpenFOAM, and the k-epsilon RNG turbulence model was used to solve the steady state of the tundish Flow field. Based on the transient scalar transfer equation solver scalarTransportFoam, a transient tracer transfer solver tracerFoam was developed to calculated the tundish RTD curve; and use the self-developed RTD curve quantitative analysis program Rtd-Post, the average residence time and dead zone volume fraction of the tundish were obtained. By comparison: the calculation results of the tundish flow field, the RTD curve, and the quantitative analysis results are consistent with the calculation results of the commercial software.

Raw Materials I

Room: Williford B

Session Chair: Scot Graddick, Imerys

10:40 AM

(UNITECR-056-2022) Iron Leaching from Non-Refractory Grade Bauxite: Individual Process Optimization and Prediction by using DOE

A. Stein*[1]; A. Sax[1]; P. Quirmbach[1]

1. University of Koblenz-Landau, Department of Chemistry, Germany

Bauxite is an important raw material for the production of refractories. The availability of refractory grade ore worldwide is limited, and high iron contents in particular reduce the quality of the material. For refractory applications, a maximum iron content of 2 % is acceptable. In this study, acid leaching with HCl is used to decrease the iron content in different non-refractory grade raw bauxites. Computerized design of experiments (DOE) and statistical methods are used to determine optimum process parameters and influencing factors for different bauxites individually. Compared to previously published studies, the applied approach makes it possible to process even very iron-rich bauxites (e.g. 31 % Fe_2O_3 in calcined substance) and to lower their Fe_2O_3-contents below the permitted 2 %. In addition, larger grain sizes (around 5.5 mm) can be used. Statistical planning and mathematical modeling also allow the prediction of the minimum achievable iron content within the investigated parameter ranges. For selected parameter combinations, the achievable Fe_2O_3 content can be predicted relatively accurately without the requirement for practical testing of the corresponding experimental setup.

11:00 AM - WITHDRAWN

(UNITECR-057-2022) The impact of reactive alumina powders on properties of corundum based refractory castables

H. Tang[1]; W. Yuan*[1]

1. Wuhan University of Science and Technology, China

Reactive alumina powders have been widely used in the refractories industry at high temperatures due to its high reactive and sintering activity. Generally, the powders' characteristics including specific surface area, impurities and particle size distribution have a significant influence on the final products. In order to evaluate the impact of reactive alumina powders on properties of refractory castables, three types of commercial reactive alumina powders were compared. By a series of powder characterization, phase analysis and microstructure observation of castables, it was demonstrated that the formation of intergranular liquid of alumina grain depended on the impurities of reactive alumina. Besides, the influence of particle size distribution of reactive alumina powders was more dominant according to the gray correlation analysis.

11:20 AM

(UNITECR-058-2022) The Effect of Iron Oxide Impurities on the Hot Properties of Mullite

S. Ashlock*[1]; A. D. Scheer[1]

1. Kyanite Mining Corporation, Research and Development, USA

Mullite is an important material in the refractory industry due to its exceptional hot properties. Most commercially available mullite materials are non-stoichiometric and therefore have much lower maximum usage temperatures than theoretically possible. It is often thought that the alumina content of the mullite aggregate or grain is the most important property when deciding between two materials. However, the amount of impurities is equally important. Inclusions of fluxing materials, such as iron oxide, alkalis, and alkaline earth oxides lower the maximum usage temperatures by reacting with the silica in the refractory and creating glassy phases. To test the importance of impurity level on the refractory, samples of Virginia Mullite™ with static alumina contents and varying iron oxide contents ranging down to 0.05% were tested. Hot modulus of rupture, creep resistance, and the thermal coefficient of expansion were all examined and showed that decreasing the amount of iron oxide was beneficial for the refractory grain. XRD was also used to compare glassy phase formation at different temperatures with varying iron oxide contents.

11:40 AM

(UNITECR-059-2022) Influence of Super Reactive Alumina on Rheological Behavior of Free Flowing Castables at Low and High Shear Rate

C. Dünzen*[1]; D. Janousch[1]; R. Dirscherl[1]

1. Nabaltec, Germany

The rheological behavior of refractory castables is often only described by the simple spreading test. However, castables with very low water contents are well known to exhibit a strongly dilatant behavior, even though the viscosity at high shear rate is usually not measured. The study described in this paper intends to illustrate the effect of a super reactive alumina on the shear rate dependent rheological behavior of castables. A pure alumina ULCC was modified by step by step replacing the reactive alumina (D_{50}: 2.5μm) by a super reactive alumina (D_{50}: 0.8 μm). While the spreading test is used to determine the flowability at low shear rate, a simple setup was created to measure power consumption of the mixer and thus allowing conclusions to be drawn about the viscosity of the castable at a higher shear rate. It'll be shown, that the spreading diameter remains almost unchanged for super reactive alumina contents from 20 % to 80 %. Mixer power consumption, exhibits continuous decrease, when the content of super reactive alumina is raised from 20 % to 100 % stepwise. The results offer a solution to reduce castables viscosity, especially at high shear rate. This study illustrates how super reactive alumina continuously changes the rheological behavior of a castable from rather shear thickening to rather shear thinning, by increase of its percentage.

12:00 PM - WITHDRAWN

(UNITECR-060-2022) Fabrication of Red Firing Clay Ceramic Water Filter Tempered with Iron Rich Oxide Material and Treated Mining Waste

L. I. Cabalo*[1]; E. Ibarra[1]

1. Mindanao State University-Iligan Institute of Technology, Department of Materials Resource and Technology, Philippines

Ceramic water filter with controlled permeability have been fabricated, composed of sintered red clay and non-plastic components tempered with iron rich oxide materials through slip casting technique. The iron rich oxide generally controls the pore size of the red clay based ceramics for various applications such as fluid filtration with controlled distribution. Ceramic slurries were prepared, composed of red clay, silica, treated mine waste, and iron rich oxide material. Three groups of different compositions were formulated in order to compare the permeability of the red firing clay based ceramics. The first formulations were made from red clay, silica, and iron rich oxide only, second and third compositions utilized the use of treated mining waste from CARAGA region tempered with iron rich oxide materials to further enhance the strength of the fired ceramics. Rheological characterization of red clay ceramic slurries showed shear thinning behavior. Samples were formed through slip casting using plaster mold and fired at 1100 °C. Physical properties of formed ceramics shows increasing apparent porosity as the amount of loaded iron oxide increases. Increasing apparent porosity decreases the vacuum pressure and increases the fluid flow rate of about 2.86 L/h, which demonstrates a good red firing clay based ceramics for fluid filter applications.

Raw Materials II

Room: Williford B

Session Chairs: Steven Ashlock, Virginia Kyanite; Scot Graddick, Imerys

1:40 PM

(UNITECR-061-2022) High Grade Guyanese Bauxite Source in a Class of Its Own

J. A. Karson*[1]

1. First Bauxite LLC, Sales, USA

It is a well-known fact that Guyana produces superb quality gibbsitic bauxite ores. The Bonasika Bauxite deposit in Guyana has some of the best refractory grade bauxite in the world. One particular area, which has been naturally washed for millions of years, is now operating at full capacity. The Bonasika mine, owned by First Bauxite LLC and managed by its fully owned subsidiary, Guyana Industrial Minerals Corporation (GINMIN), is producing 30,000 MT per month in a new facility located near the Demerara River in Guyana. The unique properties, when sintered, form a high corundum with a minor mullite phase put this bauxite in a class by its own. Researchers believe this bauxite can be a partial substitute for brown-fused or other high grade aluminas. The new Guyanese deposit fills a gap in the alumina portfolio as a unique sintered product at 93% alumina, with extremely low impurities, low iron, low silica, low alkalis with low porosity and high refractoriness. The paper will review the properties, markets and status of the new Guyanese bauxite deposit, now available to the global market, along with the history of the development of this source.

2:00 PM

(UNITECR-062-2022) Purification and Densification of High Purity Sintered Magnesia from Natural Magnesite in China

Z. Guo*[1]

1. Yingkou Jindai Technologies, China

There are tremendous reserves of low grades and abandoned small-lump magnesite in China, due to mining focusing on high grade magnesite in the past three decades. A unique flotation process has been in industrial operation to upgrade magnesite to the purity of >98% MgO (LOI-free), removing variable impurities, such as SiO_2, CaO, Fe_2O_3 and Al_2O_3. The floated magnesite is calcined in newly-designed suspension calciner, instantaneously in flash decomposition, to produce caustic calcined magnesia (CCM) with much higher activity and ground fineness than those made in the conventional reverberatory and multiple hearth furnaces. The successful densification of CCM briquettes has been achieved in the industrial production of sintering high purity magnesia (>98% MgO), obtaining high bulk density of 3.42 g/cm^3, from natural macrocrystalline magnesite.

2:20 PM

(UNITECR-063-2022) Study on Hydration Process of Preparing High Purity Magnesium Hydroxide from Microcrystalline Magnesite

Z. Li*[1]

1. Puyang Refractories Group Co. Ltd., China

The microcrystalline magnesite in Sichuan-Tibet area was lightly burned at 920 Celsius for 3 h and then crushed to 0-1 mm. Magnesium hydroxide was obtained by changing the hydration temperature and the amount of hydration agent (NH_4Cl), reaction time and solid-liquid ratio. The chemical composition, hydration rate, XRD and microstructure of the hydration products were analyzed to optimize the hydration process conditions. The results show that the hydration rate of microcrystalline magnesite powder increases with the increase of temperature. The hydration rate of autoclaved products at 120 Celsius was greater than 96.40% and the products were mainly hexagonal. Using NH4CI as a hydrating agent can promote the hydration of magnesium oxide to a certain extent. The optimal conditions for controlling various factors of hydration reaction are: the addition amount of hydrating agent is 0.75, the reaction temperature is 95 Celsius, the reaction time is 60 min, and the solid-liquid ratio is 1:15. Under these conditions, hydration rate was greater than 94.56% and the hydration products were hexagonal flake with good dispersion. Furthermore, the high purity magnesium hydroxide can be obtained with the content of Magnesium Oxide above 99%.

2:40 PM

(UNITECR-064-2022) Preparation of Active MgO from Microcrystalline Magnesite and Its Application in the Hydrometallurgy

X. Tian*[1]

1. Puyang Refractories Group Co. Ltd., China

Active MgO was prepared through selection, crushing, cleaning, drying, calcining, grinding and other processes,using Tibet high-purity microcrystalline magnesite as raw materials. And then the properties were tested and characterized. The results show that: 1)The MgO has high purity and low impurity content: MgO≥98wt%,CaO≤1.2 wt %,SiO_2≤0.3 wt %,Fe_2O_3≤0.1 wt %, Cl^-≤0.001 wt %,SO_4^{2-}≤0.001 wt %; 2)The specific surface area of this MgO after ground to 325 mesh can reach 35m^2/g or more; 3)The chemical activity of this MgO is high. Its citric acid activity is lower than 20s. The active MgO prepared by microcrystalline magnesite can be used in the hydrometallurgy. It has excellent performances and can satisfy the customer's requirements.

3:00 PM

(UNITECR-065-2022) Preparation of High-purity Low-activity MgO from Microcrystalline Magnesite and Its Application in the Production of Acetate Fiber

X. Tian*[1]

1. Puyang Refractories Group Co. Ltd., China

High-purity low-activity MgO was prepared through selection, crushing, cleaning, drying, calcining, grinding and other processes,using Tibet high-purity microcrystalline magnesite as raw materials. And then the properties were tested and characterized. The results show that: 1)The best process for preparing low-active MgO is the microcrystalline magnesite calcinatin at 1450 Celsius for 7.5 ~ 10h. 2)The loose density of this MgO after ground to 100 mesh can reach 1.1g / cm^3 or more; 3)The MgO has high purity and low impurity content: MgO≥98wt%,CaO≤1.0 wt %,SiO_2≤0.2 wt %, Fe_2O_3≤0.1 wt %,Cl^-≤0.001 wt %; 4)The chemical activity of this MgO is low. Its citric acid activity is more than 15min. The High-purity low-activity MgO prepared by microcrystalline magnesite can be used in the production of acetate fiber. It satisfies the customer's requirements well and achieved long-term batch use by customers.

3:40 PM - WITHDRAWN

(UNITECR-066-2022) Investigation of the passive-oxidation of SiC in the temperature range 1200 to 1500 °C

V. Reynaud*[1]; M. Dombrowski[2]; J. Poirier[3]; E. de Bilbao[3]

1. CNRS CEMHTI - Calderys, France
2. Calderys, France
3. University of Orleans, CEMHTI-CNRS, France

Silicon Carbide is a key component in the formulation of main Black Castables used worldwide for Blast Furnaces, due to its properties recognized necessary to resist the alterations met by the refractory during its service life. A comparative study of different interesting silicon carbides was carried out in the temperature range 1200 to 1500 °C whose limits correspond respectively to chemical reactions and working temperatures of castables used in Blast Furnace Main Iron Troughs. Structural, chemical, and mineral characterizations of the raw materials (min 95 wt.% of SiC) were also carried out, highlighting differences in grain size distribution, composition, and quantities of all the polytypes as 6H, 4H, or 15R between samples. Oxidation kinetics of SiC powders in air was investigated using thermogravimetry analyses, associated with X-ray diffraction in order to quantify crystallized oxidation products. If the influence of the grain size was noticed, a more important oxidation of SiC containing higher iron impurities amount was observed. The oxidation of studied SiC powders followed classical parabolic behavior, characteristic of a diffusion-controlled reaction, and activation energies were estimated from 119 up to 167 kJ.mol^{-1}. These results will be useful in selecting SiC raw materials adapted to the market needs.

4:00 PM

(UNITECR-067-2022) Synthesis and Characterization of Single-Phase Al_3BC_3

R. Maki*[1]; Y. Kusano[1]; T. Maeda[2]; H. Taira[2]

1. Okayama University of Science, Japan
2. Okayama Ceramics Research Foundation, Japan

In ternary metal borocarbides, Al_3BC_3 has been considered as promising candidate for lightweight structural components and one of the boride additives for carbon-containing-refractories. Several researchers reported that the addition of excess B_4C is required for the synthesis of single-phase Al_3BC_3. However, the reason for addition of excess B_4C is not clarified, and the formation mechanism of Al_3BC_3 has been scarcely discussed. In this study, we investigated the preparation method of single-phase Al_3BC_3 and its formation mechanism. Mixtures of aluminum, B_4C and carbon powders with a mole ratio of Al:B:C = 3:1:3 were fired at 1800°C under argon (Ar) atmosphere. The crystalline phases formed were Al_3BC_3 and Al_4C_3.

From the results of powder X-ray diffraction (XRD) and thermogravimetry-differential thermal analysis (TG-DTA) measurements, we found that Al_3BC_3 formed by a reaction between B_4C and Al_4C_3 around 1200°C. Although the sample contained Al_4C_3 as an impurity phase, the monophasic product of Al_3BC_3 was successfully obtained by remixing and reheating at 1800°C in Ar.

4:20 PM

(UNITECR-068-2022) Thermal Decomposition of Al_3BC_3 in Various Atmosphere: a New Boride Additive for Carbon-Containing-Refractories

T. Maeda*[1]; H. Taira[1]; R. Maki[2]; Y. Kusano[2]

1. Okayama Ceramics Research Foundation, Institute, Japan
2. Department of Applied Chemistry and Biotechnology, Faculty and Engineering, Okayama University of Science, Japan

B_4C is often added to carbon-containing refractories for improving oxidation resistance. However, the elastic modulus increases with the increases of additive amount of B_4C. Therefore, it is necessary to control the additive amount of B_4C for the carbon-containing refractories. This study focused on a low boron containing carbide, Al_3BC_3 as a new boride additive, and studied thermal transformation of Al_3BC_3 caused by heating at 1500°C in various atmospheres. Al_3BC_3 completely decomposed to Al_5BO_9 and Al_2O_3 by heating in air. In a nitrogen atmosphere, the amount of formed AlN and C were increased as the heating time increased, but Al_3BC_3 remained even after heating for 10 hours. On the other hand, Al_3BC_3 decomposed to Al_5BO_9, Al_2O_3 and C under a CO atmosphere. From those results, it was found that Al_3BC_3 decomposed by heating in any atmospheres. Therefore, we believe that Al_3BC_3 can be applied as a new boride antioxidant for carbon-containing refractories.

4:40 PM

(UNITECR-069-2022) The influence of curing and thermal treatment temperature on the microstructure of CAC binder with nano additives

R. Boris*[1]; V. Antonovič[1]; J. Malaiskiene[1]; R. Stonys[1]

1. Vilnius Gediminas Technical university, Lithuania

The incorporation of nano additives into the cement matrix in order to obtain "true" cementitious nanocomposites presents the important way for investigation. This work analyses, the effect of nano cones (NC) and nano silica (NS) additives on hydration of CAC after hardening under different temperatures (5,20,40°C) and after thermal treatment (800,1000°C) on the microstructure and phase composition, when W/C=1. It has been found that after 3 days of hydration were formed such crystalline hydration products: at 5°C–CAH_{10}, 20°C–CAH_{10},C_2AH_8 and AH_3, 40°C–C_3AH_6 and AH_3 hydrates. Additionally, XRD results after hardening show that samples with NC compared to samples with NS yield a higher relative intensity of hydrates. In the samples after firing at 800°C, the hydrates are decomposing, and the minerals CA, CA_2 and $C_{12}A_7$ are being formed, higher amounts of minerals are formed in the samples with NC. The results of XRD analysis showed that, after firing the samples at 1000°C, the intensities of the diffraction maximum of minerals CA,CA_2 increasing, of $C_{12}A_7$ - decreasing in the samples with NS. The results of XRD analysis showed that, at this temperature the reactions in solid state materials proceed and as a result the intensity of the diffraction maximum of mineral are increasing, while those of minerals – CA and CA_2 are decreasing.

Advances in Monolithic Technology I

Room: Williford C

Session Chairs: William Headrick, RHI Magnesita; John Waters, RHI Magnesita

10:40 AM

(UNITECR-070-2022) Contribution to environmental sustainability

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2. REFRATECHNIK Steel GmbH, R&D, Germany

At the Paris Climate Summit in 2015, the world governments agreed to keep the global temperature rise under 2° C, if possible 1.5°C, by the end of this century to avoid the worst impacts. The steel industry is actively dedicated to meeting society's needs and advancing environmental stewardship, achieving a 40 percent reduction in energy intensity and a 50 percent reduction in greenhouse gas intensity since 1990, reaching an average 1.8 t CO_2/t crude steel. The contribution of the refractory industry is more limited in this fight, but necessary regarding health safety, environment and energy deployed. We will review in this paper our main innovation concerning the reduction of fumes and BaPs during installation, some way for decreasing deeply the preheating time and consequently the energy consumed as well as the development of new insulating refractories based on natural biogenic raw materials.

11:00 AM

(UNITECR-071-2022) HYBRID - Innovative Bonding Technology for Refractory Concrete

J. Neese*[1]; B. Kesselheim[1]; S. Rollmann[1]; S. Scheffler[1]

1. REFRATECHNIK Steel GmbH, Germany

The commonly used bonding systems for monolithic refractory castables have several disadvantages. There is no system, which combines high strength development over the entire temperature range, fast heating up properties and sufficient high-temperature durability. Therefore, the aim was to develop a system which combines the characteristics named above. With the HYBRID technology all requirements are covered. In this presentation the new system is compared to the cement and silica-sol bonding and successful implemented practical applications are exposed. Already at room temperature there's a significant increase of strength in comparison to silica-sol bonding. This positive result was approved up to high temperatures, with improved performance compared to the normally used binders. The benefits of the HYBRID technology are particularly evident in practice for example in areas with high mechanical stress already at low temperatures, to produce pre-shaped components or to reduce downtimes with fast heating rates and the option to install on hot surfaces. In times with high requirements for reducing carbon emissions, HYBRID technology offers great possibilities for energy saving in industrial applications. HYBRID products can be used in versatile applications, provide all the features for modern lining and process technologies, and combines impressive performance with economic installation technologies.

11:20 AM

(UNITECR-072-2022) Advanced refractory no-cement castables based on alumina and spinel with improved thermomechanical properties

D. Madej*[1]; J. Ramult[1]; K. Warmuz[1]; A. Kruk[2]

1. AGH University of Science and Technology, Faculty of Materials Science and Ceramics, Poland
2. Pedagogical University of Cracow, Institute of Technology, Poland

This paper provides critical reviews on special strength-testing methods, which have been implemented for advanced no-cement Al_2O_3-$MgAl_2O_4$-type refractory castables. These materials are of a mostly heterogeneous composition, especially in respect to

microstructure, spinel stoichiometry, spinel content and presence of SiO_2-rich phase. No-cement containing high alumina castables with presynthesized and in situ spinel formation were studied in regard to thermomechanical properties both Refractoriness Under Load (RUL) and Hot Modulus of Rupture (HMOR). For this purpose, cement-free refractory corundum-spinel castables were prepared according to the different technological process variants (options), i.e. with and without presynthesized spinel, varying MgO and microsilica content and presence of nano-alumina particles etc. Microstructural evolutions (SEM-EDS) of castables after firing at 1500°C were different, mainly presenting their morphology, amount and distribution of in-situ formed spinel phase. Hence, the compositions affected the RUL and HMOR of specimens. Acknowledgements This study was founded by The National Centre for Research and Development within the framework of LIDER VIII project No. LIDER/5/0034/L-8/16/NCBR/2017 (Recipient: D. Madej).

11:40 AM

(UNITECR-073-2022) New calcium aluminate cement for refractory pre-cast shape production

S. Kuiper*[1]; A. Buhr[1]; S. Klaus[1]; D. Schmidtmeier[1]; G. Wams[1]; A. Spies[1]

1. Almatis, Netherlands

In many cases precast shape producers have issues with clamping inner moulds and cracking pieces. The reason for these issues can be related to volume shrinkage during hydration of the used cement. Even relative small shrinkage is causing a clamping of the inner mould and high internal stresses. The point in time to remove the inner mould is critical, because the hydration needs to be enough to have sufficient strength and should not be too much to avoid clamping. A new high alumina calcium aluminate cement (CAC) has been developed. This 75% alumina cement has a well-controlled hydration behaviour which provides advantages especially for pre-cast shape production of items which incorporate inner moulds or cores. The setting shrinkage, strength development and setting behaviour were investigated in a self-flow and a vibration castable. These properties were compared to a 70% alumina cement. A much slower shrinkage rate was achieved with the new developed CAC, while the strength development is initially slower, but continues for days resulting in higher strength levels. Also at dried temperatures higher strength levels were obtained. After firing at temperatures of 1000°C or higher, comparable strength levels were obtained.

12:00 PM - WITHDRAWN

(UNITECR-074-2022) Novel agents for refractory castables containing hydraulic binders

I. M. Milanezzi[1]; V. S. Pinto[1]; D. S. Fini[1]; B. P. Bezerra[1]; V. C. Pandolfelli[1]; A. Luz*[1]

1. Federal University of São Carlos, Materials Engineering Department, Brazil

The dry out is usually the longest processing step of refractory castables, which requires high energy consumption, has an impact on the production halt and any damage derived from this process might also imply in shorter working life of the lining. In this sense, it is of utmost importance to find out alternative routes to promote faster and safer drying of dense castables. This work investigates the action of organic salts (aluminum or calcium lactates) in optimizing the drying performance of alumina-based castables bonded with calcium aluminate cement (CAC), hydratable alumina (HA) or magnesia (M). Flowability, setting behavior, X-ray diffraction, green mechanical strength, apparent porosity, permeability and thermogravimetric measurements were used to analyze the designed compositions. The obtained results indicated that both compounds changed the binders' hydration reactions, inducing the generation of gel-like or hydrotalcite-like hydrates. Consequently, the earlier decomposition and/or water withdrawal of these new phases led to refractories with higher permeability and prevented their explosion during heating. Thus, this route is a feasible alternative to improve the castables' drying performance.

Advances in Monolithic Technology II

Room: Williford C

Session Chairs: William Headrick, RHI Magnesita; John Waters, RHI Magnesita

1:40 PM

(UNITECR-075-2022) Effect of Particle Size Distribution on Explosion Resistance During Heating of Alumina Castable Bonded by Hydratable Alumina

Z. Wang*[1]; H. Wang[1]; H. Feng[1]; X. Cao[1]; Y. Cao[1]

1. Sinosteel LIRR, State Key Laboratory of Advanced Refractories, China

Effect of particle size distribution with mass ratio of aggregates to fines changed from 60:30 to 70:20 on properties including explosion resistance during heating of alumina castables bonded by hydratable alumina was investigated with white fused alumina, hydratable alumina, reactive alumina and microsilica as main raw materials. The results show that with aggregate contents increasing, mechanical properties at room temperature of the specimens after drying at 110C for 24h gradually increase and that after firing at 1400C for 3h decrease; bulk density both after drying and firing increases slightly, and apparent porosity decreases; air permeability for green and drying at 110C increases at beginning and then decreases, the air permeability and average pore size of the specimens treated at 1400C increases gradually; explosion resistance increases first and then decreases, when the mass ratio of aggregates to fines is 68:22, explosion resistance reaches the best.

2:00 PM

(UNITECR-076-2022) Improvement in Explosion Resistance of Low Cement Refractory Castables Using Drying Agents

H. Peng*[1]; B. Myhre[1]

1. Elkem silica products, Norway, R&D, Norway

Explosion resistance of low cement castables (LCCs) containing different types of drying agents (polymer fibres and EMSIL-DRY™) has been studied both in lab- and industrial-scale specimens. To understand fast dry-out behaviour, Thermal Gravimetric Analysis (TGA) during firing and Scanning Electron Microscopy (SEM) of fractured surfaces of fired specimens were carried out. Our study showed that the type of drying agent had a profound impact on flow/workability of the fresh castables and on the explosion resistance of the LCCs during firing. Compared to polymer fibres, EMSIL-DRY™ lowered the temperature of maximum dewatering rate thus prevented explosions during the heat-up step. The LCC containing EMSIL-DRY™ showed excellent explosion resistance, as demonstrated by the production of a perfect 400kg block that was fired at 75°C/hr to 850°C.

2:20 PM

(UNITECR-077-2022) Development of Highly Densified Precast Block for Impact Zone in Teeming Ladle

M. Fujii*[1]; M. Nishimura[1]

1. Shinagawa Refractories Co., Ltd., Research Center, Japan

For decades, most of the Japanese integrated steel mills have been adopting castable lining for steel ladle. Thanks to the various technology development, Al_2O_3-MgO materials became dominant for metal line, bottom, and impact pad of steel ladles. Its many favorable characteristics have been materialized by the sophisticated microstructure engineering utilizing in-situ spinel formation reaction. For the sake of further improvement, authors attempted reduction

of mixing water. By applying novel technologies such as special deflocculant, unique particle management, etc., Al_2O_3-MgO castable requiring just 3 mass% of mixing water was invented. According to its stable dense structure, considerable improvement of strength at intermediate temperature range, which had been long term issue, was achieved, resulting in significant reduction of structural spalling. As a result, wear rate of a commercial steel ladle was reduced for 40 %.

2:40 PM

(UNITECR-078-2022) Thermal Shock Resistance of 60% Alumina Gunite with a Zircon Addition

J. Sayre*[1]

1. HarbisonWalker Internation, USA

The thermal shock resistance of refractory materials is an important selection criterion. Based on the operating conditions within a unit, thermal shock resistant materials may be necessary to extend the service life. Comparisons between the calculated thermal shock resistance parameters (R, R″, and R_{st}), the change in crushing strength, and the crushing strength after thermal cycling will be made on 60% alumina gunite materials. The change in strength and the residual strength will be correlated with the different thermal shock parameters. These parameters are used to describe the crack propagation and crack initiation using material properties. The changes in these parameters and the change in residual strength with a zircon addition will also be explored.

3:00 PM

(UNITECR-079-2022) Innovative Profile Printing System for Steel Ladle Bottom to Improve Steel Flow and Metallic Yield

V. P. Ramos*[2]; A. Nascimento[2]; D. F. Galesi[2]; H. Guimarães[2]; H. A. Lima[2]; L. Souza[2]; L. H. Souza[2]; B. C. Andrade[1]; B. N. Stoco[1]; D. S. Orosimbo[1]; G. N. Souza[1]; L. Crivelari[1]; T. Silva[1]

1. Ternium Brasil, Brazil
2. Saint-Gobain do Brasil Ltda, Brazil

During the steelmaking process, the liquid metal is poured from the converter into a steel ladle. After metallurgical treatment, the ladle is drained into the tundish in the continuous casting process. Along the casting, two fluid-dynamic phenomena occur, namely the vortex and the drain, which impair the total emptying of the ladle, resulting in a reduction in the metallic yield. Through a new and innovative refractory casting methodology, which allow a flow optimized profile printing at the bottom of the ladle, a reduction in the vortex and drain negative effects were minimized. Field trials showed that the new bottom profile system was effective compared to traditional solutions, showing results with a potential reduction around 30% of metallic losses. Along the present work, the basic principles and technology are described, allowing the understanding of the new and innovative solution for steel ladle bottom.

3:40 PM

(UNITECR-080-2022) Effect of ball pitch addition on the microstructure and properties of Al_2O_3-SiC-C castables

P. Zhou[1]; X. Liu[1]; Y. Zhang[2]; Q. Jia*[1]

1. Zhengzhou University, High Temperature Ceramics Institute, China
2. Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China

Al_2O_3-SiC-C castables were prepared using fused brown corundum, silicon carbide, ultrafine α-Al_2O_3, microsilica, calcium aluminate cement, silicon powder and ball pitch as raw materials. Effect of firing atmosphere and ball pitch addition on the microstructure and properties of Al_2O_3-SiC-C castables were investigated in this work. The results show that cold strength and corrosion resistance of the castables are decreased, and thermal shock resistance of the specimens are gradually increased with increasing of ball pitch content in oxidizing atmosphere. Cold strength of the specimens firing in reducing atmosphere is slightly lower than those firing in oxidizing atmosphere. Compared with the specimens firing in oxidizing atmosphere, thermal shock resistance and corrosion resistance of the specimens firing in reducing atmosphere are markedly improved, while the slag penetration of the specimens is slightly degraded. Firing atmosphere has also great effect on the morphologies of in-situ formed SiC whiskers in castables. The in-situ formed SiC whiskers with relatively smooth surface were observed in oxidizing atmosphere, quantities of SiC whiskers with rough surface and irregular diameter formed in reducing atmosphere. The growth process of SiC whiskers may be mainly governed by vapor-solid growth mechanism and vapor-vapor growth mechanism.

4:00 PM

(UNITECR-081-2022) Development and Production of High-density Silica Bricks for Coke Ovens

S. Dvorak*[1]

1. P-D Refractories CZ, Czechia

ABSTRACT Silica is the main refractory material for lining of the coking facilities. There are presented new silica products with a higher quality that are designed for linings of the most stressed parts of the coke ovens. Even there can be different opinions, it may be stated that present ideas of silica used as lining of coke ovens converge to products with maximal grade of transformation of quartz to cristobalite and tridymite, commensurate value of reversible thermal expansion, minimal additional expansion in heat and minimal creep under load at high temperatures. Stability of these parameters, conditioned with high levels and stability of other physical and chemical properties of the products, is obvious request. Practice in the production of silica shows that silica with bulk density higher than 1880 kg/m^3 and with apparent porosity lower than 18.5 % can be hardly produced by merely using a hydrate of lime as a mineralizer. To meet this requirement, a combination of hydrate of lime with some calcium salts of inorganic acids can be used. In this way, bulk density higher than 1900 kg/m^3 and apparent porosity even lower than 17 % can be attained, i.e. characteristics designed for products to be used especially in floor linings and for brickwork of heating walls of the coking chambers.

Poster Session

Room: Lower Level Exhibit Area

5:00 PM

(UNITECR-P001-2022) Cost Effective Model for Torpedo Ladle Refractory

A. Kumar*[1]; S. A. KHAN[2]; M. K. Singh[2]; M. Bag[2]; U. Singh[3]; P. Panigrahi[1]

1. Tata Steel, Refractory Technology Group, India
2. Tata Steel, Iron Making Refractory, India
3. Tata Steel, V.P (C.S.I), India

Tata Steel, Jamshedpur has improved the straight (without any cold repair) life of 320 ton Torpedo Ladle Car (TLCs) from 1380 trips (2015) to current levels of +1700 trips without compromising on equipment safety. This increase is without major change in input material quality or lining pattern. The maintenance strategy is centered around generating value by maximizing leftover potential life, at the same time consuming the same by incremental increase in targeted life, resulting in lower costs. This paper describes a cost-effective model of refractory maintenance followed to achieve straight campaign life close to 2000 trips in 300 tons category of TLCs.

(UNITECR-P002-2022) Research and Development, Manufacturing and Application of Series of Andalusite bricks Used for Hot Blast stove

K. Yin*[1]

1. Zhengzhou Annec Industrial Co., Ltd, Refractory Technology, China

The particles of series of low creep thermal shock resistance andalusite bricks are made of andalusite, tabular alumina and chamotte, andalusite particles are used as the main component,while tabular alumina and chamotte are used as assistant particles, which are used to adjust the content of Al_2O_3 in andalusite bricks. The matrixes of andalusite bricks are made of andalusite powder, corundum powder, α-Al_2O_3 micro powder, SiO_2 micro powder and clay powder, the ratio of mullite and corundum in the matrix of andalusite brick is adjusted by corundum powder, α-Al_2O_3 micro powder and SiO_2 micro powder, and clay powder is used as bonder. By referring to above stated physical and chemical properties of bricks and the actual production data and referring to the foreign standards of andalusite brick which edited by Danieli and Paul Worth, the China standard Andalusite brick for Hot Blast Stove has been set by us. By referring to scientific allocation and successfully application in hot blast stove and combining with application allocation of various parts of andalusite bricks in hot blast stove abroad, Andalusite brick for Hot Blast Stove has been listed the standard Technical Specification of Refractories in Top Combustion Hot Blast Stove set by us.

(UNITECR-P003-2022) Corroded alumina-spinel brick preparation in laboratory condition for thermomechanical investigations

S. Darban*[1]; R. Prorok[1]; J. Szczerba[1]

1. AGH University of Science and Technology, Department of Ceramics and Refractories, Poland

The corrosion in the refractories which are used in steel ladle is the consequence of the production process. The corrosion can cause a chemical gradient, which is accelerated by the thermal gradient within the microstructure. This alternation affects the thermomechanical behavior of the refractory linings in the steel industry. The Brazilian test is one of the assertation methods for refractory materials for thermomechanical properties. However, making corroded samples with adequate quality in the laboratory condition seems not an easy task to overcome. This study aimed to prepare functional samples after the corrosion for thermomechanical investigations. For this means the specific alumina-spinel samples were prepared. The corrosion test has been applied at 1350°C and 1450°C by implementing an industrial slag. Next, for microstructure investigations the SEM and for phase analysis XRD technique was utilized. The result illustrates that samples at 1450°C were fully homogenized while the samples at 1350°C were not impregnated.
Acknowledgments The work was partially supported by the faculty of material science and ceramics and the funding scheme of the European Commission, Marie SkIodowska-Curie Actions Innovative Training Networks in the frame of the project ATHOR - Advanced THermomechanical multiscale modeling of Refractory linings 764987 Grant

(UNITECR-P004-2022) Corrosion Mechanism of MgO-Al_2O_3-C Refractories Containing SiC with Different Particle Size

T. Li*[1]

1. Puyang Refractories Group Co., Ltd, Technial center, China

Two kinds of MgO-Al2O3-C (MAC) refractories containing SiC with different particle size were tested in the sidewall of the refining ladle for 115-135 heats. The industrial tests showed that the corrosion rate of the MAC refractories was remarkably influenced by the particle size of SiC. The reducing of the overflow rate of SiO(g) made the microstructure denser and inhibited the oxidation of carbon in MAC refractories. These all made the composition and structure of the material more stable, the strength higher and the abrasion resistance better. Furthermore, the bigger particle size of SiC decreased the contact area between the slag and the material, and then decreased the dissolution rate of MgO into slag. Therefore, compared with the MAC refractories containing SiC with the particle size of 1000 mesh, the one containing SiC with the particle size of 180 mesh had the higher corrosion resistance.

(UNITECR-P005-2022) Formation of MgO dense layer in MgO-C refractories by carbothermic reaction and its influence on refractory corrosion by high MnO slag - *WITHDRAWN*

D. Lee[1]; M. Van Ende*[1]; I. Jung[1]

1. Seoul National University, Department of Materials Science and Engineering, Republic of Korea

In order to investigate the MgO dense layer formation in MgO-C refractories, laboratory isothermal oxidation tests of commercial MgO-5wt.%C, and MgO-14wt.%C refractories were carried out in air at 1500, 1550, 1600 and 1650 °C for up to 12 hrs. The thickness of the MgO dense layer and the weight change of the refractory samples were measured with time at each temperature. It is found that the uniform formation of a MgO dense layer is largely dependent on temperature and carbon content of the MgO-C refractory. Corrosion tests of the MgO-C refractory by high MnO slag show that refractory samples in which a continuous MgO dense layer was obtained exhibit a superior corrosion resistance to slag than the original MgO-C refractory.

(UNITECR-P006-2022) Present situation and development trend of refractory raw materials in China - *WITHDRAWN*

Y. Zhang*[1]; Z. Xiaohui[1]; C. Qingxian[1]; P. Xigao[1]; W. Zhanmin[1]

1. Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China

China is rich in refractory raw materials, especially bauxite, magnesite and graphite, which play an important role in the world. However, most of ore mining in China was not standardized, and the disorder mining was frequent, which caused serious waste of resources and negative impact on the environment. In recent years, the Chinese government has strengthened the management of mining areas, while chinese refractory raw material producers have also updated the environmental protection facilities and abandoned the backward production capacity, resulting in a shortage of raw material supply and a sharp rise in prices. The prices of main refractory materials, such as bauxite, magnesia, flake graphite and silicon carbide, fluctuate greatly, which have an important impact on the production of refractories. But after that, the mining operations in China is gradually orderly and the supply of refractory raw material tends to be stable. The production of refractory materials in China will be mechanical automated, large-scale and high-quality. It provides a favorable environment for the stable operation of refractory industry.

(UNITECR-P007-2022) Investigation of recycled magnesia-carbon aggregate obtained with omitting carbon removal step

M. J. Ludwig*[1]; I. Jastrzebska[1]; R. Prorok[1]; M. Sulkowski[2]; C. Golawski[2]; J. Szczerba[1]

1. AGH University of Science and Technology, Department of Ceramics and Refractories, Poland
2. ArcelorMittal Refractories, Poland

Magnesia-carbon refractory products have been successfully applied in the steel industry for several years. They are commonly applied in basic oxygen furnaces (BOF), electric arc furnaces (EAF) and steel ladles. They are composed of magnesia, carbon, binder and antioxidants. However, the sources of the main raw materials deposits for manufacturing magnesia-carbon refractories have been running out rapidly. To overcome this issue, recycled raw materials have been taken into consideration during recent years. The purpose of

this work was to assess the properties of several recycled magnesia-carbon aggregates obtained with omitting carbon removal step and compare them to fused magnesia aggregates. Densification of presented aggregates was investigated. The phase composition was determined using the XRD method. The microstructures of the samples were assessed using the optical microscopy method, and scanning electron microscopy SEM/EDS. Finally, the properties of novel refractory products containing recycled aggregates were presented. Obtained results revealed that recycled aggregate showed worse properties in comparison to fused magnesia, however, its addition to producing new refractory products enabled to maintain the properties of the materials. This work was supported by the fund of the project of The National Centre for Research and Development No POIR.01.02.00-00-0175/16 INNOSTAL.

(UNITECR-P008-2022) Study on Slag Corrosion of the Fused Magnesia with Ultra-low content of SiO_2 and Fe_2O_3 from Microcrystalline Magnesite

T. Li*[1]; Q. Zuo[1]; J. Gao[1]

1. Puyang Refractories Group Co., Ltd, Technial center, China

A new type of fused magnesia has been manufactured from Tibet microcrystalline magnesite. The slag corrosion of the new fused magnesia in slag of refining ladle was investigated compared with the traditional fused magnesia from crystalline magnesite in Liaoning province. The results indicated that the slag resistance of the fused magnesia with ultra-low inclusions was better than that of Liaoning province, due to the ultra-low inclusions (SiO_2 and Fe_2O_3) content and higher CaO/SiO_2 ratio (more than 3). As the main raw material, the quality of fused magnesia directly affects the service life of magnesia carbon (MgO-C) refractory. The new type of fused magnesia may extend the performance of MgO-C refractory for ladles in LF and Vacuum Degassing.

(UNITECR-P009-2022) Investigation on Corrosion Resistance of Chromic Oxide, AZS/Cr and High-Alumina Refractories to Aluminaboronsilicate Glasses and Basalt Melts

V. Martynenko[1]; P. Kushchenko*[1]; I. Shulik[1]; Y. Mishnyova[1]; K. Kushchenko[1]

1. Ukrainian Research Institute of Refractories named after A.S. Berezhnoy, Ukraine

The corrosion resistance researches of widely used for the lining of glass furnaces refractories to aluminaboronsilicate glasses and basalt melts were carried out. Samples of chromic oxide, sintered AZS with addition 30 and 60% of Cr_2O_3 and high-alumina refractories were tested at 1580 °C during 8 hours by crucible (static) method for corrosion resistance to aluminaboronsilicate glasses melts: textile E-glass, light-protective medical glass, also basalt melt. Besides, samples of these refractories were tested at 1300 °C by dynamic method for corrosion resistance to light-protective medical glass and basalt melts. Properties, phase composition and microstructure of refractories after tests were researched. The features of tested refractories corrosion character by both methods were determined, as the mechanism of used glasses and basalt melts corrosion influence on refractories microstructure. Based on high corrosion resistance level of obtained results recommendations for optimal usage of researched refractories in high-load places of glass furnaces lining were composed.

(UNITECR-P010-2022) Analysis of Monofrax K-3 Refractory Corrosion Within a Research Scaled Melter

N. J. Smith-Gray*[1]; J. McCloy[1]

1. Washington State University, Materials Science and Engineering, USA

Various refractory corrosion mechanisms are simultaneously occurring during nuclear waste vitrification. Chemical corrosion occurs when the solute (refractory) and solvent (the glass) attempt to reach equilibrium. This study aims to visually show the effects of nuclear vitrification on Monofrax® K-3 refractory corrosion, utilizing a research scaled melter (RSM) that contained an Fe and Ni rich waste simulant for 11 weeks. Chemical maps along with electron dispersive X-ray spectroscopy (EDS) are used to investigate the interactions between the waste simulant and the refractory. The diffusion of Mg and Al out of the refractory leaves an enrichment of Cr and Fe, and this reaction proceeds until the reaction layer loses mechanical integrity and spalls off into the melt. At the same time there is infiltration of glass (Na, Si) and diffusion of metals (Fe, Ni) from the melt that react to form the spinel interface layer at the leached refractory boundary. Finally, backscattered electron imaging was used to visualize how forced convection at the top of the melter can cause the reaction layer to be thinner than in locations with less convection. The reaction layer can be a protective boundary for the refractory against melt infiltration. Therefore, a reduction in the reaction layer will cause an increase in refractory corrosion.

(UNITECR-P011-2022) Oxydation behavior of SiC refractory samples used in waste inceniration furnaces containing different antioxdizing compounds in the starting mixture

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1. BCRC, Research & Technological Support Department, Belgium

The refractory linings of municipal waste incinerators with energy recovering are made with SiC refractory tiles. In service conditions, these products are deteriorated mainly due to corrosion phenomenon induced by an oxidizing atmosphere and flying ashes. To try to improve the oxidation resistance of these materials, an industrial composition of these refractory materials has been modified by adding different antioxidizing compounds: 1wt% of phosphate-based or boron-based compounds. The samples made from these modified compositions have been submitted to high temperature corrosion tests under an oxygen and water steam atmosphere (oxidation conditions suggested in ASTM C863-83). A real time follow up of the oxidation status of the different samples was made by extensometer measurements. XRD and chemical analyses, weight measurements and open porosity measurements before and/or after oxidation tests on each sample composition have also been done. All the results have allowed for a classification of samples' composition according to their oxidation resistance and also compared to a reference sample.

(UNITECR-P012-2022) The Analysis of the Change in the Structure and Properties of Refractory Castable Impregnated with SiO_2 Sol

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1. Vilnius Gediminas technical university, Laboratory of Composite Materials, Lithuania

The results of research of alumina cement based chamotte castable obtained by using the standard physical and mechanical test methods (EN ISO 1927-6:2013), as well as XRF, SEM, EDS analysis methods are presented. Alkali resistance was tested according to ASTM C 454–83:2007 and thermal shock resistance was tested according to DIN 51068. The investigation has shown that alkali resistance of conventional refractory castable (CC) as well as MCC type castable (K_2CO_3 was used as reagent) can be improved by adding fine-grained quartz sand and further improved by SiO_2 sol vacuum impregnation. Impregnated refractory castable has lower porosity and higher compressive strength. However, impregnated refractory castable becomes more brittle and the thermal shock resistance of such castable may decrease depending on its porosity, deformations and internal stresses at high temperatures. It was found that the thermal shock resistance of SiO_2 sol impregnated CC refractory castable increases ~11 %, whereas the penetration of potassium into the test samples reduces ~20 % compared to the control samples. In the case of MCC, however, the porosity of which is lower than the porosity of CC and reduces even more after SiO_2 sol impregnation, the thermal shock resistance reduces about 70%.

(UNITECR-P013-2022) Corrosion mechanism of Al2O3-MgO-SiO2 sagger by Li-ion cathode materials

F. Qian*[1]

1. Sinosteel Luoyang Institute of Refractorie Research, China

Li-ion battery industry is developing rapidly in China. The process of preparing cathode materials is to calcine the mixture powder of $Ni_xCo_yMn_{(1-x-y)}(OH)_2$ and Li_2CO_3 or LiOH in Al_2O_3-MgO-SiO_2 sagger, and the Li-ion cathode materials corroded strongly on the sagger, leading to peeling or cracking of the sagger inner wall. It is believed that the first step is decomposition of Li_2CO_3 or LiOH and the reaction between Li_2O with composition of sagger. The second is that the liquid phase of reaction diffuse downward, which finally form a dense layer. It cause peeling and cracking by the differences in microstructure and thermal properties between the dense and original layer. Through further study, it is found that lithium source can react with the sagger surface in the form of Li_2CO_3 or LiOH directly. In addition, Li_2CO_3 or LiOH can diffuse into the refractories interior in liquid or gas phase, and continue to react with them. The above reaction can cause expansion, destroy the original structure, and cause the partial shedding of the refractory. At the same time, Li_2CO_3 or LiOH in the liquid phase can dissolve Al_2O_3-MgO-SiO_2 materials and diffuse downward under the action of gravity, gradually forming a dense layer, which changes continuously in thickness and structure, and finally forming a crack between the dense layer and the original layer, resulting in a large area of spallation.

(UNITECR-P014-2022) Application of Ultra-Porous Ceramics Prepared by Gelation Freezing Method to Refractories

T. Nakane*[1]; P. JIA[1]; M. Fujii[1]; A. Matsuoka[1]; Y. Tanaka[1]; F. Ozeki[1]

1. MINO CERAMIC CO., LTD, Japan

Porous ceramics have attracted much attention in a wide range of fields such as heat insulating materials, catalyst support and building materials because they have excellent heat insulation, large surface area, superior sound absorbing performance as well as lightweight properties. Among the porous ceramics produced by several methods, the ones prepared by gelation freezing method have very high strength whereas they have high porosity, which enables controlling the strength, porosity and pore form by adjusting the preparation conditions and producing various inorganic compounds. In the past we have reported the application of mullite porous ceramics to insulating firebricks by utilizing their thermal conductivity, thermal shock resistance and lightweight properties. Here we present alumina and zirconia porous ceramics prepared by gelation freezing method with the aim of applying them to refractories. We evaluated the strength, porosity and other various characteristics of the alumina and zirconia porous ceramics in comparison with mullite porous ceramics. Since alumina and zirconia porous ceramics have several attractive properties in terms of their high resistance to chemical reaction and high maximum service temperature, they are expected to be applied in different fields from where mullite porous ceramics are utilized.

(UNITECR-P015-2022) Study on preparation and properties of high temperature thermal insulating materials with microporous powders packed under vacuum

C. Ma*[1]

1. High temperature ceramic institute (HTCI), Zhengzhou University (ZZU), China

Preparation and thermal insulation properties of SiO_2/Al_2O_3 composite micropowder vacuum insulation materials are studied. We focus on effect of vacuum packaging on the thermal conductivity of core materials with different densities, effect of vacuum on the thermal conductivity of thermal insulation materials, and the change of thermal conductivity of vacuum micro-powder thermal insulation materials at different temperatures. The degree of thermal conductivity reduction of the thermal insulation material before and after packaging increases first and then decreases as the density increases. When the core material density is $0.62g/cm^3$, the thermal conductivity coefficient is from $0.063Wm^{-1}K^{-1}$ reduced to $0.054Wm^{-1}K^{-1}$. As the vacuum degree increases, the thermal conductivity of the sample gradually decreases and then tends to be gentle. Research on the thermal conductivity of the composite micropowder vacuum insulation material at different temperatures shows that: vacuum encapsulation has the greatest impact on the thermal conductivity of the sample at 200°C, with a reduction of 25.0%, but the vacuum at 400°C and 600°C The structure has been damaged, the thermal conductivity of the sample is only slightly reduced, about 5%.

(UNITECR-P016-2022) Interactions between Calcium Aluminate Cement, reactive- and calcined alumina in a Low Cement Castable system

A. Gerz*[1]; M. Schmid[1]; G. Walenta[1]; C. Dünzen[3]; N. Noel[2]; A. Sax[2]; P. Quirmbach[2]

1. Calucem GmbH, Germany
2. Universität Koblenz-Landau, Germany
3. Nabaltec AG, Germany

Low Cement Castables (LCC) with Tabular Alumina provide solutions for challenging refractory applications with high temperature demands. Beside high-performance Calcium Aluminate Cements (CACs), the selection of alumina is a key component to achieve desired LCC properties. The choice of alumina influences various castable properties like water demand, flow behavior and strength development. This study investigates the influence of CAC, calcined- and reactive alumina on LCC properties and phase evolution within typical LCCs ranges. A white Calcium Aluminate Cement with ~64% Al_2O_3 and CA as the main reactive phase is chosen as a binder. Workability, hardening properties and cold crushing strength after firing at different temperatures are compared. Refractoriness under load demonstrates the refractory properties of selected castables. XRD and SEM investigations provide an inside view in the phase changes and microstructure up to 1700°C.

(UNITECR-P017-2022) Research and development of perovskite-like refractory compounds

M. Bach*[1]; T. Schemmel[2]; M. Bühringer[3]; H. Jansen[2]; C. Aneziris[1]

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2. Refratechnik Steel GmbH, Germany
3. Alexander Tutsek-Stiftung, Germany

Perovskite-like materials are specifically used in various fields of industries due to their functional and manifold properties and qualities. Especially the structure-property relations were extensively studied in the last century since the discovery of valuable dielectric and ferroelectric properties of ABO_3 structures. The vast number of newly developed phases results in a wide range of applications especially in the field of high-performance ceramics, e.g. piezoelectrics, insulators and superconductors. Meanwhile, within the past two decades, certain perovskite structures attracted much attention as a potential refractory material. Since high-melting perovskite phases are rare in nature, they need to be synthesized. Solid-state synthesis is a suitable method to investigate novel refractory material. In addition to good phase stability at high temperatures, refractory grains should also exhibit a high bulk density and low open porosity. In this study, different earth-alkaline perovskite-like structures based on ZrO_2 are prepared and investigated. Therefore, special emphasis is put on the production by means of solid-state synthesis and the investigation to evaluate the potential as a refractory material. Novel perovskite-like structures having bulk densities of more than 95 % of the true density and open porosity of <5 vol.%, providing a good starting point for the production of refractories.

Thursday, March 17, 2022

Plenary I

Room: Williford A, B, C
Session Chair: James Hemrick, Oak Ridge National Laboratory

8:10 AM

(UNITECR-PLEN-001-2022) Riding the Tiger: Refractory raw material supply outlook

M. O'Driscoll*[1]

1. IMFORMED Industrial Mineral Forums & Research Ltd., United Kingdom

Having endured two years of refractory mineral supply disruption owing to ramifications of the pandemic, combined with the impact of several years of continuing change in the historically dominant, and much relied-upon, Chinese mineral sector, the world refractory industry could, and perhaps should, be embarking on a strategic modification of its mineral supply chains. Certain players have already been proactive in this, more will surely follow as both refractory mineral traders and consumers alike race to secure stocks and consistent supply sources for the future. Consideration of alternative sources, corporate adjustment and acquisitions, recycling, government input, and the increasing influence of environmental factors will all play a part in shaping future refractory mineral sourcing strategies. The primary trends, developments and influencing factors will be examined in this presentation.

Advancements in Silicon Carbide-based and other Non-Oxide Refractory Materials

Room: Joliet
Session Chair: Matt Lambert, Allied Mineral Company

9:20 AM

(UNITECR-082-2022) Effect of Different Catalysts on Performance of Self-bonded SiC Refractories

H. Wang*[1]; H. Zhang[2]; Y. Bi[3]

1. Shanxi Institute of Technology, China
2. Wuhan University of Science and Technolog, China
3. Henan University of Science and Technology, China

Abstract Taking transition metal M_{55} (M=Fe, Ni or Co) cluster, C=C dimer, and CO and SiO molecules as models, the First-principles calculation shows that the activities of the reactants for the synthesis of SiC could be increased via dwindling the bonding strength of C=C, C-O, and Si-O bonds. Based on this result, SiC nanowires were synthesized firing at 1573K using extended graphite and Si powder as the raw materials as well as cobalt nitrate, nickel nitrate and ferric nitrate as catalyst precursor. The cold or hot mechanical properties of self-bonded SiC refractories prepared by the present catalytic method were more than two times of those without any catalysts. The residual modulus of rupture ratio of self-bonded SiC refractories with catalysts was as high as twice of that without any catalysts when ΔT=1075K. The incorporation of catalysts not only reduced the reaction temperature by about 100K but also facilitated the in-situ formation of 3C-SiC whiskers, which interlinked and connected each other in the matrix of as-prepared self-bonded refractories acting as an excellent bonding phase, and improved the high temperature properties of self-bonded SiC refractories. Among them, the Fe NPs presented the best catalytic activity.

9:40 AM

(UNITECR-083-2022) Catalytic Preparation of High Performance Refractory Materials

S. Zhang*[1]

1. University of Exeter, College of Engineering, Mathematics and Physical Sciences, United Kingdom

The author's recent work on catalytic formation/preparation of novel refractory powders and composites is presented and reviewed. Varrious types of high efficiency micro- or nano-catalysts such as Ni, Co, Fe, and Cr and their alloys were synthesized, and their effects on the formation/preparation of refractory powders and reinforced refractory composites examined. Refractory powders with novel morphologies such as carbon nanotubes and Si_3N_4 /Sialon/ SiC/ SiO_2 nanofibers were synthesized at relatively low temperatures by using different catalysts and characterized, and the relevant catalytic mechanisms proposed. Furthermore, several important refractory composites, such as Si_3N_4 and/or sialon bonded SiC, SiC self bonded SiC, and low carbon MgO-C and Al_2O_3-C, reinforced with catalytically formed 1-D nanophases were prepared, and their microstructures and properties examined. The results indicated that 1) the use of a catalyst decreased significantly the formation/ synthesis temperature of refractory phases, e.g., in the case of Si_3N_4, its nitridation temperature can be reduced by 100-200°C; 2) the use of a catalyst accelerated considerably the in-situ formation of 1-D refractory phases; 3) the in-situ catalytic formation of 1-D refractory phases improved evidently mechanical properties of the bulk refractory composites.

10:00 AM

(UNITECR-084-2022) Investigations on nitride-bonded SiC ceramics produced from thixotropic castables

J. Angelkort*[1]; N. Fröse[1]; M. Mix[1]; M. Knoll[1]; B. Epstein[2]; S. Fromm[2]; I. Hofmann[2]

1. Intocast AG, Germany
2. VGT-Dyko, Germany

Owing to a high temperature resistance combined with a high resistance against abrasion and chemical attack, nitride-bonded SiC-based ceramics are often employed as refractory materials in highly corrosive settings. To produce complex-shaped ceramics of nitride-bonded SiC, a thixotropic mass was developed allowing to cast semi-finished products which transform during a heat-treatment in a nitrogen gas atmosphere into the desired refractory materials. During this nitridation process, the silicon metal of the precursor material reacts with nitrogen to silicon nitrides causing a strong binding between embedded SiC grains in the burnt ceramics. In this work, the effect of different amounts of silicon and additives admixed into the thixotropic masses is studied with reference to the resulting phase composition of the nitrided ceramics. Furthermore, the influences of compositional changes in the mixtures on some key properties of the ceramics (like material strength, open porosity and oxidation resistance) are also discussed.

Advances in Installation Techniques, Manufacturing, and Equipment

Room: Joliet

Session Chairs: William Headrick, RHI Magnesita; Somnath Mandal, University of California, Irvine

11:00 AM

(UNITECR-085-2022) The Use of Flame-Spray Technology to Manufacture Carbon-Free Alumina Molten Metal Filters

P. Gehre*[1]; B. Bock-Seefeld[1]; S. Dudczig[1]; J. Hubálková[1]; N. Child[2]; I. Delaney[2]; D. DeBastiani[3]; C. Aneziris[1]

1. TU Bergakademie Freiberg, Institute of Ceramics, Refractories and Composite Materials, Germany
2. Foseco International, United Kingdom
3. Vesuvius, USA

Flame-spray technology has been used to manufacture oxide ceramic filters. It is seen as a potential method for increasing the cleanliness of cast steel bodies by interacting with inclusions in the molten steel. Common Al_2O_3-C filters composed of 55 Ma.% Al_2O_3 and 45 Ma.% C, cause sporadic pore defects in the cast steel parts due to decarburization. The carbon-free filters produced, composed of 100 % flame-sprayed alumina, have an excellent thermal shock resistance, and are superior to common oxide ceramic foam filters. The filters were prepared by coating all faces of an Al_2O_3-C filter substrate by both manual, and automatic (robotic), flame spraying, then burning out the carbon-bonded filter substrate during a sintering step. The phase composition (XRD), the microstructure (SEM and X-ray tomography), and Cold Crush Strength (CCS) have all been evaluated. The flame-sprayed filters have sufficient strength (CCS of 0.16 MPa) for the evaluation of their efficiency in casting tests with molten steel. The tests were undertaken using 100kg of 42CrMo4 steel. The resultant solidified steel was examined for cleanliness using automated Scanning Electron Microscopy (SEM). The cleanliness of the steel was shown to be improved, mainly associated with a decrease in silica rich inclusions. This work illustrates the high reactivity of the flame-sprayed filter composed of amorphous and γ-Al_2O_3 phases.

11:20 AM

(UNITECR-086-2022) Gunning manipulators for the hot repair

C. Wolf*[1]

1. Velco GmbH, Germany

For many years the gunning procedure is used for the repair of refractory linings. In combination with a gunning manipulator furnaces, ladles or RH degasser legs can be repaired in hot condition. The advantages of the hot repair are: higher gunning rates giving shorter repair times. Higher quality of application, less physical strain on the operators and lower risk of accidents. Via integrated TV Cameras the gunning repair can be performed from the operator pulpit and the gunning can be recorded for quality control. This paper will give a showcase of different designs of gunning robots (fixed type, crane hanging type or on mobile diesel driven carriage) and the results from different customer sites.

11:40 AM

(UNITECR-087-2022) Optimisation of blast furnace iron trough by monitoring the wear with 3D scanner

B. Touzo[1]; M. Dombrowski*[2]

1. Imerys, Science and Technology, Belgium
2. Calderys, France

The service life of a refractory lining, depends not only on the quality of the materials used and the proper choice for the given environment, but also on the design and, when possible, the repairs that can be done. The overall Refractory consumption will be optimised when all these aspects are taken into account. Recently, with the popularization of 3D laser scanners with a very good position accuracy even on large scale, it has been possible to digitize the shape of big objects and even buildings. In this paper, the monitoring results of rion runners with 3D laser scanners are shown. The scans allow to measure precisely the extent of corrosion and damages at various locations. The analysis of these measurements help then optimise repairs because it is possible to locate accurately where the material is damage and where there are build ups. It is also very useful to refine the iron trough design, material choice, depending on the corrosion patterns.

12:00 PM

(UNITECR-088-2022) Repair Process of Hot blast Outlet Part in Blast Furnace Hot Stove Combustion Chamber

S. Jang*[1]

1. Hyundai Steel company, Ironmaking Refractories Team, Republic of Korea

Blast furnace Hot stove, apparatus for preheating air blown into a blast furnace, an important step in raising the efficiency of iron processing. blast furnaces are served by three stoves. while two are being heated, the air blast passes through the regenerative chamber of the third stove on its way to the blast furnace. Hot-blast stoves in particular consist of Silica Refractories, which take a long time to cool down. Therefore, it is difficult for workers to cool and repair Refractories. And operating with two Hot stoves has a huge impact on blast furnace production. Our Hot stove Combustion's Hot Blast Outlet part was damaged. It had to be repaired. We had a lot of thought on how to repair that part. At first, Hot stove should not be cooled, so I thought about making Heatshield and repairing it. This, however, caused difficulties in safety or repair times. Another method of repairing Ceramic Welding in glass melting furnaces was found. The combustion chamber set brick has been repaired for Ceramic Welding within the shortest time, and it has been used well so far without damage.

12:20 PM

(UNITECR-089-2022) Next Generation of Electric Furnace Bottom Technology

J. Kerr*[1]

1. RHI Magnesita, USA

In today's fast-paced manufacturing environment, equipment turnaround time can significantly impact a producer's bottom line. In the case of electric steelmaking, reducing furnace downtime can provide the advantage necessary for maintaining competitiveness in the market. The current study addresses the development of a novel EAF hearth material that offers advantages with ease-of-installation while maximizing performance and keeping costs low. To achieve this, existing technologies proven over the past several decades have been combined and carefully refined to result in a novel new approach, keeping furnaces in service and employees safe.

Refractories for Other Applications I

Room: Joliet

Session Chair: Steven Ashlock, Virginia Kyanite

1:40 PM

(UNITECR-090-2022) Development of Phosphate bonded Plastic refractory

R. Halder*[1]

1. Calcutta University, Ceramic Engineering, India

Abstract: The present work reports about the development of reliable new phosphate bonded plastic refractory product based on WTA (white tabular alumina), becoming the benchmark product in the industry day by day in several applications. In present report, we have used WTA (white tabular alumina) aggregate for the

preparation of phosphate bonded refractory. The main aim of this report is to develop phosphate bonded plastic refractory having good thermal shock and abrasion resistance. A standard process route has been developed here through proper utilization of MAP (Mono Aluminium Phosphate) and H3PO4 (Phosphoric Acid) in order to achieve significant thermo-mechanical resistance. We need to clearly define our market, where we should place this product for maximum consumption and market share.

2:00 PM

(UNITECR-091-2022) Refractory lining revamping and integrity management of aged furnaces and reactors in hydrocarbon process industries

M. Maity*[1]

1. Saudi Basic Industries Corporation, Saudi Arabia

Furnaces and reactors are essential and expensive assets in hydrocarbon process industries. These are challenging assets to construct, operate, and maintain. Over the years, capacity, operational complexities, performance requirements of the above equipment have experienced significant changes to meet the ever-increasing demand for higher efficiency, reliability, and regulatory compliances. Many equipment in the existing plants are old with conventional refractory design, have relatively lower thermal efficiencies and requires frequent maintenance. Plants usually maintain them by repairing refractories in-kind. The traditional practices usually result in missed opportunities to improve performance and reliability. In many cases, problems reoccur resulting in extended shutdown and high maintenance costs. In the past, it was good business sense to use low-cost and less energy-efficient refractories. However, with the escalating energy prices, advanced materials that were once considered expensive are now turning out to be good investments and promising significant improvement in energy efficiency and reliability. This paper describes revamp opportunities in which the improved refractories and engineering practices would outperform the traditional refractories and contribute to address the economic and sustainability objectives. Typical case studies are included.

2:20 PM - WITHDRAWN

(UNITECR-092-2022) Analysis of the damage process of high chromium refractories during the whole service life in coal-water slurry gasifier

H. Sun*[1]; H. Li[1]; K. Geng[1]; Y. Du[1]; H. Wang[1]

1. Sinosteel Luoyang Institute of Refractories Research Co., Ltd., State Key Laboratory of Advanced Refractories, China

High chromium refractories have been widely used as lining in coal-water slurry gasifiers for about 30 years. They have a non-constant rate of damage during the whole service life, which approximately 10,000 hours in a gasifier. In this study, two kinds of high chromium bricks, including conventional Cr_2O_3-Al_2O_3-ZrO_2 bricks and new bricks with phosphate were studied. And the residual thickness of high chrome bricks, which were built in the cylinder of the multiple coal-water slur gasifiers, was tracked and measured in the whole operation cycle. The residual bricks were analyzed by SEM and XRD. It was showed that, the superposition of multiple factors such as chemical corrosion, physical erosion and penetration, the spalling of structure during the gasification process caused the final damage. The unsteady damage rate is attributed to the different action intensity of various factors at different stages. And structural spalling is the main cause of increased damage because there are differences in microstructure between slag penetration zone and non- penetration zone. The high chromium bricks with phosphate has low porosity to delay the penetration of slag, and the similar microstructure between slag penetration zone and non- penetration zone improves the spalling resistance. All these have effectively prolonged the life of gasifier lining.

2:40 PM

(UNITECR-093-2022) Refractory Materials for Thermal Processing of Biomass

P. Kovar*[1]; J. Vlček[2]; H. Ovčačíková[2]

1. P-D Refractories CZ a.s., Czechia
2. VSB - Technical University of Ostrava, Faculty of Materials Sciency and Technology, Department of Thermal Engineering, Czechia

Refractory materials used in aggregates for the thermal processing of biomass and biowaste are attacked by a specific corrosion effect, which is different from when conventional technologies for burning common fuels are used. Thermal processing of biomass, which belongs to renewable resources, is one option to reduce CO_2 production and replace the classical combustion of fossil fuels. In comparison to coal, which ensures a stable combustion process, biomass has a significantly higher influence on the corrosion refractory materials, mainly alkaline attack and further combustion temperature fluctuation, which is associated with feed batch pyrolysis and its sudden flashing. Therefore, it is necessary to develop new refractory materials with higher corrosion and abrasion resistance. This paper describes the properties of wastes of ash, fly ash and slag, the study of corrosion, the assessment of the currently produced quality grades of refractory materials against corrosion resistance and the development of new high-quality refractory materials for this purpose of use.

3:00 PM

(UNITECR-094-2022) In-situ observations of alumina- and mullite-based refractory materials interacting with ash in coal-biomass gasification environments

K. Tippey*[1]; J. Nakano[1]; A. Nakano[1]; H. Thomas[1]; Ö. Doğan[1]; M. Lambert[2]; D. G. Goski[2]

1. US Department of Energy National Energy Technology Laboratory, USA
2. Allied Mineral Products, LLC, USA

A gasifier is used to generate syngas from carbon feedstock and water at elevated temperatures. Syngas primarily contains hydrogen and carbon monoxide, which can be utilized to produce power or chemicals. Refractory bricks used in a gasifier undergo severe high-temperature and high-pressure conditions. Components from the carbon feedstock form ash or molten slag depending on operation temperature and interact with refractory hot face, causing material degradation. Prolonged refractory service life is required to maintain the viable online availability of a gasifier, otherwise frequent shutdowns affect production and energy efficiency. In this work, cement-bonded refractory materials (alumina- and mullite-based) were interacted with synthetic coal ash (based on the Usibelli coal composition) with varied amounts of biomass (spruce) ash additions at 800 °C and $\log(pO_2) = -19$ (atm base). Material interactions at the interface were studied in-situ using the customized high temperature environmental confocal scanning laser microscope, followed by post-test cross-sectional SEM analysis. Solid state reactions seemed to be predominant on the surface while no substantial structural degradation was noted under the conditions used in this study.

Refractories for Other Applications II

Room: Joliet
Session Chair: Steven Ashlock, Virginia Kyanite

3:40 PM

(UNITECR-095-2022) Development of self-glazing carbon-bonded SiC castables

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2. Elkem Technology, Norway
3. Elkem GmbH, Germany

The oxidation resistance is a key issue during the application of carbon-bonded refractories and components. To prevent the oxidation, a protective surface layer such as an on-glaze is being applied. However, the glaze formation requires additional process steps, increasing fabrication costs. In recent studies, $Na_2B_4O_7$ was introduced as a self-glazing additive, resulting in a successful fabrication of carbon-bonded Al_2O_3 monoblock stoppers with self-glaze properties. However, this kind of self-glaze may not be suitable for inductively heatable carbon-bonded SiC-based refractory materials. The focus of this study was the application of the self-glaze approach developed for carbon-bonded Al_2O_3 functional bodies to SiC-based crucibles. Therefore, carbon-bonded SiC vibration flow castables, containing different glaze-forming additives such as microsilica, wollastonite and metallic silicon, and bonded with water soluble resin binder were designed, manufactured and coked at different temperatures. The physical and mechanical properties as well as the microstructure as functions of the coking temperature were investigated. The oxidation resistance was evaluated with the aid of a thermogravimetric measurement device. A successful self-glaze formation was achieved using metallic silicon and wollastonite additions, whereby the water soluble resin plays a decisive role.

4:00 PM

(UNITECR-096-2022) Corrosion of oxide-bonded SiC refractories by C-A-S slag

A. Tixier*[1]; J. Poirier[2]; E. de Bilbao[2]; C. Varona[3]; F. Valdivieso[1]; P. Ganster[1]; J. Brossard[4]; A. Villain[4]

1. Ecole des Mines de Saint-Etienne, France
2. CEMHTI, France
3. BONY SA, France
4. Veolia Recherche et Innovation, France

Combustion of household waste induces very high corrosion phenomena in the combustion chamber due to gases and fly ashes. Thus, the water wall boiler tubes used for heat transfer are exposed to severe damages. In order to protect the boiler and to promote thermal transfer, water tubes are protected by a shaped silicon carbide refractory lining. In-situ observations carried out in three waste-to-energy facilities showed the bottom part (from grate to 5 m above) was the most damaged area with a thick layer of deposit on SiC tiles. Post-mortem examinations on refractories from the lower area of the furnaces showed an important thickness decrease of SiC tiles depending on residence time. The tile surface was irregular because of the SiC grains disappearance near the hot face and an attack of the refractory bonding with the formation of low melting alkali rich glass and a crystallised phase: sanidine $KAlSi_3O_8$. A composition profile in the tile thickness showed a decrease of alkali contents up to stabilization at 12 mm from the hot surface. In addition to the attack of the bonding, SEM observations revealed surface oxidation of small SiC grains. The whole results present similarities between the three WtE facilities. From all these analyses, we proposed for this furnace area a specific damage mechanism different from the corrosion process observed in the upper area and we suggested SiC refractory improvements.

4:20 PM

(UNITECR-097-2022) $CaZrO_3$ Refractories for improved Melting and Casting Behaviour of Titanium Alloys

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1. Refratechnik Steel GmbH, Germany
2. fem Forschungsinstitut Edelmetalle + Metallchemie, Germany
3. TU Bergakademie Freiberg, IKFVW, Germany

For some applications in processing titanium and titanium alloys, ceramic materials were or are necessary if not indispensable. However, they are cursed with poor properties like bad thermal shock behaviour, high price, and insufficient chemical resistance. The latter leads to reduced lifetime of crucibles and decreased metal quality, elaborates postprocessing of casted goods or excludes applications. The present work investigated casted refractories based on a newly developed material: calcium zirconate ($CaZrO_3$). Cement-free, single phase crucibles and investment casting shells were successfully manufactured and tested. The material showed promising physical and thermomechanical properties. Melting tests as well as investment castings based on products made of the new material were examined. The results showed improved stability and good metal quality. Economically, the material might reduce post-processing cost due to a better surface of casted titanium alloy products. Additionally, it is less expensive compared to zirconia or yttria based materials and showed improved thermal and chemical stability advancing service time. It can enable more efficient technologies like vacuum induction melting in a hot crucible for processing titanium, its alloys and also other metallurgical applications.

Refractory Student and Young Professionals II

Room: Marquette
Session Chairs: Dawn Hill, Exertech LLC; Austin Scheer, Kyanite Mining Corportation

9:20 AM

(UNITECR-098-2022) Alkali resistance of the matrix of aluminosilicate refractories

K. A. Haines*[1]; D. Lankard[2]; D. G. Goski[1]; K. Byrd[1]; D. Loiacona[1]

1. Allied Mineral Products, USA
2. Lankard Materials Laboratory, Inc., USA

Aluminosilicate castable refractories, which are widely used in alkali-rich environments, typically have a matrix component that is close to mullite in composition. It is the matrix component that is most vulnerable to attack in service. For the alkali test described here, the focus is on the variables that are thought to influence the alkali resistance of the matrix. In this study, the “matrix” is identified as including the mix water and the solid constituents with a particle size less than 0.5 mm. The formulation of experimental compositions is done on the basis of volume percent to account for differences in specific gravity of the constituents. This approach fixes the volume percent of water and provides the means to replace any of the solid constituents with an equal volume of the same mesh size of other aluminosilicate materials, or other refractory materials known to have good resistance to alkali attack, such as zirconia. Aided by the use of polished thin sections, characterization procedures provide for the generation of information on microstructural, chemical, and mineralogical changes on the same areas of interest in the small, thin-walled crucibles used in the test. A quantitative ranking of performance in the alkali test is provided by SEM/EDS alkali-profiling of the post-test crucible walls, unencumbered by the presence of large aggregate particles.

9:50 AM

(UNITECR-099-2022) Utilization of Virginia Kyanite™ and Virginia Mullite™ in Refractory Applications Worldwide

S. Ashlock[1]; A. D. Scheer*[1]

1. Kyanite Mining Corportation, Research and Development, USA

The sillimanite group of minerals have long been key components of refractory recipes worldwide. These aluminosilicate minerals exhibit properties that can be utilized in the fabrication of higher end refractories such as high hot strength, excellent creep resistance, and the conversion to mullite at temperature. Of the sillimanite group minerals, kyanite stands out for having the largest expansion during heating at the lowest conversion temperature. This property can be utilized to counteract shrinkage of the refractory mix as well as increasing the density of the mix using fine mesh kyanite. This paper will discuss various uses of Virginia Kyanite™ and its calcined form Virginia Mullite™ in the refractory industry worldwide.

10:20 AM

(UNITECR-100-2022) Open-source tools for the refractory engineer of the present and the future

M. H. Moreira*[1]; M. F. Dos Santos[1]; V. C. Pandolfelli[1]

1. Federal University of São Carlos, Graduate Program in Materials Science and Engineering (PPGCEM), Brazil

Technology advances in the last century were able to reshape the world we live in. Relationships were physically and virtually changed by innovations ranging from transportation (engines, airplanes), to communication, (with phones, internet, and satellites). Considering this, the abilities and skills required for the young professionals have been shifting dramatically and the refractory industry has demanded those that understand this new world and are able to solve its challenging problems. Therefore, the complexity of materials area, that includes the latest advances in modeling and data science, generates a sophisticated blend of fundamental concepts and advanced techniques that reshapes the education process. For instance, the heat transfer mechanisms within the refractory material can be both discussed on the fundamental level, or on how to carry out advanced simulations to describe it, granting the engineer the ability to solve real-life problems. The present work aims to classify this novel set of needed tools, explore options to conciliate fundamentals with advanced ones, and propose strategies to educate the present and future professionals. As a conclusion, the minimum package of skills will be presented considering the association of industry, academics, students, and computing (as a fourth needed entity), all synergistically linked to solve the new challenges and generate true innovation.

10:50 AM

(UNITECR-101-2022) The Effect of Different Grades of Mulcoa Aggregate on the properties of Refractory Castables (Invited)

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1. RHI Magnesita, USA
2. Imerys, USA

The mechanical and thermal properties of low cement and conventional castable refractories containing different grades of Mulcoa aggregate were investigated. Each castable mix was designed for a composition of 75% aggregate by volume and 25% cement or low cement package. The low cement package is composed of calcium aluminate cement, silica fume, fine alumina, sodium hexametaphosphate, and -200 mesh bauxite. The Mulcoa aggregates being investigated are M43LW, M43, F60, M60 and M70. Thermal expansion, thermal conductivity, percent linear change, cold crushing strength, modulus of rupture, density and porosity were compared. Results were as expected based on chemistry and purity of the aggregates. Permanent linear change for Mulcoa M70 at 1500 °C was unexpected but may be due to inherent statistics of the test method. The new Mulcoa F60 was statistically equivalent to M60 according to measured properties.

11:20 AM

(UNITECR-102-2022) The role of refractory ceramic plugs in the production of clean steels

L. Z. Falsetti*[1]; D. Ferreira Muche[1]; M. R. Andreeta[1]; M. H. Moreira[1]; V. C. Pandolfelli[1]

1. Federal University of Sao Carlos, Department of Materials Engineering (DEMa), Brazil

The ceramic plug is a refractory device applied in the steel ladle which allows the injection of gas bubbles into the liquid metal, aiming at its chemical and thermal homogenization as well as the removal of non-metallic inclusions. The requirements for such device show similarities with the refractories of the steel ladle's lining, e.g., the mechanical and the thermal shock resistances, the chemical inertness and the wear resistance. Regarding this further requirement, the plug composition typically exhibits a low wettability with the liquid steel (high contact angles), so that the infiltration of such phase into the porous structure is slowed down, or even avoided. However, an additional aspect to the performance of ceramic plugs is their ability to control the size of the generated gas bubble, maximizing the probability of capturing inclusions. Therefore, this work studied the injection of gas bubbles in liquid media through capillary structures, focusing on the influence of the pore diameter and the contact angle upon the size of the generated bubble. The results highlight the composition of the plug's surface as a key aspect to improve the cleanliness of the molten steel, as low contact angles lead to smaller bubbles. Furthermore, the discussed model can be extended to the design of water models, taking into account the influence of the surface wettability on the size of the injected bubble.

Refractory Characterization and Testing III

Room: Marquette
Session Chairs: Dawn Hill, Exertech LLC; Bob Hunter, Special Shapes Refractory Co.

1:40 PM

(UNITECR-103-2022) Influence of the stabilizer types and the phase composition on the thermal shock performance and corrosion resistance of zirconia ceramics

C. Heuer[1]; P. Gehre[1]; C. Aneziris[1]; A. Priese[2]; R. Soth[2]; C. Wöhrmeyer[2]; C. Parr[2], M. Bach*[1]

1. Technical University Bergakademie Freiberg, Germany
2. Imerys S.A., France

Zirconia is one of the most promising functional materials for refractory applications. Understanding the thermomechanical and thermochemical performance as a function of the stabilization, the grain size distribution, and the sintering accompanied by the real thermal conditions during operation are unlimited tools for material and component design and developments in the iron and steel industry as well as in the non-ferrous industry. Within the present study, different types and qualities of zirconia powders stabilized either by calcia, magnesia or yttria have been investigated regarding their thermal and thermomechanical properties. Slip cast as well as vibration cast rectangular bars have been used as testing specimens. With the aid of electron backscatter diffraction (EBSD) and X-ray diffraction, the phase composition has been investigated on as received raw materials and on sintered materials before and after exposure to thermal shock. Dilatometry measurements and the evaluation of the porosity with the aid of mercury porosimetry contributed to a better understanding of the achieved properties. Furthermore, the corrosion resistance of the zirconia ceramics against liquid steel was investigated in a steel casting simulator device.

2:00 PM

(UNITECR-104-2022) Thermal shock resistance of MgO-C bricks under mechanical constraints

M. Shiohama*[1]; H. Kamio[1]; R. Hosogi[1]; K. Goto[1]; K. MORIKAWA[1]

1. Krosaki harima corporation, Technical research laboratories, Japan

A carbon containing refractory material, MgO-C has often been applied to the lining bricks for steel refining furnace like converter. Although the MgO-C bricks have suffered a thermal shock with constrained by steel shell in the actual furnace operation, the available thermal shock properties of the bricks so far were those obtained in the unconstrained condition. In order to grasp the behavior of the bricks more accurately to simulate the actual operation, the testing system was constructed and the thermal shock tests of the MgO-C brick were performed under mechanical constraints using the system with application of the digital image correlation method (DICM). As the results, cracking occurred parallel direction to the heating surface with reproducing the behavior in the actual furnace operation. According to the analysis performed, the cracking seemed to induce by the thermal stress occurred in between the heating surface and un-heating (back) surface. The results obtained by the present investigation were thought to be quite useful for understanding the thermal shock behavior of the bricks under constraints.

2:20 PM

(UNITECR-105-2022) Thermal shock testing system able to adapt and depict the service conditions of refractory materials

E. M. Brochen*[1]; M. Kaminski[1]; C. Dannert[1]; J. Klose[2]; S. Esch[2]; P. Kohns[2]; G. Ankerhold[2]

1. Forschungsgemeinschaft Feuerfest e.V., Germany
2. Koblenz University of Applied Sciences, RheinAhrCampus, Germany

Depending on the processes they are used in, refractory products undergo thermal shocks of different magnitudes and different temperature levels. The response of refractories to these different thermal loading conditions accordingly vary greatly. Materials may perform well at medium temperatures when faced with thermal shocks of high magnitude, but completely fail at higher temperature despite treated to thermal shocks with much smaller magniture. The use of standardised testing methods that assess the thermal shock resistance (TSR) of refractories with little compliance with their actual service conditions is thus not enough for research purposes. Thermal shock testing systems that adapt to the service conditions for the tested refractory product(s) are needed. A new thermal shock testing system at FGF enables the tailored automatic investigation of the TSR of refractory products by testing in different temperature ranges (room temperature to 1.700 °C), with different magnitudes of thermal shock and even applying ascending and/or descending thermal shocks. Exemplary investigations were performed on typical refractors products. The impact of the thermal shocks is quantitatively assessed in-situ with laser-ultrasonic measurements. The relevance of given materials to specific conditions can be enhanced and better prediction of the lifetime of refractory linings achieved.

2:40 PM

(UNITECR-106-2022) Investigation of the fracture behaviour of refractory materials up to service temperatures: A tribute to Prof. R. C. Bradt

E. M. Brochen*[1]; C. Dannert[1]; J. Paul[2]; O. Krause[2]

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2. Koblenz University of Applied Sciences, WesterWaldCampus, Germany

In service, refractory linings experience thermal stresses exceeding their mechanical strength. However, this does not mean catastrophic failure. They rather undergo a stepwise wear process and typically retain their structural stability despite suffering from already substantial damage. Classic tests, such as modulus of rupture measurements, solely consider the maximum strength right before catastrophic fracture and are thus inappropriate to investigate their fracture behaviour. To gain information about the fracture process and the resistance against damaging in refractory linings, Nakayama applied the concept of “Work-of-Fracture” (WoF) to refractories. Prof. R.C. Bradt, who dedicated a significant part of his work to the fracture mechanics of ceramics, further enhanced the understanding of fracture and damaging processes in refractory materials. Despite those advancements, there is still a lack of both empirical data and studies on the fracture behaviour of refractory materials, especially at high temperatures. Wedge splitting measurements, which are efficient to investigate the WoF of refractory materials, were performed up to 1500 °C on four typical refractory products and supported by microscopic investigations. A rather brittle behaviour below 900 °C was systematically observed, then some materials undergo a kind of brittle-to-ductile transition.

3:00 PM

(UNITECR-107-2022) In-situ monitoring of magnesia spinel refractories during thermal shock tests by an advanced experimental device (ATHORNA)

R. Kaczmarek*[1]; R. L. Oliveira[2]; J. Dupré[3]; P. DOUMALIN[3]; N. Tessier-Doyen[1]; I. Pop[4]; M. HUGER[1]

1. University of Limoges, UMR CNRS 7315 - IRCER, Centre Européen de la Céramique, France
2. University of Coimbra, ISISE Institute, Department of Civil Engineering, Portugal
3. University of Poitiers, Pprime Institute, UPR CNRS 3346, France
4. University of Limoges, GC2D, France

A novel experimental device (ATHORNA) addresses researchers' needs related to a better understanding of refractories behaviour during thermal shocks. The experimental procedure consists in sudden heating of a large refractory sample (Ø100x10 mm^3) from the top surface using a well-controlled CO_2 laser source. During the test, the sample is monitored by visual, infrared and acoustic sensors. The set of two visual cameras (stereoscopic system) coupled with a Digital Image Correlation (DIC) method allows 3D monitoring of the kinematic fields on the bottom sample surface. In addition, the occurrence of any cracks can be monitored using: i) six peripherally-distributed acoustic emission sensors, allowing spatiotemporal location of acoustic emission events, and ii) an enhanced 2P-DIC method for spatiotemporal location of cracks. This investigation is focused on comparative analysis of model magnesia-spinel refractories which exhibit significant differences in thermomechanical behaviour. Presented crack opening displacement and crack length evolutions were mainly obtained using visual sensors and the above-mentioned image correlation methods. Experimental parameters originating from these curves were correlated with wedge splitting test results and interpreted in relation to materials' microstructural design.

3:40 PM

(UNITECR-108-2022) Identification of Mechanical Properties of an Asymmetric Creep Law Applied to Refractories Using the Integrated Digital Image Correlation Technique

L. B. Teixeira*[1]; P. Leplay[2]; J. Gillibert[1]; E. Blond[1]; T. Sayet[1]

1. Univ. Orléans, Univ. Tours, INSA-CVL, LaMé, France
2. Saint-Gobain Research Provence, France

Refractory materials are designed to work at high temperatures, reaching 1600°C at the hot face in equipments such as the steel ladle, and therefore creep strains play an important role in the mechanical behavior of the refractory lining. These materials often demonstrate asymmetric creep behavior, I.e., different creep strain rates are observed under tension and compression. To characterize the behavior of an alumina-spinel brick used in steel ladles, an innovative experimental setup composed of Brazilian tests associated with an integrated digital image correlation (I-DIC) technique is proposed. The details of the optical techniques suitable to acquire high quality images are described, as well as the features present in the I-DIC software that allow the determination of the material

parameters. Further, a four points bending test is simulated using the identified parameters, and the numerical displacements fields are compared to experimental results.

4:00 PM

(UNITECR-109-2022) Influence of Mineralogical Composition on Strength Deterioration by Thermal Cycling of High Alumina Bricks

S. H. Camelli*[1]; P. Marinelli[2]; M. Dignani[1]

1. Instituto Argentino de Siderurgia, Refractory Area, Argentina
2. Ternium Argentina, Refractory Area, Argentina

High alumina bricks are used in the middle and lower parts of the hot stove's regenerator. These bricks are subject to multiple wear mechanisms, such as: abrasion, thermal shock, deformation under load and chemical attack. The main cause of lining degradation of the division wall is the cyclic thermal changes during operation. The proper selection of stove refractories is essential to satisfactory operation and long life. Consequently, the aim of this work involves the comparative evaluation of three types of high alumina bricks in order to characterize the materials and check the relationship between those brick's mineralogical composition and the strength deterioration caused by cyclic thermal change. The characterization of the bricks was performed by chemical analysis, X – ray diffraction phase identification, permanent lineal change, mechanical and physical properties determination and microstructural analysis by optical microscopy, electronics and EDS analysis. Also, two types of thermal shock treatments were carried out: according to the ASTM C 1171 standard and ten thermal cycling with cooling in hot water.

4:20 PM

(UNITECR-110-2022) Thermoelastic properties of microcracked aluminium titanate based materials at high temperature

M. Mouiya*[1]; Y. Tamraoui[2]; N. Tessier-Doyen[1]; H. Hannache[3]; J. Alami[2]; M. HUGER[1]

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2. Mohammed VI polytechnic university, MSN, Morocco
3. Mohammed VI polytechnic university, MSN, Morocco

A commercial aluminum titanate (AT) material doped with silica was investigated in order to highlight its thermoelastic properties using various techniques of characterization operating at high temperature such as long bar mode method, acoustic emission and dilatometry (up to 1500°C). The Young's modulus (MoE) as a function of temperature evolves in the form of a hysteresis loop with a maximum value of about 170 GPa, due to the closure and healing of microcracks during sintering. A sharp decrease in MoE occurs on cooling at 780°C, corresponding to the opening of the microcracked network due to a high level of stress around AT grains. In addition, the dilatometric analysis shows in cooling a quasi-linear shrinkage followed by sudden non-linear expansion from 738 °C. The thermal expansion coefficient value determined between 1000 ° C and 800 °C was about 9×10^{-6} $°C^{-1}$ (this range corresponding to the healing of the microcracks). By recording the evolution of the cumulative number of hits as a function of temperature, the results of the acoustic emission clearly confirm the reopening of the microcrack at near 765 ° C due to a significant amount of microcracks. These preliminary results help to understand the more sensitive parameters involved in the high thermal shock resistance of aluminum titanate refractories.

4:40 PM

(UNITECR-111-2022) Anelastic relaxation phenomena in alumina-spinel refractories

I. P. Kieliba*[1]; T. Tonnesen[1]; M. HUGER[2]; R. Telle[1]

1. RWTH Aachen University, GHI, Germany
2. IRCER - University of Limoges, France

Due to the desired combination of properties like high melting point, excellent corrosion resistance to steel-making slag and superior thermal shock resistance spinel is increasingly incorporated into multiple refractory solutions. Despite the heavy focus on spinel in various fields of science and engineering as well as extensive research conducted, there is still little known about the stress relaxation ability of spinel-containing materials. The objective of this work is to investigate the anelastic relaxation phenomena in various alumina – spinel refractories, to determine the underlying mechanism and assess their influence on thermo-mechanical properties. Acknowledgments This work was supported by the funding scheme of the European Commission, Marie Sklodowska-Curie Actions Innovative Training Networks in the frame of the project ATHOR - Advanced THermomechanical multiscale modeling of Refractory linings 764987 Grant. The authors are also grateful to the JECS Trust for funding the visit of Ilona Kieliba to IRCER - University of Limoges. (Contract No. 2018169).

Steel Making - Mag-Chrome Brick

Room: Waldorf
Session Chairs: Rakesh Dhaka, U.S. Steel; Scot Graddick, Imerys

9:20 AM

(UNITECR-112-2022) Zero Carbon Tempered $MgO-Cr_2O_3$ bricks for RH Degassers: Advances from Customers' Trials

B. L. Borges de Melo*[1]; C. Pagliosa[1]; M. S. Borges[1]; A. A. Campos[1]; V. G. Madalena[1]

1. RHI MAGNESITA, R&D, Brazil

The ultra-low carbon steel is obtained due to a secondary refining process and the RH degasser becomes an important equipment. The operation conditions of RH degasser in a steelmaking industry are critical due to slag compositions, high temperature, different steel types, operational intermittence, duration and number of degassing processes; all these factors may affect the refractory lifetime leading to different wear mechanisms. Magnesia chrome refractory bricks are been used in different regions of the RH Degasser since early 1960s. Most of these materials are direct bonded bricks and they are known for their ability to develop ceramic bonds due to high temperature firing above 1700°C. Main characteristics for MgO-Cr2O3 bricks applications are high mechanical properties, corrosion, erosion and thermal cycling resistance. A novel tempered $MgO-Cr_2O_3$ brick was developed using a zero carbon binder, delivered to the customer just tempered at 200°C. During operation, a fast sintering mechanism is developed for an effective ceramic bonding. Field trials confirmed the performance of this new system in all critical areas of RH degasser such as snorkel, throats and lower vessel. The aim of this work is to present the progress of this technology with costumer trials performance of the tempered $MgO-Cr_2O_3$ bricks compared to the fired material with the microstructure of both materials.

9:40 AM - WITHDRAWN

(UNITECR-113-2022) Phase diagram and additive selection for chrome-free spinel refractories

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1. University of Alabama at Birmingham, USA

Chrome-containing refractories such as $MgO-Cr_2O_3$ and Al_2O_3-Cr_2O_3 are yet to be replaced, despite toxicity and health hazards, due to their superior hot modulus of rupture (HMOR) and slag corrosion resistance compared to chrome-free $MgAl_2O_4$ spinel.

The HMOR and erosion depends on the bonding of aggregates with the matrix (extent of solid solution) and the amount of liquid phase. Appropriate additive selection can significantly enhance the HMOR and corrosion resistance of magnesia-spinel and alumina-spinel refractories. Phase diagram plays a vital role to select additives for searching chrome free alternatives. The oxides abundant in earth such as SiO_2, CaO, TiO_2, V_2O_3/V_2O_5, MnO/Mn_2O_3, FeO/Fe_2O_3, ZnO, SrO, ZrO and BaO SiO_2, CaO, TiO_2, which are also inexpensive, have been investigated as the candidate additives. The solid solution range and solidus temperature of additives with spinel, MgO and Al_2O_3 were extracted from the corresponding phase diagrams. It was found that only ZnO, ZrO_2 and TiO_2 additives are suitable for steelmaking (>1600°C). The solid solution range and slag corrosion resistance of these selected additives are also investigated with the oxides (CaO, SiO_2, FeO_x), which are primary constituents of the slags commonly present in RH degasser, basic oxygen furnace, AOD converter, cement rotary kiln and copper converter. These findings are compared with the literature reports and discussed.

10:00 AM

(UNITECR-114-2022) Improvement in Properties and Performance of Re-bonded Magnesia Chrome Bricks for RH Snorkel

A. Mitra[1]; S. Hazra*[1]; S. Nagpal[1]

1. Dalmia Cement Bharat Limited, India

Due to increased demand of clean steel particularly with very low carbon and hydrogen content, RH degassing process is gaining popularity among steel manufacturers. RH degasser is one of the best among various secondary refining process due to its high refining efficiency and productivity. The RH vessel involves complex reaction between molten steel, gas, slag and refractory. The Magnesia Chrome refractory lining in the RH snorkels are subjected to severe operating conditions due to high speed liquid steel circulation, chemical reaction, temperature fluctuation and vacuum conditions inside. Due to operating conditions as stated above, highest wear is observed in the area of snorkel and throat. The objective of this work is to improve the thermal and thermo-mechanical properties as well as the performance by using a special ultra-fine additive and increasing the firing temperature. The thermo-mechanical and thermal properties such as Hot Modulus of rupture, thermal spalling, slag corrosion resistance, pore size distribution along with micro-structure with different amount of additive and fired at different temperature have been studied. The result shows that 2% addition of special ultra-fine additive has a great effect on the critical properties and thereby the performance of RH Snorkel bricks has improved significantly.

10:20 AM

(UNITECR-115-2022) New Generation Semi-Rebonded Magnesia Chrome Refractories for RH Degasser

S. Das*[1]

1. TRL Krosaki Refractories Ltd, R&D, India

Due to increase in demand of Interstitial free (IF) grade steels RH degassing process gain importance in secondary steel making process for its higher productivity and lower processing time. The performance of refractory in leg, bottom, snorkel, and lower area of the barrel of RH degasser is very crucial to reduce the downtime and increase the degree of steel cleanliness. Refractories of these areas are exposed to erosion by liquid metal and hot gas, thermal shock, corrosive attack of FeO and MnO rich slag. In order to withstand such thermo-mechanical stresses, refractory bricks should possess high hot strength and high structural integrity. Direct bonded magnesia chrome brick is successfully used in these areas for long time successfully due to its excellent thermo-mechanical properties. In this paper different bricks have been designed in semi re-bonded route with several additives. The effect of Cr_2O_3 % on different properties of MgO – Cr_2O_3 semi re-bonded bricks is also studied. Newly designed bricks show low porosity, high hot strength, good thermal shock, and corrosion resistance by controlling the pore size distribution & formation of in-situ secondary spinel phases in the matrix. The newly designed product has been tried in one of the integrated steel plants with excellent performance in RH degasser application.

Steel Making - Dry-Vibe Ramming Mix

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Scot Graddick, Imerys; Matt Lambert, Allied Mineral Company

11:00 AM

(UNITECR-116-2022) Resin free and environmentally friendly binder for dry vibratable tundish linings

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The Magnesia-based dry vibratable tundish lining technology is dominated by resin binders. There are good reasons for using a Novolac resin as the primary binder, but also considerable concerns in regards to the health, safety and environmental impact of the resin. During the tundish heat up, the resin pyrolyses, which generates carbon residues in the lining, causing unwanted carbon pickup in the steel. High temperature exposure in the steel process causes resin to release smelly and hazardous gases in large quantities. The goal of the study was to develop a binder, which is resin free and does not contain substances, which are hazardous for the environment or human health. By changing the binder system, the properties of the lining and the steel should not be impacted negatively. Multiple tests were performed, with respect to the physical properties of the lining and its impact on the steel. The tests for the lining also included binding strength measurements at different temperatures. With a metal casting simulator which included a tundish, we analyzed the steel quality, using the reference binder and the new development binder to compare. As for the steel properties, the inclusions and the elemental composition of the steel were evaluated.

11:20 AM - WITHDRAWN

(UNITECR-117-2022) Studies on the Properties and Performance of Dry Coating Mass for Tundish working Lining: Effect of raw materials and sintering additives

A. K. Samanta*[1]

1. TRL Krosaki Refractories Limited, Technology, India

With the global advancement in metallurgical steel making technology with acute compromisein its quality, now refractory sector is assigned to maintain the purity of advanced steel during processing. Insteel manufacturing process, till casting, tundish comes last to carry refined and tuned steel before casting. So, this tundish refractory has a big role in maintaining steel purity to satisfy the requirement of metallurgicaltechnology development such as clean steel making, high speed casting, lowering of non-metallic inclusionetc. For this, a new refractory technology of dry coating mass over wet spraying mass is adapted to minimizehydrogen pick up before casting. While designing the dry coating mass, selection of base raw materials andbinders are very important to achieve the desired performance along with strength at intermediate temperaturewhich is essential for hot tundish practice. In this present work, different attempts have been taken to study the consolidation behavior of dry coatingmass while using different additives to take care the strength development during secondary heating for hottundish practice and to control the sintering at operating temperature for easy removal of skull. The plant trialshave been conducted with this newly developed material in different integrated steel plant with different tundishcapacity

11:40 AM

(UNITECR-118-2022) Comparison of Two Dry Vibratable Tundish Linings Through Laboratory Experiments

T. Richards*[1]; J. Smith[1]; R. O'Malley[1]; T. Sander[1]

1. Missouri University of Science and Technology, Materials Science and Engineering, USA

A rotating disc experiment was employed to replicate the interactions between molten steel and dry vibratable material (DVM) used for tundish linings. Two compositions of DVM were tested, both of which are commercially available: one containing approximately 70 wt% periclase (MgO) and 30 wt% olivine ($(Mg,Fe)_2SiO_4$), the other containing periclase with no olivine. The exposed refractory samples were analyzed using cathodoluminescence, backscattered scanning electron microscopy, energy dispersive spectroscopy, and X-ray diffraction. These results are compared to post-mortem samples obtained from industry supplied tundish lining samples. These investigations provide insight into the mechanics of refractory corrosion in the continuous casting of steel, as well as how these interactions influence the quality of the final steel product.

12:00 PM

(UNITECR-119-2022) Magnesia Based Dry Ramming Mass for Induction Furnace Suitable for Steel Refining

H. S. Tripathi*[1]; S. Sinhamahapatra[1]; V. P. Reddy[1]; K. Dana[1]; A. Ghosh[1]

1. CSIR-Central Glass & Ceramic Research Institute, Refractory & Traditional Ceramics Division, India

Refractory lining material presently used in induction furnace is not suitable for refining in steel due to highly basic environment. This hinders the production of good quality steel in induction furnace. In this context, magnesia based basic ramming mass has been developed from commercially available raw materials. Effect of different additives/ secondary components on the properties of the ramming mass has been analysed. Performance of few selected formulation was evaluated in laboratory scale induction furnace using a charge mix of 79% DRI and 19% MS scrap and standard flux for de-phosphorisation. It was observed sintered magnesia with preformed magnesium aluminate spinel gives the optimum result. Average lining life of 13-16 heats was achieved in laboratory induction furnace. Phosphorus level was reduced from 0.085% to 0.045%

Iron Making - Casthouse Monolithics

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; William Headrick, RHI Magnesita; John Waters, RHI Magnesita

1:40 PM

(UNITECR-120-2022) Repair Methodology by Injection of Refractory Mass in Blast Furnaces

M. Souza*[1]; R. Couto[1]; R. G. Magalhães[3]; G. Silva[2]

1. Usiminas, Refractory maintenance, Brazil
2. Usiminas, Blast furnace ironmaking, Brazil
3. Vesuvius, R&D, Brazil

Currently, Usiminas has directed efforts to develop repair methodologies of lining of the blast furnace, by combining automation of maintenance activities and use of high performance refractories. In this context, it is presented and discussed the technique of injection of refractory mass for repair of the lining of blast furnace, especially in the zones considered critical because of the premature wear of the lining and the overheating of the shell, due to anomalies in the refrigeration system. The developed methodology allowed to recover the lining by applying refractory mass of the Al_2O_3-SiC system, colloidal silica bonded, with the use of automatic pumping machines with high application rates. Since the implementation of this technique it was possible to minimize the risk of damages associated with the elevation of the shell temperature. This benefit reflected in increase of availability and operational safety of the blast furnaces of the Ipatinga industrial plant.

2:00 PM

(UNITECR-121-2022) Influence of Type and Grain Composition of High-alumina Coarse Batch Component on Blast Furnace Trough Castable Properties

P. Kushchenko[1]; L. Savina[1]; K. Kushchenko[1], V. Martynenko*[1]

1. Ukrainian Research Institute of Refractories named after A.S. Berezhnoy, Ukraine

An influence of high-alumina coarse batch component grain composition - fused brown alumina, tabular alumina and bauxite - on blast furnace trough castable properties, were carried out. Flow behavior of prepared castables and properties of samples from them after cured at room temperature for 24 hours and next drying at 110 °C during 24 hours in dependence from type and grain composition of high-alumina coarse batch component was researched. The dependence of fired samples properties after firing at 1500 °C from type and grain composition of high-alumina coarse batch component was determined. Samples from castables with different type of high-alumina coarse batch component after drying at 110 °C and pre-fired at 1500 °C were comparatively tested for corrosion resistance to blast furnace slag and iron melts. Phase composition and microstructure of tested samples had been explored and based on obtained results castables with used high-alumina coarse batch components were recommended for different places and constructions of blast furnace troughs.

2:20 PM - WITHRDAWN

(UNITECR-122-2022) Development of high toughness refractory for iron runner with metal fiber

Y. Okuhara*[1]

1. Nippon Crucible Co/.Ltd, Sourcing & Procurement, Japan

We reported and took the measure from the structural aspect of the blast furnace iron runner at the Unitecr 2019, whose title was "Effort to prevent cracks by changing the runner structure at the tip of iron runner". For this time, we would like to focus on the measure of the product design aspect and to evaluate by adding various types of metal fibers. The test result was successful. While maintaining the normal fluidity and the kneaded characteristics, we succeeded to develop iron runner material having aimed high toughness with the maximum transition tolerance. Thus, we could prevent cracks with this developed material during the operation which contributed to the stable operation. We would like to report this development this time.

2:40 PM

(UNITECR-123-2022) Trends and Differences in Blast Furnace Main Iron Runner Design

S. Chiartano*[1]; Y. MONVILLE[1]; Y. PRUVOST[1]

1. TRB, France

The subject is dealing with a deep investigation on the design of blast furnace main runners. The main items which characterize the global performance of blast furnace main runner are its reliability, lifetime, and low cost of use. To improve these items, TRB has used its skills and expertise to create and propose the best design for the different layers composing a main runner. Thermal, thermomechanical, and fluid numerical simulations were used by our engineers to improve the usual design towards new concepts. In addition, this theoretical approach has been corrected or reinforced through a worldwide benchmarking.

3:00 PM

(UNITECR-124-2022) Design of improved Al_2O_3 – SiC – C Trough Castable suitable for high MnO in slag

A. K. Samanta*[1]

1. TRL KROSAKI REFRCTORIES LIMITED, Technology, India

Good quality iron ore is depleting day by day and steel makers have started to use low grade iron ores having high quantity of impurities particularly manganese oxides. Manganese oxides present in iron ore reduced to MnO by CO and partially into Mn. Both Mn and MnO dissolved into molten metal and slag followed by aggravate the refractory corrosion and erosion. The consistent performance of trough castable is very important to maintain the whole chain of steel production while giving constant supply of hot metal. The erosion and corrosion of Al_2O_3 – SiC – C trough castable happen in three stages namely decrease in viscosity of slag, increase the wettability of refractory surface and formation of different low eutectic compounds which penetrate easily into the refractory lining. The optimum use of silicon carbide is also important to control the penetration of slag inside the castable lining. In this present work, one new Trough castable in Al_2O_3 – SiC – C system is designed while taking special care in matrix part. An improved matrix is designed in combination of various reactive alumina, carbon sources and antioxidants, thereby enhancing, one, it's non wettability to molten metal/slag and, two, its packing density upon casting. The improved castable is installed in several integrated steel plants and there is significant improvement in performance where MnO in slag is remarkably high.

Steel Making - Flow Control Shapes

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Manoj Mahapatra, University of Alabama at Birmingham; Matt Lambert, Allied Mineral Company

3:40 PM

(UNITECR-125-2022) Degradation mechanisms of zirconia-containing refractories in continuous casting nozzles of steelmaking

A. Fallah-Mehrjardi*[1]; J. Berton[1]; D. Dumont[1]

1. Vesuvius GH, Belgium

Corrosion of zirconia containing refractory is one of the chronic issues that limits the service life of continuous casting nozzles resulting in shortening the casting time. In the present study, various degradation mechanisms of the lime-stabilized-zirconia grains are discussed focusing on microstructural and phase analysis. A classification of corrosion mechanisms is performed based on the phase assemblage and compositions of the reaction products resulting from the chemical interactions between mold-flux slag and zirconia containing refractories. Next, a systematic seven-step approach for the slag/refractory interaction and the identification of the optimum slag/refractory combinations are proposed. The developed method is focused on experimental approach, thermodynamic modelling, and materials characterization techniques. The approach is generic and may be used for most high temperature reaction processes to investigate the chemical refractory degradation. The strategy is to ascertain microstructural and compositional information on the slag/refractory interactions from all possible sources such as end-life used nozzles and slag samples, followed by simulation by a thermodynamic model and lab-scale experiments to develop strategies on increasing the performance of the zirconia containing refractories.

4:00 PM

(UNITECR-126-2022) Interactions Between Glazed Carbon-Bearing Refractories and Steel Melts

T. Richards*[2]; J. Smith[1]; R. O'Malley[1]; T. Sander[1]

1. Missouri University of Science and Technology, Materials Science and Engineering, USA
2. Missouri University of Science and Technology, Peaslee Steel Manufacturing Research Center, Department of Materials Science and Engineering, USA

A commercially produced ladle shroud used in the continuous casting of a special bar quality steel and an unused ladle shroud of the same type were examined to investigate the effects of refractory glaze on steel-refractory interactions in the tundish. A laboratory rotating disc experiment was also employed to replicate the refractory-steel exposure conditions in a laboratory setting, using carbon-bearing refractory samples coated with a protective refractory glaze. Post-mortem analysis of the samples was performed using cathodoluminescence, backscattered scanning electron microscopy, energy dispersive spectroscopy, and X-ray diffraction to characterize the surface of the refractory. These analyses provide insight into the mechanisms of refractory corrosion in the steelmaking environment, with particular consideration for the effects of pre-applied glazes on the quality of the steel.

4:20 PM

(UNITECR-127-2022) Study of Zirconia-Carbon Refractory containing Y/Ca stabilized zirconia for SEN Application

B. S. Sahu*[1]; A. ADHIKARY[1]; L. P. MALLA[1]; S. CHATTERJEE[1]

1. DALMIA CEMENT (BHARAT) LIMITED, India

Zirconia-Carbon refractories are high-duty refractory material employed in the slag zone of the Sub Entry Nozzle (SEN). It has superior corrosion resistance and excellent resistance to chemical attack by slag compared to MgO-C and Al_2O_3-C refractories. However it suffers from poor thermal shock properties. The main factors that interact and lead to spalling of zirconia carbon refractories are stabilization characteristics of cubic phases, carbon content and apparent porosity. In the present work an attempt has been made to evaluate the effect of dopant such as Calcia/ Calcia Yttria in combinations and carbon percentage on the properties of the zirconia carbon refractory. Phase composition and structure of Zirconia particles were investigated by X-ray diffraction. Samples were prepared with Zirconia: Carbon ratio 90:10, 91:9 & 92:8. Refractory samples were fabricated using the cold Isostatic method following Low pressure technology and coked in a reducing atmosphere. The effect of dopant and carbon percentage on bulk density, apparent porosity and spalling resistance were evaluated. Optimized composition showed superior properties such as BD- 4.0 gm/cc, AP-17% and spalling resistance improved from 1150° C to 1350°C upto 20 nos thermal cycles.

4:40 PM

(UNITECR-128-2022) Development of aluminum oxynitride based anti-clogging lining material for submerged entry nozzle

J. Kim*[1]; C. PARK[1]; S. Lee[1]

1. Chosun Refractories Co., Ltd., Republic of Korea

In order to suppress and minimize the build-up of Al_2O_3 clusters around submerged entry nozzle(SEN) as a way of not only prolonging service life but also improving steel quality, there have been quite a few methods introduced such as gas injection and applications of C-free material and/or CaO-ZrO_2-C (CZ) material. Among these, the application of CZ material, which is lined-up within SEN, has been spotlighted recently with an outstanding effect of reducing Al_2O_3 build-up during steel making process. However, it occasionally demonstrates a critical issue of micro-size inclusion entrapped, which mainly comes from the anti-clogging mechanism of CaO containing low melting compounds, giving rise to a fatal risk

in preserving the steel quality. In this work, we introduce a newly devised lining material, Aluminum Oxynitride-based AlON-BN (AlON), which represents a positive effect of preventing alumina build-up enough to take the precedence of CZ SEN, while maintaining an equal level of anti-clogging performance.

5:00 PM - WITHDRAWN

(UNITECR-129-2022) Research and Application of Long Service Life ZrO_2-C Material Used in SEN

J. Wang*[1]; J. Chen[1]; Y. Liu[1]

1. Puyang Refractories Group Co., Ltd, China

The ZrO_2-C material which is generally used as the slag line material of SEN is one of the key points in the continuous casting. To reach a longer service life of this material, effect of the new type of partial stablized zirconia and micro powder of m-ZrO_2 on properties of the ZrO_2-C material was researched in this paper, with the new type of partial stablized zirconia, micro powder of m-ZrO_2 and natural graphite as main raw materials. The results showed that the properties,including bulk density, bending strength and property of erosion resistance,of C2,CY1 and CY2 which were made with the three new type of partial stablized zirconia as raw materials were better than the properties of C1 which was made with the original partial stablized zirconia as raw material. With the added amount of micro powder of m-ZrO2 increasing from 0 to 6%, the bulk density, bending strength and the coefficient of thermal expansion increased firstly and then decreased, the temperature when the highest coefficient of thermal expansion appeared decreased gradually. The service life of ZrO_2-C which was manufactured with the CY2 as the main raw material, with the micro powder of m-ZrO_2 as additive, reached 17 hours in the continuous casting of lower carbon steel grade. Key words

5:20 PM

(UNITECR-130-2022) Application of the fused magnesia with high purity and large crystal size in ladle shroud for continuous casting

L. Pan*[1]

1. Puyang Refractories Group Co., Ltd., China

In view of high corrosion rate and low service life of the slag line of ladle shroud for continuous casting caused by high proportion of calcium treated steel, more slag flowed down from ladle and high basicity of tundish slag, the high purity and large crystal fused magnesia produced by microcrystalline magnesite in Tibet and flake graphite are used as the main raw materials, a new MgO-C material for the slag line of ladle shroud with high corrosion resistance to high basicity slag and high thermal shock resistance was prepared by adding antioxidants and additives. The composite ladle shroud with the MgO-C material as slag line material has been used in some steel plants, it has good effects.

Refractory Technology and Techniques for Energy Savings

Room: Williford A

Session Chairs: Steven Ashlock, Virginia Kyanite

9:20 AM

(UNITECR-131-2022) Use of Novel Refractory Design and Installation Techniques for Improved Energy Efficiency in Iron and Steel and Other Energy Intensive Industries

J. G. Hemrick*[1]

1. Oak Ridge National Laboratory, USA

In this presentation we will describe the initial work in a Department of Energy funded project to bring together the key players necessary to develop and deploy new technology which could increase the thermal efficiency of these industries leading them to higher energy efficiency and reducing their overall energy and environmental footprint. The described project brings together a vertically integrated collaborative team consisting of the end user, material producers/suppliers, raw material suppliers, and research organizations with the objective of designing and producing new refractory materials based on novel aggregates, improved particle packing, and engineered surface texture. In addition, the recycling and use of spent refractory materials will be investigated and a novel installation technique will be developed taking advantage of new additive manufacturing technology and existing refractory shotcrete technology. It is hoped that the combination of these new technologies will allow for the improvement of the energy, environmental, and economic efficiency of the steel industry while also reducing the environmental footprint of the refractory and steel industries. Additionally, the developed technology is expected to be applicable to other energy intensive industries.

9:40 AM

(UNITECR-132-2022) Thermotechnical Properties of Macroporous Foam Ceramics

M. Rath*[1]; R. Stoettner[2]

1. spumix Daemmstoffe GmbH, Management Board, Austria
2. spumix Daemmstoffe GmbH, R&D, Austria

Macroporous foam ceramics have so far not prevailed as fiber-free insulating materials for applications up to 1800°C due to the complex and cost-intensive production processes. A novel process presented at UNITECR in 2015 now made it possible to produce efficiently materials from various raw materials on an industrial scale. The thermal insulation properties of this novel foam ceramic were to be investigated and compared with previous materials such as Insulating Fire Bricks (IFB) and ceramic fibers to evaluate their potential use. The novel process was used to produce different densities of the foam ceramics for each classification temperature. After sample preparation, the density was measured gravimetrically and the thermal conductivity was measured by the hot wire method. The temperature conductivity was determined. The results show a pronounced increase in thermal conductivity with increasing temperature compared to other materials. Starting from a low level with values similar to ceramic fiber, the thermal conductivity increases with higher temperature to the level of IFB despite the considerably lower density of the foam ceramic compared to IFB. In terms of thermal conductivity, the foam ceramic shows an unknown hybrid position between IFB and ceramic fibers. When the low density is taken into account, this reveals highly interesting thermotechnical properties for use in both cyclic and continuous processes.

10:00 AM - WITHDRAWN

(UNITECR-133-2022) Macroporous refractory ceramics prepared with ultrastable foams stabilised with Al_2O_3 and calcite

T. dos Santos*[1]; O. H. Borges[1]; I. Finhana[1]; V. R. Salvini[2]; V. C. Pandolfelli[1]

1. Federal University of São Carlos, Materials Microstructure Engineering Group (GEMM), Materials Engineering Department, Brazil
2. College of Technology (FATEC), Sertãozinho, Brazil

Bubbles can be stabilised with ceramic particles, giving rise to ultrastable foams used for the production of macroporous solids with homogeneous microstructures and high porosity. These materials can be applied as thermal insulators and their performance is dependent on their composition, microstructure and temperature of service. Also, the dimensional stability of these materials during firing and in service is important. Aiming at the production of refractory macroporous samples with high porosity and lower linear shrinkage after firing at 1600 °C, the in situ formation of hibonite ($CaAl_{12}O_{19}$) was induced in alumina-based compositions by adding $CaCO_3$ (calcite) as CaO source. Macroporous ceramics were prepared with alumina-stabilised foams, a calcium aluminate cement liquid binder, and calcite (added as a dry powder or an ultrastable foam). The results pointed out that the combination of alumina and calcite particle-stabilised foams resulted in lighter samples with good mechanical strength, low linear shrinkage (5 % after 1600 °C for 5 h), and lower thermal conductivity, ranging within 0.5 and 0.8 $W.m^{-1}K^{-1}$ between 200 °C and 1200 °C. Therefore, combining liquid foams stabilised with different refractory ceramic particles can be an interesting approach for the development of macroporous materials with different compositions and improved thermal and physical properties.

10:20 AM - WITHDRAWN

(UNITECR-134-2022) Novel strategies to enhance the properties of macroporous thermal insulators produced with ultrastable Al_2O_3-stabilized foams

I. Finhana*[1]; O. H. Borges[1]; T. dos Santos[1]; V. R. Salvini[2]; V. C. Pandolfelli[1]

1. Federal University of São Carlos, Materials Microstructure Engineering Group (GEMM), Materials Engineering Department, Brazil
2. College of Technology (FATEC), Sertãozinho, Brazil

Environmental and health issues urge the replacement of fiber-based high-temperature insulators by macroporous refractories, which could have better performance (lower thermal conductivity and longer lifespan) and no toxicity depending on the manufacturing route used. In this regard, particle-stabilized foams have been drawing attention as they give rise to highly porous ceramics with homogeneous microstructure. Nevertheless, growing efforts to control their setting kinetics, pore size distribution, and sintering-induced shrinkage are being made to allow its large-scale production. Some strategies to overcome these challenges are, respectively, the simultaneous use of bonding systems with shorter setting time, the use of pre-foamed colloidal materials that increase the number of smaller bubbles in the fresh foam, and inducing the in situ formation of expansive phases, like hibonite ($CaAl_{12}O_{19}$). In this work, the addition of calcium aluminate cement aqueous suspension (0 - 10 wt%), a colloidal alumina foam (0 - 10 wt%), and calcium carbonate (0 - 12 wt%), to an alumina-based ultrastable particle-stabilized foam, produced by the direct foaming method, was studied. The setting kinetics, total porosity, mechanical strength, pore size distribution, shrinkage after firing, and thermal conductivity of the designed compositions will be presented and discussed.

10:40 AM

(UNITECR-135-2022) Nb_2O_5 containing alumina foams for high temperature applications$_2$

V. R. Salvini*[1]; M. F. Dos Santos[2]; É. França[3]; D. P. Fridman[3]; R. A. Mesquita[3]; M. A. Stuart[4]; V. C. Pandolfelli[5]

1. Solve High Temperature Ceramics, Brazil
2. RED Lab, Brazil
3. CBMM, Sales & Applications Technology, Brazil
4. St3 Consulting, Brazil
5. UFSCar, DEMa - GEMM, Brazil

High temperature industrial equipment and processes operate in the IR infrared wavelength range (λ=100µm to 0.7µm) and consume a high amount of energy. Technological innovation to reduce heat loss, the consumption and energy costs of these processes and equipment includes the use of thermal insulating ceramic alumina foams. A good thermal insulating ceramic material should be able to reduce the intensity of the radiation emitted within the IR temperature range. Literature data indicate the existence of an ideal pore diameter range of 0.5 to 3.0µm that minimizes thermal conductivity in the range between 1000 and 1700°C. In this project, it was found that the thermal insulation efficiency of high Al_2O_3 foams can be increased by adding 1wt% Nb_2O_5 to their composition. The thermal conductivity and compressive strength of these materials are respectively 0.8W/mK and 23MPa (91% Al_2O_3 foam) and 0.4W/mK and 5MPa (98% Al_2O_3 foam). Thermal and energetic analysis of Fe-Nb alloy ladle lined with these ceramic foams as backup revealed gains in the temperature of the metal bath, lower temperature on the shell and a lower thermal gradient at the refractory working face.

11:00 AM - WITHDRAWN

(UNITECR-136-2022) Analytical and Numerical Determination of the Volumetric Rate of Thermal Energy Generation in a Refractory Castable

T. M. Portilho*[2]; M. F. Dos Santos[2]; R. A. Angelico[1]; V. C. Pandolfelli[2]

1. Universidade de São Paulo, Aeronautical Engineering Department, Brazil
2. Universidade Federal de São Carlos, Materials Engineering Department, Brazil

The pre-heating of refractory linings is usually a time-consuming procedure, which affects the costs, energy consumption and refractory performance. This work focused on the development of two methodologies to determine the rate of energy change per unit volume (q of a calcium aluminate cement (CAC) castable and compare their differences according to the total energy required for heating a steel ladle castable lining. For both methods, the CAC had their properties evaluated and the temperature changes recorded while heating. The data collected supplied the analytical and numerical methods with the information required for calculating the q. Validation was carried out comparing with the experimental temperature difference analysis, to check each methodology performance. The simulation results showed a maximum temperature difference of 6 °C and 8 °C for the analytical and numerical methods, respectively. This indicated a practical method for investigating the refractory heat-up and the likelihood to compare different linings and heating conditions in terms of energy consumption and time. Applying the numerical methodology for a steel ladle, for example, the total energy consumption increase was 3.5 % when the energy rate was considered during heating, which is a significant result regarding the representativeness of the preheating models for refractory materials.

11:20 AM

(UNITECR-137-2022) Two Case studies on energy saving refractory techniques in waste recovery coke ovens

R. Mathai*[1]

1. Jindal Saw Ltd., Coke Oven, India

The healthiness of the coke oven batteries depends upon maintaining proper temperature and refractory works inside. Two case studies were described in this technical paper pertaining to problem faced and energy saving techniques in waster recovery coke plants in India. Case study: 1 Modification of existing coke oven doors at Bhatia coke oven plant. In order to save the heat energy several experiments were attempted to modify the oven doors and trials finally got succeed to achieve desired door skin temperature by changing ratio of the refractory material mix and modification in door fabrication design to enhance the door life. Outcome and conclusion of the experiment shows that, the skin temperature of doors has been dropped from 300 to 150 degree centigrade thus savings of heat energy. Case study: 2 Development of online method to repair the silica bricks in JSW Salem coke plant. Through an innovative and in- house made effective insulated cage, able to do online repair inside. All the damaged bricks were changed in short span without loosing of heat energy and ensuring workmen's safety. Conclusion a new window has opened to restore the problematic oven ensuring energy savings and avoid conventional high repair cost.

11:40 AM - WITHDRAWN

(UNITECR-138-2022) Spinel and Titanate Structures as an Alternative Solution for High Emissivity Ceramic Coatings

E. Y. Sako*[1]; H. D. Orsolini[1]; M. Moreira[2]; V. C. Pandolfelli[2]

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2. Federal University of Sao Carlos, Sao Carlos, Department of Materials Engineering (DEMa), Brazil

High-emissivity coatings have been pointed out as a promising energy saving solution for industrial furnaces since their development in the aerospace market. However, due to a lack of deep knowledge on radiation heat transfer and thermal-optical interactions as well as the struggle in obtaining proper emissivity values, commercial versions of such coatings have not been widely established yet. In this work, an extensive evaluation of the fundamentals on the physics of solids and thermal-optical properties led to the development of engineered structures of usual inexpensive oxides, such as the titanate and spinel ones, which presented improved emissivity values, even at high temperatures (1500°C), when compared to commercial references. Besides the reliable optical property measurements, an efficiency test in a laboratory-scale furnace was also performed to confirm the actual benefits of coatings containing the investigated compounds. The findings of these compounds indicated a considerable cost-effective saving potential for large industrial furnaces.

12:00 PM

(UNITECR-139-2022) Hydrogen combustion in industrial furnaces and the impact on the corrosion of refractory materials

T. Tonnesen*[1]; T. Leber[1]; M. Kirschen[2]

1. RWTH Aachen University, Institute of Mineral Engineering, Germany
2. University of Bayreuth, Professorship Thermal Process Engineering, Germany

For the transformation to a CO_2 neutral industry fuel of traditionally fossil fired furnaces are substituted by subsequently addition of hydrogen. In these studies refractory components are identified for the corrosion of refractories in (highly) reducing atmospheres. Industry process related gas compositions were chosen: - Pure hydrogen: 9Ar $1H_2$ - Midrex: 9Ar 0.5CO 0.5 H_2 - Blast furnace sections: 9Ar CO/CO_2 Thermodynamic calculations have been performed using the FactSage computer packages taking the combustion atmospheres into consideration. MgO-Spinel and Alumosilicates have been chosen as main refractory systems. Additionly corrosion experiments up to 1500°C using a tube furnace with the mentioned atmospheres have been scheduled. Spinel and MgO-Spinel refractory bricks have been selected for these gas corrosion tests as well as castables based on andalusite and high alumina with spinel addition. Amount and phase stability due to different time and temperature coordinates and various gasflow of spinel, andalusite, mullite and CA-bonding phase have been examined by XRD. Furthermore the microstructure and in particular the bonding phase was observed by means of SEM and EDS. Microstructural components undergoing reaction or loss are identified and explained in regards of complete and incomplete hydrogen combustion. Reduction of silica and iron oxides are considered in detail.

Sustainability of Refractory Materials and Education

Room: Williford A

Session Chair: Matt Lambert, Allied Mineral Company

1:40 PM

(UNITECR-140-2022) Recycled carbon fiber composites as carbon source in refractories

M. Bach*[1]; P. Gehre[1]; M. Bühringer[2]; H. Jansen[3]; C. Aneziris[1]

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2. Alexander Tutsek-Stiftung, Germany
3. Refratechnik Steel GmbH, Germany

Sustainable research implies the responsible use of natural resources. The globally increasing amount of recyclable materials combined with the scarcity of natural resources requires innovative approaches. Thus, the continuing shortage of natural carbon sources could lead to the recycling of high-end carbon-based products in the refractory industry. In this study, recycled carbon fiber reinforced polymer (CFRP) composites were investigated as carbon source in order to reduce the graphite content for carbon-bonded alumina refractories. The influence of CFRP pretreatment (thermal or none), content of fibrous CFRP powder (1 or 10 wt.%) and graphite to be reduced (fine or flaky) are investigated. The replacement of flaky graphite by 1 wt.% CFRP shows similar physical, mechanical and thermo-mechanical properties compared to the reference. Therefore, the study provides an optimum of recyclable CFRP to reduce natural graphite in refractories, which could benefit both the refractory industry and the global carbon market.

2:00 PM

(UNITECR-141-2022) Development of an optimal system to prevent waste refractory dust scattering in HYUNDAI STEEL

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2. Allswell, Republic of Korea

After using the Ladle(Teeming/Charging) at the refractory relining shop in the integrated steel mill, the tilting process using a crane is performed inside the factory to process the waste refractories. In the tilting process, as waste refractory materials fall from the teeming ladle, dust is generated and scattered. Due to this, all normal operations and activities near the refractory repair shop are impossible until the scattered waste refractory dust settles down on the factory floor or surrounding facilities. To solve these problems, Hyundai Steel introduced a dust scattering prevention system using air flow control and air purification technology. This system is composed of a supply/exhaust facilities and an air purification facility (Cyclone & Filter type). The air sucked into the hood installed inside the structure passes through the cyclone (no filter device) to remove most of the dust in the air. and the rest of the air passes through the HEPA filter and only clean air is discharged into the factory. Finally, compared to before the introduction of the system, the concentration of scattering dust inside the factory was reduced by more than 95%.

2:20 PM

(UNITECR-142-2022) Steel meets Refractory – a new platform for technical exchange in Germany

A. Buhr*[1]; P. Quirmbach[2]; J. Pischke[3]; E. Steinle[4]

1. Almatis GmbH, Product & Market Development, Gibraltar
2. DIFK, Germany
3. Salzgitter AG, Germany
4. VDFFI, Germany

The technical exchange between steel and refractory industries has long tradition in Germany, Austria, and The Netherlands. For decades the refractory committee of the German Steel Institute VDEh was the platform enabling exchange and networking between the stake holders. When VDEh decided in 2018 to abandon all their technical committee work, it became clear that without a new platform the fruitful technical exchange and network could not be sustained on the long run. Personal changes in organizations and missing opportunities for getting in contact with new people would inevitably lead to loosening of the network and all exchange would be reduced to only personal relationships. All stake holders were highly interested to continue the pre-competitive exchange on important overarching topics such as EHS (e.g. classification of refractories), specific technical issues (e.g. recycling) and innovation (e.g. heating of monolithic installations). Through an initiative of the network of refractories experts within the ECREF European Centre for Refractories, the German Refractories Association in cooperation with the Ministry of Economics of the Federal State Rhineland-Palatinate have established in 2019 the “Steel meets Refractory” meetings as industry dialogue format. The paper will discuss the establishment and first experiences with this new platform for an important technical exchange in the industry.

2:40 PM

(UNITECR-143-2022) How to Benefit from the CDIO Approach to Meet Refractory Education Needs for Innovations

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1. Ecole Polytechnique, Mechanical Engineering, Canada
2. University of Orleans, France

The CDIO initiative started some 20 years ago, to promote the needed adjustments for all the undergraduate engineering education programs, to meet the new challenges, our world will have to face in the 21st century. To keep focus on innovations, FIRE, in the last 15 years, established master and doctoral research programs inspired from the CDIO syllabus, to fit with the refractory industry innovation needs in Research and Development. The CDIO approach is about how to Conceive-Design-Implement and Operate complex, value-added products, process and systems to meet specific demand of users. After an analysis of the FIRE achievements so far it will be concluded that FIRE do need to continue its efforts to strengthen the Education part of its mission and look for more inputs from all the stakeholders in the industrial and academic worlds to support initiatives such as: edition of books, organization of summer schools and other forms of specialized training, as much as possible following the CDIO approach.

New Developments in Refractory Formulation I

Room: Williford B

Session Chairs: Ashley Hampton, Allied Mineral Products, LLC; Angela Rodrigues-Schroer, Wahl Refractories

9:20 AM

(UNITECR-144-2022) Controlling the sintering process of mullite-zirconia bonded refractories made from zircon and andalusite

A. Villalba Weinberg[2]; J. Poirier*[1]; D. Goeuriot[3]; C. Varona[2]; X. Chaucherie[4]

1. University of Orleans, Fr, CEMHTI-CNRS, France
2. Bony SA, France
3. MINES Saint-Étienne, France
4. SARPI-VEOLIA, France

Although mullite–zirconia composites made from zircon, alumina, and andalusite meet the requirements for many high temperature applications, little effort has been made to transfer these composites to the bonding phase (the 'matrix') of refractory bricks. In this research, we investigate how this could be achieved through better control of secondary oxides: P_2O_5, Na_2O, and TiO_2 during the sintering. Thermodynamic calculations were performed to determine the phases at high temperatures. The calculations were compared to the microstructures, mineralogy, and properties of the composites. The results revealed that the system is very sensitive to Na_2O, which harmed the microstructure considerably. By contrast, TiO_2 and P_2O_5 additions proved beneficial, allowing complete zircon decomposition at 1550 °C while providing the required green strength. Decohesion between the matrix and aggregates due to high matrix shrinkage can be prevented by partially substituting andalusite with the volume-increasing mineral kyanite. Based on these findings, a novel refractory brick was developed and tested with success in hazardous waste incineration rotary kilns. The material resisted much longer than mullite- and alumina–chromia-bonded refractories.

9:40 AM

(UNITECR-145-2022) ZnO induced spinel-like phase formation on alumina-based castables

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2. Federal University of São Carlos, Materials Microstructure Engineering Group (GEMM), Materials Engineering Department, Brazil

The steel-making industries currently demand ~ 70 % of all ceramic refractories produced worldwide. Additionally, the steel ladle ceramic lining account for almost 25 % of the cost related to refractories in integrated steel plants. Until the 1990's the use of chrome-containing refractories was widespread as it forms a plethora of spinel-like phases with other elements, leading to high corrosion resistance. More recently, environmental concerns urged the replacement of chrome-containing refractories to magnesium ones, which reacts with alumina at high temperature (> 1200 °C) to form the spinel $MgAl_2O_4$. Nevertheless, few studies have evaluated the possibility of adding other chemical elements as inducers of spinel-like phase formation in refractory castables. In this regard, zinc oxide is a promising alternative as it can react to alumina at lower temperatures (~ 800 °C), giving rise to the spinel $ZnAl_2O_4$ (gahnite), which is nontoxic, has high refractoriness (> 1900 °C), low thermal expansion coefficient, and high corrosion resistance. In this work, the addition of ZnO in alumina-based castables was studied by evaluating their in situ elastic moduli, mineralogical content, linear dimensional change with temperature, flexural strength, and thermal shock resistance. The results were compared to $MgAl_2O_3$-containing refractories.

10:00 AM

(UNITECR-147-2022) Refractory castables dispersed by phosphates (Part 1): influence of chain length, concentration and citric acid on dispersion and stiffening

J. Kasper*[1]; A. Röser[1]; C. Dannert[1]

1. Forschungsgemeinschaft Feuerfest e. V. at the European Centre for Refractories, Germany

The interactions between alumina fines, CA cement, phosphate-based dispersing agents and citric acid in refractory castables during deflocculation up to the first stiffening were examined. Zeta-potential measurements as well as flow measurements and sonic velocity measurements were performed to analyse their dispersion and stiffening behaviour. Results showed that the dispersion behaviour of hydraulically bonded refractory castables is strongly dependent on the chain length of the phosphate molecules therein. The mechanisms were found to shift from pure electrostatic repulsion to a distinct electrosteric repulsion in between particles. In addition, it could be shown that the dispersion behaviour of citric acid exceeds that of sodium-tripolyphosphate. The dominance of the dispersion by citric acid decreases strongly as the chain length of the phosphate molecules increases. The well-known effect that citric acid prolongs the open time of a refractory castable was confirmed. Additionally, the first stiffening was found to be retarded if the concentration of phosphate molecules with high chain length increases. A more comprehensive understanding on the mechanisms of the dispersion and first stiffening of phosphate dispersed, hydraulically bonded refractory castables was achieved.

10:20 AM

(UNITECR-148-2022) Refractory castables dispersed by phosphates (Part 2): influence of chain length, concentration and citric acid on hardening and CA cement hydration

J. Kasper*[1]; A. Röser[1]; C. Dannert[1]

1. Forschungsgemeinschaft Feuerfest e. V. at the European Centre for Refractories, Germany

The interactions between alumina fines, CA cement, phosphate-based dispersing agents and citric acid in refractory castables during the hardening and hydration were examined and their

influence on the dormant period of the CA cement hydration was figured out. Measurements of the sonic velocity and the hydration temperature were performed to analyse the hardening behaviour during the reaction of CA cement with water. A systematic shift of the main hydration of CA cement due to varying phosphate chain lengths and the increase of the phosphate respectively citric acid concentration was observed. The well-known effect that citric acid retards the hydration of CA cement, and therefore the hardening of refractory castables, was confirmed. Short chained phosphates were found to accelerate the hydration. Long chained phosphates tended to retard the hydration. A more comprehensive understanding on the mechanisms of the hydration of CA cement in phosphate dispersed, hydraulically bonded refractory castables was achieved. The main conclusions are focused on the influence of phosphates and citric acid on the formation of the passivation layer on CA cement particles and its depletion by time.

10:40 AM - WITHDRAWN

(UNITECR-149-2022) Preparation and Properties of Microcellular High-Strength Thermal Insulation Materials by High Temperature Micro-Foamed

X. Li*[1]; M. Pan[1]; X. Wu[1]; X. Zhan[1]; H. Ma[1]; C. Ma[1]

1. School of Materials Science and Engineering Zhengzhou University, Henan Key Laboratory of High Temperature Functional Ceramics, Zhengzhou 450052, China

High temperature thermal insulating materials with low bulk density, high compressive strength and low thermal conductivity were fabricated from a powder mixture of granite waste, SiC and feldspar by using a micro-foamed method. The microstructure, mechanical and thermal insulation properties were investigated comprehensively. Results show that the firing temperature, SiC particle size and the granite waste content in the mixture are key factors. Increasing firing temperature and prolonging holding time both led to a significant increase in porosity, while thermal conductivity and compressive strength showed a downward trend. Reducing the particle size of SiC leads to an increase in closed-cell porosity, thereby promoting the improvement of thermal insulation performance. In addition, as the amount of granite waste is increased, the thermal conductivity initially increases but then decreases. When the granite waste content is 90% and SiC particle size is 6.5 μm, the density decreases to 0.48 g/cm^3, compressive strength is 7.2 MPa, a higher porosity of 81.6% and the thermal conductivity is 0.23 W/(mK) at 350 °C.

11:00 AM

(UNITECR-150-2022) Designed porous aggregates – a new path towards more sustainable steel ladle refractories

C. Wöhrmeyer*[1]; J. Gao[1]; M. Szepizdyn[1]; S. Graddick[1]; C. Liu[1]

1. Imerys, France

High alumina steel ladle refractories typically use dense aggregates like white fused alumina (WFA) or tabular alumina (TA) as the backbone of these high purity products. The grain porosity is often below 5 Vol. % which minimizes slag penetration into the aggregates. However, the overall porosity of the formulated refractory products are often in the range of 10 to 20 Vol. %. This is due to the relatively higher matrix porosity. Consequently, slag penetration and corrosion starts in the matrix and becomes the performance limiting factor. This paper investigates to which extend dense alumina aggregates could be replaced by newly designed grains with elevated porosity, without deteriorating the service life of the refractory material. The advantages would be: the density of the ladle lining could be reduced and a better heat containment and a lower material requirement be achieved. This could improve the sustainability and reduce at the same time the cost per ton of steel, under the condition that service life is kept at least constant and that it allows a save ladle operation. The addition of porous aggregates could also improve the thermal shock resistance. These aspects will be investigated in this paper by comparing monolithics containing a newly designed density-reduced multi-component refractory aggregate with reference materials that use dense high purity alumina aggregates.

11:20 PM - WITHDRAWN

(UNITECR-151-2022) The effect of Nano-Iron on microstructure and phase evolution of MgO-C refractory treated by iron nitrite

H. Rastegar[1]; m. bavand-vandchali[1]; F. Golestani-fard*[3]; A. Nemati[2]

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3. Refracto-Ceramic Consultancy LTD, United Kingdom

In the present article, the effect of iron nitrite addition to MgO-C primary batch and its effects on nano-Fe formation in phenolic resin is reported. Samples containing 0-6 wt% (Fe/phenolic resin) were formulated based on low carbon MgO-C refractories and coked at 800-1400 °C. Phase and microstructural evolution were studied by XRD and FESEM analysis. It was found nano-Fe particles of 60-80 nm were formed during firing in reduced atmosphere and promoted graphitization by catalytic behavior. Different nano-crystalline shapes of carbon whiskers of MgO, MgAl2O4, Al4C3 and AlN were also detected in samples coked above 1000 °C. our study showed the CNTs and ceramic whiskers could possibly form in the bonding phase via L-S and V-S growth mechanism.

11:40 AM

(UNITECR-146-2022) Design and production of coarse-grained aggregates for (Nb/Ta)-Al_2O_3 refractory composites

P. Gehre*[1]; T. Zienert[1]; D. Endler[1]; J. Hubálková[1]; C. Aneziris[1]

1. TU Bergakademie Freiberg, Germany

Modern high-temperature processes require smart refractories with e.g. electric properties beside superior thermo-mechanical behaviour. Refractory composites based on refractory metals and refractory oxides are a promising new class of smart materials for high-temperature applications. Here, electrical and thermal conductive and ductile refractory metals such as niobium and tantalum were combined with fine- and coarse-grained oxide ceramic aggregates such as corundum to develop refractories combining functional properties with low shrinkage during sintering, creep resistance at high temperatures, and an improved thermal shock behaviour. The shaping of such smart refractories was realised utilising ceramic technologies such as castables and pressure slip casting. The first step in developing this new type of refractory materials was the production of presintered coarse-grained (Nb/Ta)-Al_2O_3 refractory composite aggregates. As the aggregate's properties are a function of chemical composition and morphology, they were influenced by the chemistry (type and purity) of the raw materials, amount of the refractory metal portion (5 and 40 wt.-%), sintering temperature, and process technology (extrusion and 3D-printing). The different design strategies and their influence on the material properties of the coarse-grained refractory composites were presented and evaluated.

New Developments in Refractory Formulation II

Room: Williford B

Session Chair: Angela Rodrigues-Schroer, Wahl Refractories

1:40 PM

(UNITECR-152-2022) Dispersion-strengthened Al_2O_3-MgO-C refractories

K. S. Chandra*[1]; D. Sarkar[1]

1. National Institute of Technology (NIT), Ceramic Engineering, India

Carbon containing resin-bonded refractory materials are an important class of multiphasic systems with small-scale matrix microstructure. Significant microstructural changes in the resin-bonded refractory matrix with particulate dispersions offer unique opportunities for improving their mechanical properties at room as well as high temperature environments. Such studies have been performed on resin-bonded Al_2O_3-MgO-C refractories with ceramic particulate dispersions and compared the experimental results with the commercial resin-bonded systems. Analysis indicated that the ceramic dispersoids arranged themselves in such a way to form a strong and tough intergranular bonding framework as a continuous reinforcement throughout the refractory matrix microstructure, which is credited for the considerable improvement of mechanical properties including the satisfactory thermal shock performance of the dispersion strengthened systems of this modern class over the commercial resin-bonded refractories.

2:00 PM

(UNITECR-153-2022) Advanced strontium zirconate refractories for investment casting titanium alloys

S. Uwanyuze*[1]; S. Schaffoener[2]; P. Alpay[1]

1. University of Connecticut, Materials Science and Engineering, USA
2. University of Bayreuth, Ceramic Materials Engineering, Germany

Refractories for metallurgical applications have to withstand severe corrosion and thermomechanical stresses. During investment casting of titanium alloys, metal-mold reactions occur with most conventional refractories. Unfortunately, such reactions impair the knock-out removal process of the cast part, cause detrimental changes in the alloy microstructure, and limit near-net-shape casting. In this study, we investigate the high-temperature corrosion of novel strontium zirconate refractory in comparison to conventional ones such as alumina, yttria, and yttria-stabilized zirconia. We develop here a robust and relatively uncomplicated procedure to examine the liquid-solid and solid-solid interactions of these ceramic oxide refractories with cp-Ti, Ti-6Al-4V, and TiAl. Our findings show that conventional refractories were much more susceptible to high-temperature corrosion than strontium zirconate. Therefore, strontium zirconate is proposed as an advanced refractory for investment casting titanium alloys. Mitigating metal-mold reactions is important for saving time and costs associated with the mechanical or chemical removal of the reaction layers.

2:20 PM - WITHDRAWN

(UNITECR-154-2022) Review of the Design Principles for Corrosion Resistant Refractories

P. Walls*[1]

1. Hitech Materials Pty Ltd, Australia

No matter the application, refractory materials have to withstand some form of corrosive attack for the application in which they are installed. This can be by direct reaction with molten metals, alloys or glasses, indirectly from volatile species generated in the working atmosphere, from slags, or from the products being formed during processing. With such a range of exposure environments, this is why there are such a variety of refractory materials in the market place, as there is no 'one formulation that fulfils all situations'. The formulation and behaviour of refractory composite systems will be reviewed, with a focus on the desired behaviour of the aggregate and bonding phases and technological refinements of these to improve corrosion resistance.

2:40 PM

(UNITECR-155-2022) Comparative analytical characterization of two carbonaceous binders used in refractory materials

P. Quirmbach[1]; J. Doll*[1]

1. University of Koblenz-Landau, Germany

The introduction of carbon into refractory materials leads to significant improvements in technological properties, especially with regard to thermal shock resistance. However, regulations are becoming more stringent due to negative impact on human health and the environment. In this context, organic binders such as coal tar pitches containing high levels of polycyclic aromatic hydrocarbons (PAH) are of particular scientific interest. Despite intensive research, their specific chemical composition is still not completely clarified. In this study, two commercial binder systems with different softening points used in refractory materials were investigated. For this purpose, a non-target approach was applied. Due to the complexity of the samples and the large fractions of semi- and non-volatile compounds, a combination of different analytical methods was used. In particular, high-resolution time-of-flight mass spectrometry (HR-TOFMS) proved to be a powerful tool for gaining deeper insights into the structure of these samples, such as molecular-weight-distribution or aromaticity. In addition, further information on the occurrence and distribution of heteroatomic compounds such as S, N and O-derivates could be obtained.

3:00 PM

(UNITECR-183-2022) Challenges in characterization of Ferro silicon nitride and determining its suitability for use in taphole clays for Blast Furnaces

P. Srinivasa Rao*[1]

1. Vesuvius Refractory India Private Limited, India

Ferrosilicon nitride (Fe-Si3N4), commonly referred to as FSN has been used as an additive in Anhydrous Taphole Clays for Blast Furnace applications to enhance the high-temperature strength, corrosion and oxidation resistance. Given the multitude of suppliers and complexities involved in detailed characterization of FSN, an attempt has been made to develop a characterization protocol and benchmark globally available FSN suppliers using this protocol. An improved understanding of this key ingredient enables future performance improvements in taphole clay formulations. This study discusses the complexities involved in characterization of refractory minerals and presents the results of benchmarking. Preliminary results indicate that nearly identical chemical compositions can yield significantly different phase compositions. Differences in chemical and phase compositions of FSN can potentially impact the performance of taphole clays in service.

Refractories for Cement and Lime

Room: Williford C
Session Chair: Kelley Wilkerson, Missouri S & T University

9:20 AM

(UNITECR-156-2022) Magnesia-Spinel Brick with Excellent Coating Adherence for Cement Rotary Kilns

M. Ohno*[1]; S. Takeuchi[1]; H. Toda[1]; Y. Yoshimi[1]

1. MINO CERAMIC CO., LTD., Technical Research Laboratory, Japan

Magnesia-spinel bricks are widely used in cement rotary kilns because they have excellent resistance to thermal shock, long-term repeated heat cycles, chemical attack and mechanical stress. However it is generally recognized that the coating adherence of magnesia-spinel bricks is inferior to that of other basic bricks, limiting the application to the center of burning zone. We believe magnesia-spinel brick capable of forming stable cement coating is an optimum material for burning zone because of its good properties in thermal, chemical and physical aspects, considering harsh conditions due to the increasing use of waste as fuels and raw materials. In this paper we describe the superior coating adherence of our magnesia-spinel brick to other types of basic bricks by evaluating the adherence strength in 3-point bending test, in which the bonded brick piece with coating were prepared and its bonding strength was measured. Electron microscopic study indicated high refractoriness compounds formed in our brick bound the brick to cement coating, resulting in high adherence strength. By applying this technique, we have developed magnesia-spinel brick with excellent coating adherence. In addition to the coating properties, the developed brick achieved superior trade-off properties, high corrosion and spalling resistance by approximately 90% MgO content and different types of spinel with proper size.

9:40 AM

(UNITECR-159-2022) Development of alkali corrosion resistant high temperature materials

P. Ghere*[1]; C. Dietze[1]; T. Schemmel[2]; M. Bühringer[3]; H. Jansen[2]; C. Aneziris[1]

1. Technische Universität Bergakademie Freiberg, Institute of Ceramics, Refractories and Composite Materials, Germany
2. Refratechnik Steel GmbH, Germany
3. Alexander Tutsek-Stiftung, Germany

The demand for alkali corrosion resistant high temperature materials exists due to the increased use of alternative fuels, which introduce larger amounts of alkalis into high temperature systems. The alkali attack leads to degradation and life time shortening of the lining materials of industrial furnaces. One concept is to develop materials corresponding to the corrosion products of the attacked ceramics. Such materials are ternary alkali aluminosilicates in the case of conventional aluminosilicate lining materials for example used in the cement industry. This idea was successfully realised in the past by producing a porous insulation material – starting from the composition of the potassium aluminosilicate $KAlSiO_4$ - whose superior alkali resistance was proven using various testing methods. Based on these results the focus of the recent study is set on the generation of high temperature materials for the application in the inner front of lining systems exposed to a high alkali load. The influence of raw materials and process parameters on the materials properties was examined. Resulting microstructure and phase composition were analysed via x-ray diffraction and scanning electron microscopy. To investigate the materials alkali corrosion resistance the so-called disc test was applied, which provides not only optical but also numerical results.

10:00 AM

(UNITECR-157-2022) Energy efficient periclase-magnesium aluminate spinel refractory for cement rotary kiln

W. Yan*[1]

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An energy efficient periclase-magnesium aluminate spinel refractory (LPSR) with high mechanical properties and high cement clinker resistance for cement rotary kiln was fabricated using the microporous magnesia aggregates to replace traditional dense magnesia aggregates. The microstructures and properties of the LPSR are compared with those of traditional dense periclase-magnesium aluminate spinel refractory (DPSR) containing fused magnesia aggregates. The apparent porosity of the microporous magnesia aggregates was 43.1%, and those of fused magnesia aggregates was 5.5%, respectively. Scanning electron revealed a better interface bonding between the microporous aggregates and matrix in LPSR, which significantly improved the strength and thermal shock resistance of the LPSR. Additionally, the microporous magnesia aggregates absorbed some amount of the penetrated slag from the matrix, and then prevented the slag further penetration in the LPSR. Thus, after substituting the microporous magnesia aggregates for dense magnesia aggregates to fabricate the LPSR, the bulk density reduced from 2.87 g/cm^3 to 2.61 g/cm^3, the compressive strength and flexural strength increased from 48.7 MPa to 73.1 MPa and 6.0 MPa to 10.1 MPa, respectively. Meanwhile, the same cement clinker resistance was also obtained for the LPSR compared to DPSR.

10:20 AM

(UNITECR-158-2022) Sustainable Linings For Rotary Kilns

H. Klischat*[1]; P. Groger[2]; H. Wirsing[1]

1. Refratechnik Cement GmbH, Research & Development, Germany
2. Refratechnik Cement GmbH, Sales Department, Germany

Reduction of the carbon footprint by saving energy is a major challenge for the mineral industry using thermal processes, like production of cement, lime, calcined clay, or magnesia. Latest progress on refractory brick development for hot kiln zones results in products characterized by an, up to now, unknown high porosity with values up to 24%, ensuring a significantly reduced thermal conductivity. All other relevant properties, like structural strength, gas permeability, and refractoriness correspond to values of dense products. The installation of these innovative new bricks based on high temperature resistant minerals, like magnesia or andalusite, in various types of rotary kilns results in remarkably lower kiln shell temperatures and thus in a significantly lower energy consumption of the kiln. This is achieved by a completely new design of the brick structure, which can be related to fine-ceramic articles. Since these new basic and non-basic brick grades can be installed like standard bricks, no unstable two-layer-lining or two-layer bricks are needed. As the weight of the lining is decreased, even less operating power is needed. Energy saving, CO2- and carbon footprint reduction, and efficiency increase can be easily achieved in a safe and simple way.

11:00 AM

(UNITECR-160-2022) Effect of fuel composition on refractory linings in cement clinker production

K. Weber[1]; J. Södje[1]; S. Uhlendorf[1], H-J. Klischat*[1]

1. Refratechnik Cement GmbH, Research & Development, Germany

The firing of alternative fuels plays an important role for cement plant operators in order to achieve ecological and economical goals. In several cement plants, the share of alternative fuels is almost 100%. Today's refractory products put a special focus on the increased use of alternative fuels and raw materials, they must withstand severe burning conditions to avoid frequent exchange and kiln stops. However, varying fuel compositions often change the chemical/

thermochemical stresses acting on the refractories and the metal shell. Furthermore, the coating behavior of the clinker material may vary as well. Alternative fuels introduce a variety of impurities, e.g. S and Cl, as well as alkalis (e.g. K, Na) and heavy metals (e.g. Pb, Zn, Bi, Ni). In addition, the particle size of the fuels also has a decisive influence on the combustion conditions and often determines the locally reducing or redox environment. The combustion conditions significantly change the wear pattern of the refractory material due to the complete change of reaction phases. In this paper, numerous investigated wear cases from real use are reviewed and the effects of changing fuel composition on basic and non-basic refractories under actual operating conditions are shown. The focus is set on the effects of a reducing burning environment on refractories with the formation of sulfides and carbonates under the boudouard equilibrium.

11:20 AM

(UNITECR-161-2022) Spinosphere Technology - an Innovative flexibilization technology

M. Geith*[2]; R. Krischanitz[1]; S. Jörg[2]

1. RHI Magnesita GmbH, Global Product Management, Austria
2. RHI Magnesita GmbH, Research & Development, Austria

Cement rotary kilns have special demands on its lining. Due to the high melting point and corrosion resistance, sintered magnesia is an ideal material for cement rotary kiln brick production. However, it's high thermal expansion result in low flexibility. Since this is a crucial property for the application in cement rotary kilns, flexibilisers must be added, which are basically different types of spinels. However, the use of spinels to increase flexibility results in a weakening of hot strength and clinker melt resistance. This is attributable to the formation of low-melting phases in reaction with CaO of the clinker, but also with secondary phases present in the brick. In development of highly flexible bricks this causes the dilemma, that an increased spinel-amount invariably leads to a lower hot strength and clinker melt resistance, so that product development had to decide for one, flexibility or hot strength. Significant progress has now been made with the new Spinosphere Technology. The novel technology enables to increase the flexibility without any substantial impairment of hot strength or clinker melt resistance. This was accomplished by a new production process for MA spinel, which reduces the alumina content of spinel by ~70% without diminishing its flexibility. By this procedure the formation of low-melting calcium aluminates can be significantly reduced during brick production and in application.

Refractories for Aluminum

Room: Williford C
Session Chair: Ashley Hampton, Allied Mineral Products, LLC

1:40 PM

(UNITECR-162-2022) Influence of Modern Aluminum Alloys on the Reaction Behavior of Refractory Linings

T. Tonnesen*[1]; W. R. Reichert[1]; R. Telle[1]

1. RWTH Aachen University, Institute of Mineral Engineering, Germany

For production of modern Al alloys, constituents of silicon, zinc and magnesium contribute mainly to the degradation of refractory furnace linings. The alloy constituents increasingly penetrate into the material via vapour phase. This study focuses on the impact of zinc and magnesium, as a gaseous component on refractory linings. The examined materials of this study are different bauxite based bricks with particular phosphate bondings and high alumina bricks with mullite bonding. The experimental setup of the corrosion tube furnace consists of an added crucible filled with the metal to be melted and two identical bars of the refractory sample, whereby the feed material is weighed before and after. Metallic Zn and Mg are used as well as the Al alloy AL7075. Testing temperature was 1050°C for 8 h and 24 h. Microstructural changes such as phase transitions, especially the formation of different spinel phases, resulting in volume changes, were examined by means of SEM /EDS and XRD. Volume changes result in shear strain parallel to the refractory's hot-face lowering the mechanical performance. Physical property changes of porosity and mechanical strength (Young's modulus and MOR) as well as gas permeability have been performed to work out the correlation to the microstructural change due to the special corrosion by the alloy constituents.

2:00 PM - WITHDRAWN

(UNITECR-163-2022) Development of New Generation Tie-rod Refractory Brick for Anode Baking Furnace Application

J. P. Nayak*[1]

1. TRL Krosaki Refractories Ltd, Technology (R&D), India

Baking process is an important part of the primary aluminum production process, where anode is being manufactured. By indirect contact with the hot gas flowing in the flues; anodes are baked thoroughly. All the flue walls of anode baking furnace (ABF) are constructed with aluminosilicate refractory bricks, which are subjected to withstand various type of stresses during baking process. These stress cause alteration of properties of lined refractory, resulting refractory failures due to cracking and bending of flue walls mainly. Thus, selection of suitable refractories is an important criterion, which can restrict the damage of flue walls for a long run ABF. Tie Rod brick among other refractories used in ABF plays a vital role to enhance the performance of flue walls. This brick should exhibit high volume stability, high thermal shock resistance, and good creep resistance. Based on this approach; present work describes the development of a new generation Tie Rod brick by selecting high pure raw materials and robust process parameters. The product is characterized for physical, chemical, phase and microscopy analysis. Important property like creep, hot modulus of rupture, permanent linear change and thermal shock resistance has been evaluated. The specially designed product is put into operation in ABF of a leading aluminum manufacturing plant, and product is running successfully.

Friday, March 18, 2022

Plenary II

Room: Williford A, B, C
Session Chair: James Hemrick, Oak Ridge National Laboratory

8:10 AM

(UNITECR-PLEN-002-2022) Frontiers in Refractories

D. G. Goski*[1]

1. Allied Mineral Products, LLC, USA

Materials science discoveries emerge. Manufacturing processes and industrial/digital optimizations advance. Applications computational modelling progresses. Environment and sustainability responsibilities exist. Refractory ceramic systems play a critical role in the economic success of many high temperature processing industries. These engineered materials require predictable performance and controlled functionality. How will we seize upon these challenges as opportunities? How do we bridge new technologies? How will we inspire the next generation of materials pioneers?

Iron Making - Shapes and Monolithics

Room: Joliet
Session Chairs: Scot Graddick, Imerys; William Headrick, RHI Magnesita

9:20 AM

(UNITECR-164-2022) Improvement in torpedo ladle refractory corrosion rate by mist cooling

K. Taniguchi*[1]; H. Matsunaga[1]; K. Takahashi[1]
1. JFE steel corporation, Japan

Torpedo ladles transport hot metal from the blast furnace to the steelmaking plant, and in many cases, the liquid iron is treated in the ladle to remove impurities. Since an injection lance is used in hot metal pretreatment, slag is splashed against the roof wear bricks and the bricks are corroded. In order to extend the service life of the torpedo ladle refractory, the upper part of the outer steel shell of the torpedo ladle was cooled with water mist to reduce the brick corrosion rate. First, a heat transfer analysis was conducted to verify the effect of reducing the brick surface temperature by cooling the steel shell. When the cases of cooling or not cooling the upper part of the outer steel shell during hot metal pretreatment were compared, the effect of cooling to reduce the brick surface temperature was −11.8 K. Second, Rotary Slag Testing was performed to evaluate the influence of the brick surface temperature on the brick corrosion rate. Third, a demonstration experiment was conducted, in which the upper part of the outer steel shell was cooled with mist. As a result of this project, it was found that the corrosion rate could be reduced by 20 % by cooling.

9:40 AM

(UNITECR-165-2022) Study and application of wet shotcrete castable sprayed on iron ladle working linings

Y. Wang*[1]; w. chen[1]; Y. Wang[1]; Y. Wang[1]; Y. Qin[1]
1. Puyang Refractories Group Co., Ltd., China

The effects of amount of calcium aluminate cement, silica powder and silicon carbide on the rheological and physical properties of wet shotcrete castable using for lining in iron ladle were tested with low Al_2O_3 bauxite as the main raw material. The optimum amounts of calcium aluminate cement, silica powder and silicon carbide in wet shotcrete castable are 4%, 4% and 6%, respectively. The shotcrete lining was sprayed on the surface of working lining of wall and slag zone in iron ladle which has been used for 170 heats and then used. The results showed that the sprayed lining maintained integrity after 57 heats and spalled between 57-65 heats. At the basis of 55-60 heats for which working lining could be well protected by sprayed lining, the total heats of iron ladle working lining can be increased by 15% after one spraying construction. It can also be assumed that the safety and service life of iron ladle in harsh service environment could be greatly improved, as well as the energy loss of iron hot metal decreased during transporting and delivery process due to the protection of shotcrete lining by continuously spraying.

10:00 AM

(UNITECR-166-2022) Effect of Firing Temperature and Creep Rate Testing Temperature on Creep Resistance of Sillimanite-Based High Alumina Brick

F. LI[1]; K. Yin*[1]; T. Ge[2]; Y. Yang[1]
1. Zhengzhou Annec Industrial Co., Ltd, Refractory Technology, China
2. Zhengzhou University, China

In this paper, by using L80 bauxite-based homogenized material as particles, sillimanite, brown corundum powder andα-Al_2O_3 micro powder as matrix, so as to research the effect of firing temperature and creep rate testing temperature on creep resistance of sillimanite-based high alumina brick. The results are as follows: The creep resistance of brick will strengthen along with the increasing of firing temperature. In the brick fired at 1450°C,corundum is main crystal phase, mullitization of most sillimanite doesn't happen. Brick at 1500°C, mullite is main crystal phase, Mullitization of the egde of large particles (≥0.1mm)of sillimanite happens. Brick at 1550°C, mullite is main crystal phase. Therefore the firing temperature of sillimanite-based high alumina brick should be over 1500°C. The higher creep inspection temperature is good for brick to resist creep. By comparing the micro structures of specimens of bricks fired of the creep rate test before and after at 1350 °C, mullitization of sillimanite particles in brick still not happen after creep. Before and after at 1450 °C, the quantity of mullizated sillimanite particles increased and they combined with matrix well. Therefore, the creep rate testing temperature for sillimanite-based high alumina brick should be over 1450°C.

10:20 AM

(UNITECR-167-2022) Innovative fused silica pre-shaped refractory for coke ovens

L. Roumigiuer[2]; F. Delobel*[1]; P. Pilate[1]
1. Belgian Ceramic Research Center, Belgium
2. Belref SA, Belgium

Silica products are well known as strategical refractories in coke oven due to their high resistance to thermal shocks and gradients. However, the crystalline nature of silica bricks induces important volume changes that requires very long-time preheating period. Nowadays, coke producers claim innovative materials allowing to reduce the non-productivity period of their furnaces. To reduce the downtime and the repairing cost, the new fused silica pre-shaped refractory developed by BELREF allows replacing several wall bricks by a large monolithic block. Therefore, both time of masonry and manpower are considerably reduced. The castable composition and the fabrication process of the new precast product have been optimized by BELREF to fully comply the customers specifications which are compatible with service conditions in the coke oven. The chemical composition and the particle size distribution have been optimized to obtain a high flowability allowing the casting of defect free blocks with high green density and strength. The high mechanical resistance facilitates the unmoulding and avoids the appearance of stresses and cracks. After firing, the new product exhibits high density, low porosity, high mechanical strength and a limited crystallization rate. Moreover, the refractoriness under load confirms the thermal stability up to temperatures significantly higher than the service temperature used in the coke oven flues.

Steel Making - Argon Plugs and Slidegate Plates

Room: Joliet
Session Chairs: Manoj Mahapatra, University of Alabama at Birmingham; Scot Graddick, Imerys

11:00 AM

(UNITECR-168-2022) Improved Slag and Metal Resistance of Bottom Blowing Purging Plugs with Fused Magnesia-Alumina Spinel Doped by Chromic Oxide

V. Martynenko*[1]; P. Kushchenko[1]; I. Shulik[1]; L. Zolotukhina[1]
1. Ukrainian Research Institute of Refractories named after A.S. Berezhnoy, Ukraine

One of the important stages of ladle treatment process is steel purging with an inert gas through the bottom purging plugs. The experience of using various types of refractories for the purging plugs production has shown that, the use of magnesia-alumina spinel can significantly improve their performance characteristics. It is known that, a spinel doped by chromic oxide is characterized with higher properties, primarily, such as slag and metal resistance, low wettability with liquid steel. As a result of the carried out work, a fused

magnesia-alumina doped by chromic oxide (MAdCr) spinel with high properties was obtained. Its phase composition was represented mainly by solid solutions of Cr_2O_3 in $MgAl_2O_4$. The study of introduction influence of fused magnesia-alumina and MAdCr spinels on the main properties of vibrocasting alumina-spinel samples, as well as on their slag and molten steel resistance were carried out. It was shown that, the use of MAdCr spinel with optimal grain size composition ensures the making samples with significantly higher cold crushing strength and, especially, slag and metal resistance. The interaction mechanism of samples containing spinel additives with slag and metal was studied. The manufactured plugs with MAdCr spinel were delivered for testing to one of the metallurgical plants.

11:20 AM

(UNITECR-169-2022) Preparation of corundum-mullite castables for purging plug in ladle

G. Liu*[1]

1. Puyang Refractories Group Co., Ltd., China

Corundum-mullite castables were prepared using tabular corundum as the main raw materials, alumina micro powder and pure calcium aluminate cement as the bonding agents. Effects of mullite additions (0, 1c wt.%, 2c wt.% and 3c wt.%) on properties of corundum-mullite castables were investigated. Results showed that, with the increasing of mullite additions, the MOR and HMOR of the specimens fired at 1600 °C declined sharply, linear change rate changed from positive to negative, and the apparent porosity declined, while the retention ratio of the rupture strength dropped first, then decreased. Under the thermal shock service conditions, the cross-sectional cracking probability of corundum-mullite purging plug was reduced effectively, and the service life was improved significantly.

11:40 AM

(UNITECR-170-2022) Development of Sliding Valve Plates Containing Metal Chromium

H. Baba*[1]; N. HAMAMOTO[1]; W. LIN[1]; T. MATSUNAGA[1]

1. Shinagawa refractories CO., LTD., Japan

For slide valve plate, fired Al_2O_3-C materials are commonly applied due to their excellent performance to thermal spalling resistance and their sufficient chemical corrosion resistance for normal steel. In some cases, however, these materials show insufficient corrosion resistance for corrosive grades. In this study, we developed Al_2O_3-C material containing metal chromium (Cr) for the plates since Cr and its compounds are stable at high temperature. As a result of the dipping experiment into molten steel, it was confirmed that the thickness of deteriorated layer at working surface was decreased. This phenomena suggests that Cr and its compounds suppressed Al_2O_3 reduction at high temperature. And also, Cr containing Al_2O_3-C material has superior corrosion resistance to molten steel and slag. The behavior of Cr and its compounds were observed by the microstructure investigation. Metal Cr, which is in Al_2O_3-C material, reacted to form Cr carbide and nitride during firing. And, these reaction products decomposed during dipping test. Thus, it is assumable that these reactions suppressed evolution of surface deterioration layer of Al_2O_3-C material, leading to an improvement of corrosion resistance. The developed material was applied for industrial trials in a steel plant, and it was confirmed that the surface damages of these plates were little thanks to add metal Cr so that durability of these plates were improved.

Iron Making - Taphole Clay Development

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Matt Lambert, Allied Mineral Company; Ashley Hampton, Allied Mineral Products, LLC

9:20 AM - WITHDRAWN

(UNITECR-171-2022) Graphene-like structured tap hole clay for long lasting casting times and lower CO_2 emissions

E. Y. Sako*[1]; D. F. Galesi[1]; H. D. Orsolini[1]; D. Hespanhol[1]; N. Januario[1]; B. M. Silva[1]

1. Saint-Gobain Performance Ceramics and Refractories, R&D, Brazil

A stable blast-furnace operation is strongly associated with the performance of tap hole clay, which is usually damaged by the combined effect of slag corrosion and pig iron erosion. As such scenario has recently become more challenging due to the use of cheaper raw-materials and low-cost operational practices, Saint-Gobain developed a high-performance solution based on an innovative tap hole clay with a graphene-like structure. Owing to an outstanding chemical resistance and, consequently, a stable and long lasting metal flow, such technology allows operations with reduced fuel consumption, helping to reduce the CO_2 emissions in the iron-making area.

9:40 AM

(UNITECR-172-2022) Premature cross-linking in a resole resin and synthetic coal tar pitch binder system as cause of reduced workability of a blast furnace taphole clay

I. Cameron*[1]; S. Ramjee[1]; A. Garbers-Craig[1]

1. University of Pretoria, Materials Science & Metallurgical Engineering, South Africa

This paper investigates the cause of increased workability ageing of a blast furnace taphole clay that contains a phenol-formaldehyde resole resin (PFR) and synthetic coal tar pitch system by examining the binder system in terms of its molecular structure and rheology. This was done by using Fourier-Transform Infrared Spectroscopy (FTIR), Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC) as well as viscosity measurements at different temperatures and time intervals. The analyses confirmed that there is a chemical interaction between the resole resin and synthetic coal tar pitch which causes the resin to premature cross-link and the onset of curing of the resin to take place at lower temperatures. This reduction in onset of curing temperature results in an increase in binder viscosity, which is the primary cause of the reduced workability, increased ageing and increased Marshall extrusion pressure (MEP) of the taphole clay.

10:00 AM

(UNITECR-173-2022) Study on the thermal-pyrolysis kinetics of blast furnace THC with aging

C. Shao*[1]; C. LIU[1]

1. China Steel Corporation, Research and Development Department, Taiwan

The tap hole clay (THC) of the blast furnace would have better tapping performances after aging. To understand the influence of aging on THC, the samples with 7 and 14 days aging were sintered in coke box at 400°C, and measured the weight loss, and TG in N_2 gas. The test data was calculated by Kissinger & Crane method of the thermal-pyrolysis kinetic analysis. The results show that the weight loss decreased with the increase of the aging days. The kinetic analysis shows that the thermal-pyrolysis activation energy Ea was 83.7 KJ/mole for aging 7 days sample (n = 1.1), and 37.3 KJ/mole for 14 days one (n = 1.3). It means that there was a significant reduce in the Ea of the thermal-pyrolysis reaction of coal tar in THC with aging, and the reaction was basically a first-order reaction. In order

to achieve the purpose of using the product as soon as possible after manufacturing, a~10a wt% wetting agent was added to the THC. As a result, the weight loss of samples with wetting agent was lower than that of the ones without wetting agent. The Ea of the sample with aging 7 days was 40.9~50.3 KJ/mole, (n=1.2~1.3), which was similar to that of the ones without wetting agent after 14 days aging. It means that adding a specific amount wetting agent in THC could reduce aging period from 14 to 7 days.

10:20 AM

(UNITECR-174-2022) The Study and Application of MgO-C Based Tap Hole Clay for Submerged Arc Furnace

H. Zhu*[1]

1. Puyang Refractories Group Co., Ltd, China

As a key functional refractory, tap hole clay can be used to seal tap holes of Blast Furnace for pig iron and Submerged Arc Furnace for Fe-alloy after the ending of casting. Due to the different production processes and compositions between pig iron and ferroalloy, the tap hole clay should have different performance requirements in Blast Furnace and Submerged Arc Furnace. Compared with Al_2O_3-SiC-C based tap hole clay, MgO-C based tap hole clay shows better performance in Submerged Arc Furnace. Furthermore, the improvement mechanisms of MgO-C based tap hole clay in Submerged Arc Furnace have been discussed.

Steel Making - Future Needs

Room: Waldorf

Session Chairs: Rakesh Dhaka, U.S. Steel; Ashley Hampton, Allied Mineral Products, LLC; Angela Rodrigues-Schroer, Wahl Refractories

11:00 AM

(UNITECR-175-2022) Evaluation of the possible changes of refractory linings for green steel processes

B. Touzo[1]; B. Hiot*[2]; N. Eliazord[3]

1. Imerys, Science and Technology, Belgium
2. Calderys, France
3. Calderys, France

the recent European green deal agreement has given a new impulse to the evolution of European industries towards a carbon neutral footprint. The steel industry has been studying alternatives to the use of coal as the energy source and as reducing agent for quite a long time, as well as alternative pro-cesses to blast furnaces. Among the possible solutions, hydrogen seems a very promising one. But this will modify chemical stresses on the refractory linings which need to be evaluated and most probably adjusted. In this paper, we review the information available about the changes in operating parameters of the processes using hydrogen and suggest possible changes in composition and lining design for the refractories

11:20 AM - WITHDRAWN

(UNITECR-176-2022) Zero Carbon Tempered Bricks for Safety Lining: Complete Energy Saving Solutions for Steel Ladle

J. Sardelli*[1]; C. Pagliosa[1]; M. S. Borges[2]

1. RHI Magnesita, R&D, Brazil
2. RHI Magnesita, TE&S, Brazil

Steel ladle is a key equipment in the secondary refining of steels to attend the increase demand for low and ultra-low carbon steels. Refractory linings need a correct selection to achieve this goal and minimize the impurities that can impact on the final steel quality. Usually, the standard side wall lining supplied to the integrated steel shop is Alumina-Magnesia Carbon (AMC) bricks with carbon content in the range from 6-10%. High thermal conductivity results in thermal energy losses from the molten metal and from the shell. Many studies have been carried out to reduce and eliminate the carbon content in the ladle side wall to minimize carbon pick up and energy saving. Another contribution is also the designing of the safety lining bricks to decrease the shell temperature. Currently, the most used materials are fired 70-85% alumina bricks that also demand high energy and CO_2 emission during their production process. Same zero carbon binding technology applied to the working line was transferred to novel tempered bricks for safety linings. This work aims to present performance and contribution of energy savings of these new designed bricks compared to the fired ones for ladle safety linings.

11:40 AM

(UNITECR-177-2022) The Development and Status of advanced Refractory Technologies for Converter

Y. Zhang*[1]

1. Sinosteel Luoyang Institute of Refractories Research Co., Ltd., China

Main types and steelmaking processing of converters have been introduced in this report, the damaged mechanism of refractories used in converters are analysed in detail. The main types of refractories used in various parts of Basic Oxygen Furnace (BOF) are summarized. Besides, the development and application of refractories for BOF, such as MgO-C bricks, eco-friendly unshaped refractories and high-temperature gunning technology, purging plug (top-bottom combined blowing technology) and slag-stopping sliding nozzle plate technology, are emphasized. At last, the development direction of refractories for BOF in China is pointed out.

Refractories for Glass

Room: Williford B

Session Chair: Angela Rodrigues-Schroer, Wahl Refractories

9:20 AM

(UNITECR-178-2022) Stress elastic analysis of AZS fused cast blocks for glass furnaces

T. M. De Oliveira*[1]; M. F. Dos Santos[1]; R. A. Angelico[2]; V. C. Pandolfelli[1]

1. Federal University of Sao Carlos, Department of Materials Engineering, Brazil
2. University of São Paulo, Department of Aeronautical Engineering, Brazil

There is a great motivation for advances on the understanding of better conditions for glass melting furnace operation, the glass quality, process energy efficiency, lining lifespan, among other factors. AZS (Alumina-Zirconia-Silica) fused cast refractories are widely used in the furnace lining due to their corrosion resistance and mechanical properties. Nevertheless, operational conditions can drastically change the AZS refractory performance, limiting the furnace lifespan. Computer simulations have shown to be a powerful tool for analysis where in situ tests of the glass melting process are difficult and involves a certain risk for testing and validations. Given this, the present study aims to investigate AZS blocks with an electrode hole/holder displaying a shorter lifespan, due to cracks and intense erosion. A thermomechanical analysis was carried out via the finite element method to determine the maximum principal stress in the block during heating. The results indicated routes to increase the lifespan of glass furnaces such as, alternative electrode hole designs, new heating curves and using proper insulation.

9:40 AM

(UNITECR-179-2022) Ultra-Low Exudation of Fused Cast Alumina-Zirconia-Silicate Refractory for Glass Melting Furnaces

F. Wei[2]; W. Zhu[2]; Y. Wu*[1]

1. ICEON Glasstech Limited Co., USA
2. Anhui Sino-Refractory Technology Co., Ltd., China

Fused cast alumina-zirconia-silicate refractory are very common and important refractory due to good corrosion resistance and long campaign life for glass melting furnaces. As glass industry demanding more specialty glasses, high furnace throughput, and higher melting temperatures, the strict requirement of glass contact refractory, in particularly, fused cast AZS refractory becomes more important. For oxy-fuel glass furnaces, higher combustion temperatures require fused cast AZS as crown refractory to avoid glass quality resulted from glassy phase exudation in AZS materials. We have developed an ultra-low exudation of AZS suitable for demanding specifications of glass contact materials and crown for oxy-fuel specialty glasses. The ultra-low exudation of AZS materials improve the glass quality and extend furnace campaign life.

10:00 AM

(UNITECR-180-2022) New Yttria-Stabilized Fused Cast AZS for Glass Melting Furnaces

Y. Wu*[1]; F. Wei[2]

1. ICEON Glasstech Limited Co., USA
2. Anhui Sino-Refractory Technology Co., LtD, China

Standard sidewall and bottom refractory has been fused AZS up to 41% for glass furnaces. As higher glass melting temperatures are required for various specialty glasses under oxy-fuel combustion, high zirconia fused cast is a choice offering better high-temperature resistance and corrosion resistance than common AZS refractory with 33, 36, and 41% zirconia. However, the applications of high fused zirconia are limited by its extreme high cost and problems associated with high thermal expansion and shrinkage of high zirconia grains. We developed a new fused cast AZS having zirconia higher than 41% balancing the performance of fused zirconia offering without the expensive cost. With the new AZS fused cast, we explore zirconia content above 44% with yttria or other rare-earth minerals as a stabilizer, cooling slowly the fused AZS to obtain regular AZS refractory brick without the microcracks induced by higher zirconia content during the production process.

Use of Artificial Intelligence, Machine Learning, and Big Data in Refractory Technology

Room: Williford C
Session Chair: Manoj Mahapatra, University of Alabama at Birmingham

9:20 AM

(UNITECR-181-2022) Operational Refractory Management of Hot Metal Process Installations Using a FEM Based Digital Twin

P. van Beurden[1]; B. Luchini[1]; S. Sinnema*[1]

1. Tata Steel Netherlands, Research & Development, Netherlands

Over the last years the developments in digital technologies have grown exponentially unlocking opportunities of almost unlimited data sources and process monitoring which is of vital importance to the steel industry. To leverage a transition from traditional factory operation to smart factories, expansion of our process modelling and simulation capabilities is key. One such a digital technology is Digital Twin. A Digital Twin is "a realistic digital representation of assets, processes or systems in the built or natural environment". In various industrial sectors, Digital Twins are being used to optimize the operation and maintenance of physical assets, systems and manufacturing processes. For our steel industry this technology enables (optimization of) operational, maintenance and energy efficiency management over the entire production chain instead of focusing on individual processes and installations. Our existing FEM models for simulating thermomechanical behavior of refractories in production installations can be readily integrated into a Digital Twin. This allows for fast development of a Digital Twin based on already developed and validated physical models. Here we present the most recent results on the development of a Digital Twin for the operational refractory management of hot metal process installations using FEM models of the torpedo ladle and hot metal ladle.

9:40 AM

(UNITECR-182-2022) Improving taphole clay performance by machine learning tools

M. F. Dos Santos*[1]; M. G. Campos[2]; E. Y. Sako[2]; D. Hespanhol[2]; B. G. Rangel[2]; V. C. Pandolfelli[1]

1. Federal University of Sao Carlos, Department of Materials Engineering, Brazil
2. Saint-Gobain Performance Ceramics & Refractories, Brazil

The taphole clay is a key product for the blast furnace cast house operation and performance. It is a complex and technological refractory product, designed with a high-quality mix of raw materials specifically tailored for each blast furnace, to guarantee the stability of the taphole length and mushroom, protect the ceramic hearth, assure controlled drainage of liquids from the furnace, and reduce the greenhouse gas emission. Also, the taphole clay properties, such as high corrosion resistance, ease injectability, effective sealing of the taphole, good drillability and low crack formation, have been major aspects for the currently high performance of the cast house. In this study, machine learning tools were applied to optimize the amount of taphole clay injected depending on the casting features. The taphole length variation in every casting was associated with the taphole clay weight as well as with other relevant operational parameters. As a result, a novel optimized injection procedure is presented for a smart decision of the amount of clay to be injected, balancing the specific consumption and the best operation of the cast house. This output of predictive models was developed considering 46 operational parameters and evaluated on the average operational condition of the blast furnace in which the taphole clay weight resulted in the maximum taphole length.

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*** Denotes Presenter**

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