PRELIMINARY PROGRAM

---Monday, October 4, 2010---

08:30
Room: 3rd Floor - Plaza B
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Synthesis and Sintering of Refractories 1 (MONAM1)

Paper Start Time: 08:30
Paper No.: 5698
Paper Title: **Introduction on Michel Rigaud**
George Oprea; University of British Columbia;
Oral introduction of prestigious contributor Michel Rigaud. Advances in refractories symposium held in his honor.

Paper Start Time: 08:55
Paper No.: 5577
Paper Title: **An International Education for Refractories Engineers: The Fire's Experience**
Michel Rigaud; FIRE, University of Montreal;
The Federation for International Refractories Research and Education (FIRE) is by now five years old. This is an outsourcing network to perform pre-competitive research programs in order to train refractories engineers and to induce the technical innovations needed to support the prosperity of the refractory industry. At present, FIRE is a collaborative entity with eight academic research groups from six different nations supported by eleven multinational industrial partners, sharing the same conviction that cooperation and competition can go together, when the priorities are well defined. Forecasting the major trends which will influence the refractory industry in the next 15 years, and taking on account the new challenges that the refractory educators will have to face, once more the importance of outsourcing to have access to technology-innovation will be amplified. Considering such perspectives, the future of FIRE is envisaged with enthusiasm, to make refractory engineering as seducing as any other branch of engineering.

Paper Start Time: 09:20
Paper No.: 5612
Paper Title: **KEYNOTE: Refractory Microstructure Engineering: Fundamentals, Production and Imagination**
Victor C. Pandolfelli; UFSCar - DEMa;
The refractory industry has been successfully designing refractory microstructures for many decades. Therefore, the producers and end-users do not need to be motivated on the subject, although we all need its science as the more complex the microstructure is, the more the fundamentals and understanding are required. Most of the time we are amazed by the advances in computing and genetics, but we forget to realize and advertize the beauties and achievements of the refractory community. At the moment, there is an urgent need to present the progress made by the refractory area, not only as fragments, but at least as a broader picture. This lack is subtly spreading the wrong idea to young students that the refractory area is mostly empirical and, therefore, is not seducing the next generation. In this talk, a tiny portion of this fantastic work carried out by skillful and gifted people will be presented on the design of complex aggregates and sintered microstructures in the following systems: Al2O3-ZrO2, ZrO2(c)-ZrO2(t), Al2O3-ZrO2-CaO, Al2O3-ZrO2-TiO2 and Al2O3-ZrO2-C-Ti-Si in order to improve thermo-mechanical properties. Additionally, an invitation to observe nature not only as a supplier, but mainly as a partner and teacher will be presented, trying to trigger our imagination on novel and functional microstructures.

10:30
Room: 3rd Floor - Plaza B
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Synthesis and Sintering of Refractories 1 (MONAM2)

Paper Start Time: 10:30
Paper No.: 5111
Paper Title: **Mastering the Microstructure of Cement-bonded Al2O3-MgO Refractory Castables**
Mariana Braulio; Federal University of São Carlos; Victor Pandolfelli, Federal University of São Carlos;
Biological materials can display hierarchical structures, with increasing toughness, despite the brittle nature of most of their constituents. The nacre structure comprises layered CaCO3 platelets bonded by a thin layer of protein and displays a work of fracture of about three orders of magnitude higher than the CaCO3, due to the proper assembling of both materials. Considering this aspect, different CA6 morphology and its distribution in the Al2O3-MgO castables microstructure was designed by the suitable selection of the liquid phase source and content. As a result, outstanding creep resistance was attained, pointing out the likelihood to generate bio-inspired refractory castables.

Paper Start Time: 10:55
Paper No.: 5153
Paper Title: **The Politics of Training in Australia**
Michael C. Walton; RefMet; Michael Broadbent, IRE-Australia;
When the local branch of the IRE was finally formed in 2000, there was very littel training that prospective refractories tradesmen could undergo to achieve formal recognition of their skills. Of the many government Training organisations, only one offered a single refractories related 'competency' course within its vast umbrella. Since then the local branch has succeeded in establishing further technical 'competency' standards at the National level, based on the model of the IRE in the UK. In the decade since this excercise began, the IRE's task has not been made any easier by the actions various governments, both at State and Federal level, who have kept continuosly 'moving the goal posts', by policy changes, caused by electoral changes, and by reorganisation of the training bodies for greater efficiency. Added to this, there has been some major players in the industry not wishing to cooperate with competitors due to perceived commercial sensitivity, even on this level. We now believe these issues have been resolved, but we still face a hard road ahead, due to shortage of funding after the GFC.

14:00
Room: 3rd Floor - Plaza B
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Synthesis and Sintering of Refractories 2 (MONPM1)

Paper Start Time: 14:00
Paper No.: 5511
Paper Title: **The Effects of Different Types of Bonds on Bauxite Refractories**
AliReza Souri, University of Malayer; Behzad MirHadi, Iran University of Science and Technology; Abouzar Nabipour , Iran University of Science and Technology;
The different types of clay binders are used to produce bauxite refractories for many years, though they introduce a destructive glassy phase which reduces the hot strength. In this study at first the effects of emount and type of clay binders such as Iranian clay and RR40 clay has studied in order to reduce the amount of destructive glassy phase to increase hot strength of these kinds of refractories. Based on the results of this study, it has noticed that refractories has binded by different amounts of Iranian clay binder have showed unacceptable high temperature characteristics, but by using different amounts of RR40 clay binder such properties are improved relatively. Refractories which made of Guyanian bauxite showed more better properties than those were made by Chinese bauxite in the same amounts of RR40 clay binder. As it was mentioned earlier such glassy phase in hight amounts is present in these refractories even by using purer clay binders such as RR40 clay binder, so in order to lower its amount, it□d better to replace some clay binder by removeable binders such as organic ones. At the end it is concluded that those refractories which made of both organic and RR40 clay binders, if sintering process would done perfectly in suitable time and temperatures, have shown better properties. In this case hot strength has improved by the decrease in glass phase amount.

Paper Start Time: 14:25
Paper No.: 5677
Paper Title: **Post-Mortem Analysis Procedures for Refractories Used in Non-ferrous Furnaces**
George Oprea; University of British Columbia; D. Verhelst, Teck Metals Ltd. ; J. Lam, Clayburn Refractories ; T. Troczyszki, University of British Columbia; Rahul Lodha , University of British Columbia; J. Rigby, ANH Refractories ;
This paper presents the testing procedures used at the Ceramics and Refractories Research and Testing Laboratory at the University of British Columbia (UBCeram) for post-mortem analyses on refractories used in non-ferrous smelting, converting and refining furnaces. Selected examples of experimental work are detailed on refractories from aluminum electrolytic cells, flash furnaces for Ni-Cu and Zn-Pb smelting, Peirce Smith (PS) converters for Ni-Cu matte and bottom blown oxygen converters (BBOC) for Zn-Pb refining and Pb-Ag cupellation. The procedures refer to the collection of samples, the preparation of test specimens, and the details of all tests performed, together with the specific outcomes to be expected from each particular test, and the possible correlations between them. On selected studies, the micro-structural changes which occur in the refractories during use are correlated with the physical and mechanical properties of the used and un-used bricks in order to identify the mechanisms of wear. As penetration of, and corrosion by, the liquid and gaseous environments play decisive roles on the failure or wear, particular laboratory testing methods and experimental set-ups used to simulate the industrial conditions are also presented in a few examples in order to emphasize their role on the total wear during use.

Paper Start Time: 14:50
Paper No.: 5179
Paper Title: **Influence of Mechanical Grinding on Synthesis of Sialon Powder**
Dongrui Zhang, Zhengzhou University; Guotian Ye, Zhengzhou University; Junli Shang, Zhengzhou University; Yaosheng Chen, Zhengzhou University;

Mechanical activation was used to assist the synthesis of ß-Sialon. Starting mixtures were mechanically activated in a vibration ball-mill in air atmosphere for varying periods, and then heat treated in nitrogen atmosphere in microwave furnace at different temperatures. The starting mixtures before and after milling were characterized and analyzed in terms of crystal morphology, specific surface area and micro-structure. In comparison with powder mixtures without milling, the reaction of forming ß-Sialon was completed at 1 000 oC for samples milled 20 hours, whereas the un-milled samples at 1300 oC.

15:35
Room: 3rd Floor - Plaza B
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Synthesis and Sintering of Refractories 2 (MONPM2)

Paper Start Time: 15:35
Paper No.: 5181
Paper Title: **Influence of Firing Temperature on the Microstructure and Properties of Andalusite-based Bricks**
Suping Li; High Temperature Ceramics Institute, Zhengzhou University; Shaoji Sun, Zhengzhou University; Suping li, Zhengzhou University; Quli Jia, High Temperature Ceramics Institute, Zhengzhou University, Zhengzhou; Guotian Ye, High Temperature Ceramics Institute, Zhengzhou University, Zhengzhou; Gengchen Sun, Zhengzhou University;
The microstructure and properties of andalusite-based bricks were investigated with respect to firing temperature. The results show that the mullitisation degree increases and the amount of residual andalusite decreases with increasing firing temperature (1400~1500). However, there is still small quantity of residual andalusite after firing at 150. The linear expansion, the modulus of rupture, refractoriness under load and creep resistance increases with the firing temperature increase; while apparent porosity, bulk density, the residual strength ratio decreases. The microstructure of the bricks was examined to explain the changes of properties with the firing temperature.

Paper Start Time: 16:00
Paper No.: 5531
Paper Title: **The Influence of Iron Oxide on Microstructure and Thermo-mechanical**
Mohammad Bavand-Vandchali; Pars Refractories Company; Majid Naderpour, Pars Refractories Co.; Hassan Laeh, Pars Refractories Co.; Farhad Golestani-Fard, IUST;
Over 20-year period of magnesia-spinel refractories use, several distinct evolutionary steps in combination formulation can be identified. These distinct steps are generally referred to as "generation" within the refractory industry. First generation magnesia-spinel brick are based on the use of magnesia and in-situ spinel. The in-situ spinel is formed by adding small amount of relatively coarse alumina to the brick to form spinel during firing. Second generation magnesia-spinel brick are characterized by the use of preformed spinel in the brick. Third generation magnesia-spinel brick are characterized by the use of preformed spinel in combination with a very fine alumina addition. The fine alumina reacts with the magnesia fines in the matrix during firing to form in-situ spinel, commonly referred to as a spinel matrix. The addition of fine alumina to the refractory composition lowers porosity and permeability on firing. Recently, addition of pre-synthesized materials such as calcium zirconate, Hercynite, Galaxite or pure oxides, ZrO2, Fe2O3, SiO2, Al2O3, was considered to modify chemical and mineralogical composition improving final properties of magnesia-spinel refractories. In the present study, the influence of iron oxide addition on microstructure and high temperature properties of second generation magnesia-spinel refractories was investigated. The different formulations were designed with addition of various percent of iron oxide and some bricks were formed by hydraulic press under 1000kgf/cm2 pressure. The bricks were fired in tunnel kiln at 1740°C. Physical properties such as B.D, AP, CCS and MOR were measured according to JIS standard. Modules of rupture in high temperature (HMOR) were measured at different temperature (1000 - 1400°C). XRD and SEM/EDX were used for microstructure and phase evolution of samples. In addition to, the corrosion resistance of bricks was evaluated by static method (crucible test) in working temperature of cement rotary kilns (1450°C). The results showed a improving in physical and high temperature properties of magnesia-spinel refractories by addition of iron oxide. The microstructure analysis was showed development of direct bonding between aggregate by formation of magnesio-ferrite phases in matrix which provides more strength at high temperature and less deterioration in refractories containing iron oxide. This effect was also supported resistance of refractories against thermo-mechanical stresses by creation of flexible microstructure in the brick. As well as, other properties such as corrosion resistance were improved. Finally, the influence of iron oxide addition on phase and microstructure was evaluated with emphasis on new phases formation during firing.

14:00
Room: 3rd Floor - Plaza C
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Refractories for Non-ferrous, Cement, Gasification and Other Industries (MONPM1)

Paper Start Time: 14:00
Paper No.: 4772

Paper Title: **Acid Resisting Bricks in Hydrometallurgical Processes**
Fathi Habashi; Laval University;
Acid resisting brick is necessary for protecting reactors in hydrometallurgical processes. Leaching reactions utilizing such reactors are used for treating laterites, sulfide concentrates, complex oxides, and other mineral raw material. Glass-lined vessels and fiber glass reactors are also used. A review of reactors and processes will be presented.

Paper Start Time: 14:25
Paper No.: 5412
Paper Title: **Thermo-Mechanical Properties and Microstructure Investigation on Fused-cast Zirconia Refractory**
Cedric Patapy; GEMH; René Guinebretière, SPCTS (Limoges-France); Nathalie Gey, LETAM (Metz-France); Michel Humbert, LETAM (Metz-France); Marc Huger, GEMH (Limoges-France); Thierry Chotard, GEMH (Limoges-France); Emmanuel Joussein, GRESE (Limoges-France);
Elaborated in a very similar way to metals, high zirconia fused-cast refractories (HZ) exhibit a microstructure containing typical monoclinic zirconia dendrites embedded into a silica-alumina glassy phase. The present paper deals with the understanding of damage phenomena occurring at a low scale during the cooling process after cast-fusion. Mechanical characterizations at high temperature (elastic properties, stress-strain law in tension) are carried out in correlation with thermal expansion analysis and acoustic emission (AE) tests to identify the chronology of the microdamage. Microstructure observations using Scanning Electron Microscopy (SEM) and Electron Back Scattering diffraction (EBSD) devices complete thermal experiments and allow to identify main characteristics of microdamage mechanisms. This work is carried out in the framework of a French national research program called NOREV, which aims to elaborate numerical tools to optimize the casting process of such materials.

Paper Start Time: 14:50
Paper No.: 5467
Paper Title: **Corrosion of SiC Based Refractories by Molten Salts in Waste Incineration Plants**
Jacques Poirier; CEMHTI-CNRS; Pascal Prigent, CEMHTI-CNRS; Marie Laure Bouchetou, CEMHTI; Jacques Poirier, CEMHTI-CNRS;
SiC refractories are used successfully in incineration. They are submitted to severe thermo-chemical stresses that limit their performances. The corrosion mechanisms of SiC refractories will be presented and the main research and development works to be put into action in the future will be discussed. The combustion chambers of incinerator plants are composed with refractory bricks covering metallic tubes in which, high pressure water allows the production of steam and then electricity by means of turbines. During the combustion of waste, at a temperature between 1100°C and 1200°C, the formation of aggressive gaseous species and fly ashes occur. These compounds, in most cases hydrogen chloride and molten salts can react with the refractory lining. The first step of the degradation of the SiC refractory is due to an increase in alkali compounds. Indeed, the inorganic chlorides such as gaseous KCl and gaseous NaCl migrate into the refractory bricks by the open porosity. As the atmosphere contains gaseous SO2 and O2, these species can be sulfated and oxidized. The high potassium and sodium amount into the bricks decreases the viscosity of the liquid phase which becomes aggressive and leads to oxidation of SiC grains. The oxidation around the SiC grains causes the formation of cristobalite. The second step of the degradation is linked to an increase of calcium at the interface refractory bricks/fly ash deposit. Indeed, calcium sulfate containing in fly ashes is condensed in the refractory lining and reacts in the brick surface with silica including in the boundary phase to form CaSiO3 (wollastonite). For a better understanding of aggressive species reacting with SiC refractories , the corrosion of several SiC refractory samples by molten salts was performed in lab to produce the degradations of refractory ceramics in waste incineration plants. The effects of sodium, potassium and calcium sulphates were tested in conditions close to industrial conditions. Thermodynamic equilibrium calculations relating municipal solid waste during combustion were conducted to study the condensation of deposits on refractories during the combustion. The results show a high reactivity of calcium sulfate on SiC crystals by formation of wollastonite (CaSiO3). The sodium and potassium sulphates lead to low melting point phases which react with SiC by formation of SiO2. At 870°C, calcium reacts with silica to form wollastonite. The corrosion obtained in lab agreed relatively well with the post mortem SiC samples from incinerator plants. Volume expansion created by phase transformation (sanidine, wollastonite) increases the formation of micro cracks in refractory lining.

15:35
Room: 3rd Floor - Plaza C
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Refractories for Non-ferrous, Cement, Gasification and Other Industries (MONPM2)

Paper Start Time: 15:35
Paper No.: 5236
Paper Title: **Studies of the Gasification System by Thermodynamic Calculations**
KyeiSing Kwong; National Energy Technology Laboratory; James P. Bennett, NETL, US DOE;
Gasification is a process that converts a carbon feedstock into synthesis gas (CO+H2). Cr2O3-based refractory linings are used to protect the steel vessel that confines the high temperature, high pressure gasification environment. The chemistry of slags originating

from impurities in the carbon feedstock significantly impact the service life of Cr2O3 refractory liner materials. This paper will discuss a series of thermodynamic calculations to model the gasifier atmosphere, coal slag chemistry, and slag-refractory interactions in order to manage slag chemistry and minimize refractory wear/degradation.

Paper Start Time: 16:00
Paper No.: 5262
Paper Title: **Conditions for Cr+6 Formation in Cr2O3 Gasification Refractory Liners**
James Bennett; National Energy Technology Laboratory - USDOE; Kyei Sing Kwong, National Energy Technology Laboratory - USDOE; Hugh Thomas, National Energy Technology Laboratory - USDOE; Rick Krabbe, National Energy Technology - USDOE;
Gasification produces CO and H2 from carbon, which is used in the production of power and chemicals, and is a possible source of H2 in a hydrogen based economy. Slag is a by-product of gasification, originating from mineral impurities in coal, petcoke, and/or biomass used as carbon feedstock. In the gasification environment, slags become liquid and interact with the Cr2O3 refractory liner; causing refractory failure by wear and/or corrosion. Slag can also interact with the liner to form Cr+6, a carcinogenic and regulated hazardous material. This paper will discuss gasification slags and environments leading to Cr+6 formation.

Paper Start Time: 16:25
Paper No.: 5228
Paper Title: **MgO-MgAl2O4-ZrO2-La2O3 Refractory for Cement Kiln**
Lin Yuan;; Ruitai Technology Co., Ltd, China Building Materials Academy; Da Fan Zeng, Ruitai Technology Co., Ltd, China Building Materials Academy; Jie Zeng Wang, Ruitai Technology Co., Ltd, China Building Materials Academy; Song Lin Chen, Ruitai Technology Co., Ltd, China Building Materials Academy; Xue Feng Chen, Ruitai Technology Co., Ltd, China Building Materials Academy;
Researching and developing chrome-free refractory becomes a research hotspot at present because hexavalent chromium ions (Cr6+) may lead to environmental hazard. Holding tightly the mechanism of spinel refractory react with cement clinker, additives are wildly researched in this paper. It indicates that lanthanum oxide (La2O3) is a suitable additive added to MgO-MgAl2O4-ZrO2 brick which not only could stabilize phase transition of C2S in cement, but also do not impair the high-temperature-properties of spinel. Therefore, an environmentally friendly material MgO-MgAl2O4-ZrO2-La2O3 composite refractory is invented. The new type material is an excellent refractory for cement kiln which has high thermal shock resistance, good coating adherence, good corrosion resistance and higher mechanical strength. Furthermore, this refractory brick is longer service life than magnesite-chrome brick when they are used for sintering zone in cement kiln.

---Tuesday October 5, 2010---

08:30
Room: 3rd Floor - Plaza B
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Synthesis and Sintering of Refractories 3 (TUESAM1)

Paper Start Time: 08:30
Paper No.: 5183
Paper Title: **The Relationship Between The Mullitisation Process of Andalusite and the Particle Size of Starting Materials and Firing Temperature**
Suping Li; High Temperature Ceramics Institute, Zhengzhou University;
The particle size and firing conditions affect the mullitisation process and the properties of the materials. In this paper, the influences of particle size and calcination temperature on mullitisation process of andalusite were investigated. The results show that the starting transformation temperature and full transformation temperature of mullitisation process decrease with the smaller particle size. Andalusite disappeared in the raw material with particle size under 200 mesh, and a small amount of andalusite existed in the raw material of 3-1mm and 1-0mm aggregate after firing at 1500?.

Paper Start Time: 08:55
Paper No.: 5219
Paper Title: **Effect of Temperature and Holding Time on Porous Structure of Materials Prepared by Fly Ash**
Quan Zhu; Wuhan University of Science and Technology ; Yuanbing Li, Wuhan University of Science and Technology; Lei Zhao, Wuhan University of Science and Technology; Yawei Li, Wuhan University of Science and Technology; Shujing Li, Wuhan University of Science and Technology;
Fly ash from fused brown alumina, containing Al2O3 plus SiO2 for 72.77%, is precious secondary resources. With the purpose of studying the probability of preparing porous material using the fly ash, the fixed quartz containing samples were sintered at various temperatures (1100oC-1200oC) with different holding time (1-2h) respectively. The results indicated that the increasing expansion of the samples with the elevated temperature and prolonged holding time leads to the growth of pore size. The possible mechanism is

also discussed.(79 words)

Paper Start Time: 09:20
Paper No.: 5251
Paper Title: **Effects of Different Carbon Sources on Phase Composition and Microstructure of Al2O3-Al-C Material Matrix**
Haibing Fan; Wuhan University of Science and Technology; Lei Zhao, Wuhan University of Science and Technology; Yuanbing Li, Wuhan University of Science and Technology; Shujing Li, Wuhan University of Science and Technology; Yawei Li, Wuhan University of Science and Technology; Shaobai Sang, Wuhan University of Science and Technology;
The effects of different carbon sources, including flake graphite, carbon black, pitch and resin powder, on phase composition and microstructure of Al2O3-Al-C material matrix were investigated. The specimens were fabricated and heat-treated at elevated temperatures(1073K-1673K). The results indicated that, owing to the diversity of physical-chemical properties, the reaction mechanisms and products of different carbon sources with the additive aluminum in samples as well as microstructure of samples were repugnant. The reaction products were detected by X-ray diffraction, the morphologies and possible reaction mechanisms were observed and analyzed by SEM, EDS and TG-DSC techniques.

Paper Start Time: 09:45
Paper No.: 5273
Paper Title: **Nano Silica Thermal Insulating Material With TiO2 as Infrared Opacifier**
Yongxia Li; Wuhan University of Science and Technology; Lei Zhao, Wuhan University of Science and Technology; Shujing Li , Wuhan University of Science and Technology;
TiO2 as an infrared opacifier was compounded with nano silica porous thermal insulating material which bad thermal insulating properties at mid-high temperature for too high IR transmittance. The material is characterized by FT-IR, and its conductivity and infrared extinction ability were also measured with different mass ratio and particle size. The results showed that the introduction of TiO2 powder could greatly improve effective extinction when the mass ratio 20% was doped. Moreover, that was also verified by temperature measurement.

10:30
Room: 3rd Floor - Plaza B
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Synthesis and Sintering of Refractories 3 (TUESAM2)

Paper Start Time: 10:30
Paper No.: 5301
Paper Title: **Behaviour of Silicon Antioxidants Added to Bauxite-SiC-Carbon Monolithic Refractories**
A. Bataille, LSPES,University of Science and Technology; E. Mohammadi Zahrani, University of British Columbia; E. Karamian, Islamic Azad University; A. Monshi, Isfahan University of Technology (IUT);
This study describes the effect of silicon antioxidants on cold crushing strength (CCS) and bulk density (BD) of Bauxite-SiC-C Monolithic Refractories. Specimens were composed of a blend of Chinese bauxite, SiC containing material, fine coke, resole and different quantities of silicon and ferrosilicon. BD and CCS are measured after a heat treatment at 200 ºC and reheating at 1100 ºC and 1400 ºC for 2 hrs. At 200 ºC, the additives contributed to the formation of the resit structure, and at 1400 ºC ß-SiC whiskers of nano-sized diameter were formed, and consequently the CCS increased.

Paper Start Time: 10:55
Paper No.: 5626
Paper Title: **A Refractory Raw Material Andalusite: Properties and Application**
Xiao Yong Xiong; Damrec; Dirk Van Den Heever Dirk, Damrec;
During 1960's French based company DAMREC developed an andalusite mine at Glomel in North-West of France. From 1980's to 1990's, DAMREC took control of another three andalusite mines in the Republic of South Africa, while finally in 2007 DAMREC acquired a share in the Chinese andalusite mine YILONG in Xingjian Province. Globally DAMREC owns and operates 5 mines and 6 processing plants with total an employment of 800 people. Annually Damrec produces approximately 300.000 tons of andalusite, more than 85% of the world yearly production. Andalusite belonging to the sillimanite group together with kyanite and sillimanite is a pure alumino silicate, and occurs mainly as needles crystals in host rocks composed mainly of quartz and micas. While the processing of andalusite consists to separate the andalusite from the quartz and the micas, the nature and size of the andalusite crystals limits the maximum size of the andalusite grain, and makes it very difficult to produce coarse sizes of pure andalusite. Over the years DAMREC has developed and refined andalusite processing technique, and can successfully produce up to 8mm size fraction. The chemical composition of andalusite is a bi-oxides of aluminium and silicon: Al2O3.SiO2 with a density 3.15 g/cm3. Because andalusite is a reactive mineral that transforms into mullite during temperature increase (above 1250°C), its properties changes with temperature. Consequently, depending on the application, andalusite can be used directly as a refractory raw material without any thermal treatment

(crude) or mullitised (fired refractories). After mullitisation of the andalusite, the excess of SiO2 content is transformed to glass and captured inside the mullite phase, while a small part of this glass is on the surface of the mullite crystal. At high temperature, the glass captured in the mullite phase softened or fused and absorb the volume change of the mullite at high temperature. In this way, the mullite transformed from andalusite has the more thermal stability than the other type mullite. This softened glass can penetrate into possible crack fissure of mullite as a welding agent to repair the damaged mullite during the use. Andalusite has a higher refractoriness under load and a higher resistance to creep than other silico-alumina materials such as bauxite, chamotte etc...The principle of andalusite applied to refractory can be summarised as following: 1)as mullite: Mullite is reputed as the best of the materials with a high thermal stability and a high creep resistance. Mullite based products are used specially in the equipment subjected at high temperature and during a long time and in a frequent thermal shock environment. 2)advantage of the low expansion:After fired, the andalusite based products remain at a low expansion (PLC at 1500°C: +1%). This expansion is useful to control the fired process of product. This low expansion can avoid the split between the bricks, and the cracking of castable. 3)as bonding agent: The thermal transformation of andalusite powders to mullite can form the bond between mullite. The excess of SiO2 on the mulitte surface can react with the alumina powders to form a second mullite and also a bonding system. This bonding system formed in the middle temperature range (1200°-1400°C) has the very high refractoriness as mullite. We can imagine diffrerent application of andalusite with 3 main characteristics: -a product based fully on the andalusite possesses the same characteristics of a mullite product; -a product with andalusite powder as matrix and the bauxite or corundum as grain has high thermal stability and high creep resistance as mullite products, and the high abrasive resistance and high refractoriness as bauxite and corundum products. Nowadays, the andalusite based products are largely applied to the iron and steel making, ceramic industry, cement industry, aluminium making, glass industry, etc.

Paper Start Time: 11:20
Paper No.: 5244
Paper Title: **Stability of Partially Stabilized Zirconia with Alumina, Silicon and Ferroferric Oxide at High Temperature**
Ming Luo; Wuhan University of Science and Technology; Shaobai Sang, Wuhan University of Science and Technology; Yawei Li, Wuhan University of Science and Technology; Juliang Xu, Wuhan University of Science and Technology; Shan Ge, ;
Partially stabilized ZrO2 (PSZ) is usually adopted as raw material to prepare ZrO2-C slagline of the submerged nozzle due to its phase transformation toughening effect and excellent slag corrosion resistance. However, the stabilizing agent is likely to diffuse or dissolved into steel slag during working service, which induces the disintegration of PSZ particles and caused the degradation of ZrO2-C nozzle. In this work four kinds of partially stabilized ZrO2 such as Calcium -PSZ, Magnesium-PSZ, Yttrium-PSZ and Calcium-Yttrium-PSZ at high temperature have been investigated as Al2O3, SiO2 and Fe3O4 are added. The results show that the stabilities of PSZs depend on whether there occurs chemical reaction between PSZ particles and oxides at 1600 degrees, which is in agreement with the thermodynmical calculation.

08:30
Room: 3rd Floor - Plaza C
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Refractories for the Iron and Steel Industries (TUESAM1)

Paper Start Time: 08:30
Paper No.: 5068
Paper Title: **Zero-emission Ceramically Bonded MgO-C Bricks (CBMC) with Superior Properties in Steel-ladle Applications**
Helge Jansen; Refratechnik Steel; Leandro Schöttler, Deutsche Edelstahlwerke;
CBMC exhibit an unique combination of flexible carbon bond with a rigid ceramical bond. They get their final properties before installation and do not contain any volatile substances, thus, can be preheated without emitting fumes and odors. In the steel-industry the benefits of a Zero-Emission-Brick are regarded to be very helpful. Up to now approx. 2000 to. have been tested mainly in steel-ladle linings very successfully. Throughout all applications the lining lifetimes were even slightly increased. In this paper the development of the CBMC brick and its succesful introduction into steel-ladle linings of stainless steel-maker DEW are presented.

CBMC présentent une combinaison unique de liaison carbone souple, avec une liaison ceramical rigide. Ils obtiennent leurs propriétés finales avant l'installation et ne contiennent pas de substances volatiles, ainsi, peut être préchauffé sans émission de fumées et d'odeurs. Dans l'acier-industrie les avantages d'une Zero-Emission-Brick sont considérées comme très utiles. Jusqu'à présent, env. 2000 à. ont été testés principalement en acier, garnitures de poche avec beaucoup de succès. Tout au long de toutes les applications de la durée de vie doublure étaient même légèrement augmenté. Dans ce document, le développement de la brique CBMC et son introduction réussie dans la poche de coulée d'acier garnitures du fabricant d'acier inoxydable DEW sont présentés.
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Paper Start Time: 08:55
Paper No.: 5390
Paper Title: **New Generation of Taphole Tar Mixes for Small Blast Furnaces**

Aloísio Ribeiro; Magnesita Refratários; Guilherme Frederico Bernardo Lenz e Silva, Magnesita Refratários SA; Humberto Chiaretti Bassalo, Magnesita Refratários SA; Modestino Alves Brito, Magnesita Refratários SA;
Taphole mixes for blast furnaces are usually based on Al2O3-SiO2-SiC-Si3N4-C systems, bonded by tar, resin or synthetic oils yet. The choice of tar or resin as a binder system is dependent of such technical requirements as numbers of tapholes of the blast furnace, kind of the taphole blocks (ceramic or microporous carbon) and the environmental work conditions. This paper will show the development of a new generation of taphole tar mix for small blast furnaces (< 3000 t/day 1 or 2 tapholes) with enhanced and optimized properties, focusing the South America ironmaking market.

Paper Start Time: 09:20
Paper No.: 5569
Paper Title: **The Development of New Spinel Containing MgO-C Refractories for Application in Steelmaking Ladles**
Mohammad Bavand-Vandchali, Pars Refractories Company; Farhad Golestani-Fard, Professor, Iran University of Science and Technology
In recent years, new types of MgO-C refractories with improved physical and mechanical properties have found widespread applications in different types of steelmaking vessels, because of a demand for further improvements in refractories performance against to more severe and diverse service conditions encountered in steelmaking practice. The usage of new resin binder with flexible crystalline structure, addition of nano-carbon powder and application of new antioxidants such as synthesis ceramic powders are the main studies that were reported to improve thermo-mechanical properties and corrosion resistance of MgO-C refractories. The new development of this group of refractories is done in resin-bonded MgO-C bricks used in slag line and metal zone area of steelmaking ladles with addition of Mg-Al spinel which maybe preformed or in-situ in nature. The present paper will address the development of new generation of MgO-C refractories containing in-situ (so-called spinel-bonded MgO-C refractories) and non-stichiometric spinels (so-called MgO-spinel-C refractories). Reactive alumina and two different magnesia and alumina rich spinels were added to MgO-10%C base formulation and physical and mechanical properties were evaluated after curing and coking at 1000-1600°C. The influence of different spinel types on corrosion resistance of above mentioned samples against different CaO/SiO2 ratio silicate slags was also evaluated by rotary slag testing at 1650°C and 10hrs. The phase and microstructural analysis of corroded samples were also investigated by XRD and SEM/EDS techniques. Results show that the reaction of reactive alumina and fine magnesia in the matrix of MgO-C refractories develop a spinel bonding that improves the physical and mechanical properties. Therefore, it was clarified that the expansion reaction of in-situ spinel could effectively integrate the refractory texture and hold of the graphite flakes which resulted in better corrosion resistance against silicate slags with different composition. However, the magnesia and alumina rich spinel addition could not strongly affect the mechanical properties of MgO-C refractories but had significant influence on corrosion resistance. It was found that the corrosion behavior of MgO-Spinel-C samples could be related to spinel content and the local reactions with slag that accommodate Fe and Mn ions. Finally, the role of each type of spinel on corrosion resistance was discussed and an industrial experience in an Iranian steel company is reported where these refractories are employed.

Paper Start Time: 09:45
Paper No.: 5136
Paper Title: **BOF Taphole Improvements at Dofasco**
Richard Moore; ArcelorMittal Dofasco;
Dofasco has only one high productivity BOF steelmaking converter. A project was completed to improve the refractory performance and reduce steelmaking delay time. The project includes state of the art graphite and additives to improve spalling resistance in the taphole refractory, new repair materials for taphole installations, improved gunning materials and an upgraded one piece taphole block.

10:30
Room: 3rd Floor - Plaza C
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Refractories for the Iron and Steel Industries (TUESAM2)

Paper Start Time: 10:30
Paper No.: 5159
Paper Title: **Optimization and Improvements in Dofasco's 165 MT EAF Ladle Design**
Sanjay Sagar; ArcelorMittal Dofasco;
In September 1996, Dofasco commissioned a 165 Mt twin shell EAF furnace and an associated ladle fleet. During and after this startup, refractory performance in the ladles has continually been optimized on a holistic approach through several initiatives that increased ladle refractory retention times from 7000 to over 18000 mins (200 heats). This dropped the overall refractory costs by 50% while ensuring a consistent and predictable ladle performance. The paper gives an update on current performance and outlines the technology that led to each breakthrough in performance.

Paper Start Time: 10:55

Paper No.: 5108
Paper Title: **Technical and Economic Review of High Alumina Raw Materials for Steel Refractories**
Andreas Buhr; Almatis; Marcel Spreij, Almatis;
The ongoing development of the steel producing technology has also required changes in the refractory lining. Refractory materials based on natural high alumina raw materials were replaced by higher performance materials based on synthetically alumina raw materials in some applications. The tremendous growth of steel production in China has led to a high internal demand for refractory raw materials. This had a considerable impact on the availability and pricing of important high alumina raw materials, bauxite and brown fused alumina, for the refractory industry worldwide. Therefore the discussion of technical and economical alternatives has intensified at refractory producers but also in the steel making industry. This paper discusses technical and economic trends in high alumina raw materials and refractories in the past 20 years. The typical data of various high alumina materials are presented and discussed for selected steel applications. This also provides a basis for the consideration of raw material substitutions in other applications.

Paper Start Time: 11:20
Paper No.: 5110
Paper Title: **Advantages of Dense Calcium Hexaluminate Aggregate for Back Lining in Steel Ladles**
Dale Zacherl; Almatis, Inc.; Dagmar Schmidtmeier, Almatis GmbH; Marion R Schnabel, Almatis GmbH; Doris Van Garsel, Almatis GmbH; Andreas Buhr, Almatis GmbH;
The dense calcium hexaluminate aggregate Bonite is known for its chemical purity, high refractoriness and temperature stability and its resistance to molten metal, alkali vapors and carbon monoxide. In spite of the high density aggregate (around 3 g/cm³) Bonite based refractories have a low thermal conductivity of about 1.7 W/mK at 1000°C. High density, stability, and wear resistance in combination with low thermal conductivity provide a new combination of properties which is of special interest for back linings. In many steel ladles a thinner lining is desired to increase the capacity of the vessel. However, the reduction of heat losses and ladle shell temperatures below 400°C are important targets for modern steel ladle lining concepts. Safety linings with low thermal conductivity can simplify the back lining concept with regard to a reduced number of different layers. The paper discusses the properties of Bonite based refractories with special focus on steel ladle back lining applications. The testing includes thermomechanical properties, slag resistance, and thermal conductivity. Calculation of heat transfer is done to demonstrate the economic advantages of Bonite based back linings when compared to conventional materials.

Paper Start Time: 11:45
Paper No.: 5245
Paper Title: **The Evolution of Multi-walled Carbon Nanotubes (MWCNTS) in Carbon Containing Refractories Using Silicon as Anti-oxidant Additive**
Ming Luo; Wuhan University of Science and Technology; Yawei Li, Wuhan University of Science and Technology; Ming Luo, Wuhan University of Science and Technology; Shaobai Sang, Wuhan University of Science and Technology; Shengli Jin, Wuhan University of Science and Technology; Wenrui Zhang, Wuhan University of Science and Technology;
The evolution of multi-walled carbon nanotubes(MWCNTs) is investigated using silicon (Si) powder as antioxidant in carbon bed at 1300-1500oC. SiC coating was formed uniformly on the surface of MWCNTs at 1300-1400oC. Up to 1500oC nearly all the MWCNTs transformed into SiC nanorods with about 200nm in diameter. The oxidation resistance of the treated MWCNTs can be improved greatly. Non-isothermal kinetics illustrated the oxidation activation energy of as-received MWCNTs was 160KJ/mol while it was 210KJ/mol for MWCNTs treated at 1400oC.

Paper Start Time: 12:10
Paper No.: 5637
Paper Title: **Life Improvement of Magnesia-carbon and Alumina-magnesia-carbon Refractory Bricks for use in Steel Ladle**
Nader Khalili; MehrGodaz Refractories Co.; Mahdi Naeimi, Mehr Godaz Refractories Co.; Mohsen Nouri, Mehr Godaz Refractories Co.;
Having the capacity for production of 15 million tons of steel, Iran produced more than 10 million tons of steel in 2009. About 150,000 tons of refractory products were consumed for this steel tonnage. Meanwhile, refractories for Steel ladle played an important role because of their severe working condition in steel ladle. Magnesia-carbon refractories were used for slag line, while other parts like sidewall and bottom were covered with Alumina-magnesia-carbon (AMC) bricks. In the current study, the effect of additives on lifetime improvement of magnesia-carbon and Alumina-magnesia-carbon refractories has been investigated. A kind of additive was used in magnesia carbon bricks which improved the microstructure to some extent leading to increase of lifetime by 20%, while another additive used in AMC bricks raise the brick life up to 30%. Also the effect of these additives on physical properties such as Porosity, density and CCS at different temperatures has been discussed. The micostructure was studied and the results showed that the improvements are relevant to changes in microstructure.

14:00
Room: 3rd Floor - Plaza B
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V

Session: Refractory Castables and Other Monolithics 1 (TUESPM1)

Paper Start Time: 14:00
Paper No.: 5388
Paper Title: **The Effect of Some Additives on Chamotte Based Low Cement Refractory Castables**
AliReza Souri; Iran University of Science and Technology; Abbas Ramezani, Malayer University; Fereydoon Rahimi, Malayer university; Farhad GolestaniFard, Iran University of Science and Technology;
In the present study the effect of some additives like TPP, Castament FS20 and Budit on flow properties of low cement alumina silicate castables was studied. These additives are dispersant agents which affect the electrostatic layer and influence the deflocculation characteristic of micro silica containing LCC and ULCC refractories. The amount of additives was determined on the basis of optimized flow properties. The samples were heat treated at 110, 1000, 1200 and 1400 degrees Density, porosity; PLC and CCS were measured and evaluated discussed with emphasis on applications. Results showed that Budit had better influence on flow properties compared to other additives. The Castament FS20 demonstrated a better effect on PLC and cold crushing strength.

Paper Start Time: 14:25
Paper No.: 5451
Paper Title: **Water Wettability and Dispersivity of Titanium Carbide Coated Graphite Synthesised from Molten Salt**
Shaowei Zhang; University of Sheffield; Xiaoguang Liu, University of Sheffield;
Titanium carbide (TiC) coated graphite for refractory castable applications was prepared by using a low temperature molten salt synthesis technique. Ti and graphite in the mass ratio of 1:5 were reacted in a LiCl-KCl binary salt in Ar at 950oC for 4h. The resulting TiC coatings were homogeneous and crack free, and showed beneficial effects on the water-wettability/dispersivity of graphite and the flowability of graphite-water suspensions. Water contact angle was reduced from ~101o (on uncoated graphite) to ~58o (on TiC coated graphite). Zeta potential of graphite was also increased evidently after TiC coating. In addition apparent viscosity of water suspension containing TiC coated graphite was reduced substantially.

Paper Start Time: 14:50
Paper No.: 5225
Paper Title: **New Calcium Aluminate Binders and Additives for Refractory Monolithics**
Chris Parr; Kerneos SA; Hervé Fryda, Kerneos SA; Genine Assis, Kerneos SA; Jean Michel Auvray, Kerneos SA; Christoph Wöhrmeyer, Kerneos SA;
The successful development of high performance castables relies upon the optimisation of both their placing characteristics and their installed properties. This is normally achieved through combinations of suitable aggregate systems together with a deflocculated binder phase. This latter component is comprised of high purity Calcium Aluminate Cements in conjunction with reactive fine fillers and additives. As the number of castable placing technologies have developed over recent years, the constraints upon the refractory formulator have multiplied, as reactions between the different components within the binder have become more and more complicated.This paper investigates some of the challenges linked to raw materials and how control of the interdependent reactions within a castable during the processing phases can be harnessed via the use of newly developed calcium aluminates and additive systems. These new calcium aluminates and additives deliver castables with both improved processing properties and more predictable behaviour. A series of model systems representing a low cement castables designed for placing by self flow and vibration techniques containing newly developed calcium aluminates and additive systems have been studied using and compared to reference systems. Examples of will show how the control of the hydraulic reactivity of different calcium aluminates can be advantageously used to deliver castables with improved workability/hardening profiles with reliable and predictable performance. Experiments are conducted using, wet mixed, model systems through the phase of initial flow, flow decay and stiffening using parallel measurement techniques. Classical flow measurements are used to evaluate placing properties and these are coupled with ultrasonic measurements and exothermic profiles to assess castable hardening. These experiments are able to describe the flow, workability and hardening relationships and show the improved performance that the new binders can offer. These physical measurements are complemented by pore solution analysis which provide an insight into the underlying mechanisms and hydration reactions. Conclusions will show these calcium aluminate binders and additives can deliver predictable performance to the placing properties of deflocculated castables.

15:35
Room: 3rd Floor - Plaza B
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Refractory Castables and Other Monolithics 1 (TUESPM2)

Paper Start Time: 15:35
Paper No.: 5246
Paper Title: **Study on the Phase Composition and Properties of Nonoxide Bonded Alumina Castables by In-situ Nitridation Reaction**

Quanli Jia; High Temperature Ceramics Institute, Zhengzhou University; Ye Fang Bao, High Temperature Ceramics Institute, Zhengzhou University;
Nonoxide bonded alumina castables were prepared by in situ nitridation reaction using tabular alumina as aggregates, fused Alumina fine, Si powder and ultrafine alumina as matrixes. The phase composition and microstructure of samples were characterized by XRD and SEM. The results show that phase composition of specimens is alumina,alfra-Si3N4,beta-Si3N4 and Si2N2O at 14000 and 14500 degrees and is alumina,beta-Sialon and O-Sialon at 15000C. Hot MOR of specimens is noticeably improved. SEM images show that the nonoxide grains are granular, lathe shape or prismatic crystals.

Paper Start Time: 16:00
Paper No.: 5094
Paper Title: **Thermodynamic Aspects of the SiC Oxidation in Carbon Containing Refractory Castables**
Ana Paula da Luz; Federal University of São Carlos; Victor Carlos Pandolfelli, Federal University of São Carlos;
In this work thermodynamic calculations have been carried out using FactSage software in order to explore and understand the SiC oxidation in Al2O3-SiC-C (ASC) and Al2O3-MgAl2O4-SiC-C (AMSC) castable compositions. The collected results showed that, at 1500oC and under a reducing atmosphere, there is no evidence that spinel might directly affect SiC oxidation. Therefore, the lower SiC content in the AMSC castable is a result of the refractory's phase transformations. Additionally, based on the equilibrium data, the mechanisms of the SiC transformations in the carbon containing castables over the temperature range of 1100oC-1600oC, were discussed.

Paper Start Time: 16:25
Paper No.: 5112
Paper Title: **Magnesia or Alumina Grain Size: Which One Plays the Major Role in the In Situ Spinel Formation?**
Mariana Braulio; Federal University of São Carlos; Guilherme Morbioli, Federal University of São Carlos; Luís Rodolfo Bittencourt, Magnesita Refratários S. A.; Victor Pandolfelli, Federal University of São Carlos;
The reduction of MgO or Al2O3 grain sizes in Al2O3-MgO refractory castables results in lower spinel formation starting temperature and lower overall expansion level. In order to understand the MgO and Al2O3 roles in the in situ spinel formation, castables containing different MgO grain sizes (from

14:00
Room: 3rd Floor - Plaza C
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Testing, Characterization and Simulation of Refractory Behavior 1 (TUESPM1)

Paper Start Time: 14:00
Paper No.: 5357
Paper Title: **Damage and Creep Modelling for Refractory Structures Sizing**
Fabien Nazaret; Aurock; Thierry Cutard, Clément Ader Institute; Olivier Barrau, Aurock;
Refractory castables present a damage mechanical behaviour up to a transition temperature ranged from 800°C to 1100°C. This transition temperature depends on the material composition. Beyond this temperature, the mechanical behaviour becomes mainly viscoplastic. The present work deals with the damage modelling for temperature values lower than this transition temperature and creep modelling for higher temperature values. Simple constitutive laws are used to simulate damage and creep. Experimental curves needed to identify material parameters are presented. This approach allows to obtain qualitative results to size refractory structures submitted to mechanical and thermal loads.

Paper Start Time: 14:25
Paper No.: 5568
Paper Title: **Novel Spinel-family Refractories for High Temperature, High Alkaline Environments**
James Hemrick; Oak Ridge National Laboratory; Angela Rodrigues-Schroer, MINTEQ Internatinal, Inc.; Jeffrey D. Smith, Missouri University of Science and Technology; Dominick Colavito, MINTEQ International, Inc.;
Currently available refractory materials (bricks, castables, gunnables, etc) are limited in their application by many factors. These include chemical reactions between the service environment and the refractory material, mechanical degradation of the refractory material by the service environment, temperature limitations on the use of a particular refractory material, and the inability to install or repair the refractory material in a cost effective manner or while the vessel is in service. Therefore, there is a need to develop new innovative refractory compositions utilizing novel aggregates, binder systems (bonds), methods of phase formation, and refractory application systems. This paper will discuss the development of new innovative refractory compositions based on the spinel or alumina structure. In particular, compositions composed of a family of materials containing magnesia/alumina or other similar elemental combinations to form unshaped refractory compositions (castables, gunnables, shotcretes, etc) utilizing new aggregate materials, bond systems, protective coatings, and phase formation techniques (in-situ phase formation, altered conversion temperatures, accelerated reactions, etc) will be

discussed. This family of refractory compositions is tailored for use in high-temperature,high-alkaline industrial environments like those found in the aluminum, chemical, forest products, glass, and steel industries. Both practical refractory development experience and computer modeling techniques were used to aid in the design of this new family of materials. Discussion is also given to the initiation and formation of an un-biased, comprehensive database of thermophysical and wear/corrosion properties concerning currently used and newly developed refractory materials, a needed but unavailable resource highly desired by the refractory user community.

Paper Start Time: 14:50
Paper No.: 5143
Paper Title: **Development of a Microstructural Methodology to Establish Structure/Property Relations of Refractories and First Results for Magnesia Spinel Materials**
Renaud Grasset-Bourdel; GEMH-ENSCI; Nicolas Schmitt, LMT-Cachan, ENS de Cachan; Dietmar Gruber, Chair of Ceramics, University of Leoben; Harald Harmuth, Chair of Ceramics, University of Leoben; Arnaud Alzina, GEMH-ENSCI; Marc Huger, GEMH-ENSCI; Thierry Chotard, GEMH-ENSCI;
Improving performances of refractories, such as thermal shock resistance, for an extended linings lifetime, becomes a crucial challenge for the very next future. This study aims at understanding the links existing between the microstructure of magnesia-spinel refractories and the associated thermo-mechanical properties. Two-phases model materials composed of a magnesia matrix with spinel inclusions have been elaborated with different inclusion volume fractions. Different experimental techniques have been applied to characterise the thermo-mechanical properties. Thermal and mechanical FEM simulations have been carried out in order to compare both experimental and numerical results. Periodic homogenisation, taking into account damage within the matrix, has been considered in the simulation.

15:35
Room: 3rd Floor - Plaza C
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Testing, Characterization and Simulation of Refractory Behavior 1 (TUESPM2)

Paper Start Time: 15:35
Paper No.: 5167
Paper Title: **Overhead Protection Systems (OPS) - Some Recent Applications**
Michael C. Walton; RefMet; Bill Roelofs, Minvent Pty Ltd;
In most cases a refractory repair or turnaround involves dealing with used/failed refractory linings above shoulder height. This paper details a method of personnel protection involving a low pressure inflatable balloon system, installed to prevent the dislodgement and free-fall of in-situ refractories. This system has been successfully applied to numerous types of reaction vessels in the process industries in the last 2-3 years. This paper outlines details of the system, as well as gives examples of successful applications.

Paper Start Time: 16:00
Paper No.: 5201
Paper Title: **Computational Fluid Dynamics Simulations of Mass Transfer Coefficients in Gas Purged Steel Ladles**
Sandra Vollmann; University of Leoben, Chair of Ceramics; Harald Harmuth, University of Leoben, Chair of Ceramics;
Computational fluid dynamics calculations were used to determine the mass transfer coefficient in the slag area of a gas-stirred steel ladle. The mass transfer in dependence on several influencing parameters e.g. flow rate and gas throughput was investigated. Therefore multiphase simulations of the fluid flow considering diffusion for different parameter settings were performed. The dimensional analysis conducted and the parameter study done by simulations lead to a relation for the estimation of the mass transfer in the slag bath area of the ladle. The result helps to quantify refractory corrosion in dependence of process parameters.

Paper Start Time: 16:25
Paper No.: 5302
Paper Title: **High Strength Alumina Silicate-carbon Ramming Monolithic Refractories with Resole Bond for Ironmaking Application**
E. Karamian, Department of Materials Engineering, Isfahan University of Technology; A. Zadhoush, Department of Textile Engineering, Isfahan University of Technology (IUT),Isfahan, 84156-83111, Iran; E. Mohammadi Zahrani, Department of Materials Engineering, University of British Columbia; A. Monshi, Department of Materials Engineering, Isfahan University of Technology;
Two series of carbon containing monolithic were prepared from Iranian chamotte and Chinese bauxite as aggregates, SiC-containing material, coke, resole as binder and different quantities of additives. Bulk density (BD) and cold crushing strength (CCS) are measured after a heat treatment at 200 ºC and reheating at 1100 ºC and 1400 ºC for 2 hr. Current paper describes the effect of additives on the increasing of BD and CCS. Si and ferrosilicon contribute to the formation of the resit structure at 200 ºC and SiC whiskers with nano sized diameter at 1400 ºC, and consequently the CCS increased.

---Wednesday October 6, 2010---

08:30
Room: 3rd Floor - Plaza B
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Refractory Castables and Other Monolithics 2 (WEDAM1)

Paper Start Time: 08:30
Paper No.: 5284
Paper Title: **Effect of Water Reducers on the Property of Corundum-based LCC Castables**
Juan Zhao; Wuhan University of Science and Technology; Lei Zhao, Wuhan University of Science and Technology; Yuanbing Li, Wuhan University of Science and Technology;
Seven kinds of water reducers,FS10,PC,AS,PAAS,LG,STPP,were used as dispersant in the corundum-based LCC castables respectively. The influence of these water reduces on the flow valuve, the setting time, mechanical strength,bulk density, apparent porosity of the castables has been discussed. The results show that FS10 and PC belonging to ploycarboxylate ether are superior to the others on the placing and physical properties.

Paper Start Time: 08:55
Paper No.: 5606
Paper Title: **New Added Value Reactive Aluminas for Refractory Applications**
Arnaud Lafaurie; Francois Murgalé, Rio Tinto Alcan; Arnaud Lafaurie, Rio Tinto Alcan;
Reactive aluminas are mainly used in high performance castables that require a high resistance under severe conditions. The aim of this work is to present the development we are doing in Rio Tinto Specialty Aluminas, to propose a wide range of reactive aluminas for refractorists, especially in the current economical situation where price/performance has to be taken into account. Through a design of experiment (DOE) approach, involving a wide range of Gardanne calcined aluminas the optimum cost/performance balance was found. Key parameters of reactive alumina like water absorption and flowability were correlated with the properties of low cement castables.

Les alumines réactives sont principalement utilisées dans les bétons réfractaires à haute teneur en alumines pour des applications à hautes températures. Le but de ce papier est de présenter les développements en cours chez Rio Tinto qui ont pour but de proposer une large gamme d'alumines réactives compétitives pour réfractaires spécialement dans le contexte économique actuel où le ratio prix/performance doit être optimisé. A travers une approche par plan d'expérience, nous avons étudié plusieurs combinaisons d'alumines calcinées et déterminé des optimums en termes de propriétés. Notamment l'absorption d'eau ou encore la coulabilité des alumines que nous avons corrélé avec les propriétés en formulation béton.

Paper Start Time: 09:20
Paper No.: 5379
Paper Title: **Effect of Si Addition on Creep Performance of High Alumina Castable**
Jiwei LI; Henan Gengsheng Refractories Co., Ltd.; Bo Hu, Henan Gengsheng Refractories Co., Ltd.; Cheng Zhang, Henan Gengsheng Refractories Co., Ltd.; Wei Qin, Henan Gengsheng Refractories Co., Ltd.; Anhong Zhou, Henan Gengsheng Refractories Co., Ltd.; Kai Shi, Henan Gengsheng Refractories Co., Ltd.;
Kyanite, Silimanite, quartz and silicon have been added to high alumina castables, and the effects of these additions on properties of high alumina castables have been investigated, especially on the creep property at 1350 for 50h. Microstructure of some samples after preheated was analyzed by SEM and EDAX. Results indicate that the addition of Kyanite, silimanite and quartz have no obvious effects on the creep resistance of high alumina castable, which has been remarkably improved as silicon added by contrast. The benefits of Si introduction to creep resistance can be attributed to the gradually oxidation,nitridation and mullitizalition.

Paper Start Time: 09:45
Paper No.: 4953
Paper Title: **Effect of Andalusite on Physical and Thermal Properties of High Alumina Low-cement Castables**
Sadra Emami; ; Material and Energy Research Center; Seyed Amir Mohammad Amir Ahmadi, Material and Energy Research Center; Seyed Hossein Hashemi Moghaddam, Material and Energy Research Center; Farzad Soleymani, Material and Energy Research Center;
High alumina low cements castables (LCC) with andalusite considered because of their good physical and thermal properties. In this paper a castable with pure alumina selected for original sample and 3 set of samples with 15, 20, 25% andalusite with size of 1-3, 0-1, 0-0.1 mm prepared then physico-mechanical and refractory properties of this castables determined according to standard specification. Results show that thermal shock of castables increases to 20Wt% andalusite, HMOR and RUL of castables with 25 Wt% andalusite was better than 20Wt%.

08:30
Room: 3rd Floor - Plaza C
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Testing, Characterization and Simulation of Refractory Behavior 2 (WEDAM1)

Paper Start Time: 08:30
Paper No.: 5202
Paper Title: **Thermomechanical Failure Modes of Steel Ladles - Results of FEM Simulations**
Dietmar Gruber; University of Leoben; Thomas Auer, University of Leoben; Harald Harmuth, University of Leoben;
Finite Element simulations have been carried out to investigate failure of especially wear lining under the following operation conditions: Preheating with different heating rates, filling with hot metal and several operation cycles. Main loading types causing different failure modes have been identified. Among these are the difference in thermal expansion of the hot face and the shell causing compressive/shear failure at the hot face, and the temperature gradient near the hot face causing tensile failure in some distance from the hot face. Further cyclic crack growth in unshaped wear lining has been investigated.

Paper Start Time: 08:55
Paper No.: 5224
Paper Title: **Relevance of Numerical Simulation for Refractory Corrosion in Steel Industry**
Harald Harmuth; Chair of Ceramics, University of Leoben; Sandra Vollmann, Chair of Ceramics, University of Leoben; Franz Melcher, Chair of Ceramics, University of Leoben; Dietmar Gruber, Chair of Ceramics, University of Leoben; Christian Majcenovic, RHI AG, TCL Leoben;
Refractory corrosion in vessels of the steel industry is mainly influenced by dissolution of refractory oxides in slag and erosion. Dissolution on the one hand depends on the difference of the solubility limit and the concentration in the slag, and on the other hand on the mass transfer coefficient. Applications of thermochemical simulation to calculate the solubility limit and of CFD calculation to determine mass transfer coefficients are shown. Mass transfer coefficients are also related to the wall shear stresses which determine erosive wear. Thermomechanical simulation helps to e.g. investigate joint opening which increases corrosive wear.

Paper Start Time: 09:20
Paper No.: 5226
Paper Title: **The Effect of MgO-Al2O3 Spinel on Refractory Bricks Made From Al2O3-Cr2O3 Slag**
Lijun Zheng; +; Research and Development Center of Magnesia Materials;
The Al2O3-Cr2O3 slag as raw material was analyzed by scanning electron microscopy (SEM). The effects of different size distribution of MgO-Al2O3 spinel grain on physical properties of refractory bricks made from Al2O3-Cr2O3 slag was studied according to YB/T376.1-1995(water quenching), GB/T 5072-1985, GB/T 2997-1982 criterion. The results show that the main crystal phase of the refractory bricks were chromium corundum, corundum. The refractory bricks containing 10 wt% of the maximum size of 3.0 mm of MgO-Al2O3 spinel grain can significantly improve the thermal shock resistance of this refractory bricks. At the meanwhile, This kind of refractory bricks can be absolutely satisfied with the requirements about cold crushing strength, bulk density and apparent porosity.

Paper Start Time: 09:45
Paper No.: 5265
Paper Title: **Comparison Between the CCS, H-MOR and Apparent Porosity of Hydrated MgSO4 Impregnated and Non-impregnated MgO-based Bricks**
Andrie Garbers-Craig; University of Pretoria; Karabo Setlhare, University of Pretoria; Andrie Mariana Garbers-Craig, University of Pretoria;
The main reasons for the success of magnesia-based refractories are the high melting point of MgO (2800°C) as well as excellent resistance to attack by iron oxide through solid solution phase formation, and high-lime fluxes. Its principal limitations are its high thermal expansion, which makes the production of bricks with high thermal shock resistance difficult, their tendency to shrink when exposed to high temperatures for long periods of time, and its tendency to hydrate. Studies on the hydration of MgO-based refractory materials are of great importance to the platinum and titania industries in South Africa, as in these industries spare MgO-base linings are kept in storage for extended periods of time. When the time arrives that these spare linings are needed, the question often arrives whether the spare lining has hydrated over time, and whether it is still of sufficient quality to be used in the smelter. In this project the effect of the hydration of magnesia-based bricks, treated and untreated with an MgSO4 solution, on their cold and hot strengths were investigated. This was done by examining the relationship between the degree of hydration of these bricks and their cold crushing strength (CCS), cold modulus of rupture (C-MOR), hot modulus of rupture (H-MOR) and apparent porosity. Tests were also performed to determine how fast the hydration reaction occurs after water or steam comes in contact with the magnesia-based brick. The MgSO4 treated and untreated MgO-based bricks were hydrated in an autoclave at 110°C for up to 60 hours. The results obtained showed that MgSO4 treatment of the MgO-based bricks significantly decreases the degree of hydration. As hydration increases the CCS and H-MOR of the MgO-based brick decreases, while its apparent porosity initially decreases, after which it increases.

10:30
Room: 3rd Floor - Plaza C
Stream: ADVANCES IN REFRACTORIES FOR METALLURGICAL INDUSTRIES V
Session: Testing, Characterization and Simulation of Refractory Behavior 2 (WEDAM2)

Paper Start Time: 10:30
Paper No.: 5095
Paper Title: **Elastic Modulus Evolution of Carbon Containing Refractory Castables at High Temperature**
Ana Paula da Luz; Federal University of São Carlos; Marc Huger, École Nationale Supérieure de Céramique Industrielle; Victor Carlos Pandolfelli, Federal University of São Carlos;
The elastic modulus behavior of two Al2O3-SiC-SiO2-C castables containing 10wt% of carbon has been evaluated along one thermal cycle (25oC - 1500oC), in oxidizing atmosphere, using the high temperature ultrasonic technique working in a long bar mode. Additionally, thermodynamic calculations and X-ray diffraction analyses were correlated to the collected results. Although several changes were detected during one heating-cooling cycle, the E values attained at the initial and final step of the tests were similar and the curves presented an hysteresis behavior. The E evolution was related to the decomposition of the hydrated phases, antioxidant reactions, liquid phase viscosity variation and flaw generation in the microstructure.

Paper Start Time: 10:55
Paper No.: 5104
Paper Title: **New Method to Determine the Cohesion and the Friction of Refractory Materials at Room Temperature and at Elevated Temperature**
Emilie Dahlem; Dietmar Gruber, Chair of Ceramics, MUL; Harald Harmuth, Chair of Ceramics, MUL; Thomas Auer, Chair of Ceramics, MUL; Marc Huger, GEMH; Thierry Chotard, GEMH;
In many industrial applications both pure compressive and shear loads are acting on refractory linings. Material laws e.g. according to Drucker-Prager may account for this behaviour and necessitate the determination of material parameters like friction and cohesion. Presently testing methods to determine these are available only for room temperature. The present work shows an easy to perform testing procedure for elevated temperatures based on a modified shear test. Experimental results and FEM simulations will be presented for two different geometries and several materials.

Paper Start Time: 11:20
Paper No.: 5651
Paper Title: **Magnesia-rich Chromium-free Spinel-bonded Basic Refractories**
Rahul Lodha; University of British Columbia; C. Oprea, University of British Columbia; G. , University of British Columbia;
This study presents the experimental results on replacing Cr3+ with Me4+ ions in magnesia-chrome bricks, which along with Fe3+ could maintain the spinel formation capability with MgO and perform similarly to the complex (Mg2+, Fe2+)O(Cr3+, Fe3+, Al3+)2O3 spinel against fayalite slags in non-ferrous furnaces. The incorporation of iron oxide in the MgO-Al2O3-Me4+O2 systems would contribute to reactive sintering and also in decreasing the solubility of both the ferrous and ferric ions present in the fayalite slag. Phase analysis on stoichiometric mixes showed that the use of tetravalent cation oxides like tin dioxide (SnO2) and titanium dioxide (TiO2) can induce high solubility of spinel in magnesia. In order to maintain charge balance, two trivalent cations were replaced by a tetravalent and a bivalent cation causing the additional bivalent cation to occupy the octahedral position thereby creating an inversion in position of the bivalent ions similar to the behavior exhibited by Fe3+ occupying tetrahedral site in complex spinel phase of magnesia-chrome ceramics. Most of the magnesia-chrome refractories have ~60 wt. % MgO and hence our experimental mixes contained that amount and called magnesia-rich compositions, to be distinguished from the stoichiometric MgAl2O4 spinel. The incorporation of nano TiO2 powders reduces the temperature of spinel formation, as the diffusion path is shortened and thus activates both synthesis and sintering, resulting in complete spinel formation and open porosity less than 5% after firing at 1350°C for 3 hours.