

### EFFECT OF AGGREGATE SIZE COMPOSITION ON PROPERTIES OF FRESH AND SINTERED ALL-ALUMINA CASTABLES

Abílio P. Silva<sup>1</sup>, Deesy G. Pinto<sup>1</sup>, Ana M. Segadães<sup>2</sup>, Tesselano C. Devezas<sup>1</sup>

<sup>1</sup>Department of Electromechanics Engineering, University of Beira Interior, Covilhã, Portugal

<sup>2</sup>Department of Ceramics and Glass Engineering, University of Aveiro Aveiro, Portugal

This work describes all-alumina self-flow refractory castables, containing a set of aggregates and a fine matrix, which were optimized with minimum added water and no cement for high flowability index (FI) while fresh paste and high mechanical strength (cold modulus of rupture, MoR) after sintering. The self-flow matrix was prepared with three fine size classes of commercial alumina (<25µm and <63µm obtained from tabular alumina T60, and reactive alumina CT3000SG) and kept constant; the aggregate contained three coarse size classes of tabular alumina T60 (1 - 3mm, 0.5 - 1mm, 0.2 - 0.6mm). Firstly, the proportions between matrix and aggregate were varied, thus varying the specific surface area (SSA) and the distance between aggregate particles (maximum paste thickness, MPT). Afterwards, keeping the SSA constant, the effect of the aggregate size composition on the properties of fresh (FI) and sintered concrete (cold MoR, linear shrinkage LS, and apparent porosity AP) was investigated. To this aim, a simplex design of experiments was used and the results were analysed in terms of ternary response surfaces using the software Statistica. The equation that best describes the response of each variable as a function of the aggregate size classes, was calculated for all cases. The results obtained demonstrate that there is a strong dependence between FI, SSA and MPT. The fresh castable flowability increases with the volume of fine particles (matrix), and a quadratic polynomial was found to best describe the effect on FI, SSA and MPT of the aggregate size classes. The FI saturates for SSA values above 2.4m<sup>2</sup>/g (MPT > 55µm), meaning that a large increase in SSA, with the corresponding increase in the castable cost, is required to produce only a slight improvement in FI. For a set SSA value, guarantying self-flow behaviour, the aggregate particle size distribution also affects the fresh castable characteristics (90 < FI < 130%). Cold MoR in some cases was found to exceed 55MPa, while LS remained below 1.5% and AP was less than 9%.

### MAGNESIA RICH SPINEL BONDED BASIC CASTABLES

Rahul Lodha\*, Tom Troczynski and George Oprea  
UBCerem, University of British Columbia, Vancouver, BC, Canada  
Joe A. Rigby  
RHI Canada, Burlington, ON, Canada

This study presents the experimental results on chromium-free magnesia-rich spinel bonded basic castables using nano-powders as sintering additives. Through the use of ultra-fine particles, reaction bonding of spinel is achieved and this results in lower synthesis of the spinel phases and sintering temperatures. The binder system based on in-situ spinel formation technology, containing SnO<sub>2</sub>, TiO<sub>2</sub> and Fe<sub>2</sub>O<sub>3</sub> as spinel forming oxides and also as replacements for Cr<sub>2</sub>O<sub>3</sub>, with or without nano-TiO<sub>2</sub>, -Al<sub>2</sub>O<sub>3</sub> or -Fe<sub>2</sub>O<sub>3</sub>, would allow the matrix of the castables to sinter at 5% open porosity, when fired below 1500°C. Similar binder systems containing Cr<sub>2</sub>O<sub>3</sub> micro- and nano-powders and magnesia-chrome fused grains as aggregate were also studied and the after firing properties compared with the non-chromium bearing versions. The experimental results showed no significant differences in physical and mechanical properties and better slag corrosion resistance should be expected from the chromium-bearing versions, although it was not tested yet in our study.

### REACTIVE-SINTERING OF MAGNESIA-RICH BASIC REFRACTORIES

Rahul Lodha, George Oprea and Tom Troczynski\*  
UBCerem, Department of Materials Engineering, University of British Columbia, Canada

Magnesia rich spinel refractory ceramics with Cr<sub>2</sub>O<sub>3</sub> as the spinel forming oxide are used in the non-ferrous industry because of their corrosion resistance against fayalite-type slags, rich in FeO. As the steel industry is not using anymore chromium-bearing Refractories in contact with Ca<sup>2+</sup> containing slags, our objective in this study was to replace Cr<sup>3+</sup> with Me<sup>4+</sup> ions, which along with Fe<sup>3+</sup> could maintain the spinel formation capability with MgO and perform similarly against fayalite slags in non-ferrous furnaces. Our preliminary research studies showed that Cr-free spinels in the MgO-Al<sub>2</sub>O<sub>3</sub>-FeO<sub>x</sub>-Me<sup>4+</sup>O<sub>2</sub> systems could perform against fayalite slags similar to the complex (Mg<sup>2+</sup>, Fe<sup>2+</sup>)O-(Cr<sup>3+</sup>, Fe<sup>3+</sup>, Al<sup>3+</sup>)<sub>2</sub>O<sub>3</sub> spinel, the main corrosion resistant component in the magnesia-chrome refractory ceramics. The incorporation of iron oxide in the MgO-Al<sub>2</sub>O<sub>3</sub>-Me<sup>4+</sup>O<sub>2</sub> 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 of initial trials with stoichiometric mixes, the use of tetravalent cation oxides like tin dioxide (SnO<sub>2</sub>) and titanium dioxide (TiO<sub>2</sub>) 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 behaviour exhibited by Fe<sup>3+</sup> 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 MgAl<sub>2</sub>O<sub>4</sub> spinel. Our findings showed that the incorporation of nano TiO<sub>2</sub> powders reduces the temperature of spinel formation as the diffusion path is shortened and thus activates both synthesis and sintering. Compositions containing 60 wt. % magnesia with alumina, nano TiO<sub>2</sub> and Fe<sub>2</sub>O<sub>3</sub> fired below 1500°C for 3 hours resulted in complete spinel formation and open porosity less than 5%.

### WEAR OF REFRACTORIES AT THE TUYERE LINE IN PEIRCE SMITH CONVERTERS

George Oprea\*, Waiman Lo and Tom Troczynski  
UBCerem, University of British Columbia, Vancouver, BC, Canada  
Joe A. Rigby  
RHI Canada, Burlington, ON, Canada

Our study presents the experimental results on micro structural changes occurring on magnesia-chrome refractories in a nickel-copper converter. The experimental bricks, after use at the tuyere line, were investigated to identify the mineralogical changes due to interactions with the nickel-copper matte or fayalite type slag at the process temperatures. The micro structural changes were correlated with physical and mechanical properties of the brick before and after use and a wear mechanism was suggested. Although the matte does not theoretically react with the mineralogical components of the brick, a partial oxidation of the Ni-Cu sulphides was identified using a line analysis by SEM/EDS in the densified layer at the hot face, which allows for mineralogical changes at the matte-refractory interfaces, with a high probability of micro-crack formation due to the thermal cycling during use. These microcracks were also identified to open through inter-granular fractures parallel to the hot face, which appeared to be the main cause of lost lining during use. The reactions between the fayalite slag and refractory brick could eventually play a role in chemical dissolution of the brick only in the superficial layer at the hot face, as no slag components were identified deep into the brick. The results showed also that the thermal stresses could play through thermal spalling more an important role than the chemical dissolution in the slag in wearing the lining during use.