THERMAL SHOCK DAMAGE ON SELF-FLOW REFRACTORY CASTABLES OF ALUMINA

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ABSTRACT

The objective of this work was to evaluate the loss of mechanical resistance on Self Flow Refractory Castable (SFRC) of 100% alumina after 5 and 15 thermal shock cycles (ASTM C1171) at temperatures of 800, 1000 and 1200ºC. The castable samples were formed by 47.5 wt% of matrix (three fine size particles classes ("-230" and "-500" of tabular alumina mesh size, and CT3000SG of reactive alumina), and 52.5 wt% of aggregate (three different size classes of commercial tabular alumina [0.2-0.6mm], [0.5-1.0mm] and [1.0-3.0mm]). This composition was optimized in previous works done by the authors. To quantify the degradation and the corresponding loss of mechanical resistance the results after thermal shock were compared with previous results (zero cycles) analysed using the Statistica Software (DOE module) to calculate the valid surfaces responses. The variation of the ultrasonic pulse velocity (BS 1881-203:1986) after thermal shock was also determined to calculate the relative variation of the dynamic modulus of elasticity (Edyn). An increasing degradation was verified in the mechanical resistance (MoR) after the thermal shock cycles. Through images obtained using metallographic microscope the degradation effect after thermal shock was qualitatively compared. The results attained in this study were compared with similar SFRC with 1% of aluminate cement (AC).

MOTIVATION

To obtain a Self-Flow Refractory Castable (SFRC) without cement (100% alumina) ...

Why?

- minimum water content;
- no cement and no additives (constant pH, Fibres, MgO and silica free);
- high flowability in the fresh paste (FI, easy to apply);
- high mechanical strength after sintering (MoR).

METHODOLOGY

Commercial tabular alumina T60 (Almatis), available in sizes from 0.3 μm to 3 mm, and reactive alumina CT3000SG (d90= 2.1 μm) were used as raw materials divided in aggregate (coarser size classes) and matrix (<100 μm). Powders in the selected proportions [B] were mixed with water, citric acid, as described in the Portuguese Patent #103432 (2008) [A].

The specimens (25mm×25mm×125mm) without AC (MA) and with 1% of AC (MAC), were casting, drying for 24h, oven-dried at 110 ºC for 24h, and sintered at 1600 ºC, following the specifications of the ASTM C865 Standard.

Cold mechanical strength (MoR) was evaluated as three-point bending strength (ASTM C133) [B].

Resistance to thermal shock was evaluated as described by the ASTM C1171 Standard, as retained MoR after 5 and 15 thermal shock cycles from 800, 1000 and 1200 ºC.

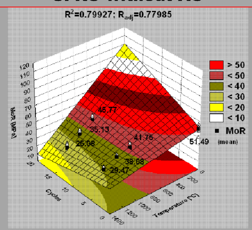
Before and after the thermal shock damage the samples were prepared to observed the damage in micrographic surfaces with magnification of 500x and 1000x [C].

For the experimental results treatment was used the Statistica Software (version 7.0). This tool is important because it allows the prediction of behaviour for this material in others situations (number of thermal cycles and temperature). In statistical validation was analysed:

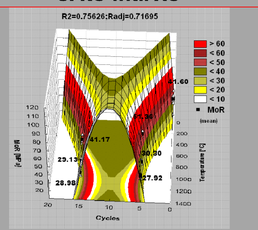
i. Precision of residuals (lower, medians and absolute residuals);
ii. Homogeneity of variance in residual plots;
iii. Independency of the observations (random data values);
iv. Higher values of R^2 and R_{adj}.

Results

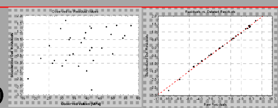
SFRC without AC	SFRC with AC



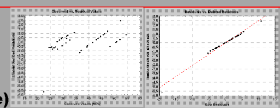
a) Response surface of the mixture MA (linear main eff.+2-ways model)



b) Response surface of the mixture MAC (lin/quad main eff.+2-ways model)

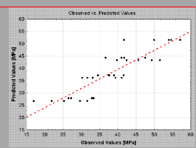


c) d) Residuals plots of MA

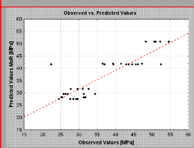


e) f) Residuals plots of MAC

Observed and predicted values for MoR in MA

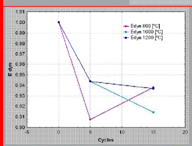


g)

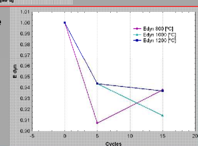


h)

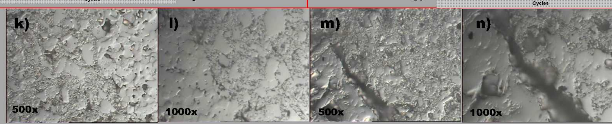
Observed and predicted values for MoR in MAC



i) Variation of the dynamic modulus of elasticity (Edyn) with thermal shock in MA



j) Variation of the dynamic modulus of elasticity (Edyn) with thermal shock in MAC



Micrographic surface of the specimens before (k,m) and after (l,n) thermal shock

FINAL REMARKS

- SFRC without AC after 15 thermal cycles at 1200 ºC shows a mechanical reduction of 51% (fig. a) and with AC, the MoR reduction is 30% (fig. b);
- The valid model adopted for the response surfaces (fig. a and b) is the one, that presents lower variation, random and higher proximity to the ideal line of the residual values (fig´s. c, d, e and f). In the (fig. g and h) it´s possible to see a lower dispersion between the observed values and predicted values in both cases (MA and MAC);
- Dynamic modulus of elasticity (Edyn) without AC (fig. i) after 15 thermal cycles at 1200 ºC shows a reduction of 4% and with AC (fig. j), the Edyn reduction is 6%;
- With micrograph surfaces images it was concluded:
  - The sintering process isn't completed so, it's necessary to review the sintering cycle (fig. k and l);
  - With thermal cycles was observed micro cracks in matrix area and also in interface matrix and aggregate. Inside of aggregate isn't observed micro cracks (fig. m and n).

References:

[A] Pinto, DG; Silva, AP; Segadães, AM; Devezas,TC: *"Influence of surface area in the flowability behaviour of self-flow refractory castables"*, Mater. Sci. Forum., 2010, 636-637: 124-129.

[B] Silva, AP; Pinto, DG; Segadães, AM; Devezas, TC: *"Designing particle sizing and packing for flowability and sintered mechanical strength"*, J. Eur. Ceram. Soc., 2010 (article online).

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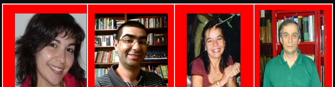
Research team:



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