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High temperature mechanical testing of cordierite porous ceramics

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Abstract – Mechanical behavior of porous ceramic prepared by starch thermogelling (potato and cassava) was evaluated. Green disks were formed by thermogelling of suspensions of talc, kaolin and alumina with addition of starch as consolidator/binder and pore forming agent. Porous cordierite materials were obtained by calcination and reaction-sintering (1330°C, 4h). Mechanical behavior was evaluated in diametral compression at RT, 800, 1000 and 1100ºC. From load-displacement curve (Fig. 2), apparent stress (σ)-strain (ε) relationship was obtained by calculus and mechanical parameters (fracture strength, apparent Young modulus and elastic limit) were determined. The obtained results were analyzed in function of developed microstructures (Fig. 1) and testing temperatures.

Green bodies were formed by thermogelling of suspensions of kaolin, talc and alumina (cordierite precursor mix) with addition of starch as consolidator/binder and pore forming agent. Disks were obtained from stable aqueous suspensions of ceramic powders (29.6 % vol.) and potato or cassava starches (11.5 % vol.) treated at 85°C, 4h. After drying (50ºC, 12h), disks were calcinated at 650ºC, 2h. Porous cordierite materials were obtained by reaction-sintering using a controlled thermal cycling up to 1330°C, 4h.

The characterization of sintered porous materials was carried out by density and porosity measurements by Archimedes method in water and DRX analyses. Cordierite was identified as the main crystalline phases together with spinel. The presence of siliceous glassy phase was also inferred from a low intensity band displayed between 20-30 °2θ. Size distribution and morphology of pores were determined by analysis of images (Image Pro Plus) obtained by SEM (Fig. 1). The microstructure of the material obtained from potato starch exhibited higher porosity associated with large channels (100 μm of mean diameter) while those materials obtained from cassava starch presented lower porosity linked to channels of lower size (≈ 30 μm) [1-2].

Mechanical evaluation of sintered bodies was performed in diametral compression (Instron 8501 servohydraulic testing machine) at different temperatures: RT [1], 800, 1000 and 1100ºC (10°C/min). The tests were carried out in displacement control, using rates between 0.2 and 0.7 mm/min. From load-displacement curve (Fig. 2), apparent stress (σ)-strain (ε) relationship was obtained by calculus. Mechanical parameters: apparent Young modulus (slope of the linear portion of curves), fracture strength (from maximum load), fracture strain and elastic limit (estimated as the stress in which the deviation from linearity was 1 %) were determined for σ-ε curves. The type of fracture was analyzed on tested specimens.

A variation of the material mechanical behavior with temperature was observed. At room temperature, a brittle response was determined, with values of apparent Young modulus, fracture strength and elastic limit higher for disks obtained from cassava starch. As testing temperature increase, the materials became less brittle showing higher deviation from linearity and, as a consequence, larger contribution of plastic deformation. We consider the glassy phase as the main responsible for this behavior, more marked as temperature increased and viscosity of the liquid phase decreased. The presence of this phase was also considered as the main cause for decrease in mechanical parameter values with temperature increase. The differences observed in the behavior of disks obtained from different starches were also related to differences in amount, size and morphology of pores.

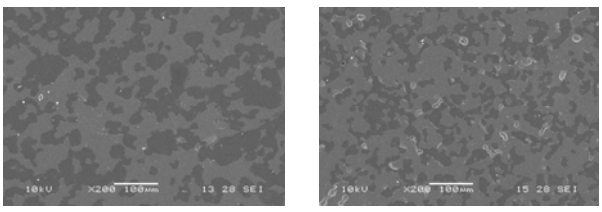

Figure 1: SEM images of microstructures of porous materials obtained from potato (left) and cassava (rigth).

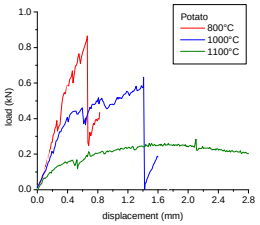

Figure 2: Stress-strain curves for disks obtained from potato.

[1] M. A. Pucheu. “Evaluación mecánica de materiales cerámicos porosos mediante ensayos de compresión diametral”. Tesis de Grado, Ing. Mecánica, UNMdP, marzo de 2009.
[2] M. L. Sandoval, M. Pucheu, M. A. Camerucci, A. G. Tomba M. “Evaluación mecánica de materiales porosos de cordierita obtenidos por consolidación directa con almidón”. Anales 52° Congreso Brasilero de Cerámica, junio 2008, Florianópolis, Brasil.