THERMAL STRESSES IN THE INTERFACE OF Al_2O_3/TiO_2 CERAMIC LAYERS

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Abstract. *Heating or cooling alters dimensions in interface of a Al_2O_3/TiO_2 porous ceramics dual layer composite. Due to materials difference, thermal stresses are induced in the interface. From thermal expansion coefficient variation of each material in porosity function, a porosity gradient with thermal stresses relief can be determined. This work presents a methodology for obtaining Al_2O_3/TiO_2 interfaces with relief of thermal residual stresses. This methodology consists of relating thermal expansion coefficient and thermal residual stresses with porosity gradient. Interface integrity quality in samples with porosity gradient aplication allows to conclude that the method use is viable.*

Keywords: *thermal stress, porosity gradient, Al_2O_3/TiO_2*

1. Introduction

Ceramic materials present interesting properties such as a good hardness, high wear, corrosion and temperature resistance which make them candidates for thermomechanical applications. However, these advantagens are counteracted by ceramics brittleness. Consequently, the presence of small defects such as pores can lead to a dramatic decrease in strength value. However, the use of ceramic composites formed by two layers being one porous and the other dense, Al_2O_3/TiO_2 ceramic layers, can allow an increase in mechanical strength. This paper reports a study of the porosity influence in the thermal residual stresses from thermal expansion coefficients and elastic moduli.

Researchs were already devoted to the study of thermal residual stresses versus thermal expansion coefficients taking into account the differences of materials (Abed *et al.,* 2001). By experimental analysis of the relation between layers thicknesses and thermal residual stresses, the authors propose a critical value to the layer thickness. Moreover, in this work, the composite is constituted by metal and ceramic layers.

In this work, the porosity gradient in ceramic layers is calculated from values of thermal residual stresses.

The elastic modulus was obtained from the equation proposed by Hasselman (Hasselman , 1962) as follows:

$$E = E_0\left[1 + \frac{AP}{1-(A+1)P}\right]$$

(Equation 1)

Where A is a constant that depends of processing technique and E_0 is the elastic modulus to zero porosity. For cold pressing, A is equal to – 4,16. Finally, *P* is the porous fraction of material.

The thermal residual stresses (σ_R) were obtained by:

$$\sigma_R = E.\alpha.\Delta T$$

(Equation 2)

Where *E* is the elastic modulus, α is the thermal expansion coefficient and ΔT is the temperature difference.

2. Materials and Methods

2.1. Materials

In this work were utilized:
- alumina from Alcoa A16SG powder;
- titanium dioxide from DUPONT powder;
- corn starch produced by REFINAÇÕES DE MILHO BRASIL.

2.2. Samples for measurement of thermal expansion coefficient

Samples of Al_2O_3 were shaped by uniaxial pressing from powder and then sintered to 1600 °C by 1 hour in order to produce a wide range of porous samples (from 35% down to 5% of porosity in volume). The pressure utilized in the hydraulics press was 40 MPa. The pores were formed in function of corn quantities added to ceramic powder and the porosity level was measurement by Archimedes' method. The dimensions of samples is shown in Fig. 1.

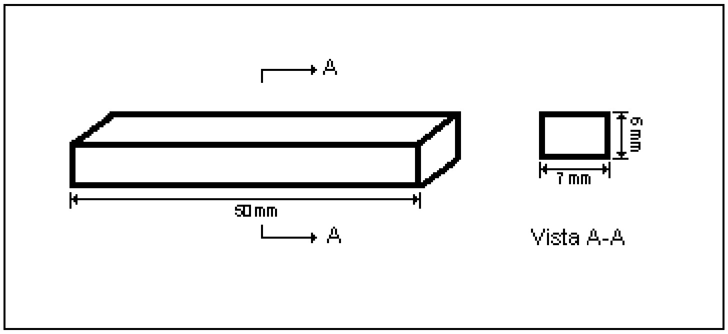

Fig. 1 – Dimension of samples for thermal expansion coefficient determination.

2.3. Experimental device

We have chosen to use a device to calculate the thermal expansion coefficient to a variation of temperature of 1000°C. This device was a RB-3000 thermal analysis system produced by BP Engenharia (Campinas, Brazil).

2.4. Ceramic compacts with porosity gradient

Ceramic composites were fabricated by uniaxial pressing using a porosity gradient. These ceramic composites are constituted by one layer of Al_2O_3 and other of TiO_2. In the Al_2O_3 layer is employed a porosity gradient from thermal residual stresses values. The process of mixture of powder to the layers was the same utilized in the specimens for thermal expansion coefficient testing. The pressure utilized in the hydraulics press was also of 40 MPa.

3. Results and discussion

3.1. Thermal expansion coefficient

The thermal expansion coefficient values (α) to the alumina are showed in Fig. 1.

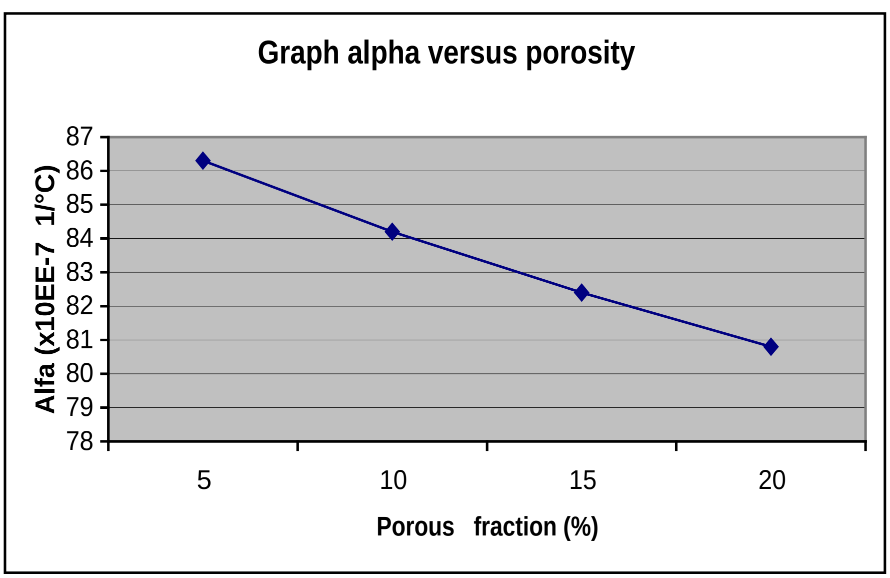

Fig. 1 – Thermal expansion coefficient versus porosity behaviour.

3.2. Young modulus calculation

From equation proposed by Hasselman (1962) the Young modulus is calculated and the values to each Al_2O_3 sample is shown in Fig. 2.

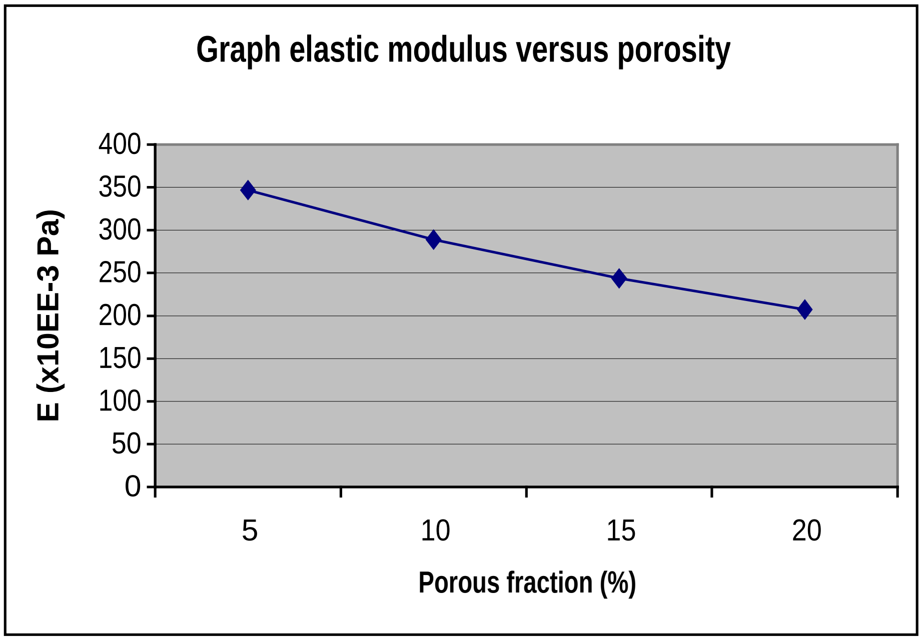

Fig. 2 – Elastic modulus versus porosity.

3.3. Thermal residual tension

The thermal residual stresses versus porosity to the alumina is showed in Fig. 3.

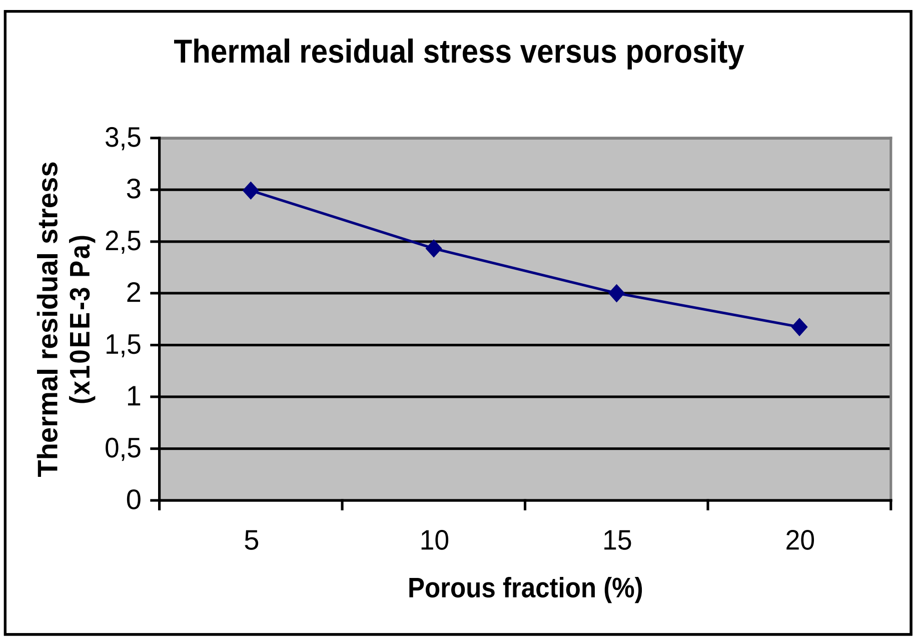

Fig. 3 – Graph thermal residual stresse versus porosity

3.4. Interface between the layers

The figure 4 shows the interface between the layers in the ceramic compact with porosity gradient. This ceramic compact is formed by four layers with 1.5 mm of thickness each one.

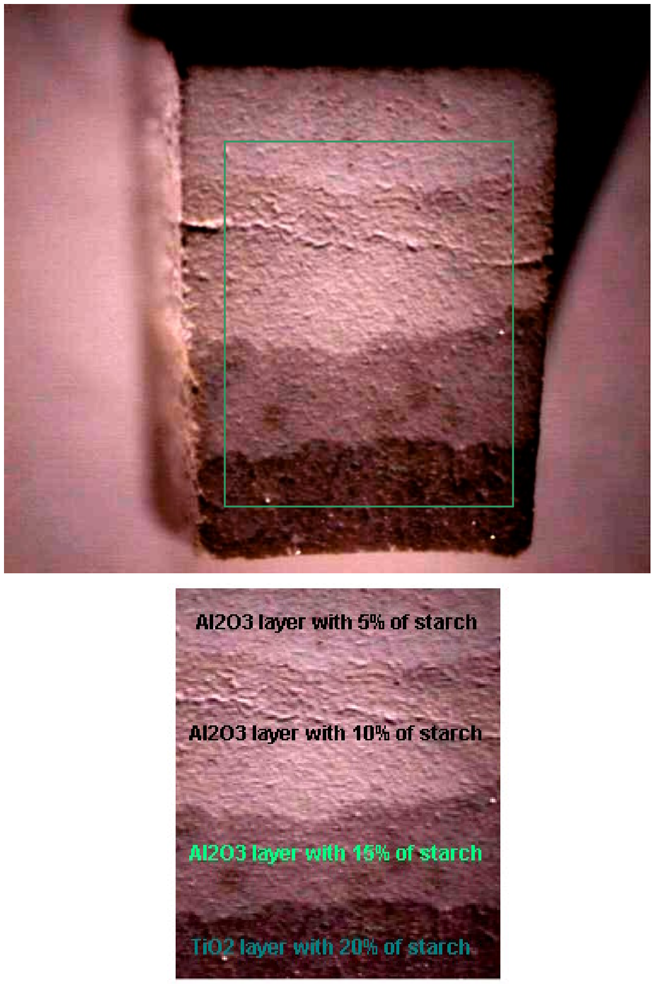

Fig. 4 – Interface between the layers in the ceramic compact. The image in distinction shows the adhesion between the layers.

4. Conclusions

The increase of porosity in Al_2O_3 layer causes a decrease in thermal residual stresses.

Al_2O_3/TiO_2 compact formed from a porosity gradient in the Al_2O_3 layers presented absence of crack and total adherence between the layers.

Interface integrity quality in samples with porosity gradient aplication allows to conclude that the method use is viable.

4. References

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Hasselman, D. P. H., 1962, “On the porosity dependence of the elastic moduli of polycrystalline refractory materials”, J. Am. Ceram. Soc., 45, pp. 452-453.

5. Responsibility notice

The authors are the only responsible for the printed material included in this paper.

6. Acknowledgements

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