Tubular Ceramic Foam Via Polymeric Sponge Method

S. M. Sharif, Z. A. Ahmad, M. R. Othman

Abstract: Tubular ceramic foams were prepared by using natural clay as starting material and 120 ppi polyurethane foam as template via polymeric sponge method. Samples were sintered with different temperatures from 1200°C to 1280°C. The result shows that 1250°C is the ideal sintering temperature where the highest compressive strength of 1.980MPa at 47.31% porosity is obtained. The highest value in compressive strength and the lowest percentage in porosity are attributed to the higher apparent density and crystallinity. These results lend support to the idea that the sintering temperature is important for the processing of tubular ceramic foam.

Index Terms: compressive strength, density, porosity, sintering temperature, tubular ceramic foam.

1 Introduction

Ceramic foams also denoted as reticulated porous ceramic, cellular ceramic, open-cell ceramic, ceramic sponges, solid sponges are special classes of porous materials comprised of cells with size ranging from a few microns to a few millimeters, where the cells can be surrounded by ceramic walls or contain solid material at only cell edges (struts), thus creating an interconnected structure (open cell foam) [8]. This special material has been used as a membrane, absorbents, kiln furniture, catalytic converter, insulation, biomedical devices and as core materials for sandwich construction [2, 6-7, 11] as well for water purification or filtration [1]. The most conventional method to produce ceramic foam is the polymeric sponge method or the replica technique which involved a polymeric sponge coated with ceramic slurry and then dried and sintered at certain temperature [6]. The schematic figure of polymeric sponge method was depicted in Fig. 1.

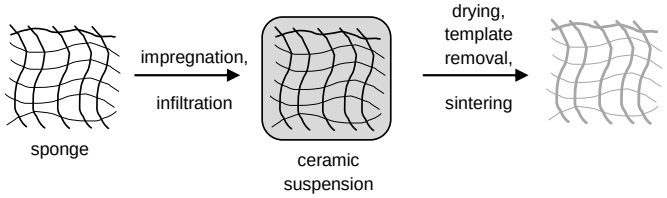

Fig. 1: Schematic drawing illustrating the polymeric sponge method.

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The basic idea of this paper was to prepare structures that were built up by ceramic tubular foam with a fixed diameter. Natural clay was chosen as the starting material using the polymeric sponge method because of its properties such as high temperature stability, high strength and resistance to chemical attack. The relationship between linear shrinkage, density, porosity and strength of sintered products with different temperature were discussed in this paper in addition to phase analysis.

2 Experimental Details

2.1 Sample preparation

The steps for the produce of tubular ceramic are as follows: PU foam with a pore size of 120 ppi was immersed in ceramic slurry with 25wt% solid content (porcelain) and was compressed whilesubmergence in order to fill all the pores. The sponge containing the slurry was form in tubular and dried in an oven at 110°C for 18 hours. The sample was sintered in a furnace at the different temperatures from 1200, 1225, 1250, 1265 and 1280°C and heating rate of 5°C/min, respectively with 2 hours holding time.

2.2 Characterization

The phase analysis was determined using X-ray diffractometry (XRD). The compressive strength was measured using a Universal Test Machine with a crosshead speed of 0.5mm/min and calculated the load at fracture by cross-sectional area. Sintered density and porosity were measured by the water immersion method or Archimedes method. The linear shrinkage of samples during the course of heating was determined using the following equation:

$$shrinkage = \frac{\ell_g - \ell_p}{\ell_g} \times 100\% \quad (1)$$

Where $\ell_g$height of green disc and ℓ_p is the height of the fired product.

3 Results and Discussions

Mullite and quartz were the two crystalline phases obtained on the XRD of ceramic foams sintered at 1200, 1225, 1250, 1265 and 1280°C. As shown in Fig. 2, when the sample was sintered at 1200°C, quartz content was more abundant than the mullite. The mullite peaks became more dominant and more intense when the samples were sintered at 1225, 1250 and 1265°C. The same study for sintering temperature 1280°C

shows that the mullet was becoming extinct at a certain phase. As reported in [3, 5, 9], generally in ceramic composition, increased temperatures result in the higher mullite formation, thereby improving mechanical properties. However, it has been observed that, at even higher temperatures, mullite crystals become coarse, consequently decreasing strength.

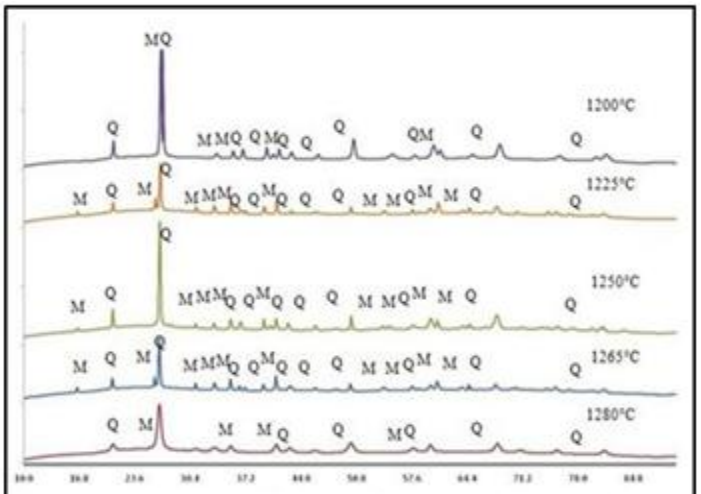

Fig. 2: XRD patterns of the ceramic foams at different sintering temperatures. (Q = quartz, M = mullite)

Fig. 3 shows the compressive strengths and densities of ceramic foams sintered to different temperatures (1200, 1225, 1250, 1265 and 1280°C). The compressive strength gradually increased together with the density of ceramic foams as the sintering temperature increased at 1200, 1225 and 1250°C. It was established that the high compressive strength, 1.980MPa was also attributed to the higher apparent density, 2.773gcm-3 at 1250°C. Above a 1250°C sintering temperature, the compressive strength began to decrease as low as 1.269MPa at 1280°C.

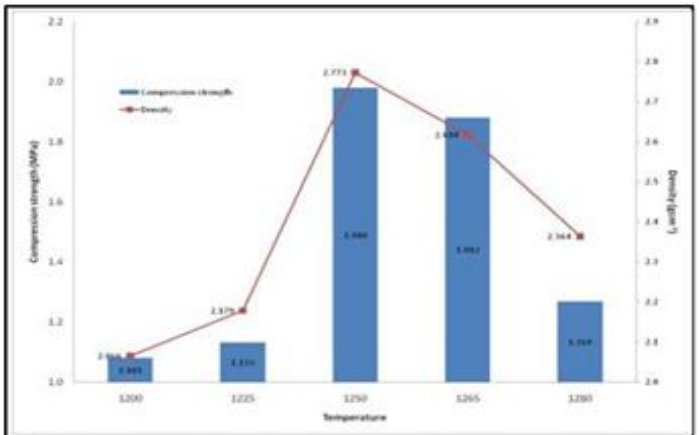

Fig. 3: Compressive strength and density of ceramic foams sintered at 1200, 1225, 1250, 1265, 1280°C.

Fig. 4 shows the percentage of porosity of samples after sintering to different temperatures (1200, 1225, 1250, 1265 and 1280°C). The porosities decreased with the increase of sintering temperature at 1200, 1225 and 1250°C but the grains grew up and have more contacting areas which become the main reason is causing the improvement of compressive strength. After 1250°C, the porosities of samples increased gradually due the growth of a few grains which was caused by overfiring. The overfiring usually results in decreased in strength, so that the sample sintered to 1265°C has a lower compressive strength than that of 1250°C.

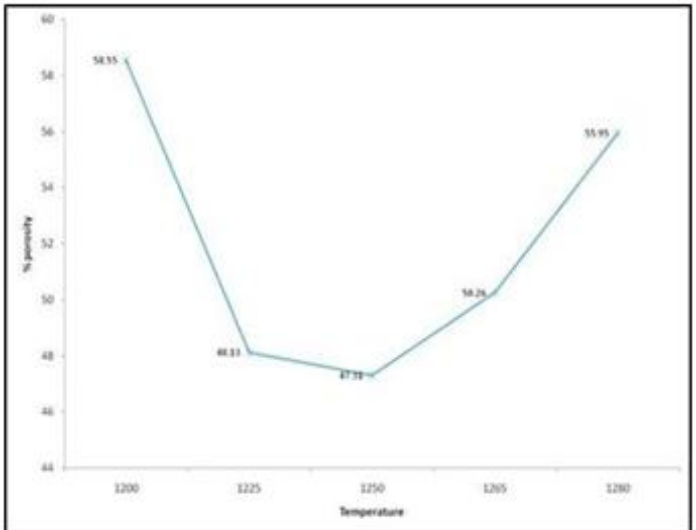

Fig. 4: Porosity of samples sintered to 1200, 1225, 1250, 1265 and 1280°C.

The linear shrinkage of samples sintered at 1200, 1225, 1250, 1265 and 1280°C are shown in Fig. 5. The linear shrinkage values increased in the range of 13.01 to 16.67% from 1200 to 1250°C and after 1250°C its values decreased. These results definitely as support to past studies by [10] that suggest as the PU sponges were removed; the particles were initially packed loosely, approached and contacted. The removal of PU sponges left holes in the center of webs as schematically shown in Fig. 6. During the sintering process, these holes which became the source of void would move from the center to the outer and the particles moved to internal surface of webs. The holes in the center of the webs became smaller and led to the shrinkage of foams. The shrinkage became intensive with the increase of sintering temperature. The shrinkage of holes and webs led to the decrease of porosity at sintered temperature 1200 to 1250°C. When the samples sintered to 1265°C, a few grains grew very large which was caused by overfiring.

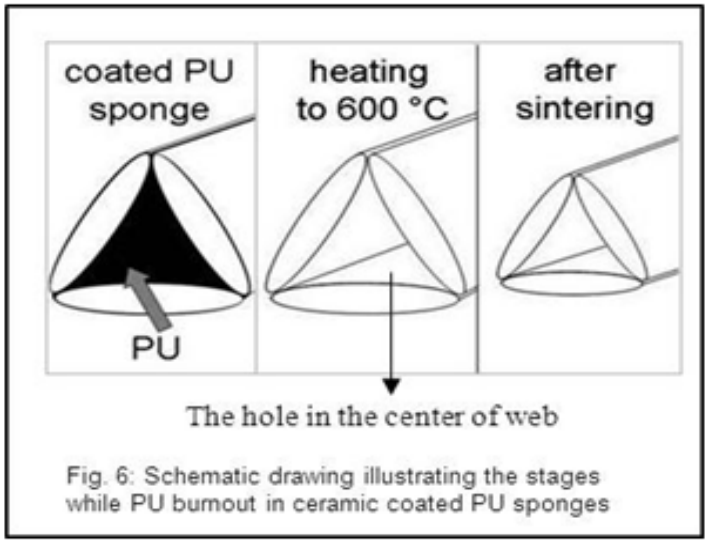

Fig. 6: Schematic drawing illustrating the stages while PU burnout in ceramic coated PU sponges

5 CONCLUSION

The results of this study show that the suitable sintering temperature to produce tubular ceramic foam via polymeric sponge method is 1250°C. At this temperature, the sample obtains the highest compressive strength 1.980MPa and the highest density of ceramic foam 2.773gcm-3 due to the lowest percentage in porosity 47.31%. It seems clear that based on XRD analysis, the mullite phase became more intense at this sintering temperature results in the higher mullite formation, thus improving its mechanical properties. But, as sintering temperature increased to 1265°C, the porosities of samples increased gradually due the growth of a few grains which was caused by overfiring. At higher temperatures, mullite crystals become coarse, consequently decreasing the compressive strength of tubular ceramic foams

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