PREPARATION OF CERAMIC FOAM BY SIMPLE CASTING PROCESS

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Abstract: A simple direct foaming and casting process using ovalbumin based aqueous slurries for fabricating alumina-zeolite ceramic foam was demonstrated. 50 to 90 vol.% of alumina was used with zeolite of clinoptilolite type. Meanwhile, yeast was used as pore former agent and ovalbumin as a binder to bind the particles and encouraging foam formation. A ceramic foam with 90 vol.% of alumina showed the highest porosity 65.09% and pore size up to 106 µm. The performance and utilization of these ceramic foams manufactured using this method may have a potential use in a range of applications including catalysis and filter.

Key Words: ceramic foam/yeast/ovalbumin/porosity/casting

1. INTRODUCTION

Ceramic foams are porous brittle materials with closed, fully open, or partially interconnected porosity. Ceramic foams are made from a wide range of ceramic materials; both oxide and non-oxide are being considered for the whole range of potential applications. These include catalysis, filtration, thermal insulation, impact absorbing structures, high specific strength materials, performs for metal-ceramic composites, biomechanical implants, and high efficiency combustion burners [1,2].

Protein such as ovalbumin has been used for the foaming and setting of aqueous ceramic powder suspensions for the preparation of porous ceramics. Overall porosity and foam microstructure could be controlled through ceramic solid loading, ovalbumin amount, foaming time and sintering temperature [1].

Engineered foams have cellular structures which are categorized as either open cell or closed cell foams. Foam consists of an assembly of irregularly shaped prismatic or polyhedral cells connected to each other with solid edge (opened cell) or faces (closed cell). Engineered foams have been manufactured from polymers, metals, glasses and ceramics. Ceramic foams are a special class of porous materials comprised of large voids (cells), with linear dimensions in the region of 10 µm to 5 mm [2].

Closed cell ceramic foams are commonly used for thermal insulation and fire protection materials. Meanwhile, open cell ceramic foams are used for metal melt filtration, hot gas filtration, diesel engine exhaust filters and other range of applications. Due to these and future potential application, there is a need to develop improved processing techniques of ceramic foams [2,3].

Ceramic foams have so far been produced in a variety of materials with various cell sizes, densities and degree of interconnectivity. Foams are usually produced with the density between 10 and 40% of theoretical and the pore sizes between 100 µm and 1 mm. The majority of the development work was carried out on a fine grained α-alumina, before moving on to alternative materials [4].

Porous ceramics are produced in many ways such as the infiltration of reticulated polyurethane which performs with aqueous particulate ceramic slurries. Another method is the use of insoluble organic fugitive materials in ceramic suspensions, which the burnout leaving the porosity. This method requires a large amount of fugitive materials in order to produce highly porous bodies. The mostly used fugitive materials are starches, carbon black and sawdust. Besides that, a fused deposition method has been used to produce porous mullite bodies [1].

In this study, a simple direct casting route is applied to produce ceramic foam with the use of alumina, zeolite and other organic binder materials.

2. EXPERIMENTAL

Alumina powder with the mean particle size of 77.89 µm and zeolite particle size of 45 µm were used in this study. The alumina loading used for the preparation of zeolite ceramic foam was in the range of 50 to 90 vol.% with 10 to 50 vol.% of zeolite (clinoptilolite). Ovalbumin (freshly extracted from the white egg) was added as a binder to the mixture after mixing. 30% yeast was used as a pore former in this ceramic foam. The slurries was cast into the mold and allowed to foam. The foam were simply dried under the room temperature. After that, the process was followed by the sintering at 1500°C for 2 hours with a ramp of 2°C/min. The sintering process of the samples was performed in the temperature programmable furnace. The sequence of operation for preparing ceramic foam is depicted in Figure 1. The sintering profile of ceramic foam is shows in Figure 2. Mechanical properties such as compressive strength and flexural strength were determined by using Autograph AG-I Universal Testing Machine. The speed rate of 0.5 mm/min was used for the compressive strength test. As for the flexural strength test, a load was
applied at a cross head speed of 1.0 mm/min. The porosity and bulk density were measured by Archimedes principal.

3. RESULTS AND DISCUSSIONS

3.1. Porosity and Density

Porosity is the dominant factor affecting the performance of ceramic materials. Figure 3 shows the graph of apparent porosity versus alumina loading. As seen in Figure 3, the apparent porosity open pore decreased slightly between 50 vol.% and 60 vol.% of alumina loading. From the past research, the use of different starting alumina compounds, the choice of sintering temperature and hold time, as well as heating rate, and the introduction of sintering aid provide the opportunity to control the formation of pores size and porosity distribution in the wide range. The shrinkage during the sintering process tends to the simultaneous decrease of the porosity of the sintered samples [5].

The porosity increased with the increasing of 60 to 90 vol.% alumina loading and provided the maximum porosity of zeolite-alumina foam at 65.09%. Previous studies indicated that the open porosity in alumina foams increased with the increment of total porosity owing to the increased number of interconnections between cells. It indicates that the cell size in ceramic foams is very sensitive to the baking condition and accelerates the cell coarsening [6].

Overall, the bulk density of alumina foams decreased with the increasing of alumina loading. On the other hand, the bulk density of sample increased slightly from at 80 vol.% of alumina. After this, it decreased slightly to 1.20 g/cm³ at 90 vol.% of alumina. This dramatic change was caused by heterogeneous of the samples which lead to the coarsening of cells particle [7].

3.2. Pore Size Analysis

Figure 4 and 5 are the SEM micrographs of ceramic foam with 80% and 90% alumina loading. These micrographs show the ceramic foams have two type of pores; larger pores having sizes in the range of 80 µm to 114 µm and smaller pores with the size ranges from 30 µm to 40µm.
Sintered alumina foam obtained by casting method consisted of pores with different sizes caused by non-uniform size of the bubbles produced in the reaction. High sintering temperature at 1500 °C caused phase transformation in the alumina foam and grain growth resulted in surface morphological changes [8].

3.3 Flexural Strength

Figure 6 shows the graph of flexural strength versus alumina loading. Flexural strength increases from 3.76 MPa at 50 vol.% of alumina up to 4.52 MPa at 60 Vol.% of alumina. After that, it decreases slightly until 2.77 MPa at 90 vol.% of alumina loading. The changes in flexural strength can be related with the increasing and decreasing of porosity in sintered alumina foam.

Porosity has a significant role to influence the flexural strength of sintered alumina foam. Figure 7 shows the effect of porosity on flexural strength for the sintered alumina foam. The flexural strength is inversely proportional to the porosity [6]. Previous works indicated that changes of foam strength as a result of grains grew up that led to the foam had more contacting areas which became the main reason for causing the improvement of foams strength at that time.

3.4 Compressive Strength

A graph of compressive strength versus alumina loading is shows in Figure 8. The testing results for ceramic foams with alumina loading between 50 vol.% and 60 vol.% show that the compressive strength of sintered foam increase from 0.22 MPa up to 0.47 MPa. The compressive strength decrease drastically to 0.11 MPa at 70 vol.% of alumina loading and the strength continued to decrease slowly until 0.06 MPa at 90 vol.% of alumina loading.
Previous investigations indicated that an increase of compressive strength could be interpreted as the effect of slurry viscosity. In this study, ovalbumin was used as the binder. The viscosity of slurry for 60 vol.% of alumina was high maybe due to the chemical reaction, introduce certain compounds into the slurry to modify its viscosity and increased its compressive strength [8].

The decreasing of compressive strength from 60 vol.% to 90 vol.% of alumina loading not only resulted from the energy losses due to foam alignment, but also from the surface cracks which particularly enhanced by the contaminants during the process. Furthermore, the size and arrangement of pores in alumina foam also affect its strength. As the larger and more numerous the pores, the thinner must be the enclosing walls of the solid material [8,10].

4. CONCLUSION

A preparation of ceramic foam using yeast as an organic pore former and ovalbumin as a binder was successfully demonstrated through a simple casting process. Sintered ceramic foam showed large (80-114μm) and small pores (30-40μm). Based on the results obtained, 80 and 90 vol. % of alumina loading were the suitable composition to fabricate ceramic foam which able to produce 62% to 65% porosity. Therefore, this ceramic foam has an important potential of development as catalysis and filter. Nevertheless, many others applications may emerge in the near future.

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6. REFERENCES