Effects of brass addition on the flexural strength and microstructure of porous clay/brass composites

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Abstract. Porous clay/brass composite was fabricated by an extrusion process with the addition up to 40 wt.% brass has been successfully done. Clay 80 wt.%, TiO_2 10 wt.%, active carbon 5 wt.%, and polyvinyl alcohol 5 wt.% have been prepared as a matrix for this study. All of wt.% has been mentioned excluding solvent water 20 wt.% and lubricant (glycerin oil, 1 wt.%). Before the moulding process, all the raw materials were mixed to obtain homogeneity. Blending process was done by adding 20 wt.% water until the mixture turned into dough. After the moulding process, the specimens were dried at room temperature for 48 hours, and then they were sintered at 800°C for 1 hour in an electrical box furnace with heating rate 1°C/min and holding time of 1 hour. The flexural strength of specimens and the microstructure of the sintered porous bodies were also investigated. The addition of 20 wt.% brass on the composite materials showed a higher on the strength, that is 0.6 MPa and 0.38 MPa on yield strength.

1 Introduction

One of the most widely used materials in the industry is a porous material. Porous materials were used as filtering and membranes. Generally, porous materials were produced from polymer, metal, ceramic and composite materials with various techniques. However, the membrane of the ceramic-based composite material has more coverage in various fields, such as for water and energy sustainability [1] water treatment and desalination [2] and separation process in chemical industry [3-5]. Some advantages of the ceramic membranes are (1) more effectives as disinfection precusor removal and (2) having higher permeability compared with equivalent polymeric membrane [6].

The commercial ceramic membranes are generally manufactured from industrial oxides such as Al_2O_3 and SiO_2 exhibiting good mechanical, chemical and thermal resistance and a long lifetime, but their cost are relatively higher. In order to reduce their cost, research has been oriented to manufacture the ceramic membrane using cheaper raw materials [7] [8], such as local materials [9-12] and waste materials [13-15]. In addition, the selection of manufacturing methods also affects production costs. For mass production, the extrusion

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method is preferred. Extrusion method is a simple, important, and the mass production method of producing ceramic membranes. It has been extensively used for the fabrication of porous ceramic tubes. In this method, a homogeneous stiff paste is forced through a nozzle to be compacted or shaped to form the final green membrane. To keep the membrane in its desired final shape, any remaining binder, solvent, and plasticizer should be evaporated [16].

2 Material and methods

2.1 Raw materials

The raw materials used in this study were clay, TiO_2, black carbon (BC), polyvinyl alcohol (PVA) and brass powder. They were similar as our research in the manufacture of porous ceramic membranes for micro-filtration [17]. This study is the subsequent effort of the previous studies related to porous ceramics [18], [19]. All materials were obtained from local place, Indonesia, except PVA which was imported from China. The clay from Pekalongan, Central Java, was used as a matrix in the manufacturing of samples (Table 1). These clays are representative and widely used by ceramic plant for the production of clay-based structural ceramics.

The reinforcement of composite material in this work is brass waste from craftsmen in Juwana, Central Java, Indonesia. Previously, the brass waste was carried out by sieving and drying treatment in order to obtain the material without impurities. After sieving using 100 mesh, the waste was sieved again by using 120 mesh. The material still left in 100 mesh was used as a composite reinforcement. After that, the brass powder was dried at 150°C for 2 hours.

Table 1. Chemical composition for each raw material used in this study

Element	Compound (%)				
	Clay	TiO_2	BC	PVA	Brass
C	16.96	-	75.49	95.91	3.29
O	38.39	40.58	8.98	0.87	20.38
Mg	-	-	0.53	-	-
Al	1.49	2.48	1.80	-	1.33
Si	1.74	0.67	4.05	-	0.66
Cl	-	-	0,49	-	-
K	-	-	2.57	-	-
Ca	-	-	1.47	-	-
Ti	-	56.26	-	-	-
Fe	-	-	1,82	-	-
Cu	-	-	2.13	3.90	57.07
Zn	-	-		-	20.33
Na	2.44	-	0.65	0.65	-

2.2 Sample preparation

The flexural strength for a range firing schedule of brass powder additions was determined for 10 test-samples. All specimens were prepared according to the standard of flexural strength testing based on ASTM Standard C158-95 [20]. While the raw materials used to make specimens were based on this study [21]. First, all raw materials except brass were sieved through 100 mesh. After that, they were mixed according to the comparison in Table 2. The addition of brass was done after the X material has been made. The X material consists of clay 80 wt.%, TiO_2 10 wt.%, BC 5 wt.% and PVA 5 wt.%. The mixing process of 1 kg raw materials was done by using ball milling for rotational speed of 62 rpm for 1 hour. The next stage is the manufacturing of ceramic green body.

The process of making a green body was prepared using a dough of raw materials by adding the water as much as 15 wt.% of the raw material mixture. To obtain a homogeneous dough, a blending process was performed at 62 rpm for 1 hour. After that, the dough was printed using the extrusion method. The extrusion punch emphasis was made of 25 MPa.

After waiting for 24 hours at room temperature, a green body was inserted into the furnace for sintering process. The sintering process was set at a temperature of 800°C (heating rate of 5°C/min and holding time for 1 hour). After that, the temperature was decreased by turning off the furnace switch. Once at room temperature, the specimen was machined for surface finishing.

Table 2. The composition of the materials used in this study

Abbreviation	Clay (wt.%)	TiO_2 (wt.%)	BC (wt.%)	PVA (wt.%)	Brass (wt.%)
A	80	10	5	5	0
B					10
C					20
D					30
E					40

2.3 Flexural strength testing

Flexural strength testing was based on ASTM Standard C158-95. Testing was done by using Universal Testing Machine (Zwick, Germany) at a crosshead speed of 1 mm/min until failure. The specimens were tested at ambient temperature and dimensions were measured with a digital micrometer (Mitutoyo, Germany) heaving precision of 0.01 mm.

The sample holder for the flexural strength test comprised three tempered steel balls with a diameter of 15 mm. The steel balls formed an equilateral with an edge length of 25 mm and the ball support degree was 135°. The load was applied to the center of length on the top specimen by using a plunger with a diameter 1.3 mm until failure. The flexural strength was calculated according to the formula of Three-point bending (Eq. 1) [22] (P = load (N); L = distance among the support (mm); B = width of the specimen (mm) and W = high specimen (mm)).

$$\sigma_{MOR} = \frac{3PL}{2BW^2} \qquad (1)$$

2.4 Scanning electron microscopy (SEM)

Scanning electron microscopy (AVA MM 20, Germany) was used to observe the specimen surface (15 kV, 150 mA, the working distance of 10-15 mm). The specimens were ultrasonically cleaned (Sonorex RK 100 H; Germany) and gold coated (sputter coater SC76, Newhaven) before the SEM examination.

3 Results

The result of the flexural strength test used three-point bending method can be shown in Figure 1. Based on the data, the flexural strength of specimens has increased with the increasing of brass content up to 20 wt.%. After that, the flexural strength has decreased. The highest flexural strength occurs in 20 wt.% of brass which was 0.6 MPa and the yield was 0.38 MPa.

The SEM images are shown in Figure 4. The addition of brass content of ceramic materials indicates a decrease in the number of porosities (Figure 2) and an increase of density (Figure 3) . This is apparent in SEM images from various brass additions. With the decline of porosity, it can affect the magnitude of flexural strength composite material.

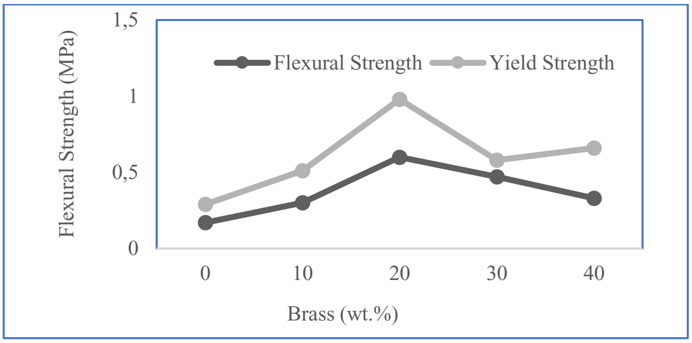

Fig. 1. Flexural strength of sintered specimen.

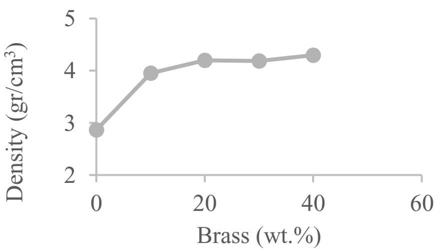

Fig. 2. Density of sintered specimen.

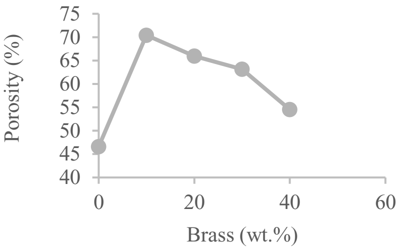

Fig. 3. Porosity of sintered specimen.

4 Discussion

The flexural strength of composite is increased by brass addition due to the higher tensile strength of brass compared with the matrix materials. The addition of brass was able to reduce the porosity of specimens, as can be observed from SEM results (Figure 4).

The observations of brass composite materials by using SEM show that the addition of 20 wt.% brass is indicated as the maximum of porosity (Figure 3). The addition of brass to ceramic materials (Clay, TiO_2, BC, and PVA) could influence the magnitude of the porosity of the composite material. The surface ratio between the composites without brass and the materials with the addition of 10 wt.% brass showed a significant difference. The addition of brass was able to change the surface became decreasing of porosity. While the addition of more brass showed subtle change of density. If the surface of the SEM result was observed further that the addition of more than 20 wt.% brass indicated the decreasing of porosity but had lower flexural strength. Addition of brass more than 20 wt.% was already able to change the natural properties of ceramic (brittle) in this study. This is supported by some previous research [23-25].

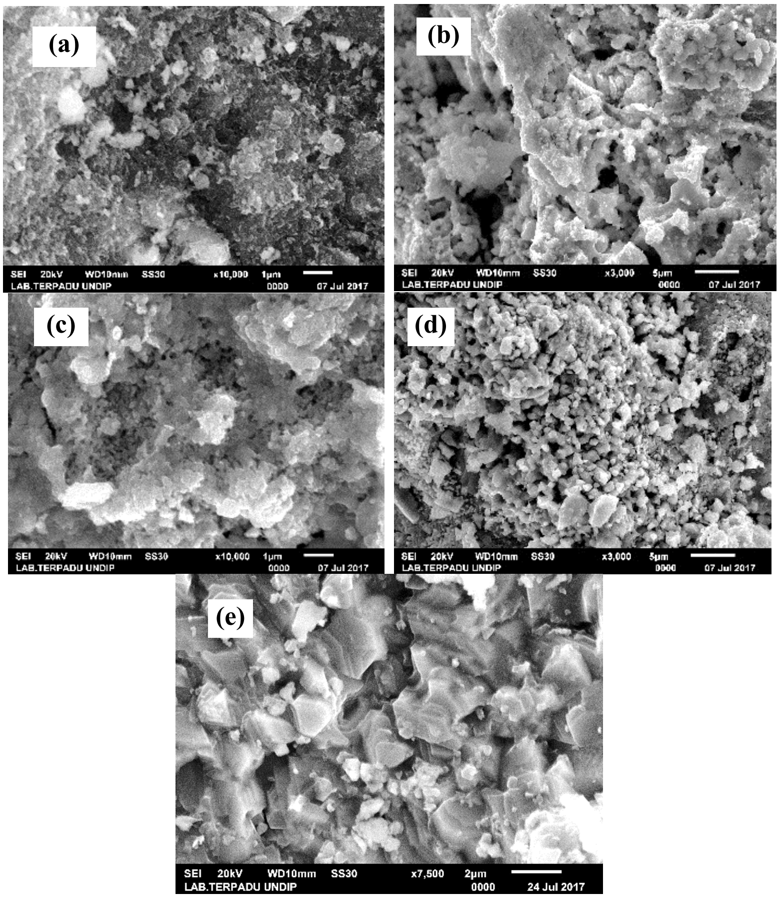

Fig. 4. SEM micrographs of addition of brass (a). 0 wt. %, (b). 10 wt. %, (c). 20 wt. %, (d). 30 wt. %, (e). 40 wt. %.

5 Conclusions

Based on the data, that the flexural strength material has increased with the increasing of brass content up to 20 wt.%. After reached 20 wt.% of brass content, the flexural strength of sintered specimen has decreased with increasing brass content.

The highest flexural strength is observed in 40 wt.% brass with 25.70 MPa. The increase of brass content in the ceramic matrix can decrease the amount of porosity so it potentially of composite.

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