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PRODUCTION AND CHARACTERIZATION OF ALUMINA BASED CERAMIC FILTER BY USING SIMPLE SPONGE

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Abstract

Sponge commonly use in daily life for door-window isolation was preferred rather than special sponges due to economic reasons. Samples were prepared in three different groups; mainly Alumina-polyvinyl alcohol (ALPA-Group), Alumina-manganese oxide (ALMO-Group) and Alumina and bentonite (ALBE-Group) raw materials. Sponge was immersed into mud prepared in three different groups and then it was dried in the oven and sintered at different temperatures. The filters obtained after sintering underwent metallographic analyses as well as physical tests such as unit volume weight, shrinking in length, water emission analysis, porosity and corrosion tests. According to the experimental studies, simple sponge was found out to be inappropriate for filter production, ALPA-Group and ALBE-Group test samples preserved their properties up to 1550˚C whereas ALMO-Group sample was observed to experience deformation at 1450˚C. When the results of all tests and analyses applied to the samples are assessed, for ceramic filter usage ALBE-Group test sample which was sintered at 1550˚C have more appropriate properties than others.

Key Words: Filter, ceramics, sponge, sintering, sample

1. Introduction

Inclusions occurred during casting lead to unwanted residuals. These inclusions cause several disadvantages, deficiencies and negativities. Such problems as inclusions due to casting deficiencies will do substantial harm to the casting to be performed and samples generated as a result of casting. In filter usages performed for casting applications, “filtering” technique was used initially to remove metallic or non-metallic impurities from the environment. The first filters produced as a result of this were used to filter simple and big particles, and for liquids as well [1].

After filters were started to be used for filtration, ideas were put forward to use them for wide liquid applications. The leading ones were “Cellular” and “Foam” filters. Cellular Filters were used in several applications from aluminum and metallic with low fusing temperature to super alloys. These filters used in casting filtration are also used in wood stoves, automotive and industrial pollution controls and catalytic combustion products in different forms due to its regular structure [2].

Foam filters are used in the production of several delicate components in plane and space industry due to the fact that it has a high fusing temperature like 1800˚C. Therefore, foam filters have many advantages, high porosity, irreversible liquid flow characteristic and flow without residue. Foam filters are produced mainly with aluminum oxide or zirconium oxide characteristics besides those produced with SIC compositions. These show chemical conformity to liquid composition which can be regarded as an advantage [3,4].

2. Material and Method
2.1 Material

Alumina oxide is one of the most commonly used ceramic materials, because of preservation its chemical,

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electrical and mechanical properties even at high temperatures. It costs rather low and can be produced easily through fabrication [5-7].

In this study, Alcoa CT 3000 SG alumina was used as raw material. The physical and mechanical properties of Alcoa CT 3000 SG alumina are shown in Table 1 [8,9].

In the studies carried out, Manganese Oxide and bentonite were used to reduce the burning temperature. Pyrolusite, psilomelane and manganite are the most common minerals in nature with Manganese Oxide combination [10].

Table 1. The physical and mechanical properties of Alcoa CT 3000 SG alumina [8,9].

Material	**Alcoa CT 3000 SG alumina**
Surface area [m^2 / g]	6.0 – 8.0
Primer crystal grain size [μm]	0.6
Grain size, Cilas D90 [μm]	1.5 –2.5
Grain size, Cilas D50 [μm]	0.6 – 0.8
Wet density [g /cm^3]	2.25
Burnt density 1450˚C / 1 h [g /cm^3]	3.90
Burnt density 1670˚C / 1 h [g /cm^3]	3.92

Bentonite used in the tests was obtained from bentonite deposit in Demirli Village in Eskisehir (Turkey). The bentonite in the region has been formed by the dissolution of rhyolitic and rhyodacitic tuffs [11].

2.2 Method

2.2.1 Preparing the Sample

There are several stages to produce Ceramic Foam Filter. These stages are selecting the foam, preparing the ceramic mud, immersing the sponge into ceramic mud, drying the muddy sponge, removing the sponge from the muddy sponge and sintering [12, 13].

2.2.2 Selecting the Foam

The most important points to be considered while selecting the sponge to be used for making Porous Ceramic Filter are the number of pores, flexibility and the ability of the sponge to vaporize (evaporating by combustion) [12, 13]. In this study, Polyurethane sponge of 4 cm length, 3 cm width and 2 cm thickness was used.

2.2.3 Preparing Blended Solid Dust and Mud

Manganese Oxide (MnO) and bentonite were preferred as blends to produce alumina-based ceramic foam filter. MnO or bentonite was added to Alcoa Alumina dust ranging between 2-10%. Dusts blended at certain rates were ground approximately for 30 min- 1 hour and then solid dust homogeneity was obtained through water vaporizing process performed in the drying oven. Binder which was ranging between 20-30% of Alcoa Alumina was added to the dust mixture stirred homogenously. It was stirred for 30-40 min in the hand mill to enable binders to melt appropriately and to achieve homogeneity along with heat and as a result the desired “sludge” was obtained.

2.2.4 Preparing Muddy Sponge

The sponge was covered in mud by immersing the organic sponge into ceramic mud which was prepared in advance. The final stage was to remove the excessive mud from the muddy sponge.

2.2.5 Drying

After the desired loading (covering the sponge in mud) was performed, the muddy sponge was dried. The drying process can be performed in air, oven and microwave heaters. In this study, the process of drying in air was used. This drying process lasted 15-16 hours under atmospheric conditions.

2.2.6 Sintering

The sponge dried in air or oven underwent a gradual increase to enable the blowing of the organics and sintering. In the first period when the organics would be blown, gradual increase was performed rather than rapid increase to prevent mud from sinking. Therefore, 1-2˚C increase was applied per minute up to 350˚C which is the temperature for organics to blow and it was kept for an hour at this temperature.
After this stage, a second heating was performed which consisted of increasing the temperature from 350˚C to 700˚C gradually with a heating rate of 4-5˚C/min to blow the organics completely. Then it was kept for half an hour at this temperature. The temperatures applied to the sponge until ceramic sponge was developed are shown in Figure 1.
Although the sintering temperature of pure alumina is approximately 1770˚C [5], in this study, the sintering temperature of alumina was reduced from 1770˚C to 1350-1500˚C. Image of the sintered samples at 1450˚C is shown in Figure 2.

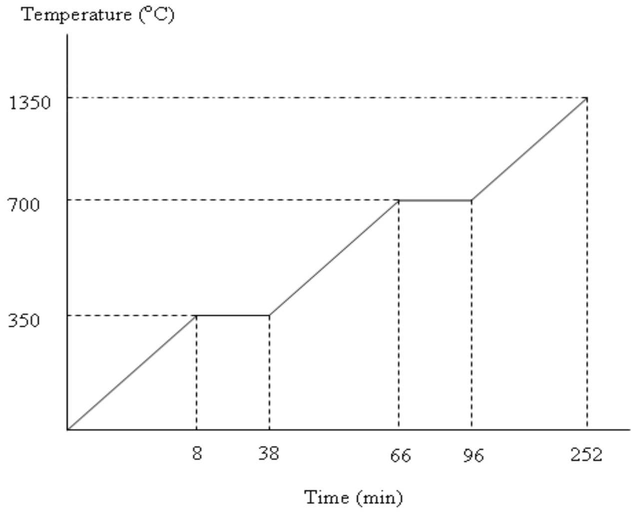


Figure 1. The graphic of temperature-time applied for sintering process of the samples.

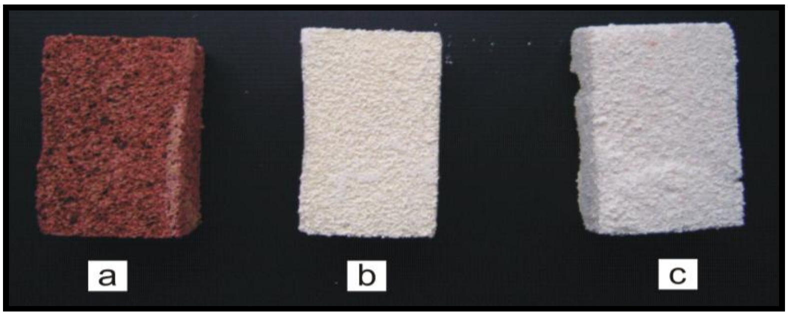


Figure 2. The sintered samples at 1450˚C, a) ALMO-Group, b) ALPA-Group, c) ALBE-Group.

3. Physical and Microstructure Analysis

Water absorption analysis, weight loss and apparent porosity tests were conducted to measure the difference in the samples before and after drying according to the water amount that they had taken. The corrosion test was performed to show the resistance of the ceramic materials used in the tests against chemical effects. The corrosion behaviors of 100% alumina and its blends in solutions comprising 5% NaOH and HCl were tested at room temperature [14].

3.1 Water Absorption Analysis

Water absorption value of ceramics should be less than 20 % (Institute of Turkish Standards – EN99) [15]. The water absorption value is evaluated by,

$$\% Abs_{water} = \frac{m_{wet} - m_o}{m_o} \times 100 \qquad (1)$$

where; is the mass of dry sample and is the mass of wet sample. The water absorption values of samples have listed in Table 2.

3.2 Apparent Porosity

The apparent porosity values of ALPA-Group, ALMO-Group and ALBE-Group test samples is calculated according to Eq. 2 [16] and have given in Table 2.

$$\% P = \frac{m_{wet} - m_o}{m_{wet} - m_{water}} \times 100 \qquad (2)$$

where, is the mass of the sample in the water.

3.3 Mass Loss Test

The total shrinkage values are proportional to the total mass loss values. The total mass loss value is calculated by using Eq. 3 [17] and have listed in Table 2.

$$\% \Delta m = \frac{m_o - m_s}{m_o} \times 100 \qquad (3)$$

where, is the mass of sintered samples.

3.4 Corrosion Test

In the experimental studies, no dispersion or degradation was observed in the samples used in acidic or basic environments. Observed corrosion percentage of samples is evaluated according to E q. 4 [14] and the corrosion test results of ALPA-Group, ALMO-Group and ALBE-Group test samples have given in Table 2.

$$\% \Delta m_c = \frac{m_d - m_c}{m_d} \times 100 \qquad (4)$$

Where md is the mass of sample before corrosion test and mc is the mass of sample after corrosion test.

Table 2. Results of physical analysis of samples.

			Material		
			ALPA	ALMO	ALBE
		m_0 (gr)	0.520	0.855	0.555
Water Absorption		m_{wet} (gr)	1.326	1.797	1.773
		$\% Abs_{water}$	155.00	110.97	219.46
Apparent Porosity		m_{water} (gr)	0.285	0.482	0.391
		$\% P$	72.55	71.63	88.13
Mass Loss		m_s (gr)	0.444	0.677	0.428
		$\% \Delta m$	14.56	20.8	22.9
Corrosion Test	Acidic	m_d (gr)	0.580	0.510	0.975
		m_c (gr)	0.581	0.508	0.982
		$\% \Delta m_c$	-0.172	0.392	-0.718
	Basic	m_d (gr)	0.790	0.585	0.620
		m_c (gr)	0.793	0.588	0.629
		$\% \Delta m_c$	-0.380	-0.513	-1.452

ALBE-Group test samples have the highest water absorption values. The water absorption values are directly proportional to porosity. In other words, if the sample has high water absorption values then it has also high porosity. This can be seen from the Table 2, the sample of higher water absorption value has higher porosity. According to Goren [3], approximately 85% apparent porosity was obtained in the ceramic foam filter and this result was regarded to be appropriate for ceramic foam filters. As can be seen in Table 2, ALBE-Group test samples, which have a porosity of 88.13% among the filters produced in this study, were better in terms of porosity compared to the other two groups.

The total shrinkage in ceramic materials is desired to be max. 25% (Institute of Turkish Standards-4897) [17]. When the weight loss values were assessed, all the samples were observed that have standard shrinkage values. In Table 2, the weight loss percentage of ALBE-Group test sample was higher than that of the other samples due to highly muddiness and binding properties of bentonite.

Also, in acidic and basic environments ALPA-Group and ALBE-Group test samples have negative changes and ALMO-Group test samples, in acidic environment difference was positive and thus they were unstable whereas in basic environment difference was negative and therefore they were stable to basic environments.

3.5 Metallographic Analysis (Scanning Electron Microscope)

Sintered samples were characterized using Leo 1430 VP model scanning electron microscopy. SEM images of samples are shown in Fig. 3.

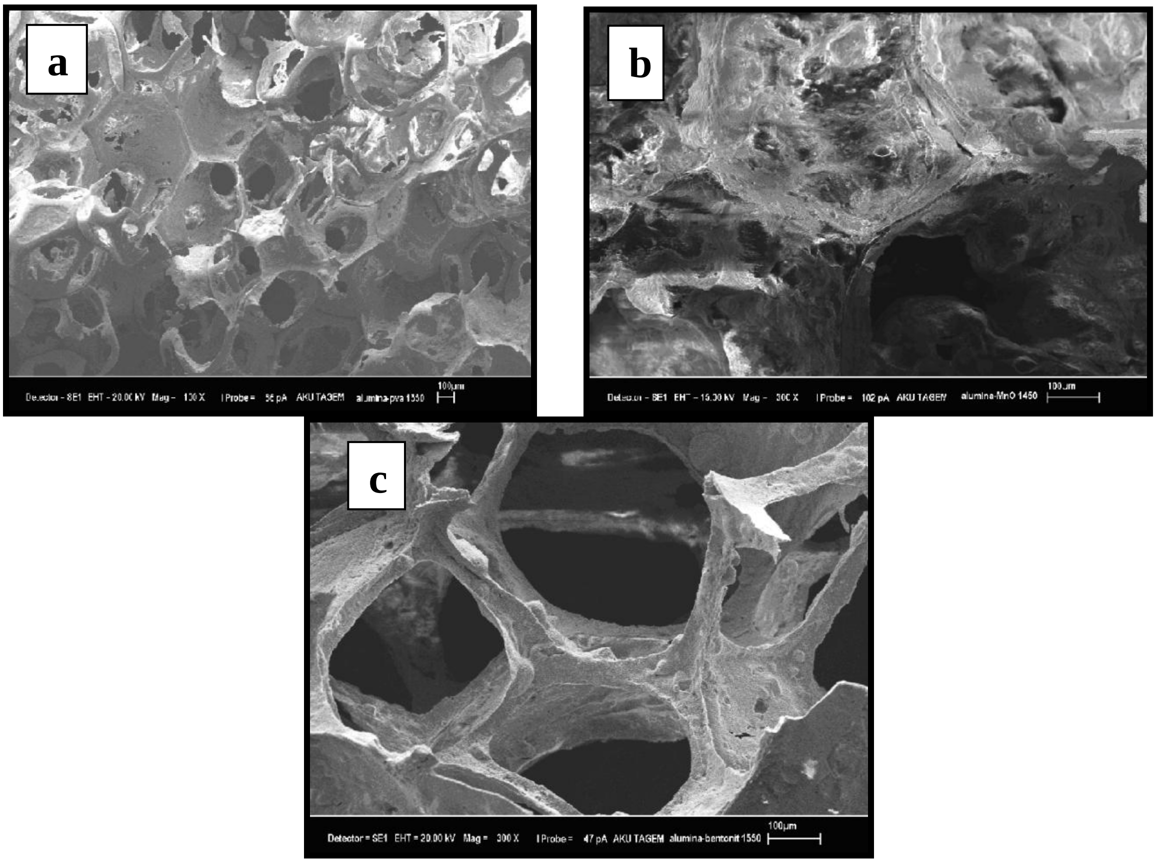


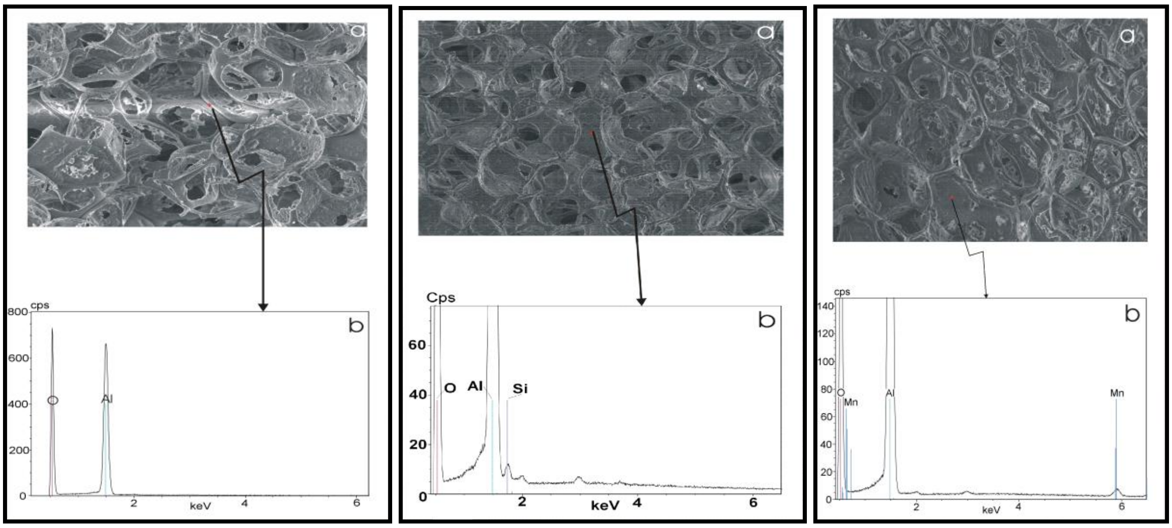
Figure 3. SEM image of (a) ALPA-Group sample sintered at 1550˚C, (b) ALMO-Group sample sintered at 1450˚C, (c) ALBE-Group sample sintered at 1550˚C.

Their binding structures developed in a much better way than the other samples due to the effect of the temperature. Furthermore, the gaps between grain limits were closed due to temperature. There are occurred fractures among bonds. The reason for this can be explained by the fact that roller was conducted on the muddy sponge rapidly while removing the unnecessary mud from the sponge.

If Fig. 3 compared in each other, the best bonded structure is AL-BE group sample, due to bentonite has the best adhesion property to alumina. The bonds achieve strength with increasing temperature and adhesion property.

3.6 Metallographic Analysis [Energy Disseminated X-Ray Spectrometer (EDX)]

According to the experimental studies, the best values were obtained in the ALBE-Group test sample. Figure 4 (a,b,c) shows EDX image of ALBE, ALPA, ALMO Groups test sample.



(a) (b) (c)

Figure 4. EDX images and graphics of (a) ALPA-Group sample sintered at 1550˚C, (b) ALBE-Group sample sintered at 1550˚C, (c) ALMO-Group sample sintered at 1450˚C.

One can see that highest peak values in Fig. 4.a belong to Al and O. This is due to Alumina-PVA sample is composed of mostly alumina. As can be seen in Figure 4 (b), peak values were equal in the bentonite sample. This is due to bentonite develops a better structure than the other samples. Bentonite's structure is homogenous; it becomes partially binding and enables strength to the structure. In addition, the peaks with the highest values on the graphic are A1 and O among the materials which form the ALBE-Group sample. This is due to the fact that Alumina material was used mostly in the sample. In Fig. 4 (c), while the highest peaks value belong to Al and O, Mn peak as high as the other peaks.

4. Conclusion

The ceramic foam filters can perform the filtration process properly and at the desired level depending on the shape, size and distribution of the open pores within the filter. The amount of open pores in the filter is measured by water absorption test [18].

In the experimental studies three groups of test samples were sintered at various temperatures. It was observed that ALPA-Group and ALBE-Group test samples were sintered at 1550˚C whereas ALMO-Group test sample at 1450˚C.

According to the results of water absorption tests, ALBE-Group sample obtained the best water absorption value with a value of 219.46%. In relation to the water absorption analysis, ALBE-Group samples also obtained the highest visible porosity (88.13%).

As a result of corrosion tests, it was concluded that ALMO-Group test sample was unstable to acidic environments while stable to basic environments and the other two test samples showed resistance to both acidic and basic environments.

When the results of all tests and analyses applied to ceramic filter samples which were prepared according to various prescriptions are evaluated, ALBE-Group test samples prepared with bentonite blend and sintered at 1550˚C were concluded to have more appropriate properties for ceramic filter usage than the other group samples.

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