

Preliminary Study of Melting Basalt Rock As A Raw of Advanced Material

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Abstract. The aim of this research is to conduct initial research on the process of melting basalt rocks using an upright shaft furnace. The preliminary process of melting basalt rock has been carried out as a raw of advanced material. The raw material of basalt was obtained from East Lampung, Lampung Province, Indonesia. Coke is used as fuel for the smelting process. Laboratory scale of shaft furnace which is designed and made by Research Unit for Mineral Technology is used for the smelting process. The basalt smelting process lasts for 4 hours, starting from the charging materials to the tapping process, with a process temperature of 1500-1600 °C. The yield of this process can reach 68,7%, while the rest was trap inside the bottom of the furnace due to lack of pressure at the end of the smelting process and the other was lost during the process. The product was basalt cast with the following dominant composition is MgO 5.244%, Al₂O₃ 21.295%, SiO₂ 48.750, CaO 10.138%, Fe₂O₃ 11.019%, TiO₂ 1.361% and Na₂O 2.132%. However, the products obtained are still brittle. Therefore, further research related to the crystallization process needs to be done to obtain products that are not brittle.

1. Introduction

Materials that are utilized in high-technology (or high-tech) applications are sometimes termed advanced materials. By high technology we mean a device or product that operates or functions using relatively intricate and sophisticated principles; examples include electronic equipment, computers, fiber-optic systems, spacecraft, aircraft, and military rocketry. These advanced materials are typically either traditional materials whose properties have been enhanced or newly developed and become high-performance materials. Furthermore, they may be of all materials types (e.g. metals, ceramics, polymers) and normally relatively expensive [1].

The need for advanced material continues to increase along with the enhancement in technological developments. The industrial revolution continued without being prevented. The order of human life in various fields is demanded to continue to adjust to the conditions of technological development, no exception in the field of material science and engineering. Various studies have been being carried out in an effort to create material that can support technological development. One of the materials that can be utilized as an advanced material is basalt rock. Processed basalt rocks can be in the form of basalt fiber and basalt cast, which are can be used as advanced material.



Continuous basalt fiber is a new type of green, high-tech inorganic material that has been extensively used in civil engineering, transportation, energy, environmental engineering, automobiles, ships, aerospace, petrochemical industry, and military because of its excellent mechanical property, resistance to high temperature, resistance to chemical erosion and environmental resistance. Basalt fiber, using basalt as the only source material, is formed by drawing the basalt melt (melting temperature of 1450-1500 °C) with a wire drawing machine. Basalt melting process is the most important step in the production of basalt fiber, because it will affect the quality of the basalt melt significantly, and they will affect the quality and performance stability of the basalt fiber [2-8].

For basalt casting technology, the basic principle is using the same technology as basalt fiber, where the difference lies only in the final product. Basalt rock must be melted in the furnace at a temperature of 1430 - 1450 °C then basalt melted need to be cast under the influenced of heat treatment. In the basalt casting process, the products are in the form of cast basalt according to the desired product form. The casting process can use sand and resin as a casting medium and permanent mold casting. Basalt rock reserves in Indonesia have a high potential deposit which reaches $\pm 12,000$ million tons and the possibility of its use can become a reference for basalt processing to become more valuable. The purpose of this study is to conduct initial research on the process of melting basalt rocks using an upright shaft furnace so that the conditions of the smelting process can be obtained in accordance with the characteristics of local raw materials.

2. Materials and Methods

2.1. Raw Material and Equipment

Basalt rocks as raw material were originating from Lampung province, Indonesia. Raw materials preparation was done through a jaw crusher to obtain a size of 2-4 cm of basalt rock. As an energy source, coke with a size of 5 cm was used. The equipment used to melt basalt is a shaft furnace type. This furnace was designed and made at BPTM-LIPI. The furnace has the following dimension, which is for the inside diameter is 40.5 cm and 156 cm for the high of the furnace. The inner walls in the furnace section are using fire bricks, and the outer wall is coated with mild steel with 6 mm thickness. The dimension of inner diameter of furnace is 450 mm and the height of the furnace is 1300 mm, which is equipped with four tuyeres as the air inlet into the furnace and a tap hole. Tap hole serves as the exit for the melting liquid and tuyere serves as a channel for air to flowing into the furnace with adequate volume and pressure so that the combustion process go on stable. The blower is used as an air source during the smelting process. The picture of the furnace can be seen in Figure 1. Material testing was carried out using X-ray Fluorescence (XRF) and X-Ray Diffraction (XRD) methods.

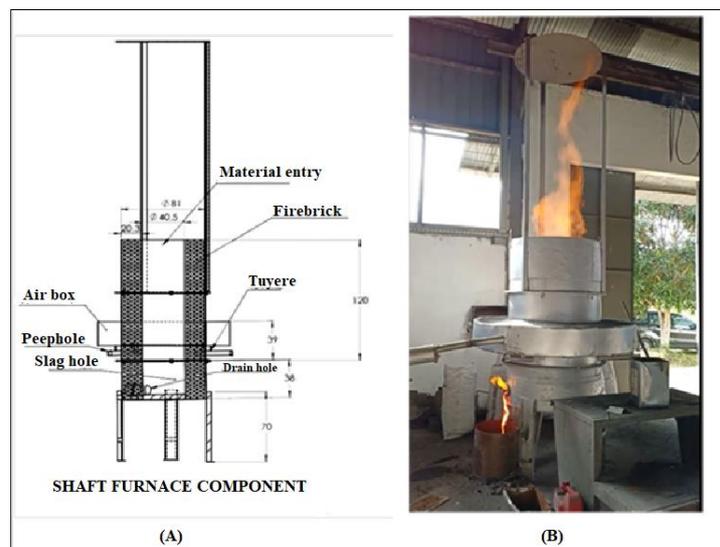


Figure 1. (a) Shaft Furnace component, (b) Basalt rock smelting furnace

2.2. Smelting Process of Basalt

The smelting process in basalt melting is almost the same as the operational procedure in iron smelting using an upright furnace. The furnace preparation process begins with the preparation of the bed furnace using sand casting with a thickness of 4 cm. For the initial combustion is carried out by wood charcoal combustion in the lower layer of the furnace. Gradually followed by adding coke as fuel until the coke burns evenly in the furnace. In order to maintain the combustion process which is taken place inside the furnace, combustion air is blown up through the tuyere hole. Air is blown into the furnace with the help of a blower.

The raw material is entered gradually into the furnace with the first order was coke, then basalt rock, and then coke again, and then basalt rock and so on. The smelting process in the furnace was carried out in a temperature range of 1500-1700 ° C. The temperature observation process is carried out by using a thermocouple which is installed in the melting furnace zone. After the basalt rock has melted, the tap hole was open to harvest the basalt liquid. The series of smelting processes last for 4.5 hours/batch.

3. Results and Discussion

An analysis of the chemical composition of basalt rock as a raw material has been carried out, including analysis for the composition of elements and compounds contained in basalt rock. The examination has been carried out before and after smelting. The results of chemical composition analysis using XRF can be seen in Table 1.

Table 1. The result of chemical composition analysis of basalt rock

Compounds	Percentage (% wt)
SiO ₂	47.234
Na ₂ O	2.998
MgO	4.046
Al ₂ O ₃	18.043
SO ₃	0.111
K ₂ O	0.592
CaO	12.348
TiO ₂	1.284
MnO	0.253
Fe ₂ O ₃	12.751
Total	99.66

Based on Table 1, the dominant element found in basalt rocks is silica with a percentage reaching 47.234%. Continued with aluminum oxide and iron oxide which is affect the smelting process in the furnace, this results was similar to Isnugroho et al., [9]. During at basalt smelting process, the visual analysis was carried out. The process temperature can reach 1700 ° C. The amount of raw materials and fuel usage during the process can be seen in Table 2. The total basalt rock which is melted is 65.5 Kg. While the product obtained have a total weight of 45 Kg as the actual smelting process. The obtained percentage level is 68.7%. This condition indicates that the smelting process still not been optimal. Based on table 2, wood charcoal was feed as initial fuel into the shaft furnace in a total of 28 kg, then coke is feed into the furnace as much as 117 kg.

Table 2. Raw Material charge

No. Feed	Time (WIB)	Char	Coke	Basalt rock	Information
1	13.00	Preheating (firewood)			
2	13.53	5	-	-	
3	13.59	5	-	-	
4	14.05	6	-	-	
5	14.11	6	-	-	

6	14.17	6	-	-	
7	14.23	-	10	-	Blower on
8	14.24	-	10	-	
9	14.25	-	11	-	
10	14.26	-	13	-	
11	14.27	-	11	-	
12	14.50	-	11	-	
13	14.51	-	11	-	
14	14.54	-	-	20	
15	14.55	-	-	23	
16	15.00	-	-	22,5	
17	15.24	-	10	-	
18	15.25	-	10	-	
19	15.26	-	9	-	
20	15.44				Tapping
TOTAL		28	117	65.5	

Based on Table 3, the furnace temperature range during the smelting process is 314-1700 ° C. Only in 57 minutes, shaft furnace temperature tends to increase rapidly, its because the blowing air from the blower through the 4 tuyeres around the shaft furnace wind box stimulate the combustion in the furnace and the relatively short height of the furnace also play a role in that process. The quickly increasing temperature causes some of the material contained in the basalt rock to evaporate in the form of gas. The rapid rise in temperature also results in a sudden decrease in temperature because the fuel has burned out when the tapping process still in progress. Which in result the liquid has not flowed completely and some of the liquid settles on the inner walls of the furnace and agglomerate at the bottom of the furnace, as shown in Figure 2.

Table 3. Temperature process

Time (WIB)	Shaft furnace temperature (°C)	Information
13.00	30	Precombustion using firewood
13.53	314	Precombustion using firewood
14.23	1090	Precombustion using coke
14.26	1116	44 Kg coke consumption
14.54	±1700	Starting basalt rock melting
15.44	±1500	Basalt rock melting
16.56	±1300	Finished smelting process



(a)



(b)

Figure 2. (a) Tapping process, (b) Agglomerate of basalt melting

The XRD results from basalt rock melting can be seen in Figure 3. To obtain the phases, which is formed in the basalt rock melting, the sample was analyzed using Match! 3 Software. From the results, the sample has an amorphous structure. It is because from diffractogram result does not have a specific or typical peak at a certain angle, so the distance between each atom does not have a pattern and tends to be random. From XRD results cannot reveal the real distance between each atom. Because there is no crystallization process happened in the cooling process, it resulted in fragile characteristic in the product. According to Birawidha et al., [10] the crystal structure is unchanged from the parent material but the mechanical characteristic of material changed.

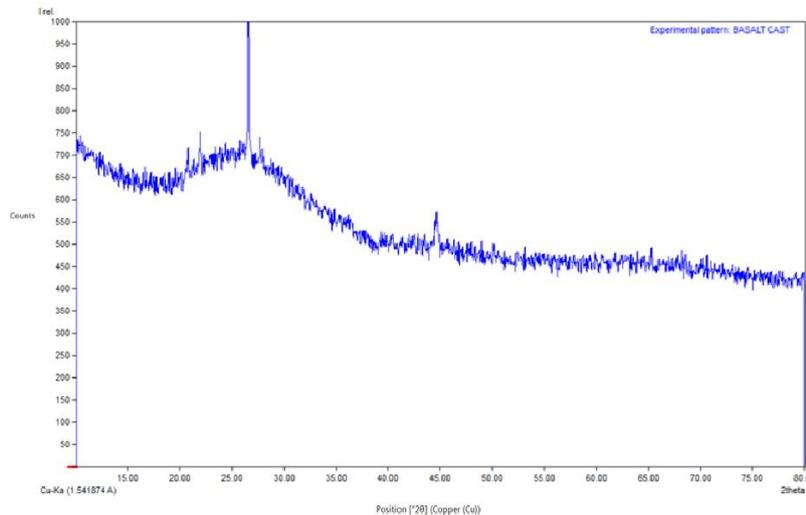


Figure 3. The result of XRD analysis after basalt rock smelting process

4. Conclusions

Smelting process was carried out at temperatures of 1500 to 1600 ° C. Based on the XRD, the sample has an amorphous structure and fragile characteristics. The main product of basalt cast such as Al_2O_3 21.295%, SiO_2 48.750, CaO 10.138%, and Fe_2O_3 11.019%. In this work, Basalt rock from Lampung Province can be utilized as an advanced material in the form of basalt fiber and basalt cast, which is through spinning and heat treatment process. The process is carried out as a series of processes in engineering material.

Acknowledgments

The authors would also like to acknowledge Research Unit for Mineral Technology, Indonesian Institute of Sciences for fund and facility support, so that this research is possible to do.

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