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Studies on the Melting Characterization of the Slag and its Continuous Fiber Spinning

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ABSTRACT

Slag is divided into large blast furnace slag and steel slag to more than 470 million tons emissions. Much of the blast furnace slag is a trend that recycled material for cement is recognized as a new resource from waste. This studies are being actively progressed as a part of the manufacturing method about mineral fibers using a slag. So, By using the slag blended with a spinning the fiber study actively. Target mineral material was replaced by the current of basalt and glass fibers environmental, economic and functional factors of carbon fiber. Basic research and radiators for the production and the application for slag fiber, deal with the manufacturing method in this paper.

Keywords: blast furnace slag, fiber spinning, basalt fiber, slag fiber, ceramic fiber, spinning machine

1. INTRODUCTION

Blast furnace slag is industrial residual product that come into manufacturing pig iron. This slag's annual occurrence is more than 470 million tons. Wasting cost to treat this slag is so huge. Following recent research to recycle this industrial residual product, the blast furnace slag has superb mechanical properties such as excellent specific strength, vibration resistant and wear resistance. Also, in the point of using industrial residual product, recycling slag is eco-friendly. And more than anything this slag has very similar chemical composition with basalt. The basalt is under spotlight because of its fiber's excellent mechanical properties though its high expense. Based on these advantage of slag, to develop high value added recycle mineral fiber that can replacement basalt fiber with high compressive strength, wear resistant and low cost, we research melting characterization of the slag and its continuous fiber spinning method.

2. Spinning system design

Generally, a spinning system needs an industrial furnace with a high heat capacity as the base material of the slag is melted at a temperature above 1300 degrees C. It also requires precise controls of heating rate, temperature and diameter of the fiber. In this study, a feasible lab scale spinning system, which meets above requirements, has been designed. The designed spinning system consists of three parts; furnace, bushing, and winding part.

2.1 furnace part

The spinning system has been designed considering the fact that the compounded slag is mainly composited with SiO_2 with high amounts of other compounds such as of Al_2O_3. The furnace part can raise the temperature up to maximum of 1600 degrees C, and the refractory of the furnace has been crafted with heat resisting and insulating materials that is frictionless and thermostable at high temperature. Figure 1 (a) presents the components of the furnace part, and (b) depicts the actual furnace part in lab scale.

2.2 Bushing part

As this is the most core construction of this spinning system, the bushing is made with alloy of Pt – Rh. The design includes two holes based on the lab scale. Also, this part is designed thermostatically, in order to prevent hardening and clogging of the bushing entrance. Figure 2 (a) shows the design specification of bushing, and (b) the actual bushing part of this design.

2.3 Winding part

Winding system is consisted of two bobbins and a guide, and has a speed control capacity of 0 ~ 6000 rpm. This part has been designed to wind a superfine fiber of 6~24 μm diameter without breaking it. Also, when a fixed amount of fiber is winded, the bobbin will shift automatically, allowing further winding. Figure 3 (a) shows the design specification of winder, and (b) the actual winding part of this design.

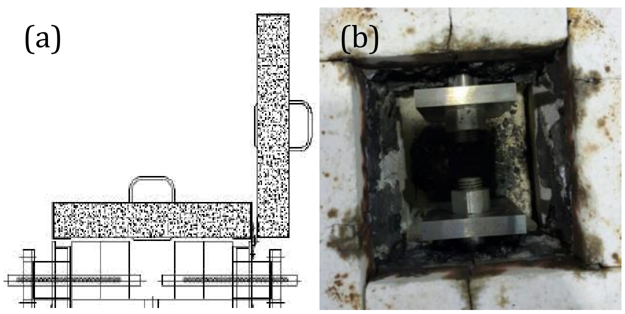

Figure 1 *Furnace part*

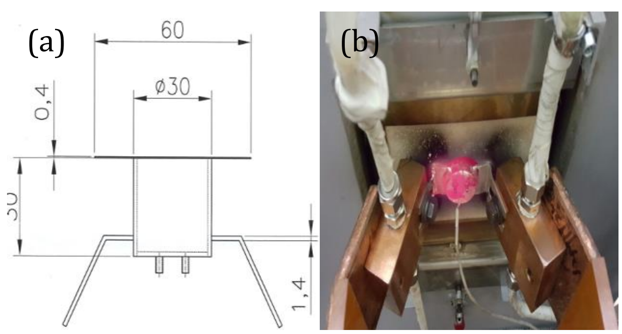

Figure 2 *Bushing part*

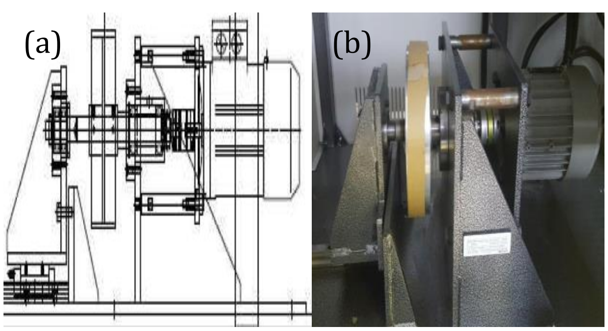

Figure 3 *Winding part*

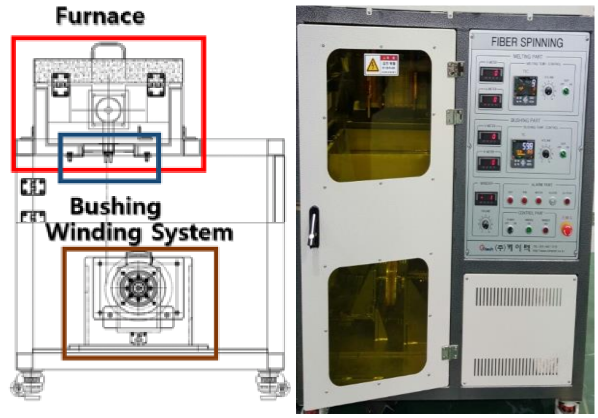

Figure 4 *Slag spinning machine*

3. Experiment

3.1 Raw material

Prior to the spinning, slag was atomizing using a ball-mill, and the raw materials were homogenized to prevent formation of heterogeneous distribution in crucible.

3.2 Clarifying

After heating the atomized raw material at 1500 degrees C for two hours, it was quenched with water to form a vitreous raw material. This step was essential, as crystallinity in raw material during spinning will cause discontinuation of the fiber at the crystallized surface. The vitreous raw material was then atomized again for spinning.

3.3 Spinning

The atomized vitreous raw materials from previous step were kept at approximately 1300 degrees C for an hour, and then were placed for spinning. The diameter of fiber was controlled by varying the winding speed of the winding machine from 0 to 1400 rpm.

4. Result

4.1 Raw material

The composition of the compounded slag closely resembles that of basalt rock. Therefore, the ideal composition of the raw material for spinning would require compositing the chemical compounds similar to that of the basalt fiber.

Table 1 shows the components that affects the fiberization of basalt compounds for spinning continuous fiber.

Table 1 The fiberization of basalt compounds for spinning continuous fiber

	SiO_2 (%)	**Al_2O_3 (%)**	**$FeO+Fe_2O_3$ (%)**	**CaO (%)**	**MgO (%)**
Basalt	47~56	14~19	7~15	8~11	3.5~10
	TiO_2 (%)	**MnO (%)**	**Na_2O (%)**	**K_2O (%)**	**P_2O_5 (%)**
Basalt	0.2~2.0	3.5~10	1.5~6.0		

Table 2 presents the composition of the slag compounds using XRF analysis. Upon comparing the composition of the basalt and the compounded slag, it can be concluded both compositions are appropriate for manufacturing a continuous fiber

Table 2 The slag compounds using XRF analysis.

	SiO_2 (%)	**Al_2O_3 (%)**	**$FeO+Fe_2O_3$ (%)**	**CaO (%)**	**MgO (%)**
Slag	49.43	15.57	12.61	8.78	8.79
	TiO_2 (%)	**MnO (%)**	**Na_2O (%)**	**K_2O (%)**	**P_2O_5 (%)**
Slag	0.68	0.386	0.36	0.5	0.62

And x-ray diffraction(XRD) analysis was used to confirm vitreous raw material. In fig 5, it can be observed that there is no peak line which means this material is clearly vitreous.

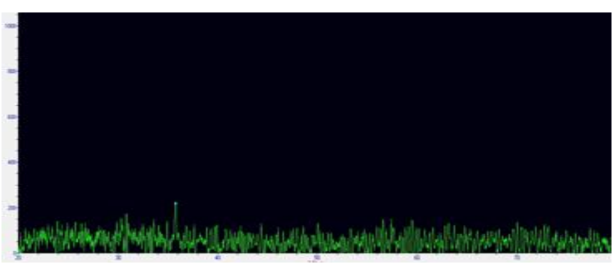

Figure 5 *XRD analysis on slag*

4.2 High-temperature properties

TG/DTA analysis was done to analysis on the thermal decomposition of the compounded slag. This condition presents Table 3.

Both basalt and the compounded slag had similar thermal decomposition behaviors. Basalt had melting point of 1258 degrees C, Tg of 813 degrees C, approximately. The compounded slag had melting point around 1325 degrees C, which was about 80 degrees higher than the Basalt, and Tg of 838 degrees C. Figure 5 presents TG/DTA analysis chart.

Table 3 Condition of TG / DTA analysis

Atmosphere	Air	**Specimen weight**	0.5g
Heating rate	10 ℃ / Min	**Max. temperature**	1475℃

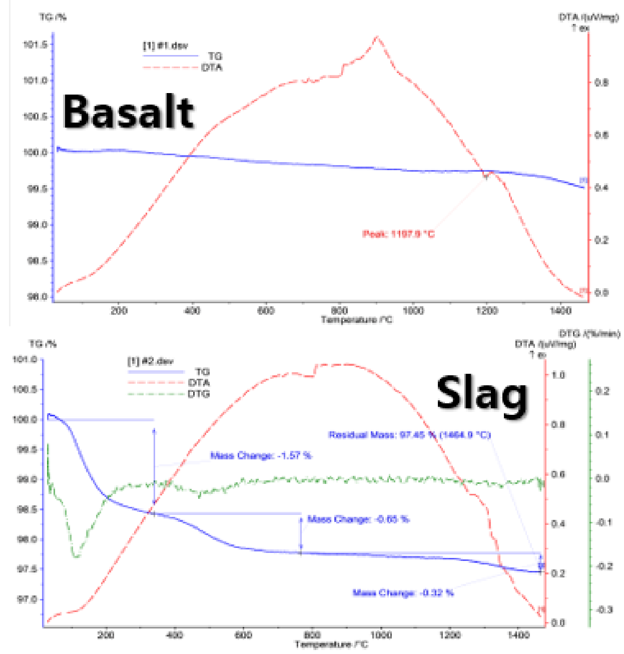

Figure 6 *TG / DTA analysis on basalt and slag*

4.3 Specimen

Figure 7 presents the surface of the fiber specimen from bushing conditions of 1300 degrees C and 1200 rpm, under optical microscope. As shown in Figure 7, the fiber from the spinning has a measured diameter of 8~20 μ m, smooth surface, and circular cross section. However, despite the fact the specimens are from the same winding speed, there are differences in the fiber diameter; this variation was suspected to be due to varying amount of melted slags inside the bushing as the experiments carries on.

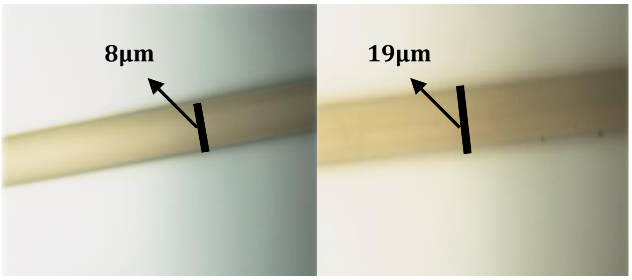

Figure 7 *Observed fiber by an optical microscope*

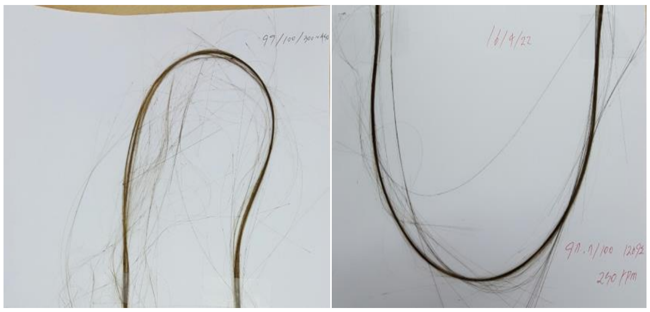

Figure 8 T*he actual spun fiber*

5. Conclusion

In this study, the new production technology and quality of the fibers using slag was to be established. In this study, a feasible lab scale spinning system, which meets above requirements, has been designed.

1. The designed spinning system consists of three parts; furnace, bushing, and winding part.

2. Through XRD analysis, it can be observed that there is no peak line which means this material is clearly vitreous.

3. Prior to the spinning, slag was atomizing using a ball-mill, and the raw materials were homogenized to prevent formation of heterogeneous distribution in crucible.

4. Despite the specimens are from the same winding speed, there are differences in the fiber diameter; this variation was suspected to be due to varying amount of melted slags inside the bushing as the experiments carries on.

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