Author Guidelines for proceeding

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Evaluation of Rheological Properties of Tap-hole Materials and Estimation of Injected Condition in the Blast Furnace

Author's information: Put an asterisk (*) after the name of the speaker.

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Headings and subheadings: Bold-faced

Abstract

Rheological properties of tap-hole materials were characterized by using a capillary rheometer method. Materials were extruded through the ... the resistance was measured. The resistance increased with time and maintained a ma... the material was extruding t... The shear rate and shear stress ... the extrusion speed and the re... From the relationship between ... the shear rate, the tap-hole ma... behave as a Bingham fluid ... changes of a tap-hole material ... with time in a real blast furnace. By comparison of lab tests and the injection pressure changes, it was estimated that the materials were injected into the furnace in the shape ... a diameter of around 80mm and length of about 30mm or less, which heaped up in free space in the furnace.

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1. Introduction

The blast furnace is a reaction chamber in which iron ore is reduced by carbon and molten pig iron is produced. Usually a blast furnace has two or four tap holes. When the molten pig iron is removed, molten slag flows out with the pig ion. ······

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These troubles in the opening and plugging operations are considered to relate to the condition of the tap-hole materials that plug the blast furnace. In other words, to suppress the problems, it is important to know how the tap-hole materials plug the furnace. Hence, the authors thought it was important to do a quantitative evaluation of the condition of tap-hole materials used to plug the furnace, from ... of rheology.

Reference

In the rheological study of tap-hole materials, Artelt et al.[1] introduced some qualitative testing methods, but their data did not provide quantitative information. Though Kageyama et al.[2] evaluated the extendibility of plugging in the lateral direction, using their own method, the theoretical basis of the method was not clear. Kitazawa et al.3) reported the measurement of resistance at two injection speeds using a small injection mold and the resistance was not proportional to the injection speed.···········

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2. Experimental Procedure

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2.1 Method of Obtaining Shear Rate vs. Shear Stress Plots[7]

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Fig. 1 shows a schematic diagram of the capillary rheometer and the measurement method. If a Newtonian fluid flows in a capillary by a pressure ... is called "pressure ...

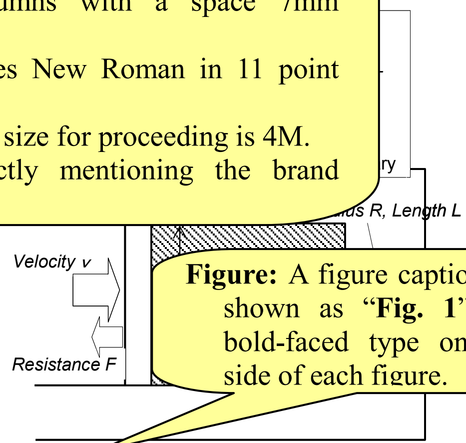

Figure: A figure caption should be shown as "**Fig. 1**" in11-point bold-faced type on the lower side of each figure.

Fig. 1 Schematic diagram of a capillary rheo-meter method and coordinates of the capillary.

2.2 Materials Tested

Table 1 shows the chemical composition of the tap-hole ma... the relative co... es. ...est materials (A to F) we... only used commercial tap-hole materials. ...density varied according to the content of coal tar and the composition was about 2200 kg·m^{-3}.

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Table 1 Chemical composition, relative content of coal tar and particle sizes of tap-hole materials

Table: A table caption should be shown as "**Table 1**" in 11-point bold-faced type on the upper side of each table.

Sample	A	B	C	D	E	F
Chemical composit... / mass%						
Al_2O_3	[illegible]	[illegible]	23	24	23	26
SiO_2	[illegible]	[illegible]	12	13	9	6
$SiC + Si_3N_4$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Coal tar** / mass%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Low viscosity typ...	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Content of grains / ...						
≧1.0mm	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
≦0.075mm	52	54	53	41	62	52

* After coking at 500℃.
** The content was relative value when the content of refractory particles was 100.

2.3 Experimental Apparatus and Method

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The mold used in this study was the same one used for the so-called Marshall Test of tap-hole materials. The radius of the capillary R was 10 mm, the length L was 20 mm, and the radius of the cylinder R_p was 35 mm. The inside of the mold was inclined by a slope of 25/73 between the cylinder and the capillary. This shape was slightly different from ··························

3. Results and discussion

3.1 Change of Resistance during Testing

Fig. 3 shows the relationship between the crosshead displacement and the resistance for material A; the temperature was 70 ºC, and crosshead speeds were 100 and 350 mm·min^{-1}. **Fig. 3** shows the movement of material (flow) in the mold and extrusion of the tap-hole material through the capillary; also shown is the relationship between the deformation of the material and the resistance. An egg-shaped mass of material was deformed by the movement of the plunger. As the material approached the capillary, the resistance increased. Moreover, as the material moved into the capillary, the resistance increased linearly. In contrast, when the material extruded from the exit of the capillary, the resistance showed a constant value. This constant value was maintained as the injection continued, and it was established as the injection force F. The patterns of resistance change shown in **Fig. 3** were almost the same for all materials tested in this study, except the cases described later.

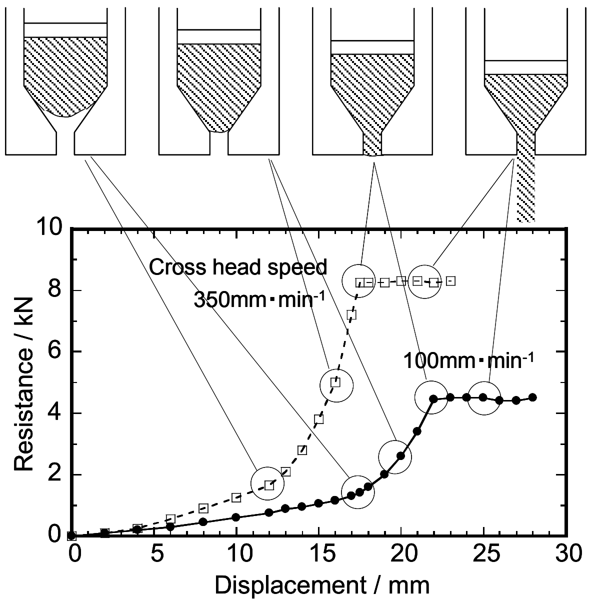

Fig. 3 Variations of resistance during extrusion and illustrations of shape changes of the material in the die.

Equation (8) can be transformed for the injection force F, as follows:

A Mathematical equation

$$F = \frac{2\pi L R_p^2 \tau}{R} \qquad (10)$$

From equation (10), we can understand the resistance change in **Fig. 3** as follows. The injection force F is proportional to the capillary wall length during injection and reaches a maximum value at the exit. Moreover, as the material continues to extrude from the exit, ·········

4 Conclusions

The rheological properties of tap-hole materials were investigated by a capillary rheometer method. In addition, the injection condition of the material into the blast furnace was presumed based on the injection pressure changes with time for a real operation.

(1) The tap-hole materials were extruded through the capillary of a mold with certain extruding velocity and the resistance changes were measured. The resistance increased with the material injection into the capillary. The resistance became a maximum value when the material reached the exit and that value was maintained during the injection. The maximum value was the extrusion force for the extruding velocity.

(2) From the extrusion force for the extruding velocity, we obtained the shear stress for the shear rate. The shear rate was changed by applying another extruding velocity, and the shear stress was obtained. Repeating similar measurements and compiling the results, we obtained plots of the shear stress and the shear [illegible]

A Mathematical equation

(3) The rheological property was fo[illegible]o be a typical Bingham fluid as shown by the r[illegible]tionship of the shear stress and the shear rate as $\tau_w = \tau_0 + \mu_B \cdot d\gamma/dt$ where τ_0 is the yield stress and μ_B is a constant corresponding to viscosity.

(4) The effect of viscosity and the content of coal tar on the yield stress τ_0, and the constant μ_B ·······

References

1) P. Artelt, H.F. Köhlau, Sprechsaal, **117** 341-346 (1984).

2) Tatsuya Kageyama, Kazushi Maruyama, Masatsugu Kitamura, and Diasuke Tanaka: Taikabutsu, **56**[3] 108 (2004).

3) Hiroshi Kitazawa, Yuji Ohtsubo, Toshiyuki Suzuki and Keisuke Asano: Taikabutsu, **56**[3] 109 (2004).

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7) Toshiaki Nakae ed.: Rheological Engineering and Its Application, Fuji Techno-system, (2000) pp. 211-214.