

DETERMINING THE SOFTENING RANGE OF BURDEN MATERIALS FOR THE BLAST FURNACE

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Abstract

The cohesive zone is amongst the most important areas within the blast furnace. It is limited by isotherms of the beginning and the end of softening of the burden materials. Both the oxide phase and the metallic phase melting processes start within this particular area. The gas flow, and effectively the efficiency of the blast furnace process, depends on the location and shape of the cohesive zone. A number of tests that are described in the subject literature has been performed in order to determine the temperatures of the beginning of softening and melting of pellets and sinters. The authors of this paper used an FRS 1600 high-temperature apparatus. This allows to precisely measure the force applied, the temperature, and the sample height changes. The applied device is intended mainly for tests of rheological parameters. However, its measuring capabilities allow it to be used also for material softening tests. Iron ore in the form of pellets, and sinters, were used for the measurements. The samples were placed in a graphite crucible shielded with argon. The sample material was subjected to the pressure of a spindle with a normal force of 19.6 N, while at the same time changes in the sample height as a function of temperature were recorded. Immediately after the softening measurement, the burden material viscosity changes, along with the temperature growth, were measured.

Keywords: Softening, cohesive zone, blast furnace, sinter, pellets

1. INTRODUCTION

The blast furnace process optimization is about producing the best quality iron whilst minimising costs. The selection of burden materials is a part of this optimization. The iron-bearing burden materials in the blast furnace process are in the form of pellets and sinters. The efficiency of the reduction process depends on their properties: the chemical composition and the form of burden materials influence their strength, their mix permeability, and their initial softening and melting temperature. The area limited by isotherms at the beginning and the end of softening is called the cohesion zone, and is amongst the most important areas within the blast furnace. Gas only flows through this area through the coke windows, and its shape and position determines the gas and heat distribution within the lump zone. The cohesion zone should be situated deep within the furnace in order to prevent the gas flow next to the shaft wall. The difference between the beginning and the end of the softening range should be as minimal as possible in order to minimize the pressure losses [1,2].

The purpose of these laboratory tests is to examine the burden material properties in terms of their suitability for the blast furnace process. Because of the complexity of the processes that occur within the blast furnace, these processes are difficult to be reflected in laboratory conditions, and therefore the test results should be considered approximate. Only the strength tests and reduction ability tests are standardized. However, their results do not allow predicting the behaviour of the burden materials in the blast furnace shaft. The tests that are defined in the literature as reduction tests and softening and melting tests are not standardized, as they most often concern a specific device and specific conditions that prevail in this device, namely its shape, the kind of burden materials, the type of blast, etc. A number of described tests can be found within the literature, but they differ by the force that was exerted to the sample, the kind of bed, its quantity and dimensions, the kind of gas and its flow, and the heating rate. The objective of these tests is to not only determine the impact of the gas chemistry and the kind of burden materials on the location of the cohesion zone, but also to change the preparatory conditions of the burden materials to obtain their assumed properties [2-9].

In this project, an FRS high temperature rheometer was used to determine the softening range of sinters and pellets. The measuring head of the device allows the normal force that is exerted to be precisely determined, along with the changes in the sample height to be measured.

2. METHODS OF MEASUREMENT

Fig. 1 presents a diagram of the FRS1600 high-temperature rheometer. The device is fitted with a vertical pipe, and a high-temperature furnace with a maximum temperature of 1600 °C and with the ability to introduce a protective gas into the working space. In order to ensure their safety, the furnace and its integrated components were placed and protected within a housing integrated with a pneumatic mechanism for controlling the upper and lower measurement piece, along with a precise mechanism for placing the cup and bob in the high-temperature zone. The furnace and the pneumatic system are fully controlled from the Rheoplus program level. The device is characterised by the following parameters:

- normal force measurement range - from 0.01 to 50 N,
- normal force measurement accuracy - 0.002 N,

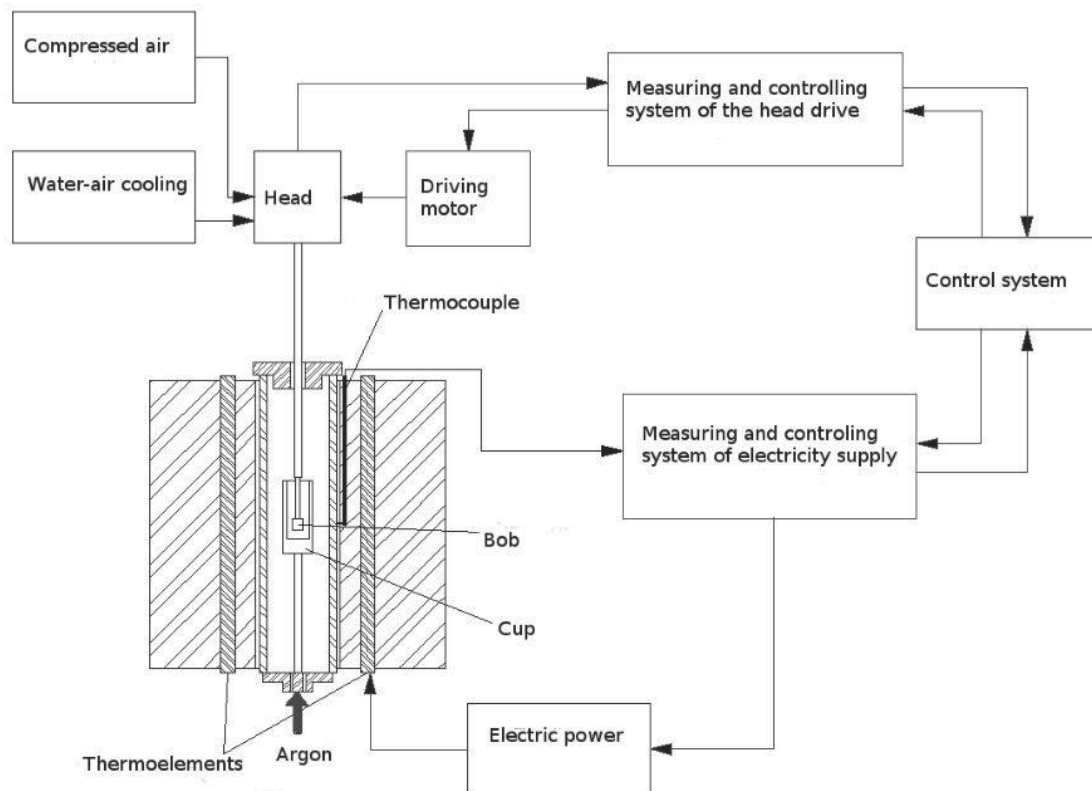


Fig. 1 The FRS high-temperature rheometer

The following measurement system was used for the tests: graphite-alundum, an alundum stamp, and a graphite crucible with an internal diameter of 30 mm. Pellets and sinter with a granularity of 3 mm were subjected to the softening test.

The sample filled the crucible to a height of 30 mm from the base. The tests were performed at the following heating regime:

- 20-900 °C 22 ° /min, with a data reading taken every minute
- 900-1050 °C 2 ° /min, with a data reading taken every minute
- 1050-1300 °C 1 ° /min, with a data reading every 20 seconds.

A normal force of 19.6 N (2 kgf) was exerted on the sample by the stamp. The point at which the decrease in the sample height by 40 % occurs was assumed to be the end of softening.

In addition - for pellets K immediately after completion of the softening test - an attempt to examine the changes in viscosity as a function of temperature was made. This was at a heating rate of 1 °/min, and a shear rate of 10 s⁻¹.

Table 1 presents the chemical composition of pellets and sinters that were used for the softening measurements.

Table 1 The chemical composition of burden materials used for the tests

	Fe	FeO	SiO ₂	CaO	MgO	Al ₂ O ₃	Mn	P	S	C	Zn	Alkalis	Basicity
Pellets K	63.37	0.70	4.89	3.80	0.19	0.36	0.01	0.02	0.08	0.05	0.003	0.13	0.78
Pellets L	65.25	0.64	5.11	0.20	0.32	0.34	0.01	0.01	0.01	0.04	0.002	0.15	0.04
Pellets P	62.15	0.98	9.21	0.43	0.68	0.39	0.01	0.01	0.01	0.02	0.00	0.14	0.05
Pellets M	62.10	0.69	8.39	1.60	0.32	0.34	0.01	0.01	0.01	0.04	0.00	0.28	0.19
Sinter DL1	50.28	10.32	12.10	12.27									1.01
Sinter DL4	48.47	8.76	11.8	12.6									1.07

3. RESULTS

Fig. 2 presents graphs illustrating the change in the sample height versus temperature for the tested materials, whereas **Table 2** presents the temperature at the beginning and the end of softening of pellets and sinters.

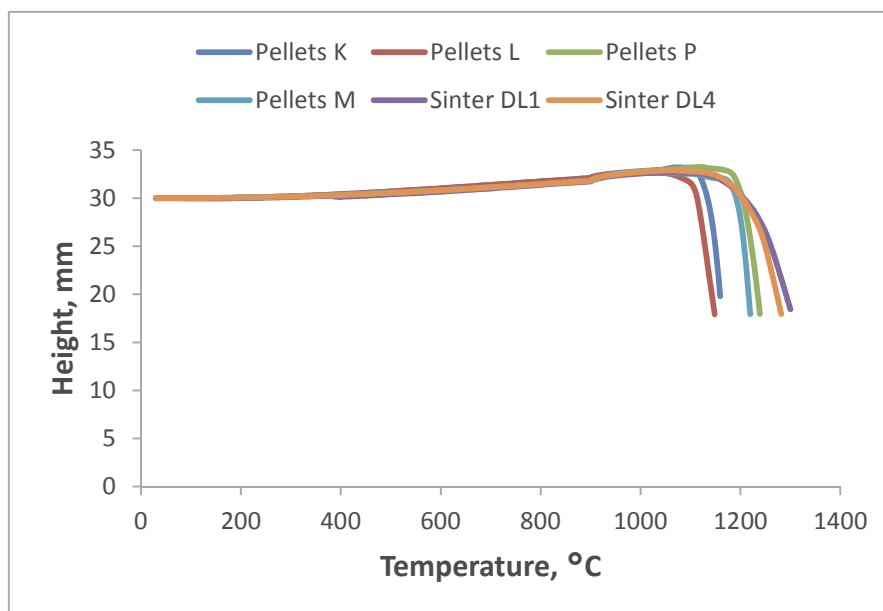


Fig. 2 Softening graphs

Table 2 Temperatures of the beginning and the end of the softening range

	Temperature initial, °C	Temperature final, °C	Range of softening, °C
Pellets K	1110	1160	50
Pellets L	1100	1150	50
Pellets P	1180	1240	60
Pellets M	1170	1220	50
Sinter DL1	1150	1300	150
Sinter DL4	1150	1280	130

Four kinds of crude pellets and two kinds of sinters have been subjected to the examination. The softening range for pellets is 50°C, whereas for sinters this is 140 °C. For all samples, material swelling was observed from about 400 °C upwards. **Fig. 3 and 4** presents the dependence between the softening range and the basicity of the burden materials. The higher the basicity, the higher the range of the softening temperatures.

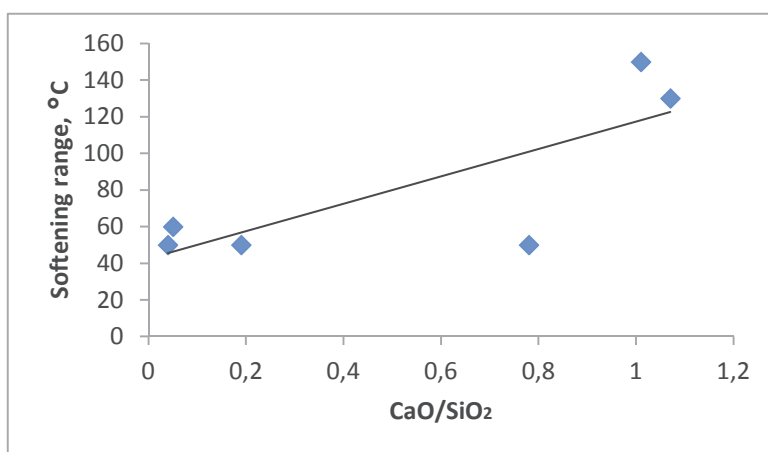
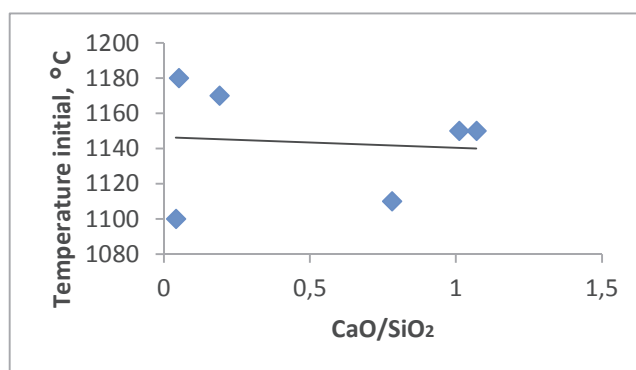


Fig. 3 The dependency of the softening range on the basicity



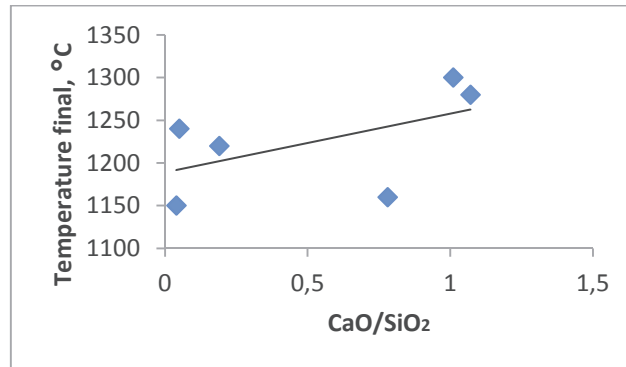


Fig. 4 The dependency of the initial and final temperature of the softening on the basicity

Fig. 5 presents a graph of the viscosity changes versus temperature for pellets K. The viscosity decreases with increasing of temperature up to 1165 °C, where the value of the viscosity stabilizes.

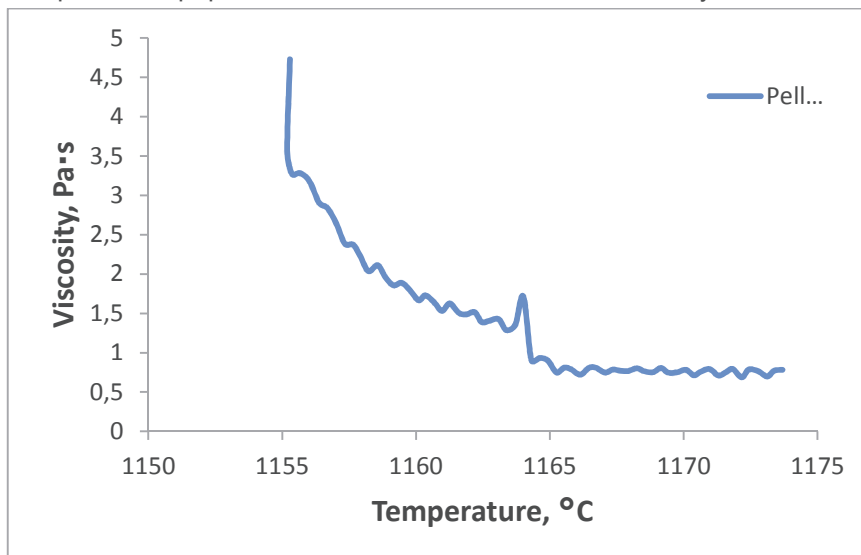


Fig. 5 A graph of viscosity versus temperature for pellets K

CONCLUSIONS

The conducted tests revealed that the softening range for pellets was 50 °C, whereas for sinter it was about 140 °C. For all samples, it was observed that material swelling occurred from about 400 °C upwards. However, with the increase in the basicity, there was also an increase in the softening temperature range.

In the future, it is planned to extend research on the softening to other materials: ores, sinters, pellets, briquettes, and waste materials, and to conduct research on viscosity changes of those materials, starting from the softening end temperature.

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