INCREASING THE EFFICIENCY OF THE SINTERING PROCESS

ČECH Martin[1], BESTA Petr[1]

[1] *VSB - Technical University of Ostrava, Czech Republic, EU*

Abstract

The aim of the presented research was to experimentally evaluate the influence of coarse-grained sinter added to the sintering strands in order to increase productivity and decrease the economic demandingness of the sintering process. The research was carried out in a selected metallurgical enterprise in the Czech Republic where the share of output materials of the sintering process at different input proportions of coarse-grained sinter was measured during one year. Within the course of this experiment, productivity of the sintering process increased by 1.35%. The article mainly discusses the effect of added coarse-grained sinter on the overall cost of the sintering process as well as on the quality of the final product.

Keywords: Sintering, coarse-grained sinter, agglomeration

1. INTRODUCTION

Strong competition and steadily rising prices for raw materials and energy are forcing metallurgical enterprises to increase the efficiency of all production processes. Key input raw materials of the blast-furnace process include metal-bearing materials. The bulkiest part of the metalline ore charge consists of raw materials which must be treated before their use in the blast-furnace process. In the Czech Republic, the preparation of metalline charge is mainly based on the sintering process. The sintering process can be characterized as a continuous process which converts fine-grained materials into a bulk sinter suitable for pig iron production in blast furnaces [1]. The resulting sinter must meet the requirements in terms of both chemical and physical properties, especially the structural arrangement of the final product, which significantly affects all downstream processes [2]. Today, however, high demands are placed on the cost of the entire process. One of the options for increasing the technical-economic parameters of the sintering process is to dose coarse-grained sinter onto sintering strands. This coarse-grained sinter is also called grate sinter. This article focuses on assessing the impact of the use of this input raw material in the sintering process. It analyzes data from the research carried out in a selected metallurgical enterprise in the Czech Republic. The effect of the use of coarse-grained sinter on the performance of the sintering process was experimentally verified during a period of one year. The article aims to examine the possibility of dosing the coarse-grained sinter and its impact on production output.

1.1. Sintering process

The sintering process, also called agglomeration, consists in heating the sinter mixture by fire penetration of added fuel to a temperature of 1300-1500°C which causes smelting of the surface of grains in the charge and creation of liquid bridges ensuring the formation of a solid porous material of different granularity (i.e. the sinter) after solidification. The basic raw materials used to prepare sinter charges include:

- A mixture of tiny metal ores
- Additives, alkaline additives
- Coarse dust and sludge from blast- furnace gas
- Rolling mill scale
- Foundry scale
- Fuel

The used fuels include coke breeze with particles sized up to 5mm, anthracite or experimental fuel additives, such as husks of sunflower seeds, which allow the user to save up to 10% of the necessary coke without significant changes of combustion characteristics [3]. The sintering process starts with mixing of the input raw materials and preparation of the sinter mixture by pre-pelletization, the purpose of which is to reduce the proportion of fine-grained particles and increase permeability of the charge layer; this enables easier passage of suction air which increases the efficiency of the sintering process. After dosing the pre-pelletized mixture onto the sintering strand, the surface layer is ignited; sintering itself takes place as the combustion front moves through the layer of sinter charge towards the grate. The sintering process is completed upon fuel burn-up and after the combustion front penetrates through the whole layer of sinter charge. The resulting product is then crushed, sorted, dried and stored in containers of blast furnaces.

1.2. Phases of the sintering process and combustion front

Ignition of the surface of the sinter charge leads to the formation of zones characterized by different ongoing physico-chemical processes. The combustion and sintering zone, indicated by number 1 in **Figure 1**, is called the sintering front; during the sintering process, it moves through the entire layer from the surface towards the grate. The zone of sinter cooling (7) emerges after burnout of the fuel and advance of the combustion front. Before the advancing combustion front, a temperature gradient is formed, characterized by ongoing physical processes. Gradually, before the combustion front, it is therefore possible to distinguish the following zones: zone of intensive heating of the charge (2), zone of its drying (3), pre-wetting zone (4), condensation zone (5) and the initial charge (6).

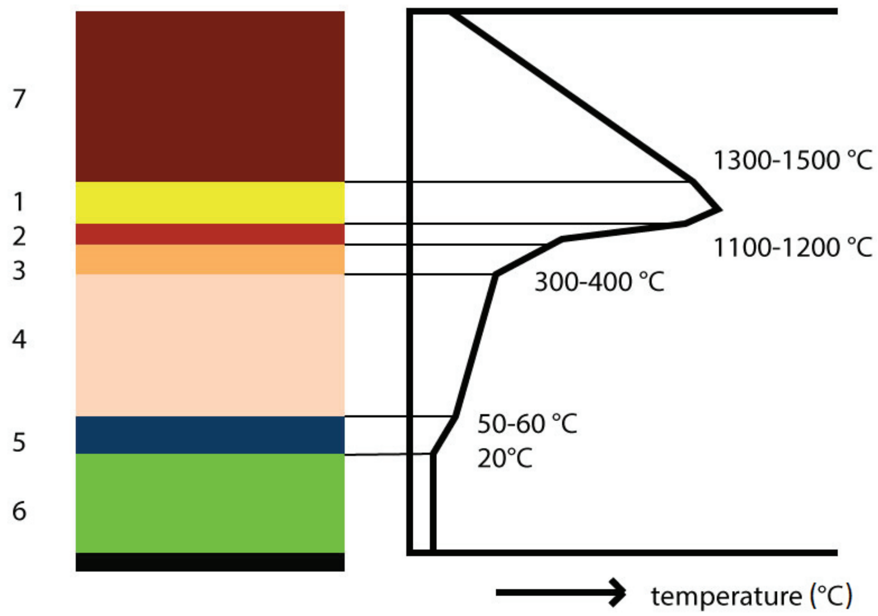

Figure 1 Zones of the sintering process [4]

1.3. Physico-chemical processes occurring during sintering

When the combustion front advances through the charge layer, different physico-chemical processes and changes in the composition of the permeating gas phase take place in each zone, such as removal of hygroscopic water - drying, removal of hydrated water, dissociation of carbonates, reduction-oxidation reactions and release of harmful substances. To a large extent, these processes especially include removal of sulphide and sulphate sulphur which escape into the air in the form of fumes and pollute the environment [5]. They also generate emissions of NOx whose amount, according to current research, is influenced by similar factors as the permeability of sinter layer, while the largest impact has the proportion of the fine fraction of return sinter [6]. Currently, an intensive study is dealing with the effects of different additives on the composition of polluting emissions as their amount can be significantly influenced by these additives while maintaining productivity and quality of the entire sintering process [7]. Combustion of the fuel, melting and subsequent solidification, cooling and recrystallization of the charge, leads to tension in the sinter and its disintegration.

1.4. Gas dynamics of the sintering process

In addition to the composition and quality of the sinter charge or fuel, the overall efficiency and productivity of the sintering process is mainly affected by the gas-dynamic properties of the charge layer, i.e. its permeability. The permeability of the grain charge layer is characterized as the amount of gaseous phase, suction / push-through air that passes through a unit surface per unit of time. Control of permeability of the sintered mixture is considerably complicated by the fact that the mixture is granulometrically very inhomogeneous and that the permeability is largely influenced by moisture of the charge, its chemical composition and physical properties. In practice, due to high difficulty of continuous measurement of permeability of the charge, we use the value of pressure loss in the granular layer, the so-called Ergun Equation [4]. Based on this relationship, it is possible to say that the pressure difference can be decreased, i.e. that the permeability can be increased, primarily by increasing the average diameter of the grain in the charge and by improving the shape factor of the grain. A fundamental part in increasing the permeability is played by the pelletizing drum which is used for the formation of micropellets during the preparation of the sinter charge.

2. EXPERIMENTAL WORK

The speed and efficiency of the sintering process essentially affects the cost aspects related to production of the main raw material for the blast-furnace process. The primary method of intensification of the sintering process is based on increasing the speed of filtration of the air passing through the sintered layer. This sintered layer consists of several zones which have different gas-dynamic properties. The key measure is to act on the zones with the greatest resistance and increase their permeability. As part of the research, we experimentally verified the dosage of coarse-grained sinter (big sinter) onto the sintering strand. The finished / produced sinter with grains sized 15 - 20 mm was dosed onto the sintering strand as a substrate layer which should ensure the improvement in gas-dynamic conditions. The mixed sinter mixture intended for sintering was then dosed onto this layer of coarse-grained sinter. Subsequently, performance indicators of the sintering process were measured over the course of 115 days. These measurements were carried out for two sintering strands. The process using the coarse-grained sinter took place on one sintering strand; the process on the other sintering strand was executed in the traditional way where the sinter mixture was dosed directly onto the sintering strand.

Table 1 Observed input process parameters

	Input side of the sintering process			
	Without big sinter		With big sinter	
	$t \cdot h^{-1}$	%	$t \cdot h^{-1}$	%
Material from the feed tables	118.4	70.6	116.9	66.2
Return sinter	42.3	25.2	46.8	26.5
Sludge as dry matter	6.9	4.2	5.8	3.3
Big sinter	0	0	7.1	4.0
Total	167.6	100	176.6	100

Table 1 shows input values of the process. For simplification, the input raw materials were classified into the following categories: material from the feed tables (homogenized mixture, alkaline additives and fuel), return

sinter and sludge dry matter. In the case of one sintering strand, the coarse-grained sinter was used as a substrate material.

Table 2 Observed output process parameters

	Output side of the sintering process			
	Without big sinter		With big sinter	
	$t \cdot h^{-1}$	%	$t \cdot h^{-1}$	%
Sinter produced	96.2	59.2	97.8	57.6
Return sinter	41.2	25.3	44.5	26.2
Sludge as dry matter	6.8	4.2	2.96	1.7
Big sinter	0	0	8.3	4.9
Losses	18.4	11.3	16.2	9.6
Total	162.6	100	169.8	100

Table 2 presents output values of the process for both sintering strands. It shows that the production of finished sinter increases in the case of using the coarse-grained sinter but with increased portions of the return sinter which is to be repeatedly returned to the process. The difference in performance of both sintering strands is 1.6 $t \cdot h^{-1}$. Higher output was continuously observed in the sintering strand with coarse-grained material dosed as a substrate.

The overall evaluation of the amount of produced sinter is shown in **Table 3**. During the monitored period, the production of sinter was higher by 1.35 % (18,651 t) in the case of using the coarse-grained substrate. The volume of return sinter significantly increased - by 10.29 % (43,121 t). When using the substrate material, however, the amount of sludge dry matter decreased by 15.07 % (7,948 t). From the perspective of the actual detected production performance, the use of coarse-grained sinter can therefore be evaluated positively.

Table 3 Evaluation of the production volume

	With big sinter	Without big sinter	Absolute difference	
	t	t	t	%
Sinter	1,381,147	1,362,496	18,651	1.35
Return sinter	419,101	375,980	43,121	10.29
Sludge as dry matter	44,802	52,750	7,948	15.07
Big sinter	120,300	0	120,320	0

3. CONCLUSIONS AND DISCUSSION

The coarse-grained sinter dosed on the sintering strand can essentially affect the performance of the sintering process. Observed productivity increased by 1.35 % within the monitored period. This value may seem marginal. However, if we consider the need of sinter mixture for several blast furnaces in the course of one year, the increased performance may represent a production volume in hundreds of thousands of tons. In this volume, the reduction of costs in the order of percentage can be a vital aspect for the final price of the metal.

Together with increases in the production of the finished sinter, however, the volume of return sinter also increased. Therefore, incomplete sintering of the charge occurs to a greater extent. This can be due to a faster advance of the combustion front in the layer of sinter mixture. Sintered material then contained a higher proportion of small parts (3 - 4 mm) which cannot be used for production in the blast furnace and which must again undergo the entire process. In such a case, the increased production of return sinter may result in higher costs of the whole process because a part of the mixture must pass through the sintering process again. In this case, higher costs are determined primarily due to fuel consumption. The optimum amount of return sinter should be between 15 - 25 %. When using the coarse-grained sinter, it will be therefore necessary to accurately monitor the amount of return sinter and the overall quality of the material produced. A lower volume of the produced sludge as dry matter can be evaluated positively. From a global perspective, the use of coarse-grained material can be considered as an interesting alternative to the intensification of the sintering process.

Under conditions where metallurgical enterprises face a lot of pressure especially in view of the final price of the metal produced, the presented method may offer a potential competitive advantage. When using this procedure, however, it will be necessary to monitor and evaluate the quality of the produced sinter more thoroughly. With regard to the higher amount of the return sinter, it can be assumed that the quality of the final sinter can also be affected although its grain size corresponds to the blast-furnace requirements. When using the coarse-grained substrate material, it will therefore be appropriate to monitor in detail the physical and mechanical properties of the material produced. The analyzed procedure, however, can have a quite significant impact on the performance of the entire process and, in compliance with all the mentioned technological requirements, it may bring lower costs of producing one ton of sinter.

ACKNOWLEDGEMENTS

The work was supported by the specific university research of Ministry of Education, Youth and Sports of the Czech Republic No. SP2016/107.

REFERENCES

[1] BABICH, A. *Ironmaking: Textbook*. Mainz: Verlagshaus Mainz GmbH, 2008. 402p.

[2] DONSKOI, E. et al. Iron ore textural information is the key for prediction of downstream process performance. *Minerals Engineering,* 2016, vol. 86, pp. 10-23.

[3] OOI, T. C. et al. The study of sunflower seed husks as a fuel in the iron ore sintering process. Minerals Engineering, 2008, vol. 21, no. 2, pp. 167-177.

[4] KRET, J. Theory of processes in the production of iron and steel. Ostrava: VSB-TU Ostrava, 2013. 83p.

[5] LONG, HM. et al. Sulfur balance calculation of new desulfurization technology in the iron ore sintering process. *Metallurgical Research & Technology*, 2016. vol. 113, no. 1.

[6] ZHOU, H. Influence of sintering parameters of different sintering layers on NOx emission in iron ore sintering proces. *Applied Thermal Engineering*, 2016, vol. 94, pp. 786-798.

[7] CHEN, YC. Reducing polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F) emissions from a real-scale iron ore sinter plant by adjusting its sinter raw mix. *Journal of Cleaner Production*, 2016, vol. 112, pp. 1184-1189.