A DEVELOPMENT OF THE ADAPTIVE TECHNOLOGY OF SINTER PRODUCTION AT PJSC MMK


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ABSTRACT

The adaptive technology of sinter production and pig iron smelting at PJSC MMK was studied when replacing the pellets of Sokolov-Sarybai Mining Production Association (SSGPO) JSC (further referred to as SSGPO) with pellets from other producers in the blast furnace charge and when increasing their share in the charge. Technological adaptation of the sinter production and cast iron production processes aiming at the manufacture of products with required properties has the following main components: adaptation of the composition and properties of the components of sinter and blast furnace charge; adjustment of the sinter and blast furnace production parameter level (parametric adaptation); change of the sequence and/or the set of technological operations (structural adaptation).

In the blast-furnace shop, the consumption of SSGPO pellets was lowered and then increased with a reverse change in the consumption of pellets from other producers. The content of pellets in the furnace charge was first increased and then lowered. The consumption of pellets of all types was in the range of 515 - 649 kg/t of pig iron, which corresponded to the content of pellets in the iron ore portion of the charge 31.8 - 42.0 %. The development of an adaptive technology for sinter production increased its basicity by CaO/SiO$_2$ in the range 1.68 - 2.01 with a decrease in the share of SSGPO pellets and an increase of pellets total share in the furnace charge.

As a result, a 0.1 unit increase in basicity coincided with 0.047 % absolute decrease in the content of 5 - 0 mm class fines in sinter. The increase in impact strength according to GOST 15137-77 was 0.89 % abs., the decrease in abrasion was 0.149 % abs. At the same time, a 0.1 unit increase in basicity coincided with a 0.29 % abs. increase of “hot” strength LTD$_{16,3}$ according to ISO 13930: 2007. The increase in sinter strength had a positive effect on the gas dynamics of the blast-furnace process, which allowed smelting with an increased consumption of natural gas.

Keywords: sinter, pellets, cold and hot strength, charge basicity, sinter machine productivity.

INTRODUCTION

The development strategy of PJSC Magnitogorsk Iron and Steel Works provides for further improvement of metal production along with overcoming the consequences of the global financial crisis. In these conditions, it is necessary to timely adapt the enterprise to the changing conditions, introducing new technological solutions to improve the quality of intermediate and final products and to reduce material costs for metal production. Sinter production with its approximate 65 % supply of iron ore contributes to achieving this strategic goal.

Due to the joint use of sinter and pellets in blast furnace smelting, it is expedient for an enterprise to use an adaptive sinter production technology which takes into account the properties of pellets used and their content in the blast furnace charge. The pellets currently used are non-fluxed. Therefore, an increase in their content in the blast furnace charge necessitates an increase in sinter basicity in order to exclude the introduction of raw limestone to the blast furnace charge, thus preventing the corresponding deterioration of the furnace performance.
An increase in sinter basicity is also necessitated by the replacement of pellets with an increased basicity by pellets with a lower basicity.

The growth in sinter basicity provides conditions for changing its other quality indicators. An increase in basicity depending on the interval of its change can both improve and deteriorate one and the same quality index [1, 2]. Among the set of sinter quality indicators, some part can change in a favorable direction, another – in an unfavorable direction [2, 3]. Therefore, the adaptive technology of sinter production was studied on the example of PJSC MMK sintering plant and the smelting of pig iron on the example of a blast furnace when SSGPO pellets in the blast furnace charge were substituted with pellets from other manufacturers and their share in the charge increased.

EXPERIMENTAL

The adaptive impact principle corresponds to the world production practice [4 - 12]. The majority of known methods of adaptive control imply that it is constructed by evaluating real production results. A new methodological approach has been developed at the Magnitogorsk State Technical University including additional computer modeling of the process with an early forecast of the complex of parameters being formed and subsequent certification tests [13 - 14].

The technological adaptation of the sintering process to manufacture products with required properties includes the following main components:

- adaptation of the composition and properties of the components of the sinter charge;
- adjustment of the sinter production parameter level (parametric adaptation);
- change of the sequence and/or the set of technological operations (structural adaptation).

The use of the manufactured sinter requires a technological adaptation of blast furnace smelting with similar components.

In the blast furnace shop, the consumption of SSGPO pellets was lowered and increased with a reverse change in the consumption of pellets from other producers, predominantly from Mikhailovsky, Lebedinsky and Kostomuksha mining and processing plants (GOK). The content of pellets in the furnace charge was first increased, then lowered. The consumption of SSGPO pellets was in the range of 0 - 198, of Mikhailovsky pellets 210 - 425, of Lebedinsky pellets 41 - 192, of Kostomuksha pellets 70 - 181, of all types 515 - 649 kg/t of pig iron. At the same time, the consumption of sinter was reduced and increased in the range of 958 - 1119 kg/t of pig iron. The content of pellets in the iron ore portion of the furnace charge was 31.8 - 42.0 %, that of sinter was 58.0 - 68.2 %. The development of an adaptive technology for sinter production increased its basicity by CaO/SiO$_2$ in the range of 1.68 - 2.01 with a decrease in the share of SSGPO pellets and an increase of pellets total share in the furnace charge. Correspondingly, the basicity of sinter was reduced at a reverse change in the composition of the blast furnace charge.

RESULTS AND DISCUSSION

The increase in the flux content in the sinter charge (F$_s$, %) for this increase in basicity was characterized by the expression

$$\frac{\text{CaO}}{\text{SiO}_2} = 1.23 + 0.07 F_s.$$  \hfill (1)

Consequently, a 1 % increase in the flux content increased sinter basicity by 0.07 units.

The dependence of the demand for coke breeze ($K_s$, kg/t of sinter) on basicity in the range of its decrease and subsequent increase was characterized by the expression

$$K_s = 54.0 - 5.47 \left(\frac{\text{CaO}}{\text{SiO}_2}\right)_s.$$  \hfill (2)

Consequently, a 1% increase in basicity lowered the coke breeze consumption by 0.55 kg/t of sinter.

The height of the burden layer was maintained at 292 mm. The rarefaction after cyclones was in the range of 9.6 - 11.0 KPa, decreasing with the increase of sinter basicity. The increase in flux consumption led to a decrease in the iron content in sinter according to Fig. 1. A 0.1 unit increase in basicity coincided with 0.28 % of abs. reduction in iron content, 0.29 % of abs. decrease in FeO content and 0.005 % of abs. growth in sulfur content, 12°C of sinter temperature reduction after the cooler. The recovery yield decrease was 4.5 kg/t of sinter.

The results of tests in the tumbler in accordance with GOST 15137-77 showed that the sinter impact strength factor (+5 mm class components after breakage) and abrasion (-0.5 mm class components after breakage) depended on basicity according to Figs. 2 and 3. A 0.1 unit increase in basicity coincided with 0.89 % of abs. increase in strength and 0.149 % of abs. abrasion reduction.
In the fractional makeup of sinter, it was most significant that the 10 - 5 mm class content decreased with an increase in the 25 - 10 mm fraction content, which is most preferable for blast furnace smelting. A 0.1 unit of basicity growth coincided with 0.047 % of abs. reduction of 5 - 0 mm class fines content. The increase in “hot” strength LTD$_{+6,3}$ was 0.29 % abs.

The productivity of sinter machines ($P_s$, t/h) by commercial sinter increased in accordance with the expression

$$P_s = 87.1 + 1.81 \left( \frac{\text{CaO}}{\text{SiO}_2} \right)_s$$

(3)

Therefore, a 0.1 unit increase in basicity corresponded to an increase in productivity of 0.18 t/h.

The productivity of sinter machines by iron ($P_{Fe}$, t/h) decreased (Fig. 4) in accordance with the expression

$$P_{Fe} = 52.6 - 1.52 \left( \frac{\text{CaO}}{\text{SiO}_2} \right)_s$$

(4)

A 0.1 unit increase in basicity coincided with a decrease of 0.15 t/h (0.31 %) in productivity by iron.

It was established that sinter “hot” strength influences the possibility of reducing the specific coke consumption by increasing the specific consumption of natural gas. A 0.1 % increase of the LTD$_{+6,3}$ factor coincided with an increase in natural gas consumption by about 1.1 m$^3$/t of pig iron. According to the results of tests at one of the blast furnaces, the following rational composition of the iron ore portion of the charge was obtained: sinter content 62 - 63 %, its CaO/SiO$_2$ basicity approx. 1.85; pellet content 37 - 38 %.

**CONCLUSIONS**

The joint use of sinter and pellets in PJSC MMK blast furnaces necessitates taking into account the properties of pellets used and their content in the charge in the technologies of sinter production and pig iron.

smelting. At PJSC MMK, for 9 months, SSGPO pellets were gradually withdrawn from the blast furnace charge being substituted with pellets from other manufacturers, and the share of sinter was decreased, then the process was reversed.

A decrease in the consumption of SSGPO pellets with their replacement by pellets from other manufacturers with an increase in the total share of pellets in the charge necessitated the adaptation of the sinter production technology.

A 0.1 unit increase in sinter basicity coincided with 0.55 kg/t of sinter for the reduction in coke breeze consumption, 0.28 % reduction in iron, 0.29 % decrease in FeO and 0.005 % increase in sulfur content.

A 0.1 unit increase in basicity, with its decrease and a subsequent increase varying in the range from 1.68 to 2.01, coincided with a 0.18 t/h increase in sinter machine productivity by commercial sinter. At the same time, iron productivity decreased by 0.15 t/h (0.31 %).

There were changes in the sintering process. A 0.1 unit increase in basicity coincided with 12°C of sinter temperature reduction as a result of a spontaneous increase in the efficiency of its cooling on the cooler. A 0.225 kPa decrease in the rarefaction after cyclones indicated an increase in the gas permeability of the sintered layer with a decrease in the recovery yield of 4.5 kg/t of sinter.

A 0.1 unit increase in basicity coincided with a 0.047 % of abs. decrease in the fines content of 5 - 0 mm class in sinter. The increase in impact strength according to GOST 15137-77 was 0.89 % abs., the decrease in abrasion was 0.149 % abs. At the same time, a 0.1 unit increase in basicity coincided with a 0.29 % abs. increase of “hot” strength LTD$_{+6.3}$ according to ISO 13930: 2007.

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