The Study of the Influence of the Grain-Size Composition of Anthracite on the Agglomerating Index and the Development of Technological Recommendations for the Preparation of Fuel for Sintering for the CherMK Conditions

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Abstract. As part of the technology fine-tuning for using anthracite in sintering, Minitab 18 program was used for planning and analysis of the experiment. The deliverables of the two-level factorial experiment (2k or Design Of Experiments) were used to adjust the technology for fuel preparation in sinter production at sinter plant.

The issue of the use of the substitutes of small-sized coke for sintering is constantly in the focus of attention of scientists and production workers. Anthracite was one of the first to get into their field of view as the closest coal to small-sized coke per the mass fraction of carbon [1, 2].

In the opinion of Japanese scientists, the use of anthracite to substitute small-sized coke for sintering shifts the optimal size of the particles of solid fuel to smaller side. Upon that, it was noted that the overgrinding of anthracite can negatively impact the burning time [3].

The experience of the German researchers of the use of anthracite showed that when substituting small-sized coke with anthracite by 50 % the productivity is reduced by 7-12% for different suppliers of anthracite, but it is not reduced any more for the substitution of up to 100%. In industrial conditions when producing Thomas sinter the substitution of 20% of coke fines with anthracite did not lead to the degradation of sintering attributes. Bowl sintering for similar conditions of raw materials showed that the substitution of small-sized coke with anthracite by 50 % positively impacts the productivity, but the strength of sinter decreases [4].

When reviewing the burning process of the main kinds of sintering fuel – coke and anthracite – the Russian scientists suggested to only limit themselves with the analysis of interaction of solid carbon with the atmospheric oxygen. Based on the results of the analysis of the kinetic curve of the burnout of different kinds of fuel, it turned out that if the optimal size of the particles of coke fines is 2.0 mm, then when using a less reactive fuel – anthracite – the optimal size of its particles should be about 1.5 mm, and for a highly reactive fuel – brown-coal semicoke – the average size of the particles should be 3 mm. With these conditions, the equality of the speed of the movement of the burning front and the speed of heat transfer will be preserved [5]. The thermograms of the sintering process, made when using anthracite as solid fuel, confirm that due to low rate of burning of the particles of low-reactive anthracite the zone of high temperatures is distributed to a higher number of elementary layers of the sintered material. On one hand it leads to the decrease of maximum temperatures (in the agglomerating zone), on the other hand, due to high gas-dynamic impedance of this stretched zone, it leads to a significant
drop in the intensity of sintering process. In industrial conditions a sintering operator does not have any operative technological leverage to influence the speed of the movement of the heat wave – the “heat transfer front”. There is a possibility to control the speed of movement over the layer of the burning zone, changing the size of the fuel particles, applying the fuel with different reactive capability and, lastly, by enriching with oxygen the air which gets into the layer. This way in order to increase the speed of the movement of the burning zone the main recommendation is the application of fuel with high reactive capability, decrease of the size of the fuel particles and increase of oxygen concentration in air.

The current situation (in the beginning of 2018) for the balances of coke production at CherMK set a challenge of using anthracite for sintering. The past experience of the periodical use of anthracite and also the analysis of contradicting theoretical and practical studies on the topic did not give any unambiguous advice on how to lower the technological risks when implementing this measure. For that reason, it was decided to perform a major study with the application of Minitab 18 software to plan and analyse the experiment. The laboratory sintering of agglomeration charge with the partial substitution of small-sized coke with anthracite was performed in the Centre of Raw Material Examination at the Ironmaking plant.

At the planning stage of the experiment the use of the Minitab 18 packet allowed us to pick the minimum number of necessary physical tests required for the development of the prognosis of target functions through variation of three values. The changeable parameters during the performance of a series of test sintering were the mass fractions of anthracite of 0-0.5mm, 0.5-3 mm and 3-5 mm, matching the general requirements of the preparation of solid fuel for the sintering process [1, 2, 5].

The prepared plan for the performance of test sintering with the various fractional composition of anthracite is presented in Table 1.

| Variant number | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 |
|----------------|----|----|----|----|----|----|----|----|----|----|----|
| -0.5 mm        | 16.7| 0  | 66.7| 0  | 33.3| 16.7| 0  | 50.0| 100| 50.0| 33.3|
| +0.5 – 3.0 mm   | 16.7| 100| 16.7| 0  | 33.3| 66.7| 50.0| 50.0| 0  | 0  | 33.3|
| +3.0 mm        | 66.7| 0  | 16.7| 100| 33.3| 16.7| 50.0| 0  | 0  | 50.0| 33.3|

Test sintering was performed when substituting small-sized coke with anthracite for 50%. Upon that the fractional composition of small-sized coke was maintained on the same level: 0-0.5mm – 35%, 0.5-3 mm – 55% and 3-5 mm – 10%.

The main results are presented on Figures 1 and 2 as triple diagrams which illustrate the influence of the variation of the fractional composition of anthracite used as a solid substitute of small-sized coke on the sinter strength indicator per GOST 15137-77 (Xₜₗₚ) and the specific capacity of a sintering unit by yield bin sinter (over 5 mm).

The results of test sintering (Figures 1 and 2) when using anthracite showed that the most optimal indicators of the process can be achieved in the area, where this kind of solid fuel has the bigger fraction of large-sized grains (3-5 mm).

For the application of the technology of partial substitution of small-sized coke with anthracite in industrial conditions it was necessary to make corrections in the fuel crushing technology. Figure 3 shows the current situation of the quality of fuel preparation. We can see on the diagram that the existing technology did not allow to achieve optimal characteristics for the preparation of anthracite for sintering, which led to overgrinding.
The application of new parameters of crushing during the preparation of solid fuel for sintering charge showed good results in production. The quality of sinter improved significantly: fraction 0-10 mm decreased by 9.9% rel., and the number of deviations from the base per mass fraction of FeO decreased by more than 40%. The latter reveals the increase of stabilization of the thermal level of the process when applying a more “coarse” anthracite.

Conclusions
Thus, the use of a non-linear method of experiment planning with the application of Minitab 18 packet allowed us on tight schedule to develop the recommendations for the selection of the optimal conditions of the preparation of anthracite as a substitute of small-sized coke for sintering. The industrial application of the technology after the correction of the conditions of the preparation of solid fuel positively affected the qualitative characteristics of the blast-furnace fluxed sinter. The main effect of the conducted study certainly is the industrially applicable change of the technology of the preparation of solid fuel during the period of substitution of small-sized coke with anthracite without losing the

Figure 1. The analysis of the change in the strength of sinter (per GOST 15137) by variation of the fractional composition of anthracite.

Figure 2. The analysis of the change in the specific capacity with various fractional composition of anthracite.

Figure 3. The area of current values of the quality of crushing of solid fuel.
quality of sinter and the productivity of sinter machines to reduce the expenses for the sintering of iron-ore raw materials.

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