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Automation of Sinter Charge Moistening during Pelletising

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***Abstract*—The influence of sintering charge moisture content on the indicators of sintering production of Ural Steel JSC was studied. It was found that the current pelletising and moistening regime has insufficient efficiency, not providing stable sinter charge with constant moisture and good gas permeability. The reason for sinter charge moisture fluctuations affecting pelletising and sintering indicators is the lack of an automatic system of moisture control and correction, which allows to respond promptly to changes in the properties of the charge supplied for pelletising. To increase the efficiency of pelletising, it is proposed to automate the process of moistening of sinter charge. The functional scheme of the automatic humidity control system is developed. The introduction of an automatic moisture control system will stabilise the quality of the sinter charge, which will improve the sintering indicators and quality of sinter.**

Keywords—sinter charge, granulometric composition, pelletizing, agglomeration, the moisture regime

I. Introduction

The efficiency of the sintering process is determined by the properties of the initial components of the charge, the composition and quality of its preparation, as well as the sintering parameters [1-3]. At constant sintering parameters, largely determined by the technical condition of the sintering machine (gas tightness of the vacuum system, power of the exhauster), the results of the sintering process depend on the properties of the charge and its preparation. Therefore, in practice and in scientific literature special attention is paid to such issues as optimisation of properties of iron ore materials [4-6], improvement of quality of solid fuel [7-12] and its distribution over the height of the sintered layer [13-17], selection of fluxing materials [18-24] and binders [25,26], which improve the results of pelletising.

The quality of sinter charge preparation, characterised by the homogeneity of its chemical composition, its particle size distribution and gas permeability [1-3, 30], is determined by the physical and chemical properties of the charge components and their ratio, as well as by the parameters of process equipment operation. Given the variety of factors influencing the results of pelletising, the present study was aimed at studying the influence of moisture on the results of pelletising and sintering, as well as the development of an automated system for control and correction of moisture content, which allows us to promptly respond to changes in the properties of the charge supplied for pelletising.

II. The Purpose and Object of the Study

It is convenient to consider the influence of technological process parameters on the results of pelletising at a specific object, which allows to optimise the number of influencing factors and provides a detailed study of the studied parameter. Therefore, the sintering shop of Ural Steel JSC (Russia, Novotroitsk) was chosen as the object of the study.

Preparation of sinter charge for sintering in the sintering shop of Ural Steel JSC is carried out in two stages: mixing (with moistening up to 3.5-4.0 %) - in a mixing drum with a diameter of 2.8m (length of 6m), installed at an angle of 2° to the horizon and rotating at a speed of 6.6 rpm; pelletising and additional moistening up to the optimum level (6.5-8.0 %) - in a drum with a diameter of 2.8m (length of 6m), installed at an angle of 1°30' to the horizon and rotating at a speed of 6 rpm.

III. The Results of the Study and Their Discussion

In the conditions of existing production, with a stable component composition of the charge, the main factor determining the quality of sinter charge preparation for sintering is the mode of humidification: the degree and stability of moisture content, water properties, method and place of its supply, use of additives, etc. Of all the humidification parameters in the production conditions of Ural Steel JSC, only process water consumption is adjusted. The correction is made manually depending on the moisture content of the sinter charge on the sintering trolley, which is controlled visually by external signs.

The range of the “optimal” moisture level is quite wide (up to 1%) and does not take into account current changes in the composition of the charge (component, granulometric, mineralogical, etc.). All this together leads to significant fluctuations in the humidity of the pelletized batch and the gas permeability of the sintered layer, affecting the results of the agglomeration process. To increase the stability of the sintering process, it is advisable to automate the process of moistening the sintering charge during its pelletization.

To assess the effectiveness of the current technology of sinter charge preparation at JSC "Ural Steel" an experiment was conducted, which consisted in sampling of sinter charge and sinter, as well as fixing the parameters of sinter machine operation. The averaged experimental data are presented in Table 1.

TABLE I. PARAMETERS OF THE SINTERING PROCESS AND SINTER QUALITY

Indicator		change interval	average value
Moisture of charge before pelletising, %		3.33-4.9	3.97
Fines content (0-1 mm) in the initial charge, %		52.4-63.4	57.22
Moisture of pelletised charge, %		6.3-9.7	7.5
Fractional composition of pelletised charge, %	+10 mm	7.85-16.2	11.55
	5-10 mm	10.21-18.8	14.22
	3-5 mm	14.46-26.79	19.46
	1-3 mm	29.91-44.7	37.84
	0-1 mm	6.41-28.33	16.92
Average diameter of granules of pelletised charge, mm		3.4-4.97	4.07
Collector vacuum, kPa		4.71-6.47	5.5
Collector temperature, °C		70-140	97
Sintering belt speed, m/min		1.5-2.1	1.77
Productivity, t/m^2/hour		0.941-1.106	1.041
Tumbler index (Russian all-Union State Standard 15137-77), %		60.22-70.1	65.03
Abrasion resistance (Russian all-Union State Standard 15137-77),%		6.40-4.66	5.41

The data obtained during the study allow us to conclude that the amount of fines (0-1 mm fraction) in the pelletised charge, which determines its porosity and gas permeability, remains at a significant level, decreasing below 10 % only when the charge is overmoistened beyond the optimum moisture content (7.0-8.0 % under the conditions of JSC "Ural Steel" [25]).

In addition, significant fluctuations in the moisture content of sintering charge and, as a consequence, unstable indicators of its quality, observed during the study period, affect the sintering indicators. For example, fluctuations in charge moisture, affecting its particle size distribution, affect the gas permeability of the sintered layer. This affects the gas vacuum and temperature in the collector and forces to adjust the sintering belt speed. The instability of moisture and gas permeability of the charge also affect the sintering process and the thermal state of the sintered layer, which in turn affects the sinter strength.

To illustrate the influence of the moisture of the sintering charge on the sintering indicators, Fig. 1 shows the dynamics of sintering parameters of the sintering machine for the period during which the charge moisture content varied from 6.5 to 8.0 %. As the charge moisture content decreased to 6.5 % (6:00 in Fig. 1), there was an increase in the collector vacuum from 5.39 to 6.37 kPa with a decrease in the collector temperature from 120 to 100 °C, which is explained by the deterioration of the pelletisation quality and gas permeability of the sintered layer.

To stabilise the sintering process, the water consumption for moistening was adjusted and the sintering belt speed was reduced from 2.0 to 1.7 m/min. As a result, the collector vacuum stabilised and there was a tendency for the collector temperature to increase. Later, after the charge with normal humidity (after 8:00 in Fig. 1) and good gas permeability was fed to sintering, the collector vacuum decreased to 5.39-5.88 kPa, which allowed to increase the sintering belt speed to 2.0 m/min at an average temperature in the collector of 110 °C.

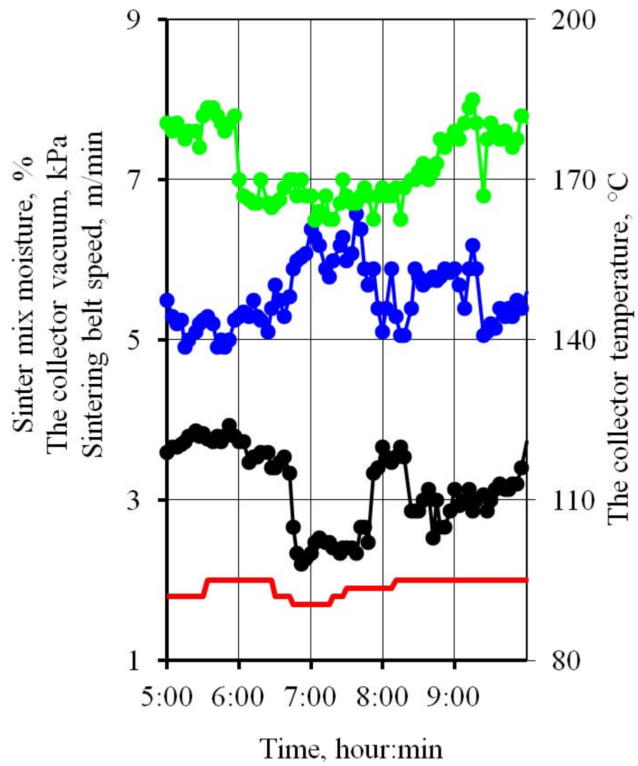

Fig. 1. Dynamics of sintering belt speed ( ), vacuum ( ) and temperature ( ) in the collector during the period of sinter charge moisture fluctuation ( ).

Thus, the applied technological regime of pelletising and moistening has insufficient efficiency, not providing stable production of sinter charge with constant moisture and good gas permeability. This limits the height of the sintered layer, the productivity of the shop and is a limiting factor in increasing the consumption of fine-grained concentrates.

One of the reasons for significant fluctuations in the sintering charge moisture, which have a significant impact on pelletising and sintering performance, is the lack of an automated system for control and correction of moisture content, which allows promptly responding to changes in the properties of the charge arriving for pelletising. Adjustment of charge moisture in the manual mode is carried out periodically and, mainly, according to the data on the temperature in the collector, which are received 15-20 minutes after charging the charge on the pallet car. In such a mode it is impossible to ensure a constant level of sinter charge moisture and pelletising results, which affects the stability of sintering indicators.

To reduce the influence of sintering charge moisture fluctuations on sintering process indicators, it is necessary to automate the adjustment of sinter charge moisture, for which purpose it is necessary to equip the water supply line for pelletising with a system of automatic moisture control.

Fig. 2 shows the functional diagram of the automatic moisture control system. Due to the correction of water consumption for humidification, depending on the current charge moisture content, the consistency of pelletisation and gas permeability conditions in the sintering process is ensured, which makes it possible to stabilise the temperature and discharge in the collector at a constant sintering belt speed.

The moisture content of the sintering charge is monitored at the inlet of the pelletiser drum by means of a moisture meter (W dry). At the outlet of the charge hopper, the charge flow rate is determined by means of a flow meter (Q charge). The operator only needs to set the required charge moisture level (W norms) before starting the process, which is entered via the control panel. Then, the water flow rate (Q water) and the required pump motor speed (n pump) are calculated from the known charge input parameters.

The required volume of water supply (Q water) is calculated using the equation:

$$Q_{water} = Q_{charge} \frac{(100 - W_{dry})}{100} \cdot \frac{(W_{norms} - W_{dry})}{100},$$

where Q charge - volume of sinter charge, kg/h;

W dry - moisture in initial sinter charge, %;

W norms - target (normal) moisture content of sinter charge, %.

According to the known operating parameters of the pump, the required level of rotation of the pump motor is determined from the expression:

$$n_{motor} = \frac{Q_{water} \cdot n_{nom.}}{Q_{pump}},$$

where Q water - required water consumption for moistening of sinter charge, kg/h;

n nom. - nominal motor speed, rpm;

Q pump - nominal pump capacity, kg/h.

The calculated values of expressions (1) and (2) allow to achieve the required moisture level of sinter charge at the outlet of the pelletiser. At the output of the pelletiser, the moisture level of the charge is checked at the output of the pelletiser by means of a moisture meter, which gives the value (W after). If there is a difference between the current (W after) and the required (W norms) sinter charge moisture level by more than ±0.1 % (abs.), the system recommends switching to manual control.

IV. Rationale for Choosing a Sensor and Controller

The moisture level is determined in the charge. In addition to its heterogeneity in shape and size, it is necessary to take into account the volume of the charge supplied to implement the technological process. In addition, the requirements for choosing a moisture analyzer must include the conditions of its use, namely, a high level of contamination of the sintering shop. The starting material for determining moisture is the charge. The main characteristics of the selected moisture meter (MOISTSCAN MA500) are listed in Table 2.

The charge flow rate, which is necessary for calculations and obtained at the outlet of the charge bin, is determined based on the readings of the free-fall bulk solids flow meter manufactured by CONVELS. Its parameters are given in Table 3.

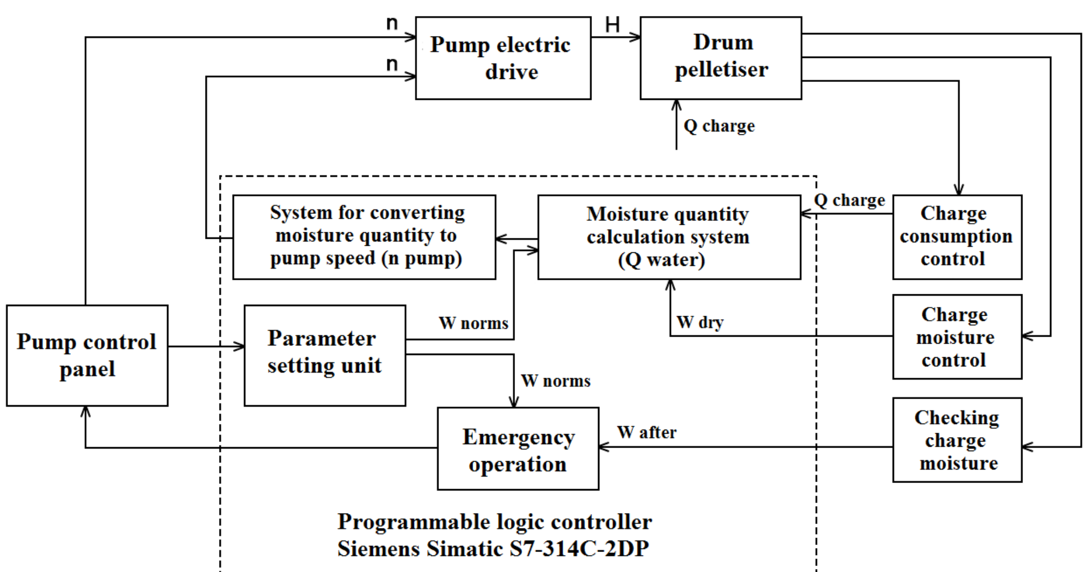

Fig. 2. Functional scheme of the system of automatic control of sinter charge moisture content.

TABLE II. MAIN CHARACTERISTICS OF THE MOISTURE METER

Parameters	Characteristics
Humidity determination accuracy, %	0.01 – 0.1
Humidity determination range, %	0 - 95
Communications	Ethernet, Profibus

TABLE III. MAIN CHARACTERISTICS OF THE FLOW METER

Parameters	Characteristics
Flow rate determination accuracy,%	0,5
Flow rate determination range, t/h.	0-1000
Communications	Ethernet, Profibus

One of the mandatory elements of each sensor is the presence of a built-in analog-to-digital converter (ADC), and the necessary communication means Ethernet and Profibus, which allow connection to the controller.

There is no need to select a controller, since the sintering machine section already has a Siemens Simatic S7-315-2DP with the necessary functional units and modules. The choice of this controller is due to the reliability of the Siemens company and the possibility of integrated use of its products.

The controller parameters are shown in Table 4. Among them, a fairly large number of inputs/outputs can be distinguished, which allows, if necessary, to upgrade the automation level of the facility.

STL was chosen as the programming language, which will allow the implementation of formulas (1) and (2). The program in the STL language should have a minimum number of necessary variables and calculate the optimal amount of moisture in the batch, as well as the speed of the pump motor.

TABLE IV. MAIN CHARACTERISTICS OF THE CONTROLLER

Parameters	Characteristics
Working memory, kb	192
Loadable memory (MMC), MB	8
Logical operations execution time, µs.	0.06
Number of flags/timers/counters	2048/256/256
Number of input/output channels, discrete/analog	16048/1006
Built-in interfaces	MPI + DP
Built-in discrete inputs/outputs	24/16
Number of fast counters (60 kHz)	4

After calculating the value of the electric motor rotation speed, the control value generated by the controller is fed through the frequency converter to the motor, which strives to maintain the specified value. This allows maintaining the required level of moisture in the charge.

In addition, a visualization system for measuring the moisture content of the sinter charge was developed, allowing monitoring the progress of the technological process of moistening the sinter charge in the pelletizing drum. Fig. 3 shows a fragment of visualisation of the automated system for controlling the sinter charge moisture. Fig. 3 shows the positions of sensors W1 and W2, which allow measuring the moisture level of the charge at the inlet and outlet of the drum pelletiser.

The introduction of an automatic moisture control system will stabilise the quality of the sinter charge, which will improve the sintering indicators and the quality of sinter.

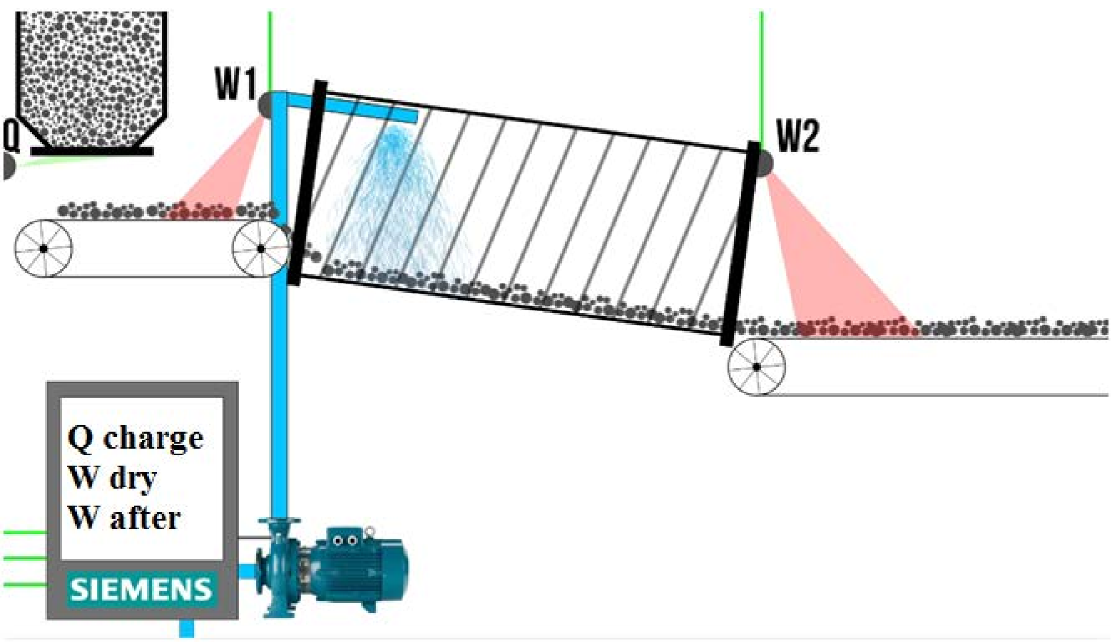

Fig. 3. Process visualisation fragment.

CONCLUSION

The influence of sintering charge moisture content on the indicators of sintering production of Ural Steel JSC was studied. It was found that the current pelletising and moistening regime has insufficient efficiency, not providing stable sinter charge with constant moisture and good gas permeability. The reason for sinter charge moisture fluctuations affecting pelletising and sintering indicators is the lack of an automatic system of moisture control and correction, which allows to respond promptly to changes in the properties of the charge supplied for pelletising. To increase the efficiency of pelletising, it is proposed to automate the process of moistening of sinter charge. The functional scheme of the automatic humidity control system is developed. The introduction of an automatic moisture control system will stabilise the quality of the sinter charge, which will improve the sintering indicators and quality of sinter.

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