APPLICATION OF NEW SURFACTANTS SINTERING AGGLOMERATE

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ABSTRACT

A set of pilot experiments to improve pelletizing through the use of sinter charge humidification of water-soluble organic surface-active agents (surfactants) has been performed in the sintering plant of JSC "Ural Steel". It has been found that the surfactants use provides improved granularity of sinter charge and increase of its gas permeability during sintering that ensures better technology and quality. Maximum efficiency from the surfactants use is manifested in the area of optimum moisture content of the sinter charge (7 % - 8 %) at a flow rate of the experimental binder of 1,2 l/h - 1,6 l/h (the surfactant concentration in the aqueous solution is 0,3 ml/l - 0,4 ml/l).

Keywords: sinter charge, granularity, pelletizing, surfactant (a surface-active agent), sintering.

INTORDUCTION

Sinter production is being carried out on four sintering machines on a sintering area of 84 m^2 at JSC "Ural Steel". Key performance indicators of the sinter plant at JSC "Ural Steel" for 2010 - 2014 are presented in Table 1. Despite the limited amount of fine-grained concentrates in the sinter charge, the acceptable specific lime consumption (29 kg/t) and the hot return use, the performance indicators of the sinter charge production of the JSC «Ural Steel» are among the lowest in the industry. This is primarily due to the poor technical condition of the vacuum system with limited power exhausters. However, it is difficult to expect a quick solution of the sinter plant technical modernization in the existing economic environment. Therefore, to improve the performance of the sinter plant at JSC «Ural Steel» special attention should be given to increase the quality of the sinter charge through changing the technology of its preparation.

The preparation of the sinter charge to be sintered in the sintering plant of the JSC «Ural Steel» is carried out in two stages: (i) mixing (with humidity up to 3,5 % - 4,0 %) in the mixing drum SB-2,8×6 that is installed under the angle of 2° to the horizon and rotating at the speed of 6.6 rpm; (ii) pelletizing and humidifying to the optimum level of 6,5 % - 8,0 % in the drum SB-2,8×6 installed at an angle of 1°30' to the horizon and rotating at 6 rpm.

The main factor determining the quality of the sinter charge preparation under the conditions of the existing production is the mode of humidification referring to the degree and stability of the moisture content of the sinter charge, the water properties, the manner and place of feed, the use of additives, etc. The consumption of

Table 1. Average monthly performance of the sinter plant.

Indicators	The performance value for the period
Specific productivity, $t/(m^2 \cdot h)$	0,93-1,15 / 1,11
The vertical speed of sintering, mm/min	17,34-24,01 / 20,32
The content of fine-grained concentrates in the charge, %	56,1-69,6 / 62,0
The vacuum in the reservoir, kPa	4,74-6,71 / 5,76
The height of the charge layer, mm	248-305 / 277,6
The returns content in the charge, %	22,5-27,5 / 25,2
The charge temperature, °C	40,0-61,0 / 51,6
The carbon content in the charge, %	3,27-5,09 / 4,04
Lime consumption, kg/t	17,9-30,1 / 28,8
The iron content in the sinter, %	50,3-55,4 / 52,7
The sinter basicity for $CaO/SiO_{2,}$ u	1,33-1,85 / 1,58
The fines content in the sinter (FR. 0-5 mm), %	13,7-17,0 / 15,7
Strength values, %: shock	65,0-72,3 / 68,2
abrasion	4,9-5,4 / 5,2
Note: in the numerator – changes interval, in the denominator - the average value.	

technical water determining the charge moisture content is the only moisture parameters so far corrected at JSC «Ural Steel».

Sinter charge samples were collected prior to and after pelletizing, while the sinter from the cooler and the parameters of the sintering machine were fixed to the production line of the sintering machine №3 JSC «Ural Steel» in 2014. This was done aiming to assess the effect of the existing technology on the sintering process indicators. The averaged experimental data referring to the indicators of sintering and the sinter charge quality during the period of the research are listed in Table 2.

The data obtained allow to conclude that the applied process conditions of pelletizing at favorable parameters of the charge have insufficient effect. They failed to provide a stable production of sinter charge of a low share of fines (1mm - 0 mm) and coarse fractions (+10 mm), while maintaining stable humidity at the optimum level (6,5 % to 8,0 % in conditions of JSC «Ural Steel» [1]). This, along with the poor technical condition of the exhaust gases path, limits the height of the sintered layer, the productivity of the shop and prevents the fine-grained concentrates increase [2 - 4].

Of all known technical and technological solutions aimed at improvement of charge preparation, one of the most promising is the use of surface-active substances in pelletizing [5 - 8], as its implementation does not require significant capital expenditures and shutdown. Furthermore, the surfactants having an organic origin, are completely removed during sintering and do not affect the chemical composition of the sinter.

The effect of the sinter charge humidification provided by aqueous surfactant solutions during pelletizing is due to the surfactants influence on the reduction of surface tension of water [8]. This brings about preconditions for decrease of the thickness of the water films and increase of the molecular adhesion forces, the strength and the size of the resulting granules.

Other properties determining the possibility and conditions of using a binder are of importance for industrial use of surfactants in the process of agglomeration. The efficient use of surfactants in wetting requires the injected

Table 2. Indicators of sintering during the study period.

The moisture content of the mixture prior to pelletizing, %		3,33-4,9 / 3,97
The fines content (0-1 mm) in non - pelletized sinter charge, %		52,4-63,4 / 57,22
Humidity of pelletized sinter charge, %		6,3-9,7 / 8,1
Fractional composition of pelletized sinter 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
The average diameter of pelletized sinter charge granules, mm		3,4-4,97 / 4,07
The vacuum in the reservoir, kPa		4,71-6,47 / 5,53
The temperature in the collector, °C		70-140 / 97
The actual speed of the sinter belt, m/min		1,5-2,1 / 1,77
Design capacity, tons/(m^2×h)		0,941-1,106 / 1,041
Drop test strength according to GOST 25471-82, %		8,96-11,48 / 10,62
Impact strength according to GOST 15137-77, %		60,22-70,1 / 65,03
Abrasion resistance according to GOST 15137-77, %		6,4-4,66 / 5,41
Note: in the numerator –changes interval, the denominator - the average value		

substance to be soluble in water. Besides, its aqueous solution should possess high adsorption and adhesion ability, and a minimum temperature of crystallization. The experimental surfactant was selected on the ground of these requirements. It is manufactured on an industrial scale. It is a biodegradable organic substance from the class of non-ionic surfactants having high adhesion, unlimited solubility in water and a crystallization temperature less than 0°C.

EXPERIMENTAL

To determine the effect of the charge treatment (during pelletizing) by the experimental surfactants on the performance of the sintering process, a pilot experiment on the production line of the sintering machine №3 at the JSC "Ural Steel" was undertaken in June 2014. Oxyethylated monoalkylated phenol of the chemical formula $C_9H_{19}C_6H_4O(C_2H_4O)_6H$ was the surfactant chosen .

A pilot installation for supplying a surfactant was constructed for the experiment. It was connected to the water pipe-line. A faucet regulated the flow of water to the pelletizing sintering machine No. 3. A schematic diagram of the apparatus for introducing the surfactant is represented in Fig. 1. The pilot installation ensured the maintenance of a given surfactant concentration in the aqueous solution fed to the pelletizing plant by adjusting the feed of the binder through the current flow rate and the water pressure in the water pipe-line.

The surfactants concentration in the aqueous solution was varied from 0,2 ml/l to 0,4 ml/l of water supplied to the of sinter charge humidification in the pelletizer. The range of the experimental concentrations was conditioned by the General regularities of the surfactants influence on the properties of aqueous solutions [9], as well as by the previous results of laboratory studies [10 - 12].

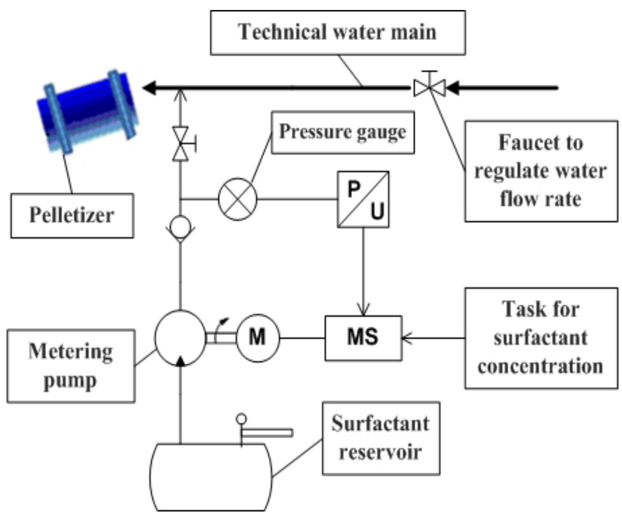

Fig. 1. Scheme of the experimental setup for surfactants supply into the humidification system of the sinter charge.

There were 3 series of experiments with surfactant concentrations of 0,2 ml/l; 0,3 ml/l and 0,4 ml/l. During the experiments a charge and sinter sampling was obtained, while the operation parameters of the sintering machine were recorded. They referred to the vacuum in the reservoir and in front of the exhauster, the temperature in the reservoir, the speed of the sinter belt, as well as the height of the sintered layer. Charge and sinter samples were selected prior to the proper experiment.

RESULTS AND DISCUSSION

The averaged experimental data referring to the performance of the sintering process are presented in Table 3. The juxtaposition of experimental data referring to the surfactants use in the sintering process and the data of the «basic» period allows provides to conclude that the introduction of the binder additives investigated to pelletizing is efficient. This is evidenced by the results of pelletizing as well as by the sintering indicators and the sinter mechanical properties.

The surfactants effect increases with its consumption increase (its concentration in the water supplied during pelletizing). Unlike the laboratory experiments [13] carried out, a significant effect of surfactants use is observed in the concentration range of 0.3 ml/l - 0.4 ml/l. This can be explained by pre-moistening of the sinter charge by water, the shorter period of pelletizing and the less efficient distribution of water over the charge burden when using the jet humidification system.

A significant improvement of the sinter charge quality due to surfactants presence refers to its fractional composition expressed mainly by the fines share decline (0 mm- 1 mm) (see Fig. 2). Thus, the increase of the surfactant concentration up to 0.3 ml/l - 0.4 ml/l, results in decrease of the non- pelletized fines content in the sinter charge by 5 % - 10 % (abs.) compared to that of the base period within the whole investigated range of humidity.

In addition, the experimental data on sinter charge granularity (Table 3) indicate absence of surfactants use effect on the process of pelletizing (FR share is +10 mm). Thus, due to pelletizing conditions improvement because of surfactants use, more favorable granularity of the sinter charge is obtained. It is characterized by minimum amount of 1mm - 0 mm fines and fractions greater than 10 mm [14 - 16].

The production of pelletized charge of a more uniform grain size with a minimum amount of fines contributes to the increase of porosity of the sintered layer, while the higher strength of sinter charge pellets allows maintaining high gas permeability during sintering, which in turn prevents compaction of the charge under vacuum action. As a result, despite the significant fluctuations in the sinter charge moisture content in presence of surfactants, a decrease in the average vacuum in the reservoir is registered (Fig. 3). This confirms the studied binders beneficial influence on gas permeability of the sinter charge. The effectiveness of the surfactant use is most significantly manifested at its flow rate of 1,2 l/h -

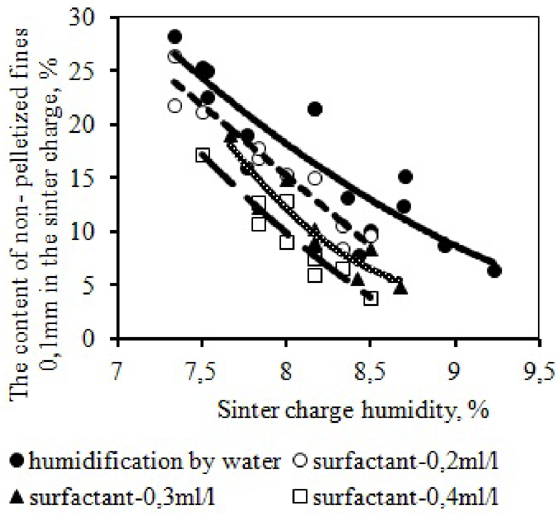

Fig. 2. Effect of humidity and surfactant concentration on sinter charge fines content in the course of pelletizing.

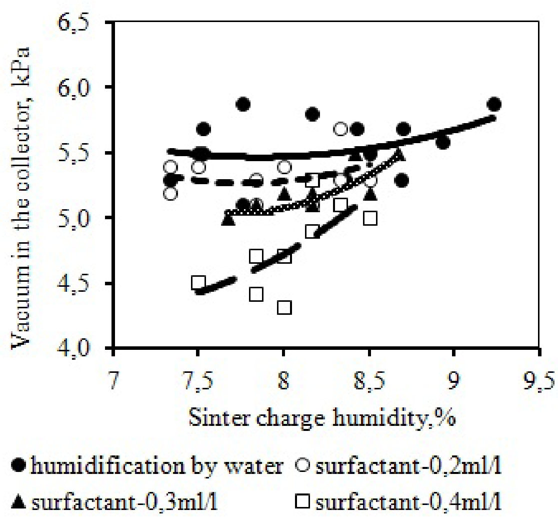

Fig. 3. Effect of humidity and surfactant concentration on the vacuum in the collector during sintering.

Table 3. Sintering process indicators followed in case of a surfactant use in pelletizing.

Indicators		Index values of the indicators under the experimental conditions*[1] applied			
		No surfactants	In surfactants presence		
Surfactants concentrations in water when pelletizing, ml/l		0	0,2	0,3	0,4
Surfactants consumption, l/h		0	0,8	1,2	1,6
Surfactants consumption, ml/ton of sinter*[2]		0	8,81-9,37 9,08	12,47-13,69 13,12	15,59-17,76 16,71
Moisture content in the mixture prior to pelletizing, %		3,67-4,71 4,12	3,17-4,33 3,73	3,17-4,33 3,78	3,50-4,33 3,91
Fines content (0-1 mm) in non-pelletized charge, %		52,89-63,36 57,24	51,99-60,75 56,83	51,89-59,74 54,50	51,93-56,66 54,28
Humidity of pelletized sinter charge, %		7,30-9,20 8,07	7,33-8,50 7,92	7,67-8,67 8,18	7,5-8,5 8,04
Fractional composition of pelletized sinter charge, %	+10mm	9,12-13,32 11,69	7,70-11,43 9,53	9,19-13,77 10,84	8,48-12,24 10,27
	5-10 mm	11,99-18,76 14,32	10,04-18,00 14,42	8,51-21,08 15,61	12,97-18,76 16,22
	3-5 mm	15,97-25,77 19,97	14,35-27,84 20,56	19,74-27,05 22,24	16,98-22,70 20,16
	1-3 mm	30,69-42,01 36,54	36,29-42,45 39,14	35,89-44,84 40,90	40,55-46,22 43,72
	0-1 mm	8,54-27,74 17,48	8,40-26,52 16,35	4,92-19,03 10,42	3,83-17,29 9,63
Vacuum in the reservoir, kPa		5,1-6,1 5,51	5,1-5,7 5,31	4,9-5,5 5,18	4,3-5,3 4,78
Temperature in the collector, °C		80-125 102	80-115 99,5	80-120 101	85-135 108
Actual speed of the sinter belt, m/min		1,6-1,8 1,73	1,6-1,85 1,78	1,75-1,95 1,85	1,7-2,1 1,92
Given speed of the sinter belt, m/min*[3]		1,65-1,85 1,74	1,75-1,88 1,79	1,80-1,90 1,85	1,83-2,13 1,96
Design capacity, tons/(m^2×h)		0,961-1,105 1,047	1,017-1,081 1,049	1,043-1,146 1,090	1,073-1,222 1,143
Strength during the drop test according to GOST 25471-82, %		9,33-11,26 10,34	9,40-10,46 9,99	8,65-9,83 9,35	8,44-9,98 9,10
Impact strength according to GOST 15137-77, %		62,55-66,60 65,24	62,09-67,13 65,90	63,22-69,71 67,14	65,64-70,81 67,92
Abrasion resistance according to GOST 15137-77, %		4,78-5,89 5,35	4,49-5,40 5,13	4,66-5,67 5,17	4,65-5,59 5,04

*[1] The change interval is the numerator, while the average value is the denominator;
*[2] A calculated value;
*[3] Speed, reduced to the constant temperature in the collector (100°C).

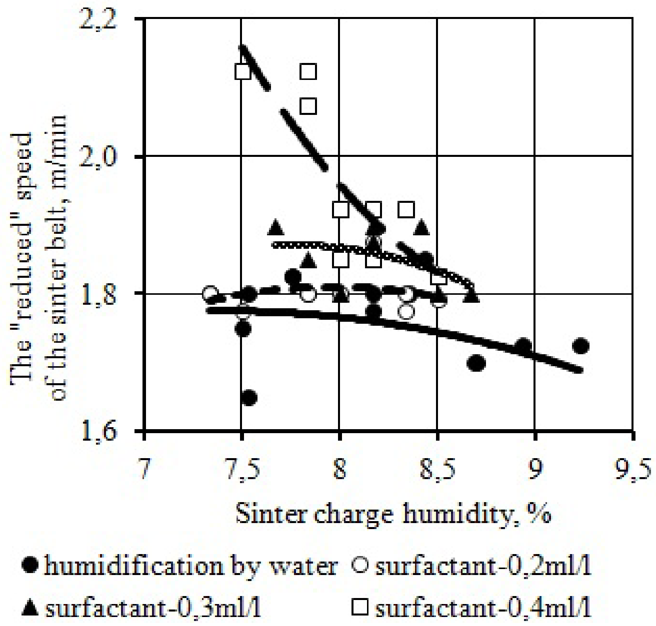

Fig. 4. Effect of humidity and surfactant concentration during on the «reduced» speed of the sinter belt.

1,6 l/h (0,3 to 0,4 ml/l) [17, 18] in the area of optimum moisture content of the sinter charge (up to 8 %).

The surfactants effect is additionally verified by the data referring to the «reduced» speed of the sinter belt (Fig. 4). It is obtained by recalculation of the actual speed at constant temperature in the collector (100°C) taking into consideration that the speed increase by 0,1 m/min leads to collector temperature decrease by 15°C - 20°C. The data obtained indicate that the surfactants used with a rate greater than 1,2 l/h (more than 0,3 ml/l) ensure the "reduced" speed sustainable increase of the sinter belt movement, and hence, increase of the productivity of the sinter machine in terms of gross sinter yield. The greatest effect is achieved in the area of optimum moisture (8 %). The efficiency of the binder use decreases in case of over humidified sintering of the charge.

The dynamics of the sintering parameters during the experimental period of surfactants use with a flow rate of 1,2 l/h - 1,6 l/h are presented in Fig. 5 to illustrate the surfactants effect on the sintering process course at a stable moisture content of the sinter charge (by 7,5 % - 8,0 %). The analysis of sintering indicators dynamics (Fig. 5) shows a high effect of surfactants use in sinter charge pelletizing. The improvement of the pelletizing quality using surfactants can significantly increase the speed of sintering, which is a reserve for productivity growth or increase of the sintered layer height. In addition, the increase of gas permeability of the sintered layer and its resistance to vacuum provide thermal stabilization of the process and production of sinter of better metallurgical properties [19 - 21].

The significant increase of the sinter strength at dumping is an important result of the investigated option of improving the process of the sinter charge pelletizing by surfactants humidification. It is visualized by the data in Table 3. The most significant increase in the sinter charge strength characteristics is observed in case the surfactant consumption is 1,6 l/h when the number of the fines formed after flushing is reduced from 10,5 % - 11,0 % to 8,5 % - 9,5 %. The sinter strength increase at flushing leads ultimately to lower fines content (0 mm - 5 mm) and increase of the yield due to stabilization of the sintering thermal conditions in a sinter charge of more uniform fractional composition.

The increase of the sinter yield in presence of surfactants, along with the increase of the sintering speed (the speed of movement of the sinter belt) leads to a higher output of a fit agglomerate (Table 3). Thus, the fit agglomerate yield increases from 1,03 t/m^{2}h - 1,04 t/m^{2}h to 1,05 t/m^{2}h - 1,10 t/m^{2}h, i.e. by 2 % - 5 % (Rel) in case of a surfactant flow rate of 1,2 l/h (0,3 ml/l) when compared to the "base" option. The increase of

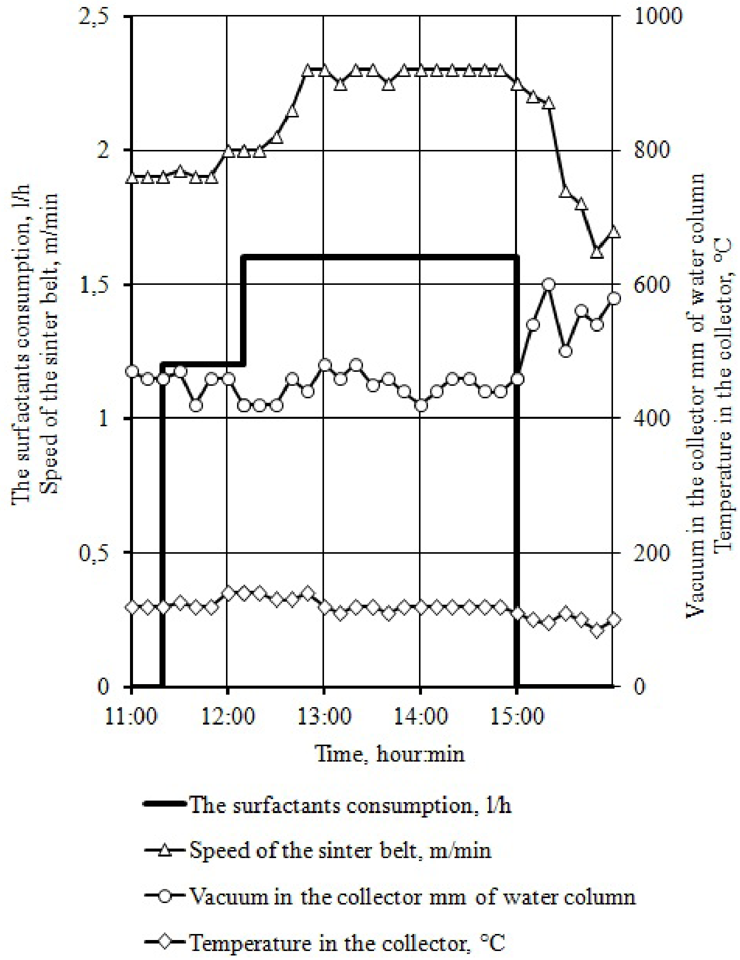

Fig. 5. Dynamics of sintering indicators during the pelletizing experiment connected with surfactants consumption of 1.2 l/h -1.6 l/h (24 June 2014).

the surfactant consumption to 1,6 l/h (0,4 ml/l) results in increase of the average productivity of the sintering machine during the experimental period up to 1,15 t/m^{2}h - 1,20 t/m^{2}h. Such a significant performance increase obtained in presence of surfactants results not only from gas permeability increase of the cold state layer, but also from conservation of the pellets strength during sintering. It should be noted that a substantial increase in the productivity of the sintering machine in presence of a surfactant is possible only in case of a stable operation of the charge feed. The efficiency of the surfactants use is significantly reduced when the particle size distribution and material composition of the charge fed for pelletizing fluctuates significantly. The use of surfactants under such conditions contributes only to flatten the existing oscillations, thereby stabilizing the process and preventing the formation of "non-sintering" which coming back subsequently to the charge leads to additional difficulties in maintaining optimal humidity of the charge.

The thermal stabilization of the agglomeration level provides a more complete and uniform process of agglomeration, which affects positively the sinter strength properties (Table 3). The strength impact increases steadily by 2 % - 4 % (abs.) when using a surfactant with a consumption greater than 0,3 ml/l regardless of the charge humidity. Abrasion resistance is steadily improving (by 0,2 % - 0,4 % abs.) when the surfactant flow rate increases to 0,4 ml/l.

Thus, the results of the pilot experiment confirm the effectiveness of surfactants use in improvement pelletizing as well as the technological and qualitative indicators of the sintering process. It is necessary to modernize the water supply to the pelletizers to implement the developed technology of surfactants use. This can be done by introduction of an installation for surfactant dispensing [22, 23].

CONCLUSIONS

A set of pilot experiments were performed to improve the pelletizing through the use of water-soluble organic surfactant during humidification of the sinter charge. The positive influence of surfactants on the quality of the charge preparation for sintering, on the progress and the agglomeration results was established. It referred to:

- improvement of the granularity and gas permeability of the sinter charge;
- depression decrease and sintering rate increase providing increase of the speed of the sinter belt and the output;
- stabilization of the heat level of the agglomeration process, improvement of the sinter quality affecting additionally the fit agglomerate yield.

The achieved quantitative effect of the experimental surfactant use was defined by the cost of the binder, the stability of the charge feed and the parameters of the sinter charge humidification. The greatest effect was achieved when the sinter charge was additionally humidified by aqueous solutions of the experimental surfactant of concentrations of 0,3 ml/l - 0,4 ml/l in case the humidity of the charge was 7 % - 8 %.

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