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TECHNOLOGICAL PARAMETERS DETERMINING PHYSICAL-CHEMICAL PROPERTIES AND REQUIRED QUALITY OF GREEN PELLETS AT THE ROASTING MACHINE No. 3 OF PJSC "MIKHAILOVSKY GOK"

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ABSTRACT

Physical and chemical properties of green (fresh) pellets, as a measure of the pellet quality, is one of the key factors determining the technical and economic performance values of the state-of-art roasting machines. The experience of modernization projects at practically all pelletizing plants in Russia and other CIS countries, proves conclusively that the operational effect of modernization of thermal routes depends on the quality of green pellets. Moreover, the latter determines the service properties of the fired pellets to a great extent.

Solving of the above-mentioned problems allows to improve substantially the technical and economic operating parameters of roasting machines, as well as the quality of the finished product. The latter is especially critical in the production of direct reduced (DR) pellets, since the requirements to fired pellets are generally more strict than that to those for blast furnace practice.

To improve the technical and economic parameters of a pellet plants, one should identify the bottleneck areas/stages in the pellet production process and develop the technical solutions to improve the efficiency of the mentioned areas. One of such areas is a green pelletizing shop and its line for handling and feeding of green pellets to a roasting machine.

This article describes the major innovative process solutions implemented at the roasting machine No 3 at PJSC "Mikhailovsky GOK" and its ancillary facilities, which enabled to maximize the quality of green and, respectively, commercial fired pellets.

Technological parameters of the process influencing the physical and chemical properties of green iron ore pellets are presented. The achievements of the implemented technological scheme and the ACS system of the roasting machine allowed to meet the conditions required for the production of high-grade green pellets of consistent quality in order to achieve the efficient technical and economic performance parameters for a new-generation roasting machine.

Innovation approach to choice of the technological route, the main technological equipment at the areas of blending, filtration, dozing, mixing and pelletizing has been realized in the technological complex of roasting machine (TCRM) No. 3 (MOK-1-592) at PJSC "Mikhailovsky GOK" (MGOK). Choice of equipment and its location are based on the scientific-technical decisions including the long-term experience and results of multiple scientific investigations and industrial testings at different domestic pelletizing plants (i.e. two operating pelletizing areas with roasting machines No. 1 and No. 2 at MGOK) [1–17].

The main innovative technological solutions [1, 11–17] allowing to improve maximally the quality of green pellets and, respectively, of commercial fired pellets are realized in the pelletizing shop TCRM No. 3 and they are listed below:

– blending of concentrate pulp in special mixers;
– dewatering of pulp at modern vacuum filters with multi-functional operating procedure;
– usage of high-efficient mixers for charge materials;
– mounting of bins for preliminary holding of charge materials (including binding additive) before pelletizing;
– usage of water-air nozzles in pelletizers;
– applying of collecting conveyor for distribution of conditional green pellets with movable discharging capsule.

Technological process of pelletizing is completely automatic due to using of the modern automatic control system. Stabilization of the quality parameters at each production stage in order to minimize the effect of fluctuations on quality of finished products is considered as the conceptual approach to automation of pellets fabrication. Consequent stabilization of the processes at all technological stages allowed to provide high quality of fired commercial pellets.

It is known that iron ore after degradation and concentration can differ in the form of particles, their physical properties and chemical-mineralogical composition [2, 18]. Nature and structure of iron ore concentrate as pelletizing material has the effect on the pelletizing process. It is more difficult to pelletize the grains with irregular shape and sharp angles, but they form more dense structure with larger contact area, while the particles with round form are easier subjected to pelletizing, but their contact area is smaller. Chemical and mineralogical composition of material has substantial influence on the adhesion forces between hard particles owing to the differences in their surface wetting ability [3]. Usage of pulp mixers in the technological route of pellets fabrication makes it possible to blend concentrate pulp, entering from the MGOK concentration complex, by its physical-chemical properties and mineralogical composition. Stability of iron ore concentrate properties allows to manufacture green pellets that are uniform in their granulometric composition with minimal root-mean-square deviations by mechanical properties in comparison with pellets from mining and concentrating works (where iron ore pulp is transferred directly to the filtration stage without preliminary blending.

The machinery chain in the dewatering sections includes both main equipment (thickeners, vacuum filters) and auxiliary equipment (pumps for pulp pumping, receivers, traps, vacuum pumps). Location of the main and auxiliary equipment in these sections is very important, because it has the effect on the technological parameters of the process. Individual route of switching-on of vacuum filters [4] has been envisaged during designing of the filtration section, despite this solution required mounting of many receivers. Transition to the individual switching route was caused by the reason that the experience of conducting investigations at mining-concentrating and other industrial enterprises [5] has revealed a row of essential problems during operation of group routes of filtration equipment. Mutual effect of vacuum filters inside such group was the main of these problems. But this mutual effect is completely excluded for the case of individual switching of vacuum filters to receiver. Thereby, flexible management of the operation procedure of the filtration section during its putting into practice and further operation has been realized. At present time uniform iron ore concentrate is transferred to the pelletizing shop TCRM No. 3 as a result of implementation of these technical solution; this concentrate is uniform in its physical-chemical properties, mineralogical composition and it is characterized by stable wetting ability meeting the MGOK technical requirements.

During manufacture of green pellets it is very important to provide high-quality mixing of charge material. The main component of charge materials — iron ore concentrate — is mixing with the binding additive (bentonite) that determines mechanical properties both green and (mostly) dry pellets [6, 11, 14]. Sufficient strength of pellets in dried state stipulates resistance to destruction of pellets in the lower layer during drying at a roasting machine after reverse of heat carrier. Additionally, presence of bentonite in composition of charge material allows to rise the "shock" temperature of green pellets and thereby to decrease possibility of destruction and forming of micro-cracks of pellets in the surface layer, entering in the heating area of roasting machines.

Blending of composition of charge materials is the important stage in fabrication of pellets. Just this process have influenced finally on stable operation of pelletizing equipment, as well as on uniformity of physical properties of green and dry pellets. Uniformity of charge material in its size, wetting ability and regularity of distribution of its components through all its mass are achieved by correct and precise dosing of the components of charge material as well as high efficiency of their mixing in mixers. Large-scale testings for evaluation of operating efficiency for mixers of different types (Russian screw mixers, Eirich and Lödige mixers from Germany) have been conducted previously in the conditions of "Karelsky Okatysh", while experiments with rotor and drum mixers have been undertaken at Lebedinsky GOK. The results of these tests allowed to recommend Lödige mixers with high mixing efficiency (more than 95%) to be put into practice at Lebedinsky GOK. Additionally, these mixers are characterized by surface activation of particles due to high speed of blades motion in a flow of mixing materials; it provides good pelletizing ability of charge material. Efficient mixing enables preparation of charge available for production of green pellets that are uniform in their parameters (size and mechanical properties). Thereby decrease of spillage amount out from under the roller feeder was achieved at TCRM No. 3, while oscillations of productivity of the roasting machine were lowered at maximal extent due to stabilization of pelletizing process.

Preliminary holding of charge material during preset time before pelletizing has been introduced in the technological process at the TCRM No. 3 pelletizing plant. Special bins with charge material were mounted within pelletizing area for this purpose, in addition to the main technological equipment. But at the most pelletizing plants (e.g. at the operating pelletizing areas of the roasting machines No. 1 and No. 2 at MGOK) such preliminary holding of charge material is absent, and charge material is transferred directly to pelletizing plants after mixers. Multiple researches [7, 15] devoted to examination of bentonite and wet concentrate interaction testified that charge material should be hold preliminarily during preset time to provide the best interaction between these two components during pelletizing. This preliminary holding enable re-distribution of interaction forces for the particles of concentrate and bentonite and thereby has substantial effect on qualitative parameters of pellets. Duration of holding is determined experimentally and connected with bin volume and material consumption.

Fig. 1 presents comparison of averaged quality parameters of green pellets entering the roasting machine No. 3

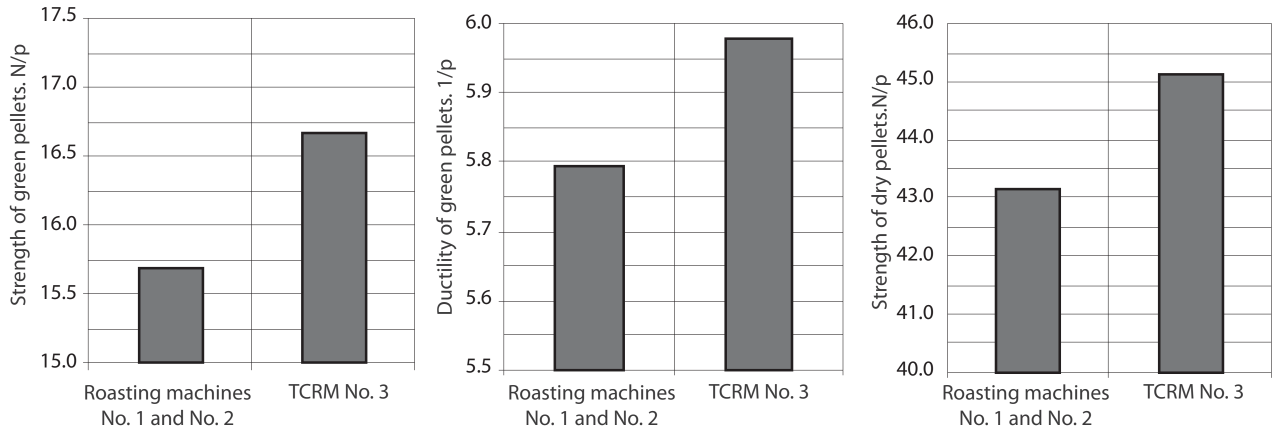

Fig. 1. Qualitative parameters of green and dry pellets in TCRM No. 3 and roasting machines No. 1 and No. 2 at PJSC "Mikhailovsky GOK"

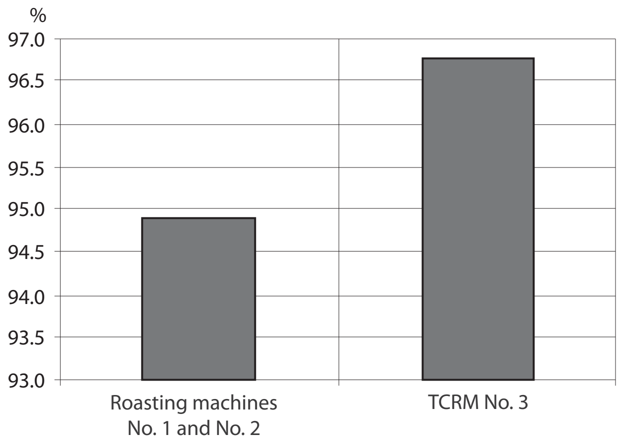

Fig. 2. Output of pellets of acceptable class (10–16 mm) from the technological pelletizing lines of TCRM No. 3 and the roasting machines No. 1 and No. 2 of MGOK

(TCRM No. 3) and roasting machines No. 1 and No. 2 at MGOK as well as quality parameters of dry pellets.

Water supply to pelletizing units was planned for the cases if stabilization of humidity of green pellets and improvement of their ductility is required. Water-air nozzles were mounted in each pelletizing unit for this purpose. Water supply to pelletizing units is provided as fine-dispersed mix using compressed air feed; as a result, uniform humidification of the whole surface of fed charge material occurs together with circulating load. Automatic water supply to pelletizing units is also envisaged.

The sensors of contact-free system "Grain size indicator" were mounted for control of granulometric composition and evaluation of physical properties of pellets above a roller screen of the each technological line. This system [8] has been developed in NPVP TOREX and was used successfully at several Russian mining and concentrating plants (e.g. at Lebedinsky GOK and EVRAZ KGOK) as well as at Donsloy GOK in Kazakhstan. The results of control of granulometric composition of a layer surface of green pellets using "Grain size indicator" system are used for load re-distribution among pelletizing units, for adjusting of binder dosing and are devoted for stabilization of mechanical properties of green pellets and, as a result, for creation of optimal heat engineering operating parameters of the roasting machine. Output of green pellets of acceptable class (10–16 mm) from the technological pelletizing lines of TCRM No. 3 increased by 2.0% (abs.) relating to green pellets from the roasting machines No. 1 and No. 2 of MGOK (see **fig. 2**).

Several works uses in the practice of their pelletizing plants pull-out conveyors for transportation of finished pellets from pelletizing units; their construction allows to vary the charging point of pellets from pelletizing unit if required in relation to the axis of collecting conveyor. Thereby it is possible to adjust loading uniformity of this conveyor as well as to correct quickly distribution of pellets along the width of the collecting conveyor if any of pelletizing lines is stopped. The new technical solution for using the drive for transfer of conveyors with finished pellets in TCRM No. 3 technological lines makes it possible to correct automatically charging point of finished green pellets to collecting conveyor.

Examinations of destruction degree of green pellets along the route of their transportation from pelletizing units to roasting carriages [9, 15] displayed that destruction part in overloading conditions at the operating pelletizing plants makes 10–12% in average, depending on quality of green pellets and productivity. About one fifth part of fines forming during transportation of green pellets is presented by losses during their transportation from collecting conveyor to charging point.

Mounting of the collecting distributing conveyor with a sliding discharging capsule allowed to provide lowering of destruction of green pellets and respectively to decrease returns from roller feeder, as well as to achieve larger productivity for dry pellets that enter TCRM No. 3 roasting machine for heat treatment (**fig. 3**).

Forming of fines during transportation of green pellets at TCRM No. 3 in comparison with roasting machines No. 1 and No. 2 decreases in average from 9.1% to 5.4% (see fig. 3) due to excluding of reloading of pellets from collecting conveyor to tilting stacking tripper, as well as due to lowering of the layer height and speed of collecting conveyor. This technological route of transportation of green pellets has never been used before at Russian pel-

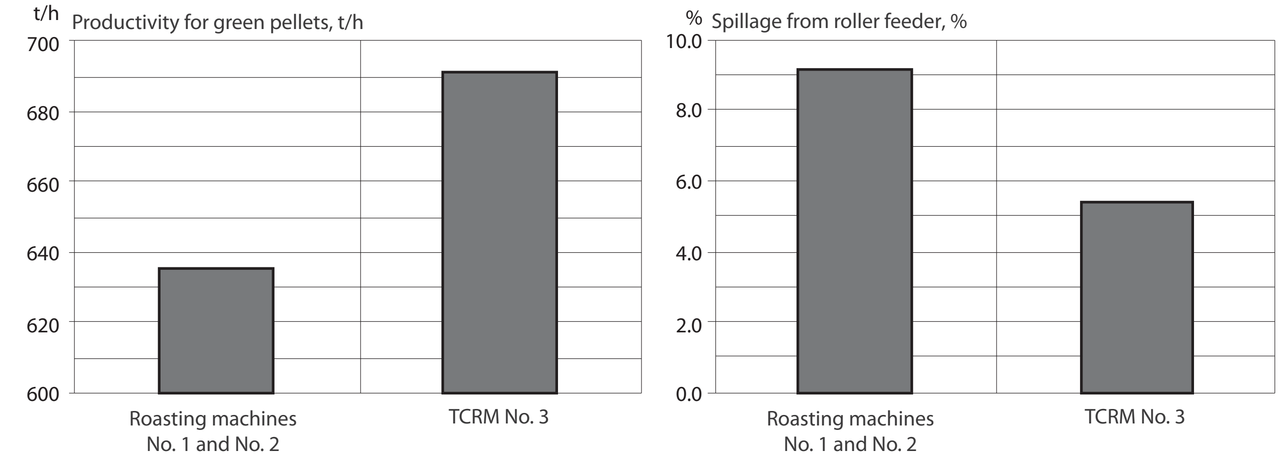

Fig. 3. Productivity for green pellets and returns from roller feeder at TCRM No. 3 and the roasting machines No. 1 and No. 2 of MGOK

Main physical properties of green and fired pellets in TCRM No. 3 and roasting machines (RM) No. 1 and No. 2 of PJSC "Mikhailovsky GOK"

No. of RM	Green pellets						G on RM, t/h	Spillage from roller feeder, %	Fired pellets: R, kN/p
	W, %	*R*, N/p	*N*, 1/p	R_{dr}, N/p	d_{cp}, mm	10–16 mm, %			
RM No. 1, No. 2	9,7	15,69	5,8	43,15	12,4	94,9	635	9,1	2,87
TCRM No. 3	9,73	16,67	6	45,11	12,41	96,8	691	5,4	3,12

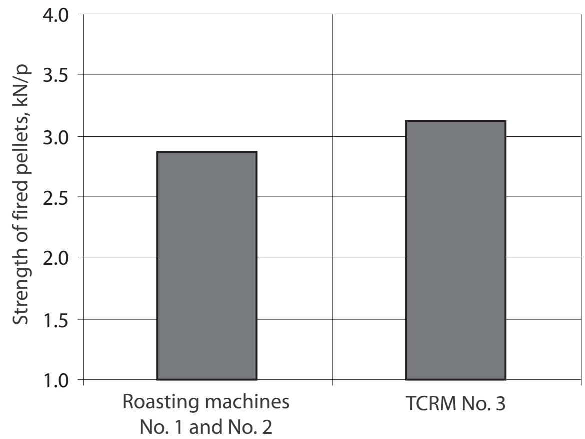

Fig. 4. Strength of fired pellets at TCRM No. 3 and roasting machines No. 1 and No. 2 of PJSC "Mikhailovsky GOK"

letizing plants. The chosen route of placing of pellets on the roasting machine is not conventional, thereby especial attention was paid to choosing of speed values and width of flow on conveyors for feeding of green pellets to the charging point. The collecting and distributing conveyor with sliding capsule is intended for delivery of green pellets from pelletizing units as well as for uniform distribution of pellets along width and length of the roller feeder and, respectively, the roasting machine. Uniform distribution of pellets along the width of the roasting machine is provided due to the speed managing contour of the feeding conveyor with sliding capsule and the rotation frequency managing contour for rolls of the roller feeder.

The table presents the data for January — June 2017 (averaged) on the main physical properties of green pellets and strength of fired pellets in TCRM No. 3 and roasting machines No. 1 and No. 2 of MGOK.

Strength of fired pellets (**fig. 4**) has been increased as a result of quality improvement of green pellets (see fig. 3) at the pelletizing area of the technological complex of roasting machine No. 3. Cold strength of fired pellets increased by 8.5%.

Therefore, PJSC "Mikhailovsky GOK" succeeded to implement the preset task — production of green pellets with high and stable quality via realization of innovative technical solutions in the development of technological route and automatic control system for TCRM No. 3. It was the required condition for achievement of high technical and economical parameters of the roasting machine of new generation (MOK-1-592) that has been developed and manufactured by the Russian scientists and engineers.

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IMPROVEMENT OF THE MELTING TECHNOLOGY AND LADLE TREATMENT OF STEELS 15Х2НМФА (15Kh2NMFA) (A-A, CLASS 1) FOR SPECIAL CRITICAL DUTY COMPONENTS IN NUCLEAR POWER STATIONS*

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Key words:

heat-resistant steels, melting, liquid semiproduct, dephosphorization, desulfurization, deoxidation, vacuum treatment, charge materials.

ABSTRACT

The ways of increase of the power engineering products resource for large-size critical components made of steel 15Kh2NMFA are described in terms of radiation and thermal brittleness criteria due to the content restriction of harmful and impurity elements, primarily phosphorus, sulfur and hydrogen. The steelmaking process for this steel grade includes smelting of liquid semiproduct in the electric arc furnace DSP-120, secondary refining process and ladle-vacuum treatment. The main technological task in melting of this semiproduct is obtaining of a final phosphorus content not more than 0.003% using deep dephosphorization process. For this purpose solid carburizers in the charge, such as pig iron and coke, are replaced by pulverized carbon-containing materials, blowing-in with oxygen or adding to slag during oxidizing period. In order to organize the process of deep desulfurization simultaneously with the removal of hydrogen, it is necessary to obtain the optimal slag composition in the required amount and high deoxidation of the metal before ladle vacuum treatment. Deep bulk deoxidation was carried out immediately during discharge of liquid semiproduct out of the electric arc furnace. Regulated content of the following elements was obtained as a result of usage of these methods: phosphorus 0.003–0.004%, sulfur 0.001–0.002%, hydrogen 0.8–1.1 ppm, oxygen activity 3–5 ppm.

1. Introduction

Rise of efficiency and safety of nuclear power engineering require increase of service life of nuclear power plants (NPP) and level of their reliability. It concerns to the shells of nuclear reactors (NR) in the most degree because just they determine the resource of nuclear power plants in general [1–3]. It also stands the new requirements to the materials for large shell products. NR shells are large and complexly loaded products and shell materials are subjected during operation to mechanical loading at high temperatures as well to thermal and radiation (for NR shell) embrittlement [4–10]. Resource of shells is determined by saving of the required level of tough–ductile properties, what requires rise of their initial level as well

*A. P. Kulikov, V. A. Tsarev, V. A. Novikov and D. S. Tolstykh participated in this research..