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INFLUENCE OF THE PRESSING TEMPERATURE OF HALURGIC POTASSIUM CHLORIDE ON THE OPERATING CONDITIONS OF THE GRANULATION PLANTS

Abstract. The regularities of the influence of the pressing temperature in the roll compactors of halurgic fine-grained potassium chloride on the performance of the granulation process and the physical and mechanical properties of the granulate under the conditions of the Sylvinite Processing Plant of JSC "Belaruskali" are determined. It is shown that an increase in the pressing temperature from 120 °C to 142 °C significantly enhances the intensity of the processes of particles recrystallization and melt formation at the particles' contact points in the zone of plastic deformation, which provides greater strength of interparticle contact bonds due to the formation of additional bonds of the crystallization type. At the same time, the particle size distribution of the granulate practically does not change. Only a slight decrease in the dynamic strength of the granulate was revealed as a result of a small increase in the number of cavities and cracks in the granules, which is not critical for obtaining a high-quality finished product. In general, an increase in the pressing temperature of halurgic fine-grained potassium chloride up to 140–145 °C enables to enhance the capacity of granulation plants up to 130 % without reconstruction of existing production lines while maintaining the high strength and granulometric characteristics of finished products. At the same time, the switch to higher pressing temperatures requires solving the problem of intensive salt caking on the working surfaces of the rolls of roll compactors based on the technical modernization of the existing compacting plants, taking into account the recommendations developed.

Keywords: roll compactor, potassium chloride, granulate, pressure, pressing temperature

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ВЛИЯНИЕ ТЕМПЕРАТУРЫ ПРЕССОВАНИЯ ГАЛУРГИЧЕСКОГО ХЛОРИСТОГО КАЛИЯ НА ПАРАМЕТРЫ РАБОТЫ ГРАНУЛЯЦИОННЫХ УСТАНОВОК

Аннотация. Установлены закономерности влияния температуры прессования в валковых прессах галургического мелкозернистого хлористого калия на производительность процесса гранулирования и физико-механические свойства гранулята в условиях сильвинитовой обогатительной фабрики ОАО «Беларуськалий». Показано, что увеличение температуры прессования со 120 до 142 °C существенно повышает интенсивность процессов рекристализации частиц и образования расплава в местах контакта частиц в зоне пластической деформации, что обеспечивает большую прочность межчастичных контактных связей за счет образования дополнительных связей кристализационного типа. При этом фракционный состав гранулята практически не изменяется. Выявлено только незначительное снижение динамической прочности гранулята в результате небольшого увеличения количества трещин в гранулах, что не является критичным для получения качественного готового продукта. В целом увеличение температуры прессования галургического мелкозернистого хлористого калия до 140–145 °С позволяет без реконструкции существующих производственных линий повысить производительность грануляционных установок до 130 % при сохранении высоких прочностных и гранулометрических характеристик готовой продукции. При этом переход на более высокие температуры прессования требует решение проблемы интенсивного налипания соли на рабочих поверхностях валков валковых прессов на основе технической модернизации существующих установок прессования с учетом выработанных рекомендаций.

Ключевые слова: валковый пресс, хлористый калий, гранулят, давление, температура прессования

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Introduction. The main method to obtain granular potash fertilizers is compacting the fine bulk material to produce a compacted strip of material (tiles), which is subsequently crushed and sent for screening to select the commercial fraction, which is a finished product (granulate). The method is based on the ability of bulk materials to be compacted under high pressure to form a stable dense structure of the substance due to the appearance of strong cohesive bonds between the particles. The method is performed using, as a rule, roll compactor by continuous feeding the material into the area between two counter-rotating smooth or profiled rolls. In general, the theoretical basis for determining the mechanical characteristics of the material while pressing (compacting) and the basic process flow diagrams and equipment have remained virtually unchanged over the last fifty years and are described in many papers [1–8]. It was found that the granules of potassium chloride obtained this way are polycrystals, and the compacting of potassium chloride, which, like all halogenides of alkali metals, has a high energy of the crystal lattice, is technologically difficult and energy consuming process. During the compacting process, numerous small defects are formed at the contact points of compacted grains, which are transformed by recrystallization processes into larger ones, forming a porous granule structure which largely determines its physical-mechanical and physical-chemical properties. The mechanical strength of polycrystals is determined primarily not by the strength of the crystals themselves but by the number and strength of interphase contacts between them.

At the same time, despite the detailed study of many important aspects of the granular potash fertilizers production, a number of provisions and recommendations require clarification, where one of the most important issues to be solved is the choice of the optimal temperature for compacting the charge in the roll compactor. This is particularly relevant for the process of obtaining granulate from fine halurgic potassium chloride. In the known sources this problem has not been studied at all. There was only some coverage of influence pattern of pressing temperature on physical and mechanical properties of granulate obtained by processing of flotation potassium chloride, and that mostly determined by laboratory studies [2, 7] and not adequately supported by the results of research under conditions of high-tonnage production. In addition, it should not be forgotten that the initial charge of halurgic fine-grained potassium chloride is significantly different in its physical, chemical and fractional composition from the charge of flotation origin, which, for example, has significantly more fine particles whose prevalence contributes to the formation of bonds between particles during their compaction based on Van der Waals forces [7]. Thus, the solution of problem regarding the choice of pressing temperature in roll compactors of halurgic fine-graded potassium chloride has an important applied meaning for Belarusian potash industry, because the Sylvinite Processing Plant of the Production Unit 4 of JSC "Belaruskali" (SPP 4 PU) has the large-capacity production of granular halurgic potassium chloride in the amount of up to 950 thousand tonnes per year, while the demand for such products in the world market grows constantly. The increase of the granulation plants capacity and the quality of the finished products will significantly enhance the competitiveness and the export potential of the Belarusian potash industry. Accordingly, the purpose of the paper presented was to investigate the influence of pressing temperature of halurgic fine-grained potassium chloride on the capacity of the granulation process and physical and mechanical properties of the granulate under conditions of JSC "Belaruskali" Processing Plant and to develop recommendations on improvement of the technological process.

Results and their discussion. The research was carried out in the potassium chloride granulation department of the Processing Plant PU 4, where the process of obtaining the granular product includes several process stages:

Stage 1: The dewatered charge consisting of the standard potassium chloride is fed from the thickening and centrifugation department to the drying and granulation department to fluid bed dryers for drying and heating. The product, heated to technological temperature, is then conveyed by a system of elevators and conveyors to three granulation plants;

Stage 2: The granulation plants compact the charge, crush and classify the oversize product to produce granulate of a commercial grade, which is sent to a granulate enrichment unit by a system of conveyors;

Stage 3: The granulate is further classified, moistened, scrubbed, dried, cooled and treated with reagents and then transported to finished product warehouse by a system of conveyors.

The research was carried out as part of technological stages 1 and 2 (production of granular product).

The research methodology involved measuring the operating parameters of the granulation equipment under three set modes of operation with temperatures in the shaft of the roll compactor at about 120 °C, 130, and 140 °C, respectively. For each mode of operation of the granulation plants their maximum capacity, physical and mechanical characteristics of the product obtained, as well as the effect of temperature on the change in the ratio of the formed flows of granulate, oversize and undersize product (retur) were evaluated. The process flow diagram of the equipment of the granulation plants being researched and of the main flows of the product is shown in the Figure 1.

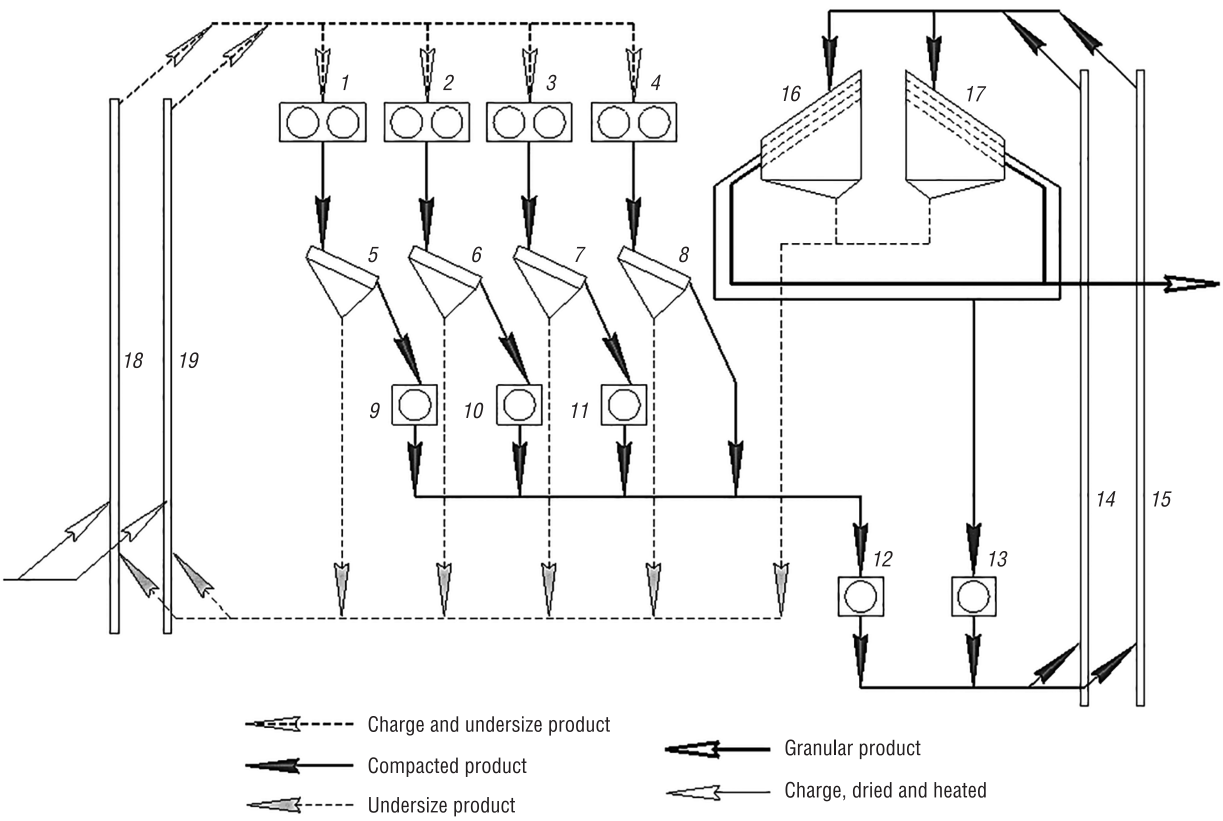

Figure 1. The process flow diagram of the granulation plant: *1–4* – roll compactors; *5–8* – roller screens; *9–11* – rotary crushers; *12* – impact crusher; *13* – hammer crusher; *14*, *15*, *18*, *19* – bucket elevators; *16*, *17* – three-product sieving machines

The temperature conditions of compacting were provided by changing the temperature of charge heating in fluidized bed furnaces within 130–160 °C in order to ensure the necessary temperature in the shafts of the roll compactors, taking into account the heat losses during transportation of material and mixing the undersize product from screens and sieving machines.

Each granulation plant includes (see Figure 1): roll compactors produced by JSC “Soligorsk Institute of Resource Saving Problems with Pilot Production”, type PVP (pos. *1–3*) and roll compactor produced by Zemag Zeiz (pos. *4*); fixed single deck roller screens (pos. *5–8*) with bar screens; PSp1 000M type rotary pre-crushers (pos. *16*, *17*); Hazemag AP-SMA 1020 impact crusher (pos. *12*); re-crushing hammer crusher of the type FAM-PHM 1012 MVD (pos. *13*); bucket elevators (pos. *14*, *15*, *18*, *19*); three-product sieving machines type DF195 × 600/3 manufactured by Rhewum (pos. *20*, *21*).

The general picture of the granulate production process at the time of the research was as follows. The charge, dried and heated in fluidized bed furnaces at the process stage 1, was fed to a collecting scraper conveyor, and from there it was spread to the granulation plants. At each plant, the charge using the elevators, pos. *18*, *19*, and the distribution conveyor, located above the roll compactors, pos. *1–4*, is distributed in the compactors’ shafts. The undersize product from the roller screens, pos. *5–8*, and sieving machines, pos. *16*, *17*, was fed into the elevators. From the distributing conveyor the mixture of charge and undersize product was transported into the shafts of the roll compactors, pos. *1–4*, through the electric cut-off valves. Four compactors were in continuous operation. In roll compactors the initial product was formed into a tile and a part of it came out as spillage. In the roller screens, pos. *5–8*, the compacted product (oversize product) and the spillage (undersize product) were separated. The oversize product, most of which passed through the pre-crushers, pos. *9–11*, was forwarded by means of a scraper conveyor to the impact crusher, pos. *12*. From the latter, through the scraper conveyor and the elevators, pos. *14*, *15*, the crushed oversize product was fed to the three-product sieving machines, pos. *16*, *17*. The oversize product from the top and middle deck was re-crushed in the hammer crusher, pos. *13*. The oversize product from the bottom deck (granulate) was transported to the enrichment unit. The undersize product from the bottom deck, together with the undersize product from the roller screens, pos. *5–8*, was conveyed by means of the elevators, pos. *18*, *19*, and the scraper conveyors for re-compacting, as mentioned above. The working pressure in the hydraulic system of roll compactors of PVP type was maintained between 15.5–16.3 MPa in accordance with the set technological requirements. The working pressure in the hydraulic system of Zemag Zeiz roll compactors was maintained between 9.8–10.2 MPa.

It should be noted that the granulometric composition of the charge supplied to the granulation plants during the whole period of testing, practically did not change and is described with sufficient accuracy by the following particle size distribution: 1.6 mm – 0.3 %; 0.8 mm – 0.6 %; 1.1 mm – 0.5 %; 0.315 mm – 10.6 %; 0.25 mm – 14.2 %; 0.2 mm – 17.9 %; 0.1 mm – 41.4 %; – 0.1 mm – 13.9 %.

The Table summarises the measurements results of granulation plants’ operating parameters, indicating the positions of the equipment as shown in the Figure 1.

The analysis of the equipment operating parameters presented in the table shows that with an increase in the pressing temperature, the output of granulate increases, i.e., the capacity of the plants increases. Thus, when we change the temperature in the shafts of the compactors from 121–124 to 140–142 °C, the output of granulate increases from 49 to 65 t/h. The reason for this allows us to set up the analysis of regularities of change in the ratio of drives’ currents of elevator groups, pos. *14*, *15* and *18*, *19*, when changing the pressing temperatures, which are graphically presented in the Figure 2.

Parameters of operation of granulation plants

Granulate output, t/h	Number of measurements	Temperature in the shaft of roll compactors, °C				Current of elevators’ drives, A			
		Pos. 1	Pos. 2	Pos. 3	Pos. 5	Pos. 18	Pos. 19	Pos. 14	Pos. 15
65	1	141	140	140	135	46.5	37.9	52.0	59.7
	2	142	141	141	141	45.3	35.7	51.8	60.7
53	3	134	133	127	132	42.6	41.2	41.9	50.1
	4	134	134	127	133	43.4	40.9	41.5	51.7
49	5	120	113	119	121	55.3	51.3	44.7	52.2
	6	123	115	122	124	54.6	51.0	45.1	52.2

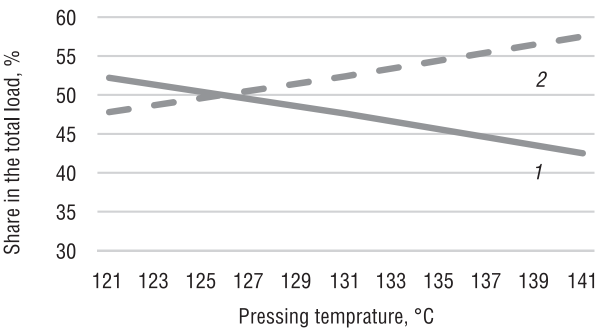

Figure 2. Change in the ratio of the relative share of the current loads of the elevators’ drives when the pressing temperature changes: curve *1* – relative share of the current load of the elevators’ drives feeding the undersize product with the charge; curve *2* – relative share of the current load of the elevators’ drives feeding the oversize product

As you can see from this figure, with increasing the pressing temperature, the relative share of the current load of the elevators, pos. *18* and *19*, decreases and that of elevators, pos. *14* and *15*, increases. This indicates that with an increase in the pressing temperature compared to the total load on the roll compactor the output of the undersize product of the roll screens, pos. *5–8*, and the sieving machine, pos. *16* and *17*, decreases, and the output of the oversize fractions increases, which in turn indicates a corresponding increase in the quality of the tiles formed in the roll compactor, including their homogeneity. In our opinion, with increasing the pressing temperature within the investigated limits there is an increase in the intensity of recrystallization of particles described in the papers [2, 4–6]. In addition, at high temperatures and pressures the process of melt formation at the contact points of particles in the zone of plastic deformation begins to have a significant influence; as a result, the subsequent cooling of the oversize product provides greater strength of interparticle contact bonds through the formation of additional crystallization-type bonds, the possibility of which was pointed out in the paper [2]. Thus, an increase in pressing temperature of halurgic potassium chloride within the investigated limits significantly increases the capacity of granulation plants by reducing the volume of circulating load of non-compacted particles (retur) on the roll compactors.

In the course of the researches, we also studied the influence of changes in the pressing temperature on changes in the physical and mechanical properties of the granulate. It was found that by increasing the temperature in the shaft of the compactors from 121 °C to 142 °C, by the corresponding change in the amount of the granulate output, no significant changes in the physical and mechanical properties of the product are observed. At all operating modes the particle size distribution of the granulate coming to the enrichment stage had the following particle size distribution: 4 mm – 2.0–4.4 %; 3.15 mm – 34.0–34.9 %; 2.8 mm – 11.9–13.3 %; 2.0 mm – 43.8–49.2 %; 1.0 mm – 0.4–1.1 %; –1.0 mm – 0.7–1.1 %. Such indicators fully meet the requirements of industry and international standards (GOST 4568-95, Technical Specification of the Republic of Belarus (TU RB) 600122610.010-2002, STO SPECS 001-98) applied to granular potash fertilizers.

Another important parameter of finished granular potash fertilizers is their dynamic strength, determined in accordance with the requirements of GOST 21560.3-82 “Mineral Fertilizers. Methods for determination of dynamic strength and abrasive resistance”. In accordance with the requirements of the mentioned industry and international standards this indicator must be not less than 80–85 %. During the research it was found that with increasing the pressing temperature there was a slight decrease in the dynamic strength of granulate from 94 to 92 %, in our opinion, because of a slight increase in the number of cracks in the granules. At the same time, the identified decrease in the dynamic strength of the granulate is not critical for the quality of the finished product. However, this fact should be taken into account in further research and development of compacting modes at higher temperatures, above 145–150 °C, in the compactor’s shaft.

In general, the results of these researches have shown that one of the ways to increase the capacity of granulation plants for halurgic fine-grained potassium chloride is to increase the pressing temperature to at least 140–145 °C. In the process of research, however, a serious technical problem was discovered that limits the possibility of direct implementation of higher pressing temperatures in the technological process. Namely, at pressing temperatures above 130 °C, a very significant intensification of adhesive interaction between potassium chloride salts and working surfaces of the rolls occurs. Rather quickly the forming elements (cells) on the working surfaces of the rolls are filled with the compacted material. The rolls become practically smooth and covered by a layer of caked salt. This reduces the capacity of the compactor and increases the density of the tiles. There are several solutions to this problem. For example, as shown in some papers (patent RU 2014231 “Anti-adhesive lubrication of molds during the formation and production of products made of synthetic polymers”; patent RU 2764206 “A method for reducing the sticking of salts on the surface of roll press granulators”), salt caking can be eliminated by applying an anti-adhesion agent or water to the work surface of the rolls. We also suggest that the problem can be solved by reducing the temperature of the rolls’ surfaces using cooling liquids. In any case, the implementation of these methods requires modernisation of the existing compaction facilities. Therefore, it was decided to start corresponding design works on improvement of roll compactors of PVP type within the framework of the creative cooperation between specialists of JSC “Belaruskali” and JSC “Soligorsk Institute of Resource Saving Problems with Pilot Production”.

Conclusion. The regularities of the influence of the pressing temperature in the roll compactors of halurgic fine-grained potassium chloride on the performance of the granulation process and the physical and mechanical properties of the granulate under the conditions of the Silvinite Processing Plant of JSC "Belaruskali" are determined. It is shown that an increase in the pressing temperature from 120 to 142 °C significantly enhances the intensity of the processes of particle recrystallization and melt formation at the particles' contact points in the zone of plastic deformation, which provides greater strength of interparticle contact bonds due to the formation of additional bonds of the crystallization type. Increase in the pressing temperature of halurgic fine-grained potassium chloride up to 140–145 °C enables to enhance the productivity of granulation plants up to 130 % using the existing production lines while maintaining the high strength and granulometric characteristics of finished products. The implementation of the compaction mode of halurgic fine-grained potassium chloride at the temperatures above 130 °C requires solving the problem of intensive salt caking on the working surfaces of the rolls of roll compactors based on the technical modernization of the existing compacting plants, taking into account the recommendations developed.

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