Effect of reactant treatment of rolling slime sewage on slime quality

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Abstract. This article considers the way to improve the quality of slime obtained from rolling based on the example of the slimes of the hot rolling mill 2500, Sheet Rolling Shop of the Open Joint-Stock Company “Magnitogorsk Iron and Steel Works” (MMK, OJSC). Hot rolling mill slimes can be used as secondary raw materials for metallurgical (blast-furnace and open-hearth steelmaking) and related manufacturing processes. At elevated slime humidity and high oil concentration its processing becomes rather difficult. Due to the improper slime quality, it is seldom applied for further production and is just accumulated in piles. Such piles pose a serious environmental threat polluting the atmosphere, groundwater, and soil. To resolve this problem, the authors studied the influence of slime sewage reactant treatment on slime quality.

1. Introduction
One of the largest water consumers at metallurgical plants are hot rolling mills. Consequently, this is the source of a significant amount of polluted waste water.

The wastewater, or sewage, originating from the cooling of bearings and hot rolling mill rolls, as well as oxide scale appearing after water descaling and underwashing, are polluted by scaling and oil [1]. The residue (slime) obtained after the cleaning of this wastewater also contains scaling and oil. Such slimes contain 10 - 95 % of scale, 10-50 % of oil products and 3-80 % of water [2].

Scale is a valuable secondary raw material for open-hearth, blast furnace and associated manufacturing processes. Iron is of economic interests, and its content in the slimes obtained from hot rolling mills can exceed 60%. Such slime can be used as an additive for a sinter-feed mixture [3]. In addition, the plant obtains its own iron-containing raw materials. Before being used as a secondary raw material, slime shall be dehydrated, and the content of oil products shall be decreased to a standard value [4].

The technology of rolling process slime treatment for the purpose of its further use can include thermal or chemical treatment, filtering in various devices, centrifugation, calcination, hydrodynamic cavitation in rotor-impulse devices, combined methods and other technologies [5-13]. The selection of one or another method depends on a particular manufacture, its scope, slime content and the feasibility report. The thermal method is the most well-developed technology. However, it is expensive and often negatively influences the environmental situation. The methods providing for the intensification of slime dehydrating and deoiling include the reactant treatment. The review of references and the existing experience demonstrated the reactant application also facilitates the process of slime sewage clarification.
2. Problem statement
Slime sewage of a “dirty” reverse cycle of the mill 2500 of the Sheet Rolling Shop -4, MMK, JSC, are cleaned from oil products and scale-containing impurities at water treating facilities. In compliance with the project, there are three stages stipulated for sewage clarification: 1 – preliminary sedimentation tank (slime pit with the hopper for scale); slime pump station; 2 – horizontal sedimentation tanks; 3 – filtering station with sand filters; as well as the separation of the slime thickening and dehydrating including processing in the equalizing tank, thickener and decanters.

Due to the existing complex economic situation the project has not been fully implemented. There is no filtering station. In the process of clarification, the sewage passes through the preliminary sedimentation tank (scale pit), two double-section horizontal sedimentation tanks with the hoppers for slime dehydrating and oil collectors.

Slime sewage from the hot rolling mill 2500 passes to a preliminary sedimentation tank (scale pit). At this stage a part of oil is separated and large-disperse scaling is precipitated which is further unloaded into the hopper for slime dehydrating. After precipitation in the preliminary sedimentation tank partially clarified sewage waters are pumped through water pipes into inlet (distribution) chambers of two horizontal final sedimentation tanks. Here slime sewage is clarified from weighed substances and oils. The clarified sewage gravity flow is fed into pump station tanks and further - to a consumer. The slime precipitating in horizontal sedimentation tanks is loaded into a dehydrating hopper with the help of a crane. The oil collected from the sewage surface is pumped at regular intervals and is forwarded for regeneration.

The absence of the filtering station and a low content of solid substances in the slime flowing from the sedimentation tanks had a negative impact on the operation mode of the thickening and dehydrating section. The amount and the quality of cleansing slimes were significantly different from design values. As a result, in order to reduce material costs and energy saving, the section of thickening and dehydrating changed its status and became a reserve facility.

The equipment of the hot rolling mill 2500 operated from 1960 is physically worn-out at the present moment. The slime forming here is characterized by the increased moisture content and oil products. Due to the reason that at present the equipment used for thickening and dehydrating is not functioning, the rolling process slime is not treated. Due to the improper slime quality it is seldom applied for further production and is just accumulated in piles, Zapadny and Vostochny (Western and Eastern) quarries of the Magnitnaya Mountain.

Such piles pose a serious environmental threat polluting the atmosphere, groundwater and earth. Such problem is urgent not only for Magnitogorsk and the Chelyabinsk region [14] but also for other Russian cities and regions as well as all over the world. Hundreds of thousands tons of oily scale are stored in slurry reservoirs of the largest metallurgical plants.

Before the project on the cleansing of hot rolling slime would be fully implemented, it is necessary to find the solution providing for the efficient operation of existing sewage facilities while the formed slime will have a proper quality.

3. Research objectives
One of the ways to intensify the slime treatment process for the subsequent use in the process of the sintering mix preparation at the mining processing facility is reactant treatment. The action of chemical reactants is based on the cleansing precipitation methods. This method advantages include its low price, the application of a well-known and well-tried equipment and reactant accessibility.

Using the example of slime sewage from the “dirty” reverse cycle of the hot-rolling mill 2500, the authors conducted the research of reactant influence on the dehydrated slime quality. The purpose of such research conduct is the search for the most efficient reactant as well as the selection of its introduction points on the cleansing process scheme for the rolling process slime sewage.
4. Research conduct

At the research conduct the authors applied a power flocculant Nalco 9601 and a liquid organic coagulant Nalco 8103 plus as reactants. According to the manufacturer’s information, these reactants facilitate slime coagulation, suspended substance precipitation, prevent oil adhesion to scaling, increase the efficiency of the water treatment facility as well as to reduce the oil content in the scale. The reactant application efficiency was evaluated by the slime quality indicators (humidity and amount of oil products) forming at horizontal sediment tanks.

At the first stage of the research the authors selected the following reactant introduction points:

1) powder flocculant Nalco 9601 in the form of the 0.2 % solution was introduced into the horizontal sediment tank No.2 (1st section). Dose – 0.25 mg/dm³ with the treated water flow rate ≈ 2,500 m³/h;

2) liquid organic coagulant Nalco 8103 plus is introduced into the scale pit being a part of a pump station. The treatment was continuous, the dose was equal to 0.8 – 1.0 mg/dm³. The treated water flow rate in the scale pit was ≈ 10,000 m³/h;

3) coagulant Nalco 8103 plus was also introduced into the suction chamber of the pump station No. 23 feeding the clarified water to the mill. Dose 0.8 – 1.0 mg/dm³. The treated water flow rate ≈ 6,000 m³/h.

The introduction points of reactants are outlined in Figure 1.

The results of the first research stage showed that the reactant introduction, in compliance with the scheme given in Fig. 1, helped to obtain the slime with the humidity 31.25 %, which is 7% lower comparing with the initial value (without reactant use) and close to the standard one (20 – 30 %). However, the slime contained an increased oil amount, it increased from 11.1 % up to 13.88 %. The research outcomes also demonstrate the deterioration in the recycled water comparing with initial data (increased content of oil products and increased amount of suspended substances in the clarified water after horizontal sediment tanks).

At the second stage of the research the authors decided to choose one point of the reactant introduction. The liquid organic coagulant Nalco 8103 plus (0.8 – 1.0 mg/dm³) was dosed into the scale pit (Figure 2).

The results of the second research stage demonstrated the increase in the average value of slime humidity by 3 % comparing with the initial value and by 10 % comparing with the indicators obtained at the first research stage. In addition, the content of oil also increased by 35% comparing with the initial data and by 8% comparing with the first stage data. However, one should note that the quality of
clarified water improved at coagulant dosing into a scale pit. The average values of humidity and oil product content in the rolling process slime, obtained with the help of the research, are provided in Figure 3.

![Figure 3. Average qualitative indicators of rolling slime obtained due to the research.](image)

 Apparently, the application of considered reactants and the change of selected introduction points did not result in the decrease in humidity and the oil product content in the slime. The dosing of Nalco 8103 plus into the scale pit resulted in the clarified water quality improvement only. The analysis of the research outcomes proved the necessity of the further search for the solutions which will improve the slime quality to subsequently use it as a secondary raw material [15].

To achieve the set purpose, the authors decided to select a flocculant which, in combination with the coagulant Nalco 8103 plus, will improve the slime quality and intensify the process of slime sewage cleansing. As a prototype model, the authors used the slime sewage of from “dirty” reverse cycle after they had passed the preliminary sediment tank. Further, the authors conducted the laboratory research to find out how the rolling process slime quality is influenced by flocculants: Nalko 9601 pulv, Nalko 8172 pulv and Inwatec aquatop PA-2050. The reactant doses varied from 1 to 4 mg/l while the process solution concentrations were assumed as 0.05 and 0.1%. Slime sewage waters were mixed after adding the flocculant estimated amount. After that the authors evaluated the intensity of plage formation and the obtained slime structure. Further, the slimes were poured on the filter cloth. The slime samples picked up from the filter cloth surface were checked in terms of the humidity and oil product content.

The reactant efficiency was evaluated by the humidity indicators and oil product content in the slime. Additionally, the authors evaluated the clarified water quality by the availability of suspended substances and the time of its clarification during which the main water volume was separated from the slime.

In terms of the aforementioned parameters the best results were demonstrated by:
- Nalko 9601 pulv and Nalko 8172 pulv - at the process solution concentration 0.1% and the reactant dose 3 mg/l;
- Inwatec aquatop PA-2050 - at the process solution concentration 0.1% and the reactant dose 2 mg/l.

The average values of slime qualitative indicators, obtained with the help of the research results, are provided in Figure 4.
Figure 4. Average qualitative indicators of rolling slime at application of various chemical agents.

The time of separation of the main volume of clarified water from the slime at the each reactant introduction with the aforementioned concentrations and doses is given in Figure 5. The analysis of results showed that the clarification of rolling process sewage is faster at the addition of the 0.1% solution of the flocculant Inwatec aquatop PA-2050 at the dose 2 mg/l.

Figure 5. The time of separation of the main volume of clarified water from slime at application of various chemical agents.

In the research process the authors identified that the introduction of various concentrations of Nalko 9601 pulv into slime sewage did not help to obtain standard slime indicators in terms of humidity and the oil product content no matter how high was such concentration. The maximum permissible values of slime qualitative indicators were obtained at the introduction of the 0.1% solution Nalko 8172 pulv with the dose of 3 mg/l. The best results in terms of humidity and the oil product content in slime were shown by Inwatec aquatop PA-2050 at the dose 2 mg/l. Furthermore, the use of such reactant allowed the authors to reduce the time of separation of the main volume of clarified water from slime by 2.5 times (comparing with the flocculants produced by Nalko).

5. Summary and conclusion
To find an optimal solution which will help to improve the slime quality and intensify the cleansing of rolling sewage from a “dirty” reverse cycle of the hot rolling mill 2500, Sheet Rolling Shop -4, MMK, JSC, the authors researched the reactant treatment influence on the slime quality.

The research results’ analysis demonstrated that the introduction of the coagulant Nalko 8103 plus (scale pit) and the 0.1% solution of the flocculant Inwatec aquatop PA-2050, the dose 2 mg/l
(horizontal sediment tanks) into the slime sewage will help to clarify sewage and obtain the slime with an improved quality. Also, it will be possible to use the rolling process slime as an additive into a sintering mix. The slime discharge piles will become smaller thus diminishing the environmental damage.

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