Methods for Converter Sludge Dehydration Intensification

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Abstract. The article considers the intensification methods for converter sludge dehydration exemplified by the sludges of the Oxygen Converter Workshop (OCW) of the Open Joint-Stock Company "Magnitogorsk Iron and Steel Works" (MMK, OJSC), one of the largest metallurgical companies in the Southern Urals.
Converter sludges can contain up to 45-70% of ferrum [21] which is interesting in terms of their use as an addition to a sinter-feed mixture. Sludge intensifies the sintering process. It positively influences pelletizing and fusion mixture melting dynamics at sintering.
Over the period of the converter sludge dehydration complex operation at the OCW, MMK, OJSC, it was revealed that processing results in obtaining of high humidity sludge. It causes sludge freezing during the winter period, thus, its transportation involves extra costs for sludge warming up. To resolve the above-mentioned problem, the following works were performed in 2016:
- experimental studies of how the application of the low-molecular anionic flocculate "SEURVEY" FL-3 influences sludge humidity reduction.
- experimental studies of how the filtering press process operation parameters influence sludge humidity reduction.
The new flocculate application didn't lower the dehydrated sludge humidity (the objective was the humidity of not more than 15%). Basing upon the conducted research results, we can make a conclusion that putting into operation the sewage water reactant treatment technology with the use of "SEURVEY", FL-3 (H-10) is not recommended.
The research of the influence the filtering press process parameters have on the dehydration process intensification demonstrated that reaching of the obtained residue humidity value lower than 15% is possible under the reduction of the filtering press chamber depths to 30 mm and with the application of additional operation "Residue drying" with compressed air.
This way of the sludge dehydration problem resolving at filtering presses of the converter sludge dehydration complex of the OCW, MMK, OJSC, can be recommended for application.

1. Introduction

Today the leading steel melting process which has become a wide-spread method in the world is oxygen converter manufacture.

Converter manufacture wastes include secondary fire-resisting materials, sludges, slags and dust [1]. Sludges are the most hard-to-dispose wastes.

Metallurgical enterprises apply complexes for converter sludge dehydration which allows not only sludge dehydration but also the return of clarified water into a reversible cycle. The key sludge characteristics are their chemical and granulometric compositions. They include ferrum, zinc, calcium, silicon, aluminum, manganese, magnesium. The obtained sludge containing 45–70% of ferrum [2,3] can be used as an addition to a sinter-feed mixture [4]. Therefore, the enterprise additionally obtains its own metal-containing raw material. To dispose converter sludge at a sintering plant, it should be pre-dehydrated.

The dehydration technology stipulates for sedimentation in tanks, filtering in various devices and, if necessary, thermal drying [5]. A wide-spread procedure includes slurry pulp thickening in radial thickeners, then its filtration at vacuum filters and drying in drum driers. However, sludge drying inside capital power consuming drum dryers is quite expensive. Besides, after drying sludges lose their hydrophilic properties which are very valuable at lumping [6].

To eliminate the problems related to insufficient residue dehydration, the following methods are being used today:

- physical;
- physical and chemical;
- thermal, etc.

Review of the literature references and the obtained experience [3,6-13] showed that it is possible to intensify the dehydration process by means of the following physical methods: feeding of over-heated steam and hot air, use of infrared emission. A positive result was achieved when the filter power was influenced both by DC and AC, the magnetic field, vibrations and acoustic vibrations [11].

However, due to complexity of its use and the necessity to install additional filtering equipment, physical intensification method hasn't become wide-spread.

The promising dehydration intensification methods are physical and chemical ones connected with application of a number of special reagents. Their effect on suspension manifests in decrease in the specific residue resistance due to the change of its structure as well as to the reduced hydration degree of the solid particle surfaces. It is possible to combine physical and chemical and thermal methods to intensify dehydration. Thus, introduction in the suspension of the surface-active substance (mixture of alkyl sodium sulfates) solution heated up to 70˚C decreases the residue humidity [12].

The following substance groups can be considered as the dehydration intensifiers: inorganic electrolytes, low-molecular surface-active substances (SAS) of a synthetic and petroleum origin, viscous organic liquids [12-15].

The choice of one or another type of dehydration equipment for wastewater sludge as well as the intensification method depend on the specific manufacture, its volumes, the wastewater composition and technical and economic justification.

2. Problem statement

The converter sludge dehydration complex at the Oxygen Converter Workshop (OCW), MMK, JSC, was commissioned in July 2014 to resolve relevant environmental and production tasks (drainage amount reduction, elimination of slurry dumps, obtaining of a ferrum-containing raw material for the agglomeration and blast-furnace manufacturing process) [16]. This is the place where the OCW wastewater - slurry discharge from the radial tanks (RT) of "dirty" reversible cycles of the converter gas cleaning water supply No. 1–3 (RT–1,3,4) and the continuous -casting machine CCM No. 1–4 (RT–5,6) - come in the amount of 300 m3/h [16].

The dehydration technology includes

- thickening of slurry discharges at the radial thickener Ø 13 m to the slurry pulp state;
- mixing of a thickened pulp in a slurry tank (surge tower Ø 2 m with a stirring unit);
- pressing at the chamber membrane filtering presses (2 work./1 cut.).

Slurry discharge gets into a thickener where solid particles continuously precipitate. At scraper bridge rotation the scraper continuously moves sludge on the pool bottom and collects it in the bevelled central part, the automatic valve at the thickener output occasionally opens to pump the thickened sludge into a surge tank (at the filtering press loading).

The filtering press works in cycles. The first step is loading (slurry pulp is accumulated in the press), further dehydrated sludge is compressed and unloaded onto a stationary belt conveyor. Dried sludge is transported to the site for storage and then carried away by railway transport or by cars.

Clarified water separated from sludge comes to the thickener peripheral collecting tray through a toothed overflow, then proceeds into a retention basin and is pumped into a degasifying chamber of the OCW biological treatment plant (a reversible cycle of the converter gas cleaning water supply).

To enhance the dehydration process efficiency, the reactant treatment of thickened sludge with the help of the flocculate 9601 PULV produced by the Company Nalko, LLC, is applied in a surge tank (before pressing at the filtering press).

However, the applied dehydration technology and additional reactant treatment do not allow for obtaining the specified humidity value of the dehydrated sludge equal to 12-15%. At the moment, the average output humidity value is 21.45% (17.9 - 24.57%).

Increased sludge humidity causes additional costs related to its transportation in the winter period. At low temperatures humid sludge freezes, thus making it necessary to warm it up for further unloading [17,18].

To resolve the above-mentioned problem, the following measures were taken:

- experimental studies of how the reactant treatment with the low-molecular anionic flocculate “SEURVEY” FL-3 influences sludge humidity reduction [19,20];
- experimental studies of how the filtering press process operation parameters influence sludge humidity reduction.

3. Research objectives

The research objective is dehydration process intensification to achieve the sludge output humidity not more than 15%.

To fulfil this objective, we need:

- to study how the reactant treatment with the low-molecular anionic flocculate “SEURVEY” FL-3 influences sludge humidity reduction;
- to choose optimum parameters for the reactant treatment and the flocculate dosing mode;
- to analyze and determine the dependency of sludge humidity on the horizontal chamber membrane filtering press process parameters;
- to determine optimum process parameters for the work of the horizontal chamber membrane filtering press at filtering of the converter sludge suspension to obtain the optimum residue humidity.

4. Research condact

The research of how the reactant treatment with the low-molecular anionic flocculate “SEURVEY” FL-3 influences sludge dehydration intensification was conducted in 2016 in the territory of the converter sludge dehydration complex, OCW, MMK, OJSC.

The low-molecular anionic flocculate "Seurvey" FL-3 was used to conduct the research. This reactant was chosen by the Procurement Service of MMK, OJSC. According to the manufacturer's information [8], this flocculate type is "intended for application in various industrial areas for sludge and residue thickening and dehydration". Application of the SEURVEY flocculates allows for a significant increase of radial and horizontal sedimentation tanks performance as well as the one of flotation plants of the filtering and other equipment".

Today the flocculate "Nalko" 9601 PULV is dosed directly into a surge tower during sludge dehydration. Analysis of the current situation showed that floccules formed as a result of their slow stirring are further crashed by the pump. With the consideration of this fact, it was decided to dose the reactant into a thickener for the research period.

The experiment was conducted with the use of the existing automatic unit for preparing and dosing of the flocculate Polydox 5000. Due to the fact that design properties of such equipment do not support the chemical reactant lower flow, a minimum flocculate dose into the thickener was taken as 0.7 mg/dm3 at the research start.

The research was conducted under the following reactant dosing mode: 10 seconds of work and 20 seconds of pausing. At the same time, the average dose was about 0.87 mg/dm3. The chosen mode was justified by the existing dosing pump technical parameters. Thus, under the mode stipulating a 5 second dosing and a 10 second pause the flocculate solution dosing pump was unable to pump it over.

The maximum flocculate dosing value equal to 4.32 mg/dm3 was applied during the periods of the thickener overflowing with sludge as well as at increase of the input suspended matter amount. Increased loads on the thickener were caused by the filtering press stop to replace the torn jackets.

The research of how the reactant treatment with the flocculate "Seurvey" influences sludge humidity reduction was conducted with consideration of the following factors:

- sludge pressure at the filtering press input;
- air pressure;
- sludge pressing out time.

The experiment was conducted with the sludge pressure equal to 6 and 7 atmospheres. The air-induced pressure was taken as 10 and 12 atmospheres for the research period. The sludge pressing out time was equal to 300, 400 and in some cases to 520 seconds.

The obtained results are shown in Figures 1, 2.

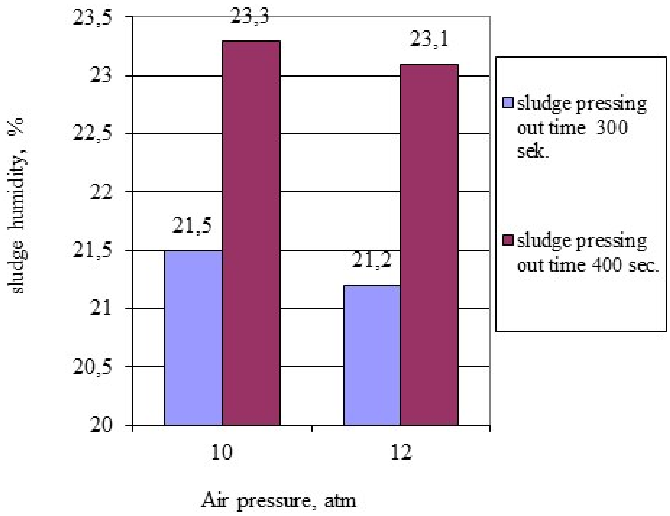

Figure 1. The average humidity value at the reactant treatment with the flocculate “Seurvey” and the sludge pressure of 6 atm.

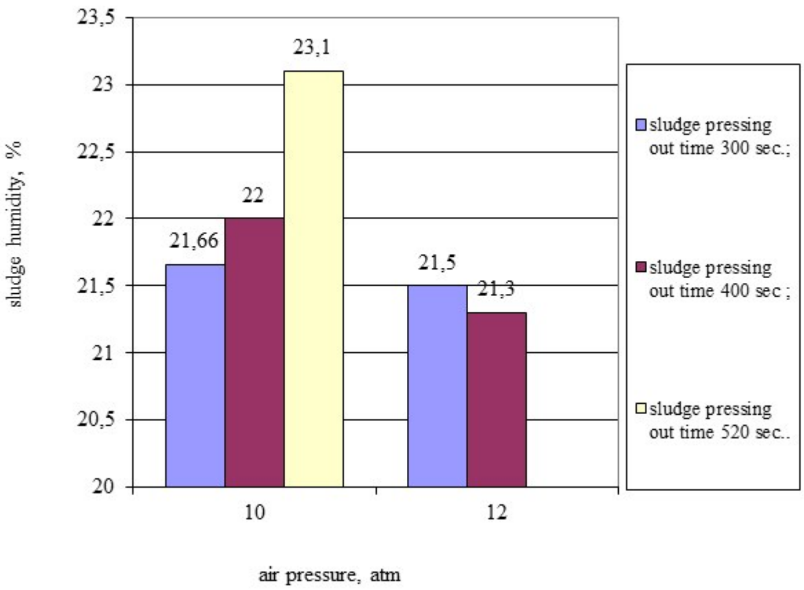

Figure 2. The average humidity value at the reactant treatment with the flocculate “Seurvey” and the sludge pressure of 7 atm.

Basing upon the results, the following optimum work parameters were chosen:

- the sludge pressure – 6 atm., the air pressure – 12 atm., the sludge pressing out time is 300 sec. At these parameters the average output sludge humidity was 21.1 %., with the maximum value of 23.2% and the minimum value of 19.5%;
- the sludge pressure – 7 atm., the air pressure – 12 atm., the sludge pressing out time is 420 sec. At these parameters the average output sludge humidity was 21.3 %., with the maximum value of 22.8% and the minimum value of 18.7%;

The research results demonstrate that increase of the air pressure inside the pressing filter membrane-holding plates also increases dehydration efficiency.

The lowest sludge humidity (18.7%) was obtained at the reactant treatment with the flocculate “Seurvey”, the sludge pressure of 7 atm., the pressing out time of 400 seconds and the air pressure of 12 atm.

However, the research outcomes showed that such reactant treatment with the flocculate “Seurvey” FL-3 (H10) is unable to reduce the output sludge humidity to the required value of 15 %. Besides, the research showed that application of the flocculate "Seurvey" FL-3 (H-10) didn't induce a larger reduction in sludge humidity comparing to the results being now obtained with the flocculate "Nalko" 9601 PULV.

At the second stage of the experiment the interdependency between the sludge humidity decrease and the filtering press operation process parameters was studied.

The research was conducted with the help of a filtered model imitating the work of a horizontal chamber membrane filtering press with the filtering surface area of 0.002 m2.

The converter gas cleaning suspension of MMK, OJSC, was chosen as a sample with the following properties:

- temperature – 25 oC;
- solid phase composition – 55%;
- density – 1.6–1.7 t/m3.

Two types of filtering fabrics, the order codes PRC7022 and P7622, with different air permeabilities and throughput capacities were preliminarily chosen as filtering membranes (basing upon the suspension properties). During the experiment the filtering fabric PRC7022 was chosen as the main one. This fabric application provided the best results in terms of the filtering rate, humidity, residue sedimentation as well as the filtrate clarity.

Key process operations conducted at the chamber membrane filtering press: "Filtering", Pressing out", "Drying" [20]. The modes chosen for these operations influence the final filtering press operation parameters, in other words, its performance and the unloaded residue humidity. Meanwhile, the performance depends on all the process operation modes whereas the residue humidity value is largely determined by the operation modes "Pressing out" and "Drying".

The "pressing out" operation is used for residue thickening. This operation predetermines the final humidity and the unloaded residue state. Due to the fact that the solid phase is microdispersed (50% of its weight is less than 4.35 um), the residue is well thickened, however, requiring quite a long time for pressing out.

The experimental determination of the optimum operation mode "Pressing out" was performed at 1.0-1.4 MPa.

The research results are given in Figure 3.

Basing upon the experimental results, the optimum parameters of the mode "Pressing out" were taken as the pressure 1.4 MPa and the duration of 300 seconds. The sludge humidity at the chamber initial depth of 40 mm, on average, was approximately 20 % while at the depth of 30 mm it was approximately 19 %.

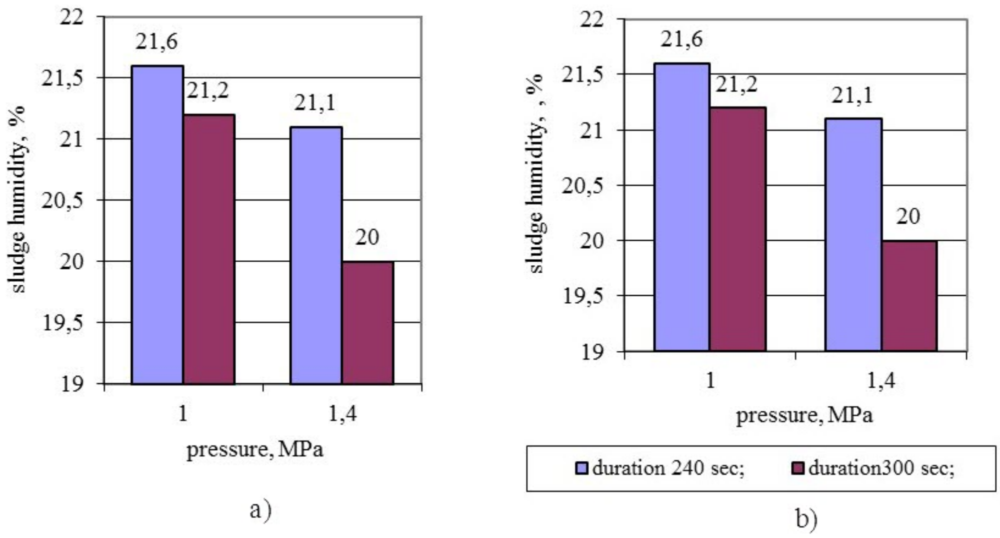

Figure 3. The average sludge humidity after the operation "Pressing out" at the chamber depth: a) 40 mm; b) 30 mm.

The operation "Drying" of the residue with compressed air allows for additional reduction of the final humidity of the obtained residue. At present, the operation "Residue Drying" at the converter sludge dehydration complex of the OCW, MMK, OJSC, was not performed because the collector plates and block structure do not provide for this operation.

The optimum mode of the operation "Drying" was experimentally determined at the pressure of 0.8 MPa.

The obtained research results are presented in Figure 4.

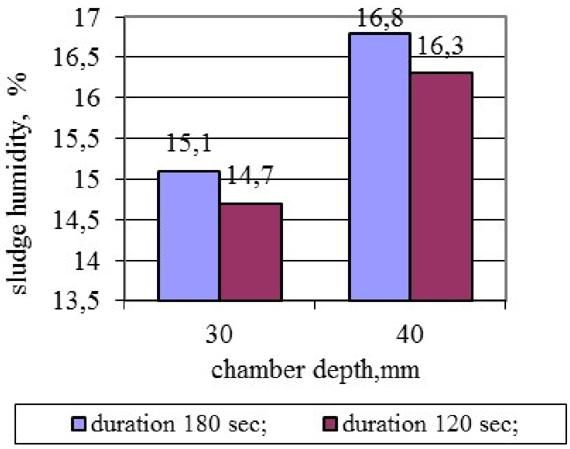

Figure 4. Average sludge humidity after the operation "Drying".

5. Summary and conclusion

The reactant treatment application involving the low-molecular anionic flocculate “SEURVEY” FL-3 for converter sludge dehydration does not allow for obtaining of a required specific humidity value equal to 15 %. Therefore, it is not recommended to put into operation the sludge reactant technology using such flocculate.

It is possible to obtain the output sludge humidity not exceeding 15% by means of the additional operation "Drying" with the compressed air of 0.8 MPa within 120 seconds at the filtering press chamber depth of 30 mm.

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This method for intensification of the sludge dehydration process at the filtering presses of the converter sludge dehydration complex of the OCW, MMK, OJSC, can be recommended for application.

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