

THE MEASURING FIELD SYSTEM OF FINE TAILINGS FLOW DURING THE DREDGING VESSEL OPERATION

Stanisław Czaban¹, Maciej Gruszczyński¹, Przemysław Tymków²

¹Institute of Environmental Engineering, Wrocław University of Environmental And Life Science

²Institute of Geodesy and Geoinformatics, Wrocław University of Environmental And Life Science

The paper presents the installation which carries out the field measurements of the global hydraulic transport parameters of the flotation tailings of copper ore. The equipment was installed on board of the dredging vessel. The presented system was designed to measure the basic parameters of the tested fluid flow: flow rate, average density of the mixture, temperature, depth of the mined layer, operating parameters of the pump, operating parameters of power supply unit. To determine the grain size composition of the flowing slurry, during the research samples were being collected. The basic parameters of the operating system were archived in the form of electronic data. The designed installation was tested and calibrated during the field test. The proposed method of measurement has proven to be very effective. The system operated efficiently up to density 1.7 Mg/m³ of the mixture. To evaluate the densified tailings deposition was used laser scanning technique.

KEY WORDS: hydrotransport, slurry flow, PE pipes, dredging

1.INTRODUCTION

In the process of the production of non-ferrous metals, about 30 million tons of mining waste is produced annually in Poland (Kudęłko et al., 2011). Most of this waste consists of after flotation tailings; i.e. obtained after the process used to enrich ores (Bernd et al., 2007). The basic method of disposal in subaerial techniques is tailings pond.

The administrator has decided to build a new tailings pond located very close to the existing facility. The new Tailings Storage Facility “South Pond” (TSF “SP”) is supposed to be about twice the storage area and about eight times smaller capacity. The unfavorable ratio of the storage capacity to the area of the new TSF “SP” compared to the Tailings Storage Facility “Żelazny Most” (TSF “ŻM”) led to the decision to change the technology. The technology to be used at the new TSF “SP” is to reduce the amount of water entering the pond. A certain number of available technologies used in other mining facilities to reduce the amount of water in the waste stream directed to new pond were considered such as thickeners, hydrocyclones, presses, vacuum conveyors etc.

Regardless of the method of thickening used, the basic problem in the process is to clean the technological water from fine particles. Small fractions of less than about 0.063 mm make it necessary to use large thickeners and large amounts of chemical reagents during the thickening process. Significant part of the investment and operating costs is spent on the processes related to the compaction of the fine fraction.

During the conceptual work on the choice of construction and operation technology of the new facility, it was proposed that the existing TSF “ŽM” tank be used as a fine fraction thickener which would allow a significant reduction in the cost of the new solution. It was necessary to verify that the TSF “ŽM” was able to extract concentrated fine waste. Dredging was selected as a method of collecting thickened fine tailings from under the technical water table, which is used in Germany, for example. The dredging system in Germany has an output of 150 m³ per hour at a distance of 200 m (Crabtree et al., 2009).

Understanding the settlement behavior of clay suspensions during settling process is essential in engineering practice for meeting the design requirement on the storage capacity of reclaimed yards (Bernd et al., 2007)(Crabtree et al., 2009). Sediment deposits can be mechanically removed from reservoirs by hydraulic dredging or dry excavation (World Pumps, 2016)(Zeng et al., 2016). The successful design of a thickened or paste tailings system requires that the system is designed to accommodate the effect of the high density slurry on pumps, pipelines and the overall system operations (Paterson, 2004).

Both the installation of the collection, transport and depositing and the measurement installation of the characteristics of these processes have been designed.

2. COLLECTION AND TRANSPORTATION SYSTEM

The installation of the collection and transportation of concentrated waste consisted of: Watermaster II dredger, floating pipeline, stationary pipeline and discharge installation (Fig.1).

The primary piping materials used for paste and thickened tailings pipelines are carbon steel and high density polyethylene (Cook Paterson, 2007). In order to transport and distribute dredged tailings to the area no. 1, discharge line was built with a total length of 948 m which consisted of:

- ✓ 120 m discharge line installed on board of dredger and the floating pipeline DN 225 PEHD 100 SDR 17 PN 10,
- ✓ 810 m deposition pipeline at embankment side, stainless steel DN 813 with a nominal wall thickness of 16 mm,
- ✓ 6 m flexible pipe,
- ✓ 12 m discharge installation constructed from pipes HDPE 100 DN 225 SDR 17. Installation with 10 spigot DN 50 in 1.0 m every one meter.

During the research concentrated tailings were excavated from eight positions by the dredging unit. Due to the length of the floating discharge pipeline, the collecting points were located in the southern part of the lateral dam.

3. MESURING INSTALATION

3.1 MESURMENTS OF FLOW

Dredger Watermaster II was used during the study. Dredger was equipped with a rotary head pump on the hydraulic arm. Flowmeters were installed on the vessel and on

the discharge pipeline. The primary instrument used to measure the flow was the Techmag Electromagnetic Flowmeter with DN 150. The device is dedicated to slurry flow measurement (Cook Paterson, 2007).

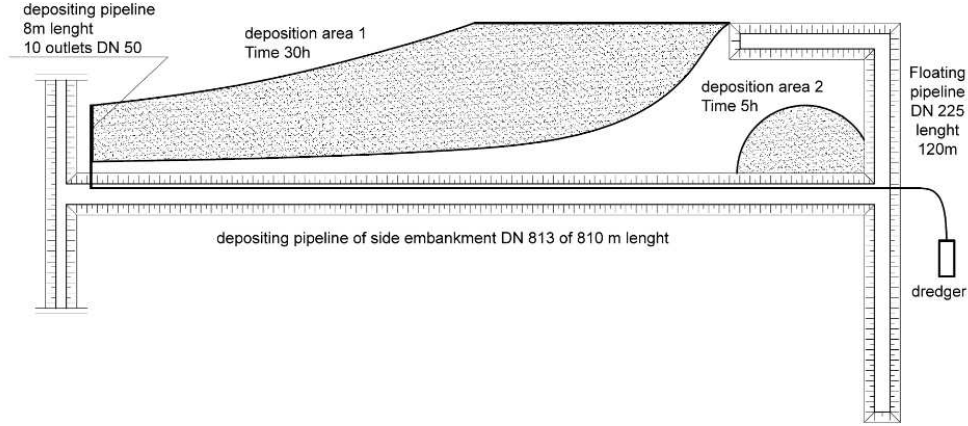


Fig. 1 Scheme of hydrotransport installation and deposition of tailings

3.2 DENSITY MEASUREMENTS

To evaluate the dredger operation, an installation for the continuous measurement of the density of the mixture based on a hydraulic densimeter was built (Mihail et al., 1991). The designed installation also enabled manual sampling to control the density determination of the mixture by weight method, as well as the collection of laboratory samples. During the field tests in 2015, a hydraulic densimeter was also used. During the analysis of the collected data it turned out that the device is sensitive to the uneven distribution of the density of the flowing medium through the measuring sections.

This situation took place when the slurry was densified more than 1.5 Mg/m^3 and average flow velocities decreased below 0.2 m/s . During the design work of the density measurement system for the purpose of this task, an attempt was made to eliminate errors occurring during the operation of the installation. An additional horizontal section of the pipeline was provided supplying a densimeter with a length equal to the vertical densimeter sections. On the horizontal section the flow resistance was tested and compared to the densimeter results. In addition, a DN 25 electromagnetic flowmeter was installed to determine the average velocity in the densimeter arms (Fig. 2). Modifications of the device allowed the elimination of gross errors resulting from aeration of impulse tubes and uneven distribution of density in the arms (equation 1).

$$\rho_m = \frac{(P_3 - P_4) + (P_6 - P_5)}{2gL} = \frac{(P_3 - P_4) - (P_1 - P_2)}{gL} = \frac{(P_6 - P_5) + (P_1 - P_2)}{gL} \quad (1)$$

where ρ_m – density of medium $[\text{kg.m}^{-3}]$
 P_{1-6} – pressure in measuring points $[\text{Pa}]$
 g – acceleration $[\text{m.s}^{-2}]$
 L – length of measuring sections.

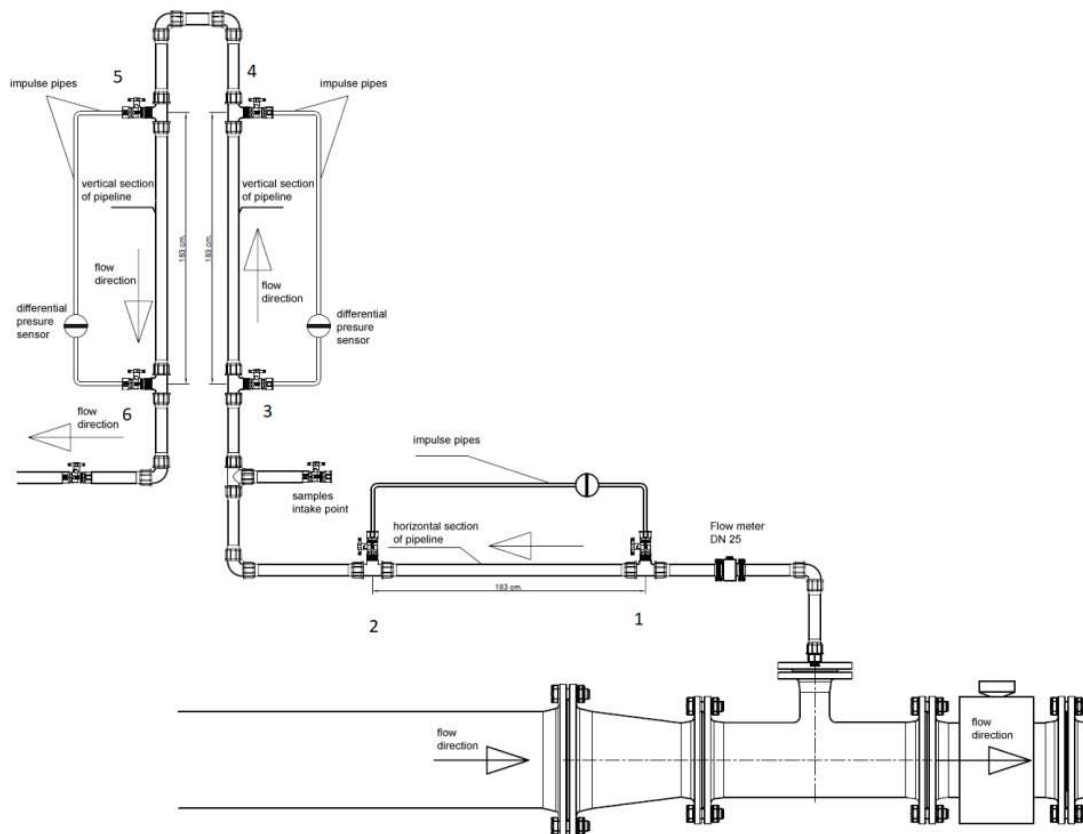


Fig. 2 Installation Scheme for continuous measurement of density

3.3 MEASUREMENT OF THE GRAIN SIZE DISTRIBUTION

During the measurements samples of collected medium in discharge region were taken manifold. Sampling collection device was located approximately 20 m after dredging pump. For this was installed the constriction and t-connector. The samples were used to determine the volume density of flowing medium and to determine the granulometric composition of the pumped material. The collected samples were secured in hermetically sealed containers. Afterwards the samples were taken to the laboratory in order to be further tested.

3.4 MEASUREMENT TECHNIQUE OF DEPOSITING PROCESS

Terrestrial laser scanning is a technique for manifold measuring of the automatic designation of point coordinates field by measuring the distances and directions. In contrast to the direct measurement techniques such as for example the method tachymetric or GPS, not in this case, the measurement of the characteristic points of the object and the measurement is carried out with reference to the entire measurement constant angular spatial resolution. Terrestrial Laser Scanning (TLS) is distinguished by data collection rate (up to a million points per second) and absolute accuracy at the level of a few millimeters. The result of the development of the data is a set of coordinates $\{x, y, z\}$ of points called a point cloud. In addition, for each point can be recorded the following parameters: the intensity of the reflection, color in the form of components of the RGB color space, obtained through the imposition of images taken most often by the camera calibrated and integrated with the scanning device. Measurements on individual positions were carried out in the local system. In the case of measurement of several

positions of the transformation of their local systems to one common (registration) is done through a common point, most branded in the field by use of special signals (e. g. targets). It's also possible to register a statistical method consisting in automatic or semiautomatic clouds seamlessly integrated measuring themselves by correlation analysis. This method is called by cloud in the cloud. This technique was used during the research to evaluate the particular steps of depositing process.

4. RESULTS

4.1 SLURRY DENSITY

The presented data was collected during a 30-hour measurement campaign of permanent pumping of concentrated tailings presents the density of tailings as a function of time (Fig. 3). Based on the presented measurement data it can be stated that the variations in the density of the treated waste were not high and the inflow to the dredging pump was continuous. Figure 4 presets eleven hours of work of dredging unit. Presented date were collected automatically with 0.33 Hz frequency.

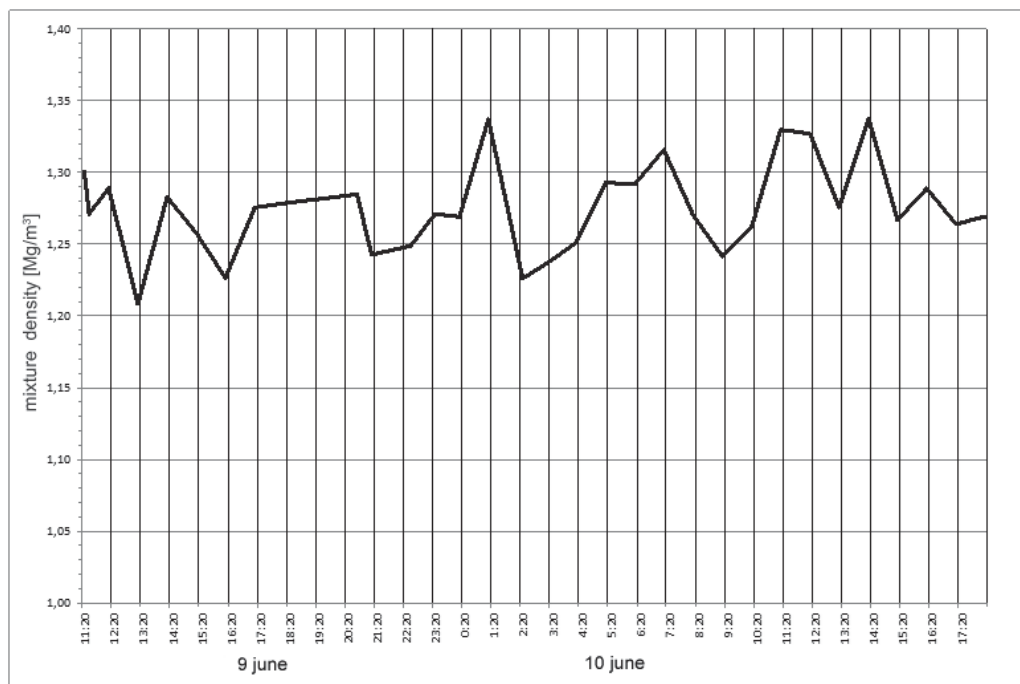


Fig. 3 Density of the mixture in 9-10.06.2016 r. prepared manually

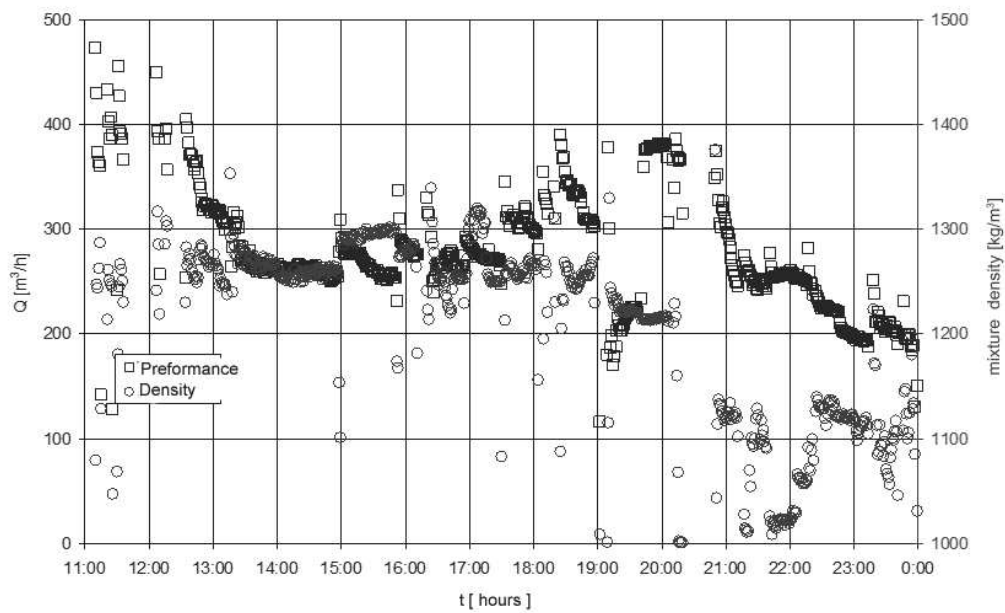


Fig. 4 Average minute performance of dredger and the density of the mixture on 9.06.2016

4.2 GRANULOMETRIC SIZE COMPOSITION OF THE SOLID PHASE

Soil separates are specific ranges of particle sizes. In the United States, the smallest particles are clay particles and are classified by the USDA as having diameters of less than 0.002 mm (Crabtree et al., 2009). Fig. 5 shows the granulometric size composition of the solid-phase samples taken during research on 9-10.06.2016. The diameter of the average ds changed from 0.0007 to 0.0026 mm. Contents of clay fraction changed from 21 to 32% silt, from 72 to 80%, and the content of the sand fraction from 0% to 2% .

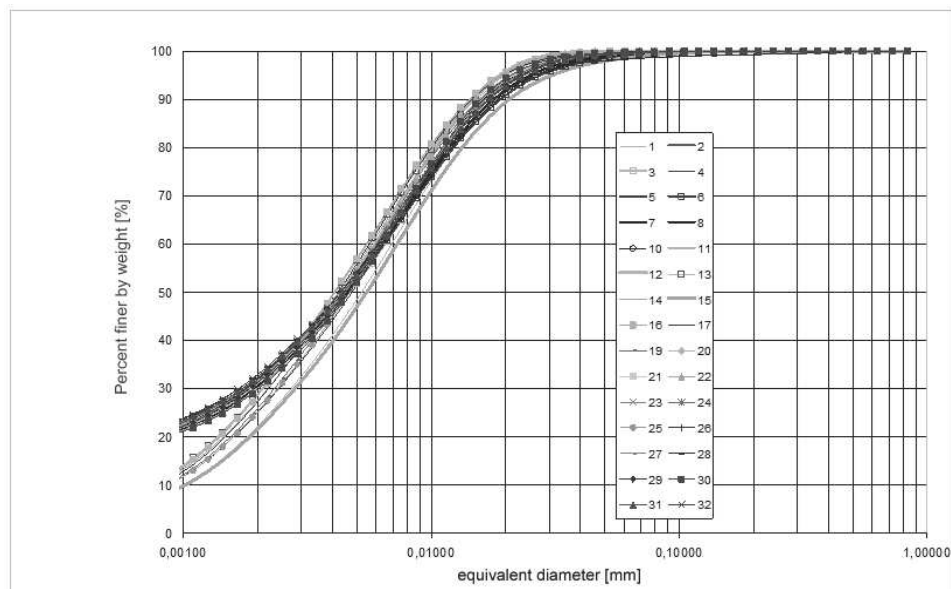


Fig. 5 Granulometric size composition of solid tailings collected by dredger from 09.-10.06.2016

4.3 RESULTS OF DEPOSITING

The area of depositions was controlled by laser scanning. In the first step, a zero (base) measurement was performed, followed by another measurement. The difference in surface levels results from comparing of steps. The table 1 shows the results of mass balance for the deposition area .

Table 1

Overview of the volume of tailings deposited in deposition region

Total surface	[m ²]	1991.24
Deposition surface	[m ²]	1960.26
Erosion surface	[m ²]	30.98
Volume deposition	[m ³]	216.40
Erosion volume	[m ³]	0.55
Balance	[m ³]	215.85

During the analysis of the measurements longitudinal sections were developed by the deposition area. The figure 6 shows the zero state and the state 1 after the deposition. The inclination of the surface of the depositing area was before 0.86% and after 0.94%.

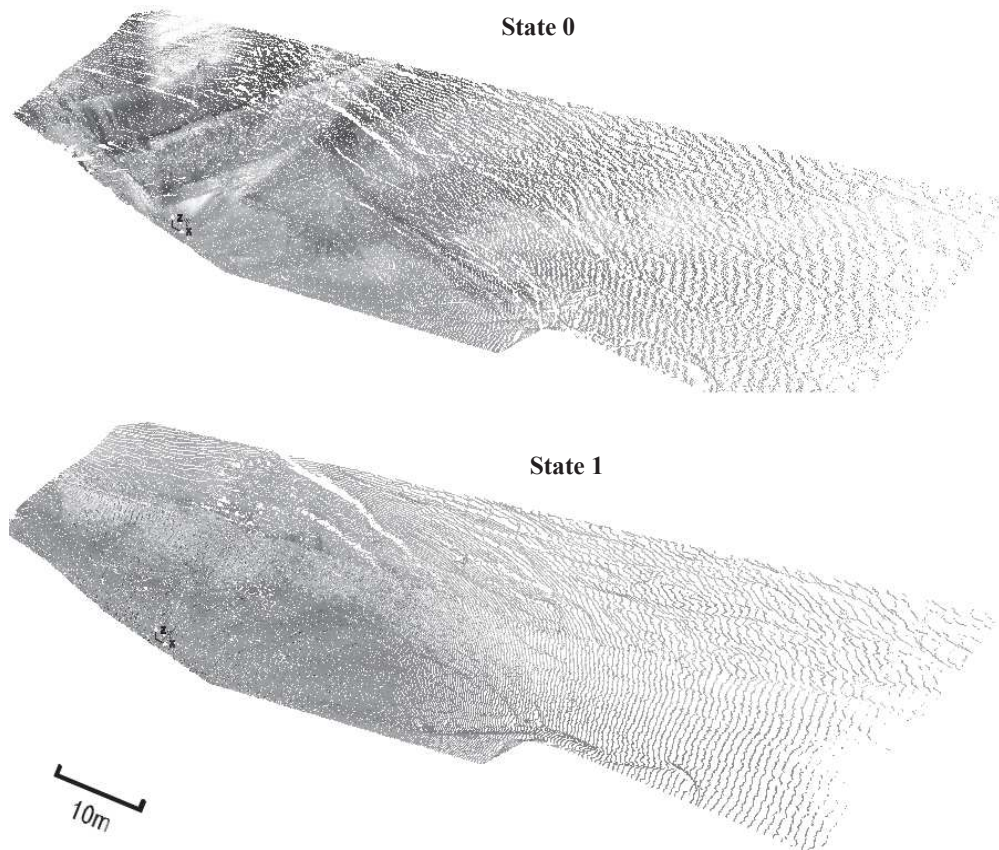


Fig. 6 Point cloud the analysis area of landfill no. 1 for the State before the deposition (State 0) and after (State 1)

5. CONCLUSION

- ✓ The proposed measurement methodology has acquired good practical confirmation. This applies to both the equipment mounted on the dredger and used to evaluate the methodology of the process of the material deposition on the beach.
- ✓ During the test, no problems were observed related to collection, extracting and pumping of tailings.
- ✓ The composition of the granulometric solid-phase samples taken by the dredger were almost similar. The diameter of the average d_s changed from 0.0007 to 0.0026 mm.
- ✓ The density of the transported mixture changed from 1069.9 to 1292 kg/m³. The smallest density of the dredged mixture was noted during the night (21, 22, 6) when the dredger was working without supervision.
- ✓ The concentration by volume of the transported mixture has changed from 0.0387 to 0.1618. The smallest volume concentrations of solids in mixture was noted in the night (hours: 21, 22:6) when the dredger was working without our supervision.
- ✓ During the research was noted a steady and consistent supply of concentrated waste to the pump on the dredger during the 30 h long test. The work of the pump was hindered only by the pollutants which contained the tailings deposited in the area of the embankment. The pollution came from the strengthening of the scarp contaminated by debris.
- ✓ The density of the pumped tailings was on average 1.28 t/m³ which was due to the location and the only possible pump position- the depth 5.5 m under water.

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