



University of Belgrade
Technical Faculty in Bor



Chamber of Commerce
and Industry of Serbia

XV International Mineral Processing & Recycling Conference



Proceedings

Editors:
Jovica Sokolović
Milan Trumić

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DETERMINATION OF LIMITING SETTLING VELOCITY IN THE SLURRY PIPELINE FROM GRINDING PLANT, USING DIFFERENT APPROACHES – A CASE STUDY

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ABSTRACT – This paper examines three different approaches of determining limiting settling velocity of the particles in the specific case. The research was carried out for the hydraulic transport of the collective ground product from the semi-autogenous mill and the ball mill to the hydrocyclone battery, where pipeline diameter value is adopted from the plant. It was shown that in this case a satisfactory result is obtained by applying only one of the calculation methodologies, while the other two methodologies gave limiting settling velocities that are higher than the actual one.

Keywords: Slurry, Pipeline Diameter, Limiting Settling Velocity.

INTRODUCTION

One of the very frequently used methods of transport in the mining industry is the hydraulic transport of slurry. Slurry consists of a solid and a liquid phase (predominantly water). Homogeneous (non-settling) slurry (Fig. 1a) is mixture of solids and liquid in which the solids are uniformly distributed. A settling slurry can be defined as a pseudo-homogeneous or heterogeneous mixture. In pseudo-homogeneous mixture (Fig. 1b) all the particles are in suspension but concentration is greater towards the bottom. In heterogeneous mixture solids are not uniformly distributed and tend to be more concentrated in the bottom of the pipe. Heterogeneous mixtures can be partly stratified (Fig. 1c) or completely stratified (Fig. 1d) [1].

Slurries containing essentially fine particles (predominantly less than 50 μm (0.05 mm) are generally considered non-settling and can normally be assessed without consideration for settling. (However, it must be noted that in high concentrations these slurries often exhibit non-Newtonian flow properties (or rheology) and require special consideration in determining suitable pump and system parameters.).

Slurries containing particles predominantly greater than 50 μm are generally considered settling (heterogeneous), which is the case in the majority of slurry pumping applications. Slurries containing solid particles essentially coarser than 50 μm are transported in suspension by a liquid in a pipe, providing the average velocity (v) that must be no less than the limiting settling velocity (v_L). [2].

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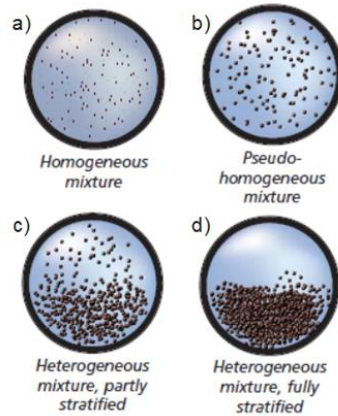


Figure 1 Types of hydraulic mixtures [1]

Limiting settling velocity is particularly important when calculating the diameter of the pipeline. At any velocity below v_L , solids are deposited in the pipeline. This may result in increased pipeline friction head loss, with reducing flow rate and may lead to a blockage of the pipeline [2, 3].

There is no explicit, mathematically derived form for determining the limiting settling velocity, but all forms are empirical or semi-empirical. They are the result of experimental research by different authors, who simulated different transport conditions, changing some of parameters. These parameters affect limiting settling velocity which can be determined by analytical methods [3]. Therefore, this research was carried out to examine how different the v_L values obtained by applying such empirical methodologies are in the specific case.

EXPERIMENTAL

For the purposes of the research, the grinding and classification plant in the Čukaru Peki Mine was selected and, within the plant, the centrifugal slurry pump that transports the collective ground product from the semi-autogenous mill and the ball mill to the hydrocyclone battery. For this purpose, the company Zijin installed a pump 350 MCR M120, manufactured by Weir Minerals, which general appearance is shown in Fig. 2.



Figure 2 MCR type pump Weir Minerals

Limiting settling velocity is calculated for the pipeline of the selected pump 350 MCR M120, which diameter was 500 mm. Calculation is performed using three different methodologies: (1) Durand-Condolios, (2) Evdokimov and (3) Cave. Formulas are given below [3, 4]:

(1) Durand-Condolios:

$$v_L = F_L \sqrt{2gD \frac{\rho_S - \rho_{LQ}}{\rho_{LQ}}} \quad (1)$$

(2) Evdokimov (for mean particle diameter $0.07 < d_{50} \leq 0.15$ mm):

$$v_L = \frac{\rho_S - \rho_{LQ}}{1700} \cdot \frac{4}{\pi} \cdot 0,2 \cdot (1 + 2,48 \cdot \sqrt[3]{p} \cdot \sqrt[4]{D}) \quad (2)$$

(3) Cave (valid if the pipeline diameter is greater than 200 mm):

$$v_L = 1,04 \cdot D^{0,3} \cdot \left(\frac{\rho_S}{\rho_{LQ}} - 1\right)^{0,75} \cdot \ln\left(\frac{d_{50}}{16}\right) \cdot \left(\ln\left(\frac{60}{C_v}\right)\right)^{0,13} \quad (3)$$

In the mentioned formulas (1) – (3), parameters have the following meaning and values for specified case:

v_L – limiting settling velocity, m/s

F_L – modified Froude number, read from a diagram in the literature [3, 4]; $F_L = 1.04$

g – acceleration of the Earth's gravity, m/s²; $g = 9.81$ m/s²

D – pipeline diameter, m; $D = 0.5$ m

ρ_S – solids density, kg/m³; $\rho_S = 3060$ kg/m³

ρ_{LQ} – liquid density, kg/m³; $\rho_{LQ} = 1000$ kg/m³

d_{50} – average particle size of solids, mm $d_{50} = 0.15$ mm

C_v – volume content of the solid phase, %; $C_v = 29.37\%$

p – coefficient representing the mass ratio of solid and liquid phase (%), and is calculated according to the formula (4):

$$p = \frac{C_m}{(100 - C_m)} \cdot 100\% \quad (4)$$

where C_m is mass content of the solid phase, $C_m = 56.00\%$, and $p = \frac{56}{(100 - 56)} \cdot 100\% = 127.3\%$

In order to verify the diameter of the selected pipeline, it is necessary to determine the real slurry velocity of the hydraulic mixture through the pipeline. The real slurry velocity through the 500 mm diameter pipeline is calculated according to the formula (5):

$$v_R = \frac{V_S \cdot 4}{D^2 \cdot \pi \cdot 3600} \quad (5)$$

Where:

v_R – real velocity, m/s

V_s – volumetric slurry flowrate, m³/h; $V_s = 2224.40$ m³/h

RESULTS AND DISCUSSION

The results of the calculation of the limiting settling velocity using different methodologies are given in the following text. According to Durand-Condolios approach, limiting settling velocity is: $v_L = 1.04 \cdot \sqrt{2 \cdot 9.81 \cdot 0.5 \cdot \frac{3060-1000}{1000}} = 4.675$ m/s; Evdokimov formula gives: $v_L = \frac{3060-1000}{1700} \cdot \frac{4}{\pi} \cdot 0.2 \cdot (1 + 2.48 \cdot \sqrt[3]{127.3} \cdot \sqrt[4]{0.5}) = 3.546$ m/s; and finally, Cave's methodology provides $v_L = 1.04 \cdot 0.5^{0.3} \cdot \left(\frac{3060}{1000} - 1\right)^{0.75} \cdot \ln\left(\frac{150}{16}\right) \cdot \left(\ln\left(\frac{60}{29.37}\right)\right)^{0.13} = 3.112$ m/s. Value of real slurry velocity is $v_R = \frac{2224.40 \cdot 4}{0.5^2 \cdot \pi \cdot 3600} = 3.147$ m/s. Figure 3 presents the values of limiting settling velocities obtained through all three approaches in relation to the real velocity of the hydraulic mixture in the pipeline.

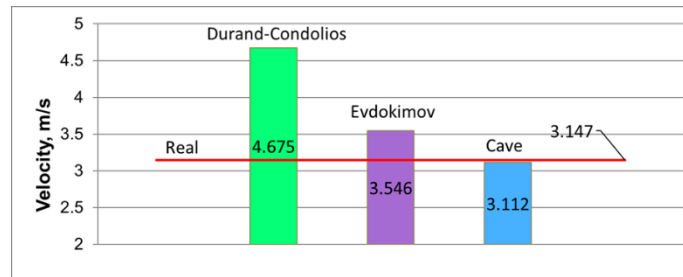


Figure 3 Limiting settling velocities vs. real velocity

As it can be seen from Fig. 3, the methodologies according to Durand-Condolios and Evdokimov give limiting settling velocities that are higher than the real one. Only Cave's methodology gives limiting settling velocity lesser than the real one, which satisfies the conditions for selecting the diameter of the pipeline. This issue can be expressed during the design of mineral processing plants, that is, during the design of devices for hydraulic transport, and can indicate the importance of choosing the calculation methodology of limiting settling velocity. However, as all the formulas are empirical, it cannot be stated with certainty whether the selected pipeline corresponds to the pulp transport conditions in the plant or not. Especially because it is a borderline case when it comes to the value of the pipeline diameter. More specific data can be obtained through laboratory research or by monitoring the operation of the plant in real conditions.

CONCLUSION

The research included determination of the particle limiting settling velocity in the pipeline, using three methodologies – by Durand-Condolios, Evdokimov and Cave in real conditions.

It was found that the first two approaches give the limiting settling velocity higher than the real, while the Cave procedure gave the value lesser than the real one. Since when selecting the diameter of the pipeline, it is necessary that the real velocity be higher than the limited settling, only in the third case is this condition fulfilled. However, it does not necessarily mean that the selected diameter of the pipeline does not correspond to the actual conditions of exploitation, because the formulas are empirical and the most adequate data can be obtained through laboratory tests or monitoring of plant operation.

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