Program for determination of zones of gold concentration on sluices of washing devices

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Abstract. Currently sluice washing devices are the most common in alluvial gold mining. Their use provides a sufficiently high performance, relatively low power consumption, and acceptable recovery of valuable components. The theoretical provisions of traditional hydraulics make it possible to determine all the main parameters of the movement of particles of rocks and gold in the pulp, however, in real operating conditions of the sluice box, their actual values will differ greatly from the calculated ones, especially if there are solid fractions in the pulp with a particle size of more than 20 mm. This is explained by significant fluctuations in the values of the surface, average and bottom velocities of the two-phase flow, vertical pulsation velocity in conditions of constrained movement of the different fractional composition of rocks. The article presents the results of experimental studies to identify the dependence of the distance traveled by an individual gold particle and host rocks in a two-phase flow through a sluice, the bottom of which is lined with trapping coatings, on the design and technological parameters of the flushing device. The mathematical model for determining this distance formed the basis of the Gold Enriching program. The program allows, in a wide range of initial data, to determine the zones of concentration of gold of a certain size at the sluice boxes.

1. Introduction

At present, in Russia and in the world, sluice boxes are most often used when enriching sands of placer deposits of precious metals [1–7].

The basic equipment remains the traditional sluice, which can basically be two types: sluice of deep (SDF) and shallow (SSF) filling. Simplicity of design, high productivity with a high degree of reduction of the source material, acceptable recovery of valuable components are the indisputable advantages of a traditional sluice.

However, its application has limitations on the extraction of small particle sizes: gold particles with a particle size of -1…+ 0.5 mm are recovered by 97–95%; particle size -0.5…+ 0.25 mm – by 80%; fineness less than 0.25 mm - by 37–60%. When enriching high-clay sands, the actual loss of gold from the sluices is 2–3 times higher than the above values [8, 9]. Despite numerous developments to improve sluices, the problem of additional recovery of fine grades of gold and other useful components has not been fundamentally (effectively) solved.
The reason for the high losses at the sluices is that the hydraulic characteristics of the streams are such that they do not ensure the settling of fine gold fractions within the length of the sluice, as a result of which they are washed into the tailings [10–12].

The process of fallout of solid particles can be described by mathematical description based traditionally on comparing the vertical component \( V_z \) of the turbulent flow velocity and the hydraulic particle size. However, in the works of the employees of the Mining Institute FEB RAS [13], it was shown that it is more justified to describe this process by using the concept of the particle soaring velocity \( V_s \) instead of the hydraulic size. The difference between these velocities, i.e., \( V_s - V_z \), gives the settling velocity of a particle that moves along the chute under the action of the translational flow. Thus, it is possible to calculate the concentration zones of particles of a given density and size.

The distance the particle is carried away along the chute will be greater when its start occurs from a greater height. Therefore, the calculated initial position of the particle should be taken as its location on the free surface of the flow. Consequently, for the calculation, it is necessary to know the depth of the flow corresponding to the accepted productivity of the flushing device and the flow rate of process water. In this case, it will be possible to determine the average speed and, through it, the characteristics of turbulence. At the same time, the intensity of turbulence (fluctuating velocity components) is related to the average flow rate, which, for a given volumetric flow rate, unambiguously depends on the flow depth.

It is known from hydraulics that the filling of the channel during uniform movement is completely determined by the hydraulic resistance. Taking this into account, the textured trapping coatings used on sluices are completely unique, from the point of view of general hydraulic engineering, examples of artificial enhanced roughness, for which it is impossible to find analogues. Therefore, an independent problem arises to study hydraulic resistance in open troughs, the bottom of which is lined with trapping coatings such as Canadian moss (Figure 1) and gold-catching rubber carpet (Figure 2).

![Figure 1. Experimental unit](image1)

2. Methods and equipment

To develop a scientifically grounded methodology for determining the parameters of the hydraulic flow at the sluices, it is necessary to reveal the values of the following coefficients at different pulp consistencies (the ratio of solid to liquid (S:L) two-phase flow): coefficient of hydrodynamic resistance – Darcy coefficient \( \lambda \); Froude coefficient \( Fr \), which is the law of gravitational similarity and characterizes the ratio of inertia and gravity forces; Reynolds coefficient \( Re \), characterizing the level of turbulence of the hydraulic flow.

To obtain general patterns of influence of various factors (volumes of processed rock mass and supplied process water, S: L ratio, angle of inclination of sluices, etc.) on the effective parameters of two-phase hydraulic flow at sluices, it is necessary to carry out laboratory and industrial experimental studies.
To carry out laboratory experimental work, a model of a sluice box was developed and manufactured (Figure 1), on which studies of the value of the Darcy coefficient \( \lambda \) for "pure water" were carried out, and then studies of the two-phase hydraulic flow at the sluice were carried out using two types of trapping coatings: gold-catching carpet and Canadian moss.

The installation includes sand pump, head distributor, sluice, process water tank. The dimensions and technological characteristics of the sluice were determined taking into account the similarity method. The length of the chute was taken as \( L = 3.5 \) m, width \( b = 0.2 \) m, height \( H = 0.1 \) m.

The method of experimental work on pure water included the determination of the flow depth using a spitzentaster at various initial parameters: the angle of inclination of the sluice \( (5^\circ, 7^\circ, 10^\circ) \), water flow rate, type of catching coating, and the presence of sluice riffles. The following parameters are determined by calculation: wetted perimeter, hydraulic radius, average flow rate in the sluice, Darcy coefficient, Shezy coefficient, Reynolds coefficient, Froude coefficient.

Analysis of the results of the performed study of the parameters of a single-phase hydraulic flow allows us to evaluate this methodological approach to experimental studies as adequate to the basic theoretical principles of hydraulics, which gives grounds to carry out further experiments to study the Darcy coefficient in two-phase flows.

For experimental work using a two-phase slurry, an averaged sample of alluvial sands of several placer gold deposits was prepared, containing gold of fine grain size \((-0.5 \) mm). The investigated range of the value of the ratio \( S:L = 1:10 \div 1:20 \), the angle of inclination of the sluice \( 5^\circ, 7^\circ, 10^\circ \), the type of trapping cover - gold-catching carpet, the type of riffle – ladder (Figure 2). At the end of the experiment, the concentrate, which had settled on the mats, was sampled at intervals, through each meter of the sluice installation. The concentrate was dried, enriched on a SKO-0.2 concentration table and sent to determine the granulometric composition of the recovered gold and its weight.

**Figure 2.** Study of the parameters of a two-phase hydraulic flow

According to the results of experimental work on the laboratory sluice, it can be concluded that the most effective operating mode of the sluice is at an angle of inclination of 7 degrees and the ratio \( S:L = 1:14 \) (table 1). With these parameters, the greatest amount of gold is observed on the 1st meter of the sluice and the least on the last. It should be noted that gold in the concentrate of the 3rd meter of the sluice is presented only by the 0.25 mm size class.

Also, studies of the fallout of gold particles on the capturing surfaces of the coating were studied in the course of experimental studies on an operating PGSh-50 sluice box equipped with deep and shallow filling sluices. In the course of the study, the water temperature, the flow depth, the \( S:L \) ratio, the content and granulometric composition of gold extracted at different distances from the beginning of the sluice were measured. The productivity of the flushing device is 50 m\(^3\)/hour, the angle of inclination of the sluice is 7\(^\circ\), the ratio \( S:L = 1–12 \div 1-20 \), the length of the deep filling sluice is 12 m. As a result of the
experimental-industrial research, an analytical dependence of the path length of a gold particle of a certain diameter before it falls out on the sluice with different initial parameters is obtained.

### Table 1. Hydraulic flow parameters at the sluice, concentrate volume and gold content in concentrate at S:L=1:14.

| Sluice tilt angle, degrees | Average flow velocity V, m/s | Average flow depth, h, m | 1st meter of the sluice | 2nd meter of the sluice | 3rd meter of the sluice |
|---------------------------|------------------------------|--------------------------|-------------------------|-------------------------|-------------------------|
| 5                         | 0.69                         | 0.024                    | 0.9                     | 0.85                    | 1.1                     |
|                           |                              |                          | 634.6                   | 47.6                    | 17.1                    |
| 7                         | 0.81                         | 0.020                    | 0.9                     | 0.7                     | 1.0                     |
|                           |                              |                          | 728.8                   | 79.7                    | 18                      |
| 10                        | 0.93                         | 0.018                    | 0.3                     | 0.3                     | 0.4                     |
|                           |                              |                          | 529.3                   | 155                     | 39.3                    |

### 3. Results and discussion

The laboratory and experimental-industrial research carried out made it possible to develop a mathematical model for determining the distance of movement of a gold particle of a certain size, taking into account the design and technological parameters of the sluice box.

The developed mathematical model formed the basis of the *Gold Enriching* program, which runs in the Windows 7/10 environment.

At the first stage, the design parameters of the deep filling sluice, the parameters and type of riffles used, as well as the parameters of the pulp are introduced. The parameters are set as follows: initial value, step of change, number of steps. The final value of the parameter is calculated (Figure 3).

![Figure 3. Input window for initial data](image)
As a result, the program calculates the values of the coefficients and parameters characterizing the two-phase hydraulic flow for each variant, the number of which is determined by the range of the initial data. For example, for the initial data shown in Figure 3, there are 648 such variants (Figure 4).

![Intermediate results](image)

**Figure 4.** Intermediate results.

For each version of the initial data, the program gives the values of the soaring velocity of the gold particles $V_{vz}$ and the enclosing rocks $V_{vp}$, the falling velocity of the gold particles $V_{cz}$ and the enclosing rocks $V_{cp}$, the time of their fallout $T_{pz}$ and $T_{pp}$, as well as the distance traveled by a particle of a certain diameter before it falls out onto the trapping surface $L_{cz}$ and $L_{cp}$. The calculation is performed for gold particles and host rocks with a diameter of 0.1 to 100 mm (Figure 5).

If the condition for falling particles onto the capturing surface is not met, the program outputs a negative value of the falling velocity of the particle $V_c$, zero value of the falling out time $T_p$ and the distance traveled $L_c$ (Figure 5).
Figure 5. Calculation results

4. Conclusion
The mathematical model of the fallout of gold particles and host rocks on the trapping surface in a two-phase flow, developed on the basis of laboratory and pilot-industrial experimental studies, makes it possible to assess the distribution zones of gold particles at the sluice boxes, taking into account their grain size characteristics.

On the basis of a mathematical model, a program has been developed that makes it possible to determine the time and distance of particles falling onto the trapping surface, taking into account a wide range of design and technological parameters of the sluice box. The data obtained as a result of the work of the program will allow at the design stage to determine the required length of a deep filling sluice, as well as justify the need to use a shallow filling sluice.
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