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TECHNOLOGICAL SOLUTIONS FOR ROCK JETTING WITH CONTROLLED CONTENT OF FINE SOIL PARTICLES IN PRESSURE WATER OF A HYDRAULIC MONITOR

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ABSTRACT

The Siberian Federal District of the Russian Federation has a significant number of placer gold deposits, composed of rocks with considerable clay content. The long time required for settling fine particle fraction of jet-broken mass leads to supplying pressure water with significant amounts of fine particles to the hydraulic monitor units. Based on the previous studies, the solutions are proposed that can be applied in developing deposits with rock jetting, water reuse from settling ponds, and significant amounts of fine particles in the developed soils. Based on these solutions, rock jetting can be conducted for both overburden and mining operations. For mining operations, it is recommended to limit the content of fine soil particles in pressure water to 60 g/l, and for overburden operations – to 100 g/l. A distinctive feature of these technological solutions is the process water supply to the hydraulic monitor with a controlled amount of fine soil particles in its composition. The accumulation of these particles in process water occurs naturally during the flushing season.

Keywords: placer deposit, hydraulic monitor, rock jetting, clay mass, fine soil particles, rock jetting performance, technological solutions, methods, jet impact force.

INTRODUCTION

The Siberian Federal District of the Russian Federation has a significant number of placer gold deposits. Many of them occur in high-clay rocks. This factor is negative in terms of mining technology and placer sand beneficiation hydraulic mining is often done with water reuse from settling ponds.

The long time required for settling fine particle fraction of jet-broken clay mass leads to supplying pressure water with significant amounts of fine soil particles to the hydraulic monitor units.

The rheological properties of process water and jet parameters, in particular, jet impact force, alter the content of these particles. Also, water volume calculation in the water reuse settling pond is based on the content of fine soil particles in water at the end of the flushing season, which affects the volume of capital mining operations and the required amount of water that the mining enterprise must provide for working.

In recent years, many researchers adopted the numerical method to investigate the failure of rock or rock-like materials by water jet impact, and their research works were mainly focused on the influences of the impact velocity, diameter, standoff distance, and incidence angle of the water jet, as well as the confining pressure and type of rock on the erosion depth, diameter, damage, and stress distributions of rock [1-4].

In their paper, Jiang Hongxiang, Du Changlong, Liu Songyong, and Gao Kuidong revealed the rock fragmentation mechanism and explained the reasons for crushing zone formation, crack initiation, and propagation under the impact load of the water jet. Their studies found that the rock fragmentation by water jet impact can also be regarded as a load/unload process and is due to the combined action of shear and tensile failure and that the surface erosion of rock is primary at low impact velocity and the actual failure (such as radial and spall cracks) will occur only when impact velocity reaches up to a certain value [5].

MATERIALS AND METHODS

Based on studies [6-8], the solutions are proposed for mining deposits with rock jetting with water reuse from settling ponds and significant number of fine soil particles in the developed soils.

Based on solutions [6-8] rock jetting can be carried out for both overburden and mining operations. However, as studies [9-15] show, significant content of fine soil particles in pressure water negatively affects the treatment process with gravitational methods. Therefore, for mining operations, it is recommended to limit the amount of fine soil particles in pressure water to 60 g/l, no more [15].

For overburden operations, the amount of fine soil particles in process water is to be limited to 100 g/l, which is mainly due to a jump in the abrasion wear of equipment.

A distinctive feature of these technological solutions is the process water supply to a hydraulic monitor with a controlled amount of fine soil particles in its composition. The accumulation of these particles in process water occurs naturally during the flushing season.

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RESULTS

The Procedure for Determining the Maximum Possible Concentration of Fine Soil Particles in Process Water at the End of the Flushing Season using Hydraulic Mining Means

The following procedure helps apply the research results [6-8] at a mining enterprise.

At the mine planning stage, the deposits are studied: sand and peat grading, or observations of the accumulation of fine soil particles in the settling pond in previous seasons (using available information or purposely taking measurements).

Figure-1 shows an example of a change in the content of fine soil particles in settling pond water during the flushing season, which is 200 days. There it can be seen that the content of fine soil particles in settling pond water is nonlinearly changed.

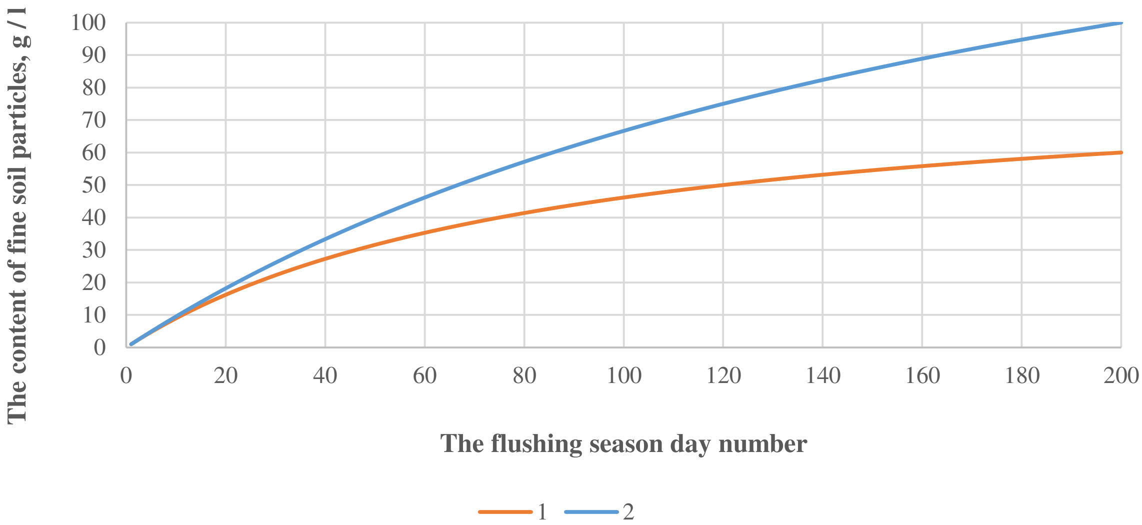

Figure-1. Change in the content of fine soil particles in settling pond water during the flushing season with the limit: 1 - to 60 g/l; 2 - to 100 g/l.

Using equation (1), a rock jetting performance curve for the flushing season is constructed, that is directly proportional to jet impact force variation. Change of rock jetting performance during the flushing season is estimated, the reference value being old-fashioned jetting performance.

$$P = A \cdot \rho + \frac{L}{10} \cdot 100^{-3} \cdot (B \cdot \frac{H_o^2}{100} + C \cdot \frac{H_o}{10} + D) + E + F, \quad (1)$$

where A, B, C, D, E, F are mathematical model coefficients:

$$A, B, C, D, E = a \cdot \frac{d_H^2}{100} + b \cdot \frac{d_H}{10} + c, \quad (2)$$

$$F = \frac{H_o}{10} \cdot (0.23 \cdot \frac{d_H}{10} - 0.81) \quad (3)$$

where a, b, c are empirical coefficients (Table-1).

Table-1. To define empirical coefficients of the equation (2).

Coefficient (1)	Empirical coefficients (2)		
	a	b	c
A	-0.36	5.31	-7.63
B	-1.79	22.46	-66.16
C	54.7	-687.4	2025
D	-414.3	525.5	15860
E	0.45	-6.25	10.62

The graph (Figure-2) shows an example, calculated with equation (1), of the dependence of rock jetting performance on the content of fine soil particles in the jet. The graph shows the rock jetting performance range for mining operations - when the amount of fine soil particles in pressure water is limited to 60 g/l and for overburden operations - up to 100 g/l (it is cross-hatched).

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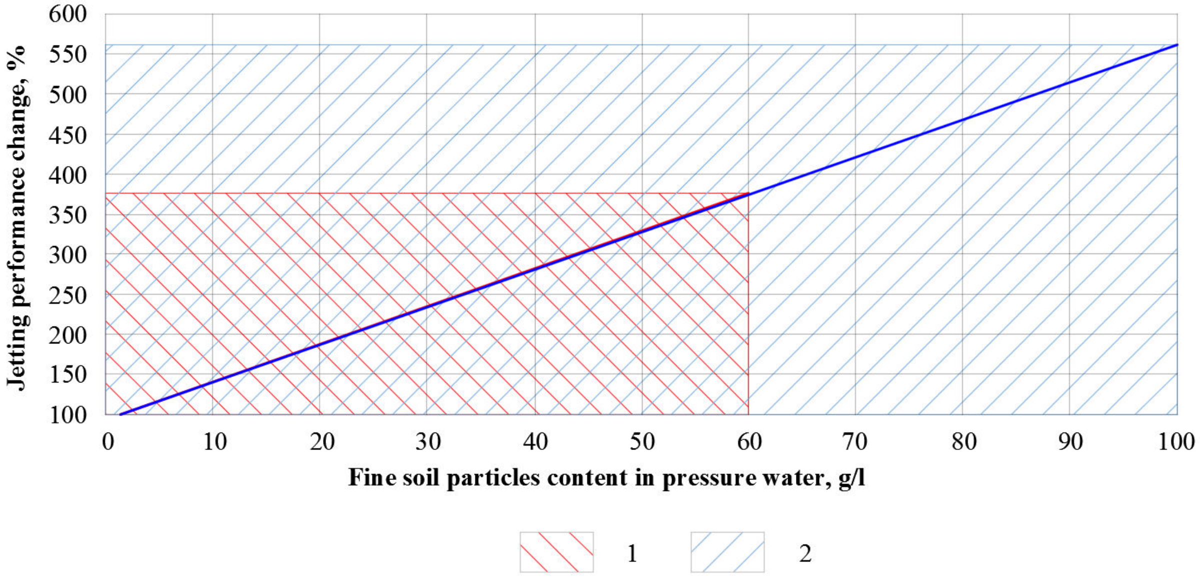

Figure-2. Relative jetting performance change depending on the content of fine soil particles in pressure water (100% is performance of jetting withpure water). The content of fine soil particles: 1 - to 60 g/l (mining operations); 2 - to 100 g/l (overburden operations).

Since the accumulation of fine soil particles in the process water of a settling pond occurs gradually, their content will increase during the flushing season and reach maximum values at the end of it. Rock jetting performance will improve proportionally. Consequently, it would be more appropriate to speak of average jetting performance for a season.

Control the content of fine soil particles in processed water is possible, for example, by adjusting the volume of water in the pond.

After determining (using a well-known technique, but taking into account the higher content of fine soil particles in process water), the required volume of the pond, it is taken how the calculated volume of process water will be placed. The required dimensions of the settling pond are set at the enterprise design stage. In case the technology is intended to apply at an operating enterprise, a given pond may be underfilled.

Figure 3 shows the change in the required volume of water in the pond (which will lead to a change in its size) to ensure the specified content of fine soil particles in process water.

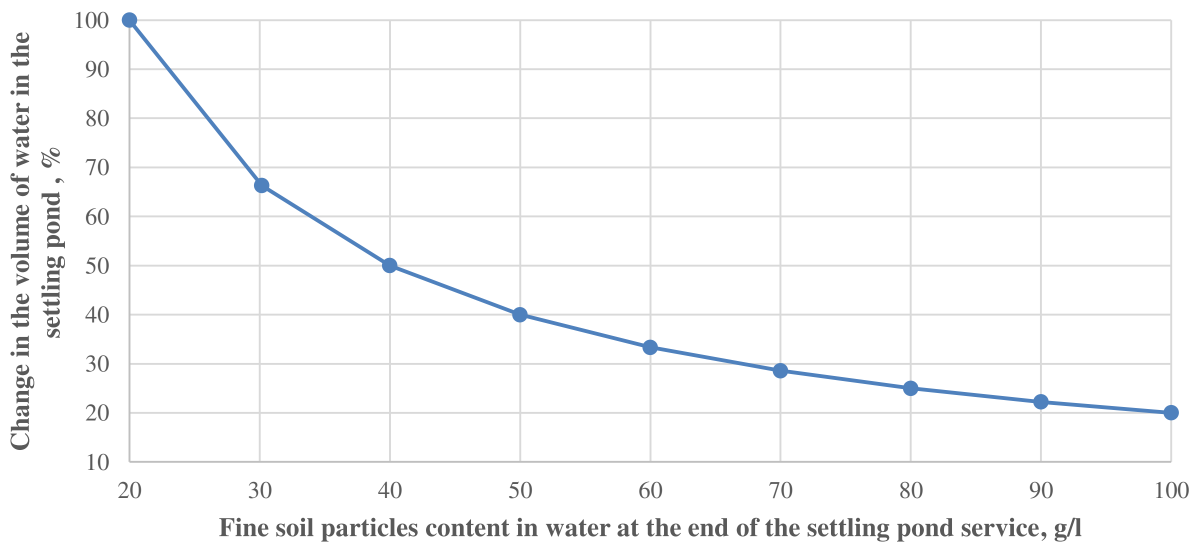

Figure-3. Change in the required volume of water in the settling pond at the end of its service due to increasing the content of fine soil particles in process water.

The required amount of water can be defined by equation (4) [16], which takes into account the content of fine soil particles in the settling pond water at the end of the flushing season.

$$C_f = 10 \cdot V_p \cdot \rho_t \cdot \frac{b}{V_o}, g/l \tag{4}$$

where C_f is clay particles content in process water at the end of the settling pond service; V_p is a number of flushed soils that go to the hydraulic spoil bank in rock mass during all its service, m^3; ρ_t is the density of the finest fractions, t/m^3; b is the ultimate yield of less sized fractions, %; V_o is the water volume in the pond, m^3.

The ultimate yield of less-sized fractions (b) is defined by developed soil grading. Data of natural settling velocity define the geometric size of soil particles.

Setting higher limit values for the content of fine soil particles will reduce the required volume of water in the settling pond.

Thus, the benefit of the proposed procedure is to reduce the required volume of water, which entails a reduction in the area of the settling pond and lands alienated for this, and to enhance rock jetting performance and reduce flow intensity for jetting.

The Procedure for Determining the Maximum Possible Concentration of Fine Soil Particles in Process Water at the End of the Flushing Season using Hydraulic Mining Means

It is also possible to break rocks with pressure water with a given content of fine soil particles throughout the entire flushing season. For this, it is necessary, using equation (1), to define the ratio of fine soil particle content and rock jetting performance for the enterprise targeted (as described above).

Using the obtained data and data on grading or observations of the accumulation of fine soil particles in the settling ponds of the enterprise, it is possible to define the minimum accumulation time for a given content of fine soil particles and build a settling pond with these parameters.

To maintain the given content of fine soil particles in the settling pond, it is performed in two sections - with a section for pure water, the settling pond is topped up with as needed.

The required water volume and the frequency of settling pond topping up with pure water are defined by equation (4), comparing the indicator of the actual quantity of fine soil particles in the settling pond water and the required one.

The quantity of fine soil particles can also be controlled by means available at the mining enterprise, for example, by using water boxes or drain pipes to provide pure water volume in the settling pond.

CONCLUSIONS

The solutions proposed including the procedure for determining the maximum possible concentration of fine soil particles in process water using hydraulic mining means will help enhance rock jetting performance and reduce flow intensity. Reducing the required volume of water in the settling pond will entail a decrease in its area and land alienated for this.

To control the content of fine soil particles accumulating naturally in the process water of the settling pond is done by limiting its maximum value at the end of the flushing season at the stage of designing the settling pond by reducing its area or the volume of water in it (for an existing settling pond). It is also possible to break rocks with pressure water with a controlled content of fine soil particles throughout the entire flushing season. For this, the settling pond is made in two sections, or the means available at the mining enterprise are used.

ACKNOWLEDGEMENT

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