Improving the design of a disintegrator for deep utilization of enrichment tailings

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Abstract. The article discusses the directions of improving the design of disintegrators for activating materials and leaching metals when disposing of solid mineral raw materials using mechanochemical technology. The results of experimental extraction of metals from non-ferrous and ferrous ores, as well as coal are presented. Disintegrator designs differing in the use of physicochemical methods of increasing activity are recommended.

1. Introduction
In mining, the relevance of the full use of raw materials extracted from the bowels of the earth is increasing. The efficiency of the functioning of a mining enterprise is characterized by material, energy and other costs for the production of commercial products, provided that the environment is reliably protected from the negative technological impact.

One of the requirements for mining is the completeness of the use of mineral resources, including the fate of mineral resources extracted to the earth's surface [1–4].

It becomes obvious that when determining the profit from the extraction of minerals, those resources that have not been extracted from the bowels of the earth, or have been extracted and not used, for example, ore processing tailings, must be taken into account.

Over time, the relevance of the development of technologies and processes increases, as a result of which inactive stocks of metal-containing raw materials are involved in production [5–8].

One of the directions of realization of the idea of deep extraction of metals from substandard raw materials is the mechanochemical activation of the processes of leaching of metals in a disintegrator [9–12].

The industrial use of the disintegrator was carried out in the 80s at the filling complex of a uranium mine in Northern Kazakhstan with a capacity of 100,000 m³ of voids per year. The DU-65 unit was equipped with 4- and 3-row rotors and 250 kW motors and was located in a building with a base area of
5×7 m on three levels.

For 10 years, the unit has met the needs of a medium-sized mine in binders for the preparation of hardening mixtures in a system of development with chambers with backfilling of mined-out space.

Processing in a disintegrator provided an increase in the strength of the mixture by 30% more than when processing in a ball mill. The output of 55% of the active class 0.076 mm upon activation of the granular tailings of the Karaganda metallurgical plant made it possible to reduce the cement consumption from 120–150 kg/m³ to 30 kg/m³. The equivalent of 1 kg of M-400 commercial cement was 4 kg of activated tailings.

The purpose of this work is to identify ways to optimize the design of the disintegrator to improve the performance of metal recovery from the tailings.

2. Results

Mechanochemical technology is based on the phenomenon of change in the state of matter in a disintegrator when processing at a speed of more than 250 m/s theoretically substantiated and experimentally proved by J. Hint (figure 1).

![Figure 1. The scheme of the mechanical activation of mineral raw materials: 1 – source raw material; 2 – motors with rotors and working body; 3 – activated raw materials.](image)

The mechanism of development of physicochemical processes in solids is based on the phenomenon of that the larger the surface of the substance involved in the process, the better the processing rates.

Since then, the basic design of disintegrators has undergone improvements.

2. Materials and methods

The phenomenon of change in the state of a substance in a disintegrator during processing at a high speed has been investigated. The quantitative values of the parameters of the extraction of metals into the solution were determined experimentally during leaching of metal enrichment tailings in a laboratory disintegrator. The recovery rates from the tailings by disintegrator leaching are compared with agitational leaching. The results obtained are used to predict the development of the sounded technology for extracting metals from tailings during their disposal.

To improve the processing performance in the disintegrator, the design of the disintegrator is modernized by introducing additional effects on the treated substance.

In order to reduce the adhesion of particles of enrichment tailings in a disintegrator, during processing, they are subjected to vibration and tossing with fluctuations from 30 to 1500 Hz with an amplitude of horizontal oscillations of 2–50 mm and an amplitude of vertical tosses of up to 30 mm (figure 2).
The tails entering the disintegrator also perform a forward motion with tossing. Contacting with the working surfaces of the disintegrator, they are deprived of the opportunity to stick together, which increases the speed of the process and reduces energy consumption to obtain the desired result.

The efficiency of activation of materials is increased by combining mechanical activation with temperature exposure (figure 3).

Using a heating element, the temperature of the liquid is brought to 90–95 °C. The tailings mix with the liquid sprayed by the nozzles and enter the disintegrator chamber. The pulp passes through the rows of fingers and is thrown onto the outer discs. Particles larger than the required size are additionally crushed due to the rotation of the discs and collision with newly arriving particles.

One of the options for increasing the efficiency of materials processing is the combination of
mechanical activation with electroacoustic action. Electroacoustic emitters are fixed along the perimeter of the working chamber, and the disintegrator is equipped with an electronic generator (figure 4).

![Figure 4. Mechanical activation scheme with electroacoustic effect: 1 – case; 2 – inlet pipe; 3 – electronic generator; 4 – disks; 5 – fingers; 6 – electroacoustic emitter.](image)

In the case of combined mechanochemical activation of metal-containing raw materials, the leaching reagent is fed into the working body of the disintegrator, and the extraction of metals into the solution occurs simultaneously with the destruction of crystals, when the solution is pressed into the resulting cracks. When combining mechanical activation with chemical enrichment, the tailings in a mixture with sulfur are pretreated with sulfuric and nitric acid (figure 5).

![Figure 5. Scheme of the chemical component of the activation of the leaching process: 1 – concentration tailings; 2 – metal-containing solution; 3 – leaching tailings.](image)

When the tailings are exposed to chemical reagents, pulp slurry is prepared from them with a solid to liquid ratio of 1: 2. The tailings are ground in a mixture with elemental sulfur (12% by weight) to a particle size of 0.01 mm. The treatment of the pulp with reagents is carried out at a ratio of the latter by mass of 2: 1. The pH is adjusted to 1 with an increase to 3 within 2 hours. In the leached mass, oxidizing agents are formed, which convert non-oxidized refractory metal minerals into easily openable forms.
After leaching in a disintegrator, the tailings are stacked, washed with water and leached first with a solution of sulfuric acid with a concentration of 10-30 g/l, and then with a solution of sodium sulfidotrioxosulfate with a concentration of 10-20 g/l.

The combination of leaching processes in the disintegrator and in the stack allows the tails activated in the disintegrator to release metals, increasing their recovery in comparison with both methods separately without combining.

The possibility of mechanochemical leaching has been proven experimentally when processing tailings of enrichment of Sadon polymetals, coal from the Russian Donbass and ferruginous quartzites KMA in a DU-11 disintegrator designed by the Center for Applied Mechanochemistry "Gefest". It has been determined that the technology under consideration makes it possible to extract metals from 50 to 80% of the original content in the tailings, and with a decrease in the residual content to the background level, it can be obtained by increasing the processing cycles.

After activation, the tailings can be used in the composition of the hardening mixture not only as inert fillers, but also as binding components, since an increase in the activity of the components by 20-25% increases the strength of concrete products up to 1 MPa.

The concept of deep utilization of waste from processing metal ores meets the principles of interaction between a Human and the biosphere and is especially relevant for solving the problems of diversification of mining in market conditions [13–15].

The results of the study are an element of the system of works of Russian scientists in the direction of resource conservation in mining [16–21].

4. Conclusion
Mechanochemical activation of metal-containing substandard raw materials during deep utilization of tailings makes it possible to extract metals and increase the activity of solid minerals to a state where they exhibit the desired properties.

The design of disintegrators is being improved through the use of new physical and technical processes, solving the problem of increasing the completeness of the use of bowels of the earth, including returning to production raw materials containing metal components inaccessible to traditional enrichment technologies.

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