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Experimental Study Of Non-Waste Recycling Tailings Ferruginous Quartzite

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Abstract
The article seeks to substantiate the technology safe and cost-effective disposal of tailings on the example of ferruginous quartzite. The results of experiments on the preparation of hardening mixtures based tailings after extraction of metals leaching process within a single processing tails with mechanical activation in the disintegrator and chemical leaching, variants that differ destination and duration of training, as well as the values of variables. The parameters of the effect of activation in disintegrators strength hardening mixtures. The possibility of using not only the tailings as inert fillers, and as binders. It is shown that product activation in the disintegrator is a material different from the raw material quality and safety of the content of metals. It is recommended to use the secondary tailings for making hardening filling mixtures in the transition from the open mining enterprises to underground mining.

Keywords: materials, waste, tailings, ferruginous quartzite, experiment, hardening mixture, metal leaching, activation, disintegrator, an inert filler, binder, development, field.

Introduction

By extraction of minerals on the ground surface the technogenic deposits from tailings of the primary ore beneficiation are formed the necessity of providing the industry with mineral raw materials does not allow reducing the volume of drawing there from the interior.

The open-cut mining method came into collision with the fundamental interests of the mining regions featuring fatal economic and environmental defects. The forthcoming transition of many enterprises, for example KMA, to the underground method requires provision with hardening mixes for filling of the process cavities the mining of which in the volumes required will make the environmental conditions in the regions even worse.

It is widely accepted that ore refinement tailings may be used as a raw material for production of the hardening mixes. In the deposits of Russia there are up to 100 billion tons of solid wastes. Annually about 15 million tons of wastes are produced whereof not more than 10% are recovered. Alone at the KMA enterprises there have been accumulated over 320 million tons of the iron-ore concentration tailings.

The accumulated experience in the use of the mining wastes for production of concretes cannot be recognized as positive. The obstacle for the wide use of concentration tailings as raw material for construction consists primarily in the presence of metals that have not been extracted previously by processing. Recovery of tailings without extraction of these metals is dangerous both from the economic and environmental perspective [1].

The metal-containing minerals contain valuable and deficit metals the cost of which may be comparable with the cost of metals extracted.

Thus, minerals of the Lebedinsky deposit contain – along with the title metal – iron – cobalt, nickel, copper, arsenic, palladium, silver, stibium, tellurium, platinum, plumbum, lead, beryllium and other metals.

Along with the own mineral phases significant amounts of metals are concentrated in sulfides, sulpho-arsenides and other ore minerals as the result of processes of the precious metals genesis in ferruginous quartzite.

Presence of non-extracted metals in the commercial products threatens with chemical and radiological contamination since metals contained in the wastes under influence of the processes of natural leaching migrate to the environmental ecosystems and causing drastic consequences.

The scope of recovery of mineral wastes is limited by capabilities of the processing equipment used. Recovery may be applied to wastes with minimal components content which at the same time exceeds the sanitary norms. Huge reserves at the technogenic deposits that are below standard for metal extracting technologies perform environment-destroying activity the scope of which is enhanced as the selective mining trend assuring the here-and-now profit is developed.

The possibilities of the metal extraction from concentration tailings were enhanced by assimilation of the chemical leaching technology, for example, by means of leaching, heap or percolation with the process activation through mixing in agitators. However, by low metal concentrations the duration and impossibility of extraction up to the sanitary safe level do not allow enhancing the area of application of this method.

Recently there was accumulated a slight experience of metal extraction from the mining tailings by means of combining the processes of mechanical activation and leaching which allows recovering metals up to the level of the maximum permissible concentration by two orders faster than by agitation digestion [2,8].

In the technology of preparation of hardening mixes the phenomenon of changes in the material properties in disintegrators is used more and more frequently which ensures maintenance of the required rated strength at the poor quality of the primary components (Fig.1) [3,9,10].

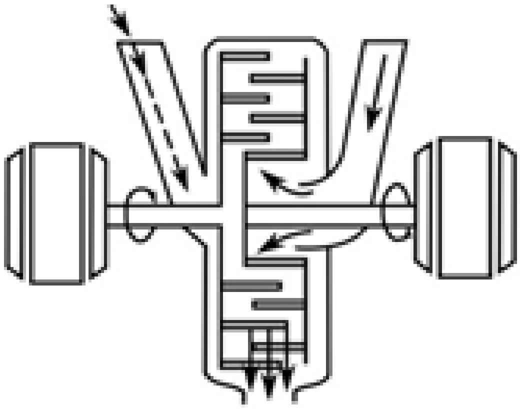

Fig.1. Disintegrator structure

In the mining industry by recovery of the ore concentration wastes the objective is optimization of compositions of the hardening mixed for the purpose of ensuring the rated strength of the filling masses in the goaf. This is achieved by selection of the mix components and the use of methods of intensification of the metal leaching. Thus, the mix strength may be significantly increased by means of close-size grading. The most topical is the trend of using the tailings from the mineral processing aas part of the hardening mix not only as inert aggregates but as binders as well.
Fine concentration fractions up to 0.076 mm containing carbonate components are used as binding agents. Grinding of the concentration tailings to fine-dispersed fraction allows producing stowing mixes featuring strength that is sufficient for filling the major volume of the technogenic cavities. The physico-chemical processes in solid matters run the faster and more complete the greater the surface of the involved substance is.
In the modern manufacturing processes the phenomenon of changes in the state of the matter when being exposed to mechanical energy in the disintegrator chamber is rather widely used [4, 10].
By processing in a disintegrator additional energy is accumulated in the matter the value of which may reach 30% of the entire energy spent on processing. The impact velocities arising in a disintegrator are by an order higher than in mills and the acceleration reaches millions of the gravity accelerations. In the disintegrator operating chamber the particles are grinded by collisions with the maximum velocity about 175 m/s. Activation of the concentration tailings in the disintegrator allows fine fractions competing with the cement.
We study the phenomenon of combination within the single process of the processing of tailings from mechanical activation in a disintegrator with chemical leaching. Basically, the product of activation in a disintegrator is the new material differing from the source concentration tailings through the improved quality and safety of the metal content (Fig.2).

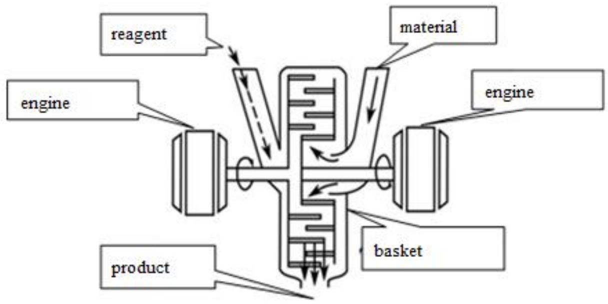

Fig.2. The leaching of the tailings in the disintegrator

This paper is dedicated to substantiation of the safe and cost effective recovery of the concentration tailings by the example of the KMA ferruginous quartzite.

Procedure of the experiment

The efficiency of the technology of mechano-chemical activation of tailings from concentrtaion of ferruginous quartzite is evaluated by means of comparing it with the performance of agitation leaching in percolators according to the criterion ‘metal recovery’ with the result interpretation in the form of logarophmic or pilynomial interpolation.
The reduction of the cement consumption for preparation of hardening mixes while ensuring the rated strength of the filling mass, enhancement of the tailings recovery area environmental improvement are achieved as the result of implementation of several trends.

Ermolovich E.A. [5] suggests including into the composition of the stowing mix:

- as a binding agent – additional use of grinded blast-furnace acid slag and as an aggregate – mix of the tailings from ferruginous quartzite concentration with broken slag;
- grinded by-product of vanadium production and as the aggregate – the concentration tailings;
- grinded acid granulated blast-furnace slag and as the aggregate – tailings from the wet magnetic separation of ferruginous quartzite, the by-product of vanadium production and super plasticizer.

Lesovik R. V. recommends using as the aggregate the concentration tailings and Portland cement grinded in a disintegrator.
Korneeva E.V., Pavlenko S.I. include in the composition of the stowing mix the steel casting slag and activizer – combustion rock from the mining dump and sludge from electrolyte lime neutralization.
Rylnikova M. V. et al. propose to use for the goaf stowing the residues of leaching of the concentration tailings, quicklime and sodium lignosulfonates.
The trends considered suggest using the concentration tailings primarily as the aggregate without extraction of the valuable and saleable metals which reduces the efficiency of the subsurface use.

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The analysis of parameters of the single process of tailings reprocessing – mechanical activation in a disintegrator with chemical leaching – was performed in the unit DESI-11 produced by the Center for applied mechano-chemistry "Gefest" (Fig.3).

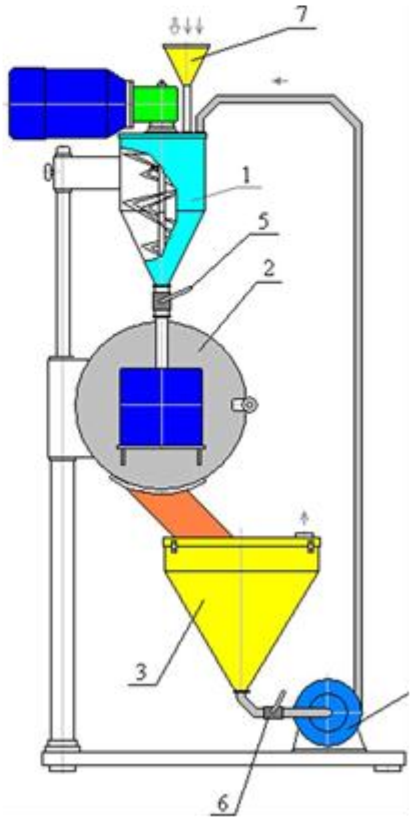

Fig. 3. Design of the laboratory disintegrator DESI-11 for mineral activation: 1-mixer; 2-disintegrator; 3-receiving bin; 4-pump; 5, 6-crane; 7 – cone

For assessment of the activation influence on the hardening mixes strength the mixes with the constant composition have been analyzed:

- concentration tailings size-1 mm;
- components ratio: inert, binders, water-1445:100:380;
- curing period 7, 14 and 28 days;
- disintegrator rotor frequency 200 Hz;
- reagent composition: 10 g/l of sulfuric acid and 160 g/l of sodium chloride

The options of the tailing activation in the mix composition include:

1. Without activation.
2. Mechanical activation in the dry condition.
3. Leaching in an agitator without activation.
4. Mechanical activation with agitation leaching.
5. Leaching in disintegrator.
6. Multiple leaching in a disintegrator.

Chemical composition of tailings, %: SiO_2 – 64, Fe – 8, Al_2O_3 – 5,2, Mn – 3,2, K_2O – 0,7, P – 0,1, Ca – 0,8, Mg O – 0,2, Cu – $5{\cdot}10^{-3}$, Ni-$4{\cdot}10^{-3}$, Zn-$5{\cdot}10^{-4}$, As, Ba, Be, Bi, Co, Cr, Li, Mo, Nb, Pb, Sb, Sn, Sr, Ti, V, Y – at the level $(30\text{-}50){\cdot}10^{-5}$.

Results

The results of the strength tests of hardening mixes are summarized in the Table.1.

Table 1 The results of testing the mixes with cement and tailings without activation

Consumption of Portland cement, kg/m^3	30	60	80	100	120	180
Strength, MPa	0,79	0,92	0,101	1,20	1,41	1,80
Coefficient of test variation	27	26	28	12	15	18

Note: water consumption 380 l/m^3.

For the purpose of increasing the mix strength the tailings are classified by size (Table 2).

Table 2 Specifications of additives to tailings

Fraction	Rest on sieves in %, mm								Decantation losses, kg/m^3	Specific area поверхность, m^2/kg	Density, kg/m^3
	10	5	2,5	1,25	0,63	0,315	0,14	-0,14			
Coarse	29,0	20,5	15,0	7,7	12,5	4,7	6,4	4,2	3,6	5,0	2700
Fine	13,6	16,7	31,7	4,3	17,4	10,0	4,3	3,5	5,0	5,1	2680

The strength of mixes in which the concentration tailings are combined by the optimal coarseness (50% coarse and 50% fine) is increased by 1,15-1,25 (Table 3).

Table 3 Прочность смесей с комбинированным по крупности заполнителем, MPa

Consumption of Portland cement, кг/м^3	30	60	80	100	120	180
Strength, MPa	0,85	1,02	1,23	1,40	1,57	1,85
Variation	21	25	17	19	14	11

Note: water consumption 380 l/m^3.

The mix strength is changed depending on the method of preparation during the metal leaching. Changes in the mix strength prepared with the use of cement are characterized by the figures (Table 4).

Table 4 Impact of preparation on the strength of mixes with the binding cement

№	Kind of activation	Mix composition			Strength, MPa, s		
		tailings	cement	water	7	14	28
1	Without activation	1445	100	380	1,04	1,11	1,20
2	Mechanic activation	1445	100	380	1,16	1,25	1,32
3	Leaching without activation	1445	100	380	0,52	0,61	0,72
4	Mechanical activation with agitation leaching	1445	100	380	0,68	0,73	0,88
5	Leaching in a disintegrator	1445	100	380	0,73	0,77	0,94
6	Multiple leaching in a disintegrator	1445	100	380	0,92	1,10	1,22

The parameters of the mix strength under the same preparation but without the use of cement are summarized in the Table 5.

Table 5 Impact of preparation on the strength of mixes without the binding cement

№	Kind of activation	Mix composition			Strength, MPa, s.		
		tailings	cement	water	7	14	28
1	Without activation	1445	0	380	0,64	0,81	1,01
2	Mechanic activation	1445	0	380	0,86	0,95	1,12
3	Leaching without activation	1445	0	380	0,42	0,57	0,62
4	Mechanical activation with agitation leaching	1445	0	380	0,60	0,69	0,78
5	Leaching in a disintegrator	1445	0	380	0,63	0,71	0,84
6	Multiple leaching in a disintegrator	1445	0	380	0,82	1,00	1,12

The results obtained are compared to the strength of the mix with the use of the concentration tailings activated in a disintegrator as a binding agent (Table 6)

Table 6

№	Kind of activation	Strength, 28 days, MPa		
		cement 100 kg/m^3		activation w/o cement
		w/o activation	with activation	
1	Without activation	1,30	-	1,01
2	Mechanic activation	-	1,52	1,22
3	Leaching without activation	-	0,92	0,62
4	Mechanical activation with agitation leaching	-	1,08	0, 78
5	Leaching in a disintegrator	-	1,20	0,94
6	Multiple leaching in a disintegrator	-	1,54	1,12

The tailings of mechanochemical activation of the by-product coal represent a dispersed mass stacked in particles of about 0,1 mm that differs through more homogenous structure which increases the quality substantially. The effect thereof is illustrated by the increased strength of concrete made under otherwise equal conditions with the use of different methods: grinded in a mill and activated in a disintegrator.

Discussion of results

The strength of concretes on the basis of the concentration tailings by activation thereof in disintegrators is increased from 1,30 to 1, 52 MPa and by the factor 1.17.

Leaching of the concentration tailings in a disintegrator as compared to activation without leaching reduces the mix strength due to the increase in moisture content.

The concentration tailings activated in a disintegrator after the recovery of metals up to the sanitary required rate may be used for manufacturing of the commercial products even without cement including masses from hardening mixes ensuring the desired strength under the specified geomechanical conditions.

The peculiar feature of the proposed integration pattern consists in the fact that its links constitute a unified system within the frameworks of the mining and extractive industry and the proceeds improve its financial status (Fig.4).

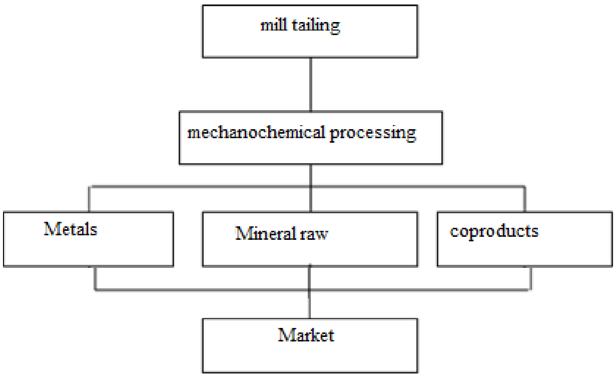

Fig.4. Conceptual model of tailings recovery

The stowing mixes on the basis of the tailings from concentration of ferruginous quartzite assure the desired strength of the artificial masses at compression of 6-13 MPa which meets the requirements to artificial masses more than enough.

In the developed countries the most emphasis is placed on the environmental safety and in first line on the increase in the volume of recovery of technological wastes [6].

In the international practice increase in the wastes recovery rate is ensured by means of the use thereof in the composition of a hardening mix as inert fillers without extraction of hazardous components. Such approach contradicts to the requirement of assuring compliance with the economic and ecological requirements to the technology. Heavy metals contained in tailings transit under influence of the water environment into a mobile state and become the reason of the ecosystems degradation.

The practice of moving the concentration tailings to the mined-out area may be acknowledged to be appropriate only upon reduction of the metal content in the wastes to the MPC rates or to the background rate.

Thus, more complete achievement of the goals of the minery production is ensured by the use of the concentration tailings in the form of moving them to the mined-out space after the metal recovery.

The technology of manufacturing of the commercial products from the secondary ore-concentration tailings shall ensure:

- product recovery from the refuse ore with the density no less than 2,4 t/m^3;
- the use of the mature refuse ore tailings;
- the strength of hardening mixes by uniaxial compression 0,5-1,5 MPa that is sufficient for stowing most of the mined-out space;
- reduction of the cement consumption for preparation and delivery of mixes by times as compared to the reference value.

From the technological and economic perspective it makes more sense to use the current metal ore refuses with integration of the treatment and mix preparation processes into a single system.

After extraction of metals and salts the tailings may be used in the mix composition not only as inert aggregates but as binding agents as well (Fig.5).

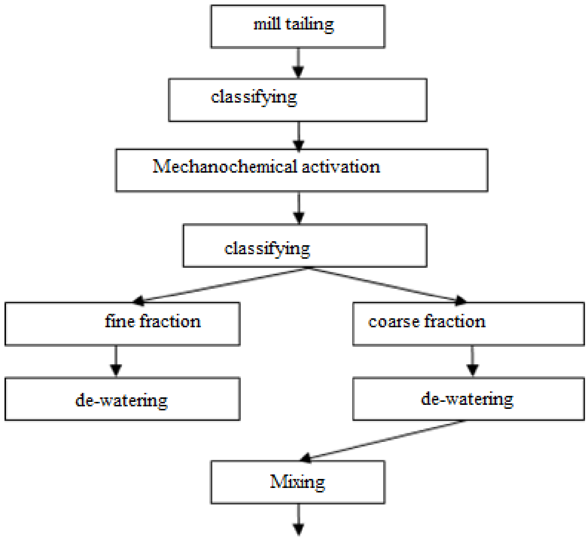

Fig.5. Scheme of preparation of the hardening mix on the basis of the concentration tailings

Cement-free mixes on the basis of the activated concentration tailings may be used at the areas released from critical stress forming the three-hinged refuse arch (Fig. 6) [7].

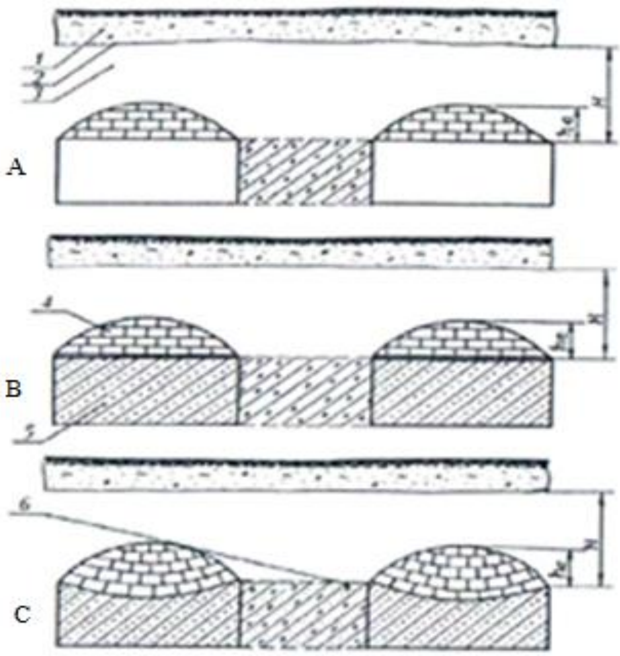

Fig. 6. Control of the mass status: a – w/o filling; b-filling with low strength mixes by flat roof; c – filling with low strength mixes at arched roof: 1-overburden; 2-loose deposits; 3 – primary rocks; 4-rocky blocks; 5-soft filling; 6-strong filling; H – pillar height to the surface; h $_c$ – height of arch of the natural rock seizure

The concrete block takes the rock load within the limits of its natural pressure arch (4) this is why in the ore field areas separated by solid concrete blocks (6) or ore pillars into the safe sections in terms of critical stress the block of reduced strength may be sued (5) both by preservation of flat spans and in case of destruction of the seized rocks carrier.
The materials – products of mechano-chemical treatment – utilized without sanitary restrictions may constitute nearly unlimited raw material vase for the related branches of the national economy (Fig.7).

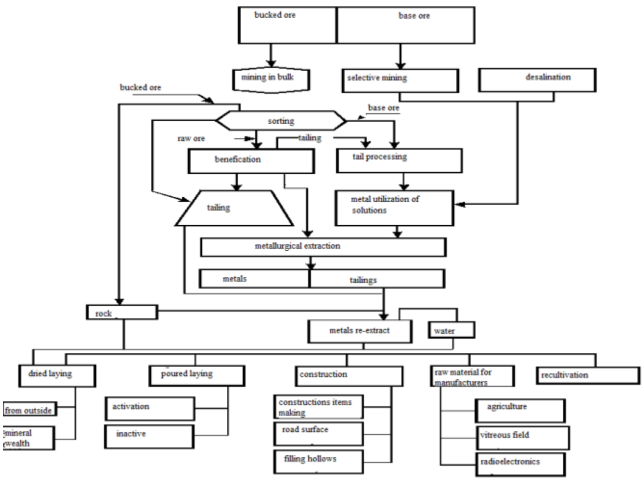

Fig.7. Scheme of the material production and areas of application

Neutralization of the chemical environmental pollution by the concentration tailings is a step towards humanization of the mining industry [11, 12].

Summary

The results of the multifactorial experiment with analysis of the specified options of activation of the concentration tailings during the leaching process have confirmed the reasonableness of the technology of the metal extraction from ore refuses by means of the combined chemical processing and mechanical activation of minerals in a disintegrator.
It has been theoretically and experimentally during minutes significantly improves the quality of the secondary mill tailings and strength of the concrete blocks made from them.
The technology ensures non-waste disposal of the concentration tailings and features economic and environmental advantages as against the traditional technologies.

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