Discharge-impulse methods application in technologies of mineral resources mastering

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Abstract. Present-day condition and objectively established trends of developing mineral and crude base of non-ferrous metallurgy have predetermined two main directions in mineral raw materials processing. The first direction is based on some traditional technologies of free-milling ore processing with receiving of mono selective concentrates at the enrichment stage with following recycling them using already known pyro-, chemico-, hydrometallurgical methods. The main way of developing this direction is invention of high-performance combined processes and combined technological schemes. The second direction covers difficult raw material. It is based on combined technologies providing a discharge of advantageous components into the mono selective concentrates at the step of enrichment. At the other steps – transfer of refractory mineral assemblages into a polymetallic products and their further selection using enrichment, pyro- and hydrometallurgical methods. Among various methods of influence on the mineral assemblages, there are two groups, applicable in combined technology systems, to highlight. These are enrichment based on energy and chemical-metallurgical impacts at the finalizing step, where the necessary increase of completeness and complexity of crude ore applying might be provided only by processing it using combined technologies, which optimally match the both of selected groups.

1. Introduction

Problem assay based on system analysis has shown [1] that nowadays discharge-impulse methods in the field of mineral processing has found application mostly in operations of dragging and degradation [2]. Herewith, the overwhelming majority of authors in this field believe that the general degradation of solid mediums comes at the expense of direct compressional wave, and some researchers note the possibility of tensile forces application for solids degradation. With insufficient knowledge of the direct compressional wave influence the role of reflected waves nearly has not been founding place in theoretical researches [3].

Energy impacts have found application in crude preparation for the main processes of enrichment in schemes of the main enrichment and in chemicometallurgical methods [4], [5].

While softening and expansion of mineral assemblages apply mechanical pulsating loads, impact of shock waves energy, heat treatment and influences based on the effects of electrostriction, magnetostriction, electric breakdown and electrochemical machining [6], [7].

Directed variation of the surface properties of minerals’ is being reached by the energy influences under a variety of methods: electrochemical, thermochemical, hydrothermal, thermal sulfurizing, supersonic, radiation method, cathode-ray, plasmous, electroexplosive and other [8], [9].
From the methods based on energy impacts, the most studied one is electrochemical method. Other methods are studied less, and electroexplosive is almost unknown.

Generalization of perceptions about both physical basics and connection of well-known theoretical developments with base effects of the electroexplosive influence allowed to propose a classification of a high-energy impulse impact, based on a group of attributes, characterizing it with the term “discharge-impulse impact” and to distinguish fields where independent discharge-impulse technologies are based on this impact and fields, where discharge-impulse methods are constituent of combined technologies.

Analysis of published data representing physical basics of discharge-impulse influence allowed to develop a scheme of base physical processes’ inter-linkages of such influence in enrichment and, at this basis, to highlight at liquid and solid phases processes either fully unexplored (dynamic processes in technological field, shift of chemical equilibrium, selective disclosing, change of solid phase surface properties) or not enough researched (electrode erosion and possibility of its appliance for practical purposes, conditions of forming reflected waves, processes in gaseous phase of multi-component environment).

The factor, deterrent wide appliance of discharge-impulse methods in industry, is a workability of impulse energy capacitors, limited with the number of impulses $10^6-10^7$. At the same time, the resource of impulse capacitors might be much increased without any change of construction. Decrease of rated discharge voltage of impulse storage on 35-40% provides the increase of resource by the number of impulses by a factor of 100.

2. Results and discussion

Expediency of impulse methods is determined, on one hand, by optimal ratio of real expenses at impulse equipment and rig, on the other hand – by the summarized effect from these methods application in industrial technologies of mineral resources processing.

Technological efficiency of impulse methods is based on extremely-combined influence at technological object, at which realized specific effects: an effect of capacity’s spatial concentration, which appears in technological object and might be controlled by the choice of technological object and its characteristics; non-stationarity effect, determining a possibility of controlling with energy concentration in time and preset space by changing the length of impulse, pressure at impulse front and form of the latter; an effect of impulse capacity’s increase, allowing to reach transformation of impulse source’s capacity from nominal to short moment maximal and appearing in cases when processes in technological object possess a threshold nature, which radically changes conditions of technological object’s chemical balance; an effect of inhibiting, appearing while material changes its aggregative state, characterizing with new properties of technological object.

Impulse influence is being accompanied with a range of processes, which accompany exactly this kind of influence: initiation of tight low-temperature plasma’s in a discharge channel; pyrolysis of liquid; forming of complex system of direct and reflected waves of compressing and extension waves, countable in mega pascals, cavitition processes, saturation of technological environment with reactionary active gases and ions of metal-electrodes; structure changes of liquid phase with formation of new hydrogen bonds and appearance of products of recombination active radicals.

On the stage of preparation of mineral crude, impulse methods intensify selective expansion of mineral assemblages in the whole range of coarseness original classes independently from initial material’s oxidation level, its structure and texture; in a combination with mechanical degradation, impulse methods decrease costs of time and power-consuming of degradation for 25% with decreasing of slurry particles’ output; efficiency of degradation combined schemes is estimated with the learnt dynamic processes, which take place with impulse influence on technological object, wherein pulp's dispersions of minerals are brought to a tension by compressing waves, whereas unloaded by extension waves along with fragmentation of mineral associations at places of concentration of local defects and composition planes; determined optimal conditions of impulse methods’ practical usage in combined schemes of preparation mineral crude for enrichment.
Discharge-impulse methods can not represent themselves as independent in a process of degradation and disclosure of mineral assemblages both from the point of view of technological requirements for further enrichment and due to the energy considerations; such methods are effective and expedient in combined schemes of degradation of refractory ores with complicated structure, as they allow decrease degradation time for about 10-15% before grain-size controlling class’ output.

Impulse influence at mineral products in a process of preparation to the main processes of enrichment initiates structurally-chemical changes and increase the intensity of mineral reflexes, contributing the increase of their reaction ability and floatability. Main effects, originated by such influence (increase of reaction-active gases’ concentration, controllable change of hydrogen index and redox potential, a significant shift of electrolytic potential of oxidized ores to the negative-valued region, etc.) allow to recommend discharge-impulse methods as effective instrument of sulphidization of oxidized refractory ores’ mineral surface.

Research capability of discharge-impulse activation of reagents in industry conditions has proven that during the main enrichment, impulse methods allow effective managing of technological properties of reagents before feeding them into process; discharge-impulse preparation of agent-collector shifts a redox potential’s index to the positive-valued region independently from the initial reagent’s concentration. At the same time the increase of equilibrium contact angle’s measure is observed due to transition of a part of xanthate in an oxidized form – dixanthogenide that allows improvement of flotation indicators along with decreasing an agent-collector’s consumption for 20%. Discharge-impulse activation of reagent-modifier (soda liquor) increases its activity due to hydrogen index shifts per 1,5-2 units to an alkaline side, whereupon a selective adsorption of molecules increases at a mineral surface and selection indicators increase during the enrichment of polymetallic ores.

Proven a capability of whole or partly exclusion of highly toxic and high-priced reagents from the process of the main enrichment in account with controlling of electrodes erosion products by ionic composition of pulp, which are made from appropriate materials, that especially important in concentrates’ selection operations.

Appliance of discharge-impulse methods in combined schemes of sulfide polymetallic ores’ enrichment increases flotation indicators: the change of a physicochemical and wetting properties of activated water due to surface tension’s caused by partial “water-repellency treatment” of water molecules, leads to increase of galena recovering into a collective concentrate for 2,6% and sphalerite for 5,1%; during impulse processing of pulp, recovery of plumbum and zinc’s into a collective concentrate increases respectively for 5,2% and 4,5%, and by using of cupric electrodes – for 5,5% and 5,8% respectively; according to the results of the research, was discovered that flotation with application of activated by discharge-impulse methods reagent-collector is more effective rather than in cases of impulse processing of water and pulp, - enrichment of Gorevskaya ore in that case allows to extract plumbum and zinc for 9% and 6% more, and from Tokobsky ores – more than for 14%, whereas the flotation is according to the basic schemes.

Researches of oxidized refractory ores have shown almost the same efficiency of discharge-impulse processing of pulp and liquors of reducing reagents; flotation of Kalmakyrskaya ore (Kazakhstan) according to the combined scheme has increased the level of plumbum in a concentrate for 2,9% with a growth of extraction from 65,3 to 74,3%.

Conducted researches allowed to highlight those stages (or operations) in hydrometallurgical processes where impulse impacts appear to be most effective: leaching; separation of solid and liquid phases, in particular, during the densification and settling; extraction from the liquors of clean compounds and metals; preparation of liquors to the extraction of clean compounds and metals from them.

Discharge-impulse methods are a reliable cleaning instrument for technological and wastewater of enrichment industry from mechanical pollutants’ fines fractions, implementing the selective contact interactions according to the most effective for a given conditions contacts with bigger aggregates formation, reducing total settlement time of solids in 7-8 times; these methods allow to clean of drain tail-end from organic impurities, increase the acidity medium, decrease hydrogen ion exponent,
decompose xanthates, oxidize cyanides with further hydrolyzation and formation of less toxic compounds - liquid phase is prepared for appliance in closed water rotation systems and provides necessary indices of subsequent flotation.

Densification of concentrates using discharge-impulse methods reduces in time; settlement speed of densification particles increases from 0,25 to 25 sm/min; necessary for the cleanness of draining time decreases from 40 to 10 minutes, whereas solid phase losses within the draining of hydroseparator decreases from 20 to 0,8 g for 1 L of draining; study of the impulse explosion-type fields influence on water dispersed colloidal systems’ properties allowed to establish rather significant change of surface electrical properties of dispersed particles and electrophysical properties of the system in general: electric conductivity increases from \(2,8 \times 10^{-4}\) to \(4,0 \times 10^{-4}\ \text{ohm}^{-1}\ \text{sm}^{-1}\); electrokinetic potential decreases from 54 to 10 mV, that conduces avalanching settlement of colloidal particles with grain size less than 10 µm and increase of plant effluent’s cleaning speed from such particles in 1,5-2 times.

Combined technological schemes on a base of high-energy impulse impacts are notably effective while processing of auriferous wastes of metal scrap’s enrichment and sulphide aggregates of fine grains; discharge-impulse activation of auriferous crude, particularly, with supplementation of nitric acid in the grain size -1,5+0 mm and subsequent enrichment using jigging machine and re-cleaning of industry product on a concentrating table allowed to determine gold grade of a concentrate and an industry product 4,25% with general extraction 96,94%. Proposed combined schemes are tested and incalcated at Saralin’s mine and at the “Makmalzoloto” combine (Kyrgyzstan).

3. Conclusion
Discharge-impulse methods open wide opportunities for intensification of hydrometallurgical processes of secondary noble metals extraction. In particular, impulse processing of platinum-palladium catalysts based on aluminium oxides comprising small amounts (0,1-1%) of platinum metals weakens connections “platinum metal – base” – activates disperse particles of platinum metals and liquidates a part of surface centers, thereby decreasing adsorption activity of the base. With the use of high-energy methods, a concentration of oxidant decreases for 30%. For leaching more “soft” reagents may be used, that allows to simplify instrumentation and to decrease costs for this process; combined scheme of leaching has allowed to reach the extraction of platinum metals up to 99,4% and to decrease their level in a solid residue to the authorized limits.

In industry conditions, on a pulp aimed to autoclave-oxidizing leaching proved the ability of effective nickel and cobalt settlement with application of discharge-impulse methods. Proposed combined scheme of processing pyrrhotite concentrate NGMK allowed to increase extraction of nickel up to 99,9% within its residual concentration in a liquid phase of pulp 0,08-0,13 g/L. Following sulfur-sulfide flotation allows to obtain a high-quality concentrate with a low assay of nickel in flotation tailings.

Discharge-impulse processing of pulp on a stage of nickel settlement allows to reduce consumption of expensive metallized pellets for about 20-25%, and even exclude applying them if the cuprum is totally settled, by decreasing residual of cuprum in a liquor down to 0,1 mg/L.

On the grounds of comprehensive study of electrophysical, structural, physic and other changes in technological objects, subjected to discharge-impulse influence, grounded and industry-tested technologies, allowing the increase of completeness of mineral resources mastering within a decrease of anthropogenic impact on environment.

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