Methods of Increasing the Recovery of Non-Ferrous Metals From the Low-Grade Copper-Nickel Ores for Heap Leaching

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Abstract

The paper discusses two methods of ore pre-treatment. In the first case, ore crushing with sulfuric acid agglomeration was applied and followed heap leaching was applied. The second method involved electropulse destruction of pre-crushed ore, and then the heap leaching was performed.

Keywords: natural and anthropogenic sulphide-containing raw materials, non-ferrous metals, electric pulse destruction

Introduction

In view of the overall decline in the copper-nickel ores quality and the content of non-ferrous metals reduction in these ores, there is a need for processing the low-grade ore. The Murmansk region has such interesting and promising objects. Heap leaching is one of the most convenient ways, from the point of view of economics and technological process. The paper presents the ore deposits of the Nud Terrasa and Moroshkovoe Lake. The study of the material composition of ores shows that the needs to find the ways of releasing of the sulfide grains in of material preparation for heap leaching.

As shown by the hydrometallurgical practice worldwide, heap leaching of non-ferrous metals is quite advantageous when applied to lean ores and mining and processing wastes. In Russia, however, heap leaching is not wildly used being, which is partly due to severe climatic conditions at most of the mined ore deposits. Sulphide oxidation is known to proceed by the exothermal mechanism, therefore high sulphide contents (including iron sulphides) in the ore can promote heating of the heap's substance and facilitate leaching. Decomposing of sulphide minerals can be enhanced by employing new, environmentally friendly and power-saving methods involving physical, physical-chemical and mechanical-chemical effects (Svetlov et al., 2015).

Objects and methods of research

In this paper, two deposits were chosen as research objects – the Nud Terrasa and the Moroshkovoe Lake. The heap leaching of non-ferrous metals study was conducted on the samples of Nud II ore. The Nud Terrasa object was chosen as maximally similar to the Nud II in mineral composition.

The deposits are characterized by high variability of ore types exhibited in inpersistent layers and stock-like bodies associating with the rocks of the «Crytical horizon», development of uneven sulphide impregnation, streaks and large nests and schlierens varying from 0.5 to 7.0 m in size. The combination of syngenetic and epigenetic ore types with predominating Cu-Ni metallogeny is common. The Nud Terrasa deposit is confined to the norite and olivine norite complex and the «Crytical horizon» rocks of the Nude massif. The structure of the deposit is mainly bedded. The ore does crop out. The disseminated ore bodies occur in layers. In the olivine norites and pyroxenites there is chalcopyrite-pyrrhotite dessimination from 1–2 to 3–5% with RGE+Au content 1.5–3 ppm (Pripachkin et al., 2013). The Moroshkovoe Lake deposit is confined to the north-west-striking tectonic zone at the border of norites of the Nyud-Poaz massif and host metadiorites. The Cu-Ni mineralization is located within the shear zone composed of actinolite-chlorite, actinolite and quartz-chlorite schists, which are the products of dynamic metamorphism of contact norites. The ore is mainly disseminated, and occurrs in lenses, veinlets and rarely in pockets up to 20 cm in size. High Ni content is typical of the ore composition. Nickel-bearing pyrite with pentlandite admixture predominates in the mineral composition (Rundvist et al., 2013).

The heap leaching experiments of non-ferrous metals were carried out on following objects: the Moroshkovoe Lake deposit and the Nud II. The interaction of

Tab. 1. Contents of nickel and copper in ores

Tab. 1. Zawartość niklu i miedzi w rudzie

Content, %			
Nickel		Copper	
Moroshkovoe Lake	Nud Terrasa	Moroshkovoe Lake	Nud Terrasa
0.547	0.465	0.036	0.044

Tab. 2. Contents of nickel and copper in ores processed by EPD

Tab. 2. Zawartość niklu i miedzi po wzbogacaniu elektrycznym EPD

Ore	Content, %	
	Ni	**Cu**
Nud Terrasa	0,314	0,160
Moroshkovoe Lake	0,67	0,22

ore in fractions -3+2 mm with leaching agent in a dynamic mode in columns with the diameter 40 mm at the temperature 18±2°C during 42 days was studied. The ore weight was 150g. Preliminarily, the ore had been watered before the leaching. There was no solution recycling. The water upload was 150 g. 25 ml of the acid were applied every 3–4 days. 2% sulfuric acid was used as a reagent (Svetlov et al., 2015). Output solutions were analyzed by the method of atom-absorption spectrometry (AAnalyst 400 PerkinElmer). The solid phase was analyzed using X-ray diffraction (XRD) at a DRON-2 diffractometer (Cu Kα radiation).

The ore sample of Moroshkovoe Lake deposit contained: %: Ni 0.36 and Cu 1,5.

The ore sample of Nud II deposit contained, %: Ni 1.70 and Cu 0.50 (the experimental sample was taken from densely disseminated ore). Copper was leached out poorly.

According to XRD, there was no qualitative difference between the output and input ore substances. There was observed a decrease in intensity of pyrrhotite reflexes relatively the silicate reflexes especially evident in the upper layer of the column. At the same time, the column walls acquired a thin green coating which composition was analyzed and found to be, for the most part, a newly formed sulphate belonging to the group of halotrichite $FeAl_2(SO_4)_4.22H_2O$ (pickeringite $MgAl_2(SO_4)_4.22H_2O$, and wupatkiite (Co,Mg,Ni) $Al2(SO_4)_4.22H_2O$).

Agglomeration. Taking into account the surplus of sulphuric acid produced by Kola MMC and the problem of its implementation, a process of granular sulphatization, in which sulfuric acid can be used as a binder, is promising for hydrometallurgical processing raw materials (Svetlov et al., 2015).

To intensify acid leaching process of non-ferrous metals from unconditioned copper-nickel ores, experiments were carried out on their grinding followed by agglomeration on sulphuric acid. The contents of nickel and copper in the ore samples used for agglomeration are given in Table 1.

The agglomeration was carried out with a 10% H_2SO_4 solution. We used the ratio S:L equal to 3:1. Grinding of ores was carried out to classes -1, -0.5, -0.25, -0.1 and -0.05 mm. Pellets were loaded into columns with a diameter of 40 mm, the loading weight was 150 g. During the day, water leaching was conducted, distilled water was supplied in an amount of 300 ml (two 150 ml steps). Then, after 3 days, the sulfuric acid leaching was started with a 2% solution of acid, which was supplied in an amount of 25 ml every 3 days. The total duration of the experiments was 32 days. Output solutions were analyzed for nickel and copper by methods of voltammetry ("Ecotest VA") and spectrophotometry ("SF-2000"). The solid phase was analyzed using XRD at a DRON-2 diffractometer (Cu Kα radiation).

Electric pulse destruction (EPD). The second way to intensify the leaching process was the method of pretreatment of ore with a pulsed current. To improve the recovery of metal was took two steps at this level. Firstly ores were grinding to classes -3+2 mm, and secondly these ores samples were had processing by EPD (Usov and Potokin, 2014).

Preliminary preparation of ores by EPD for heap leaching, in theory, ensures better opening of the sulfide minerals grains and good preservation from destruction. This is a consequence of the specific physical mechanisms of force loading and cracking peculiar to this method, which is characterized by high selectivity of destruction.

Processing of ore material fractions -3+2 mm was carried out at U = 180 kJ, in a portion crusher without a screen with rainwater. The processing difference consisted of the number of pulses applied. So, for the samples placed in the first couple of columns Nud Terrasa and Moroshkovoye Ozero, 200 impulses were applied. In the second couple of columns the samples were obtained with 400 impulses.

Samples of EPD crashed ores were loaded into columns with a diameter of 40 mm, the loading weight was 150 g. During the day, water leaching was conducted,

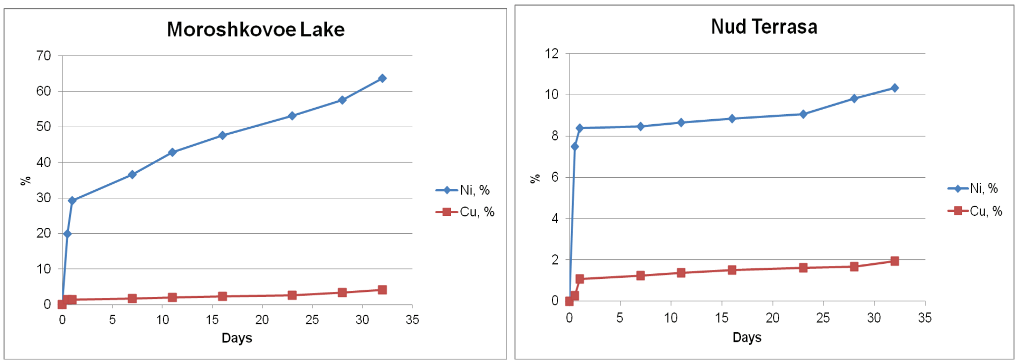

Fig. 1. Presents the metal leaching kinetics from Moroshkovoe Lake ore samples after agglomeration

Rys. 1. Kinetyka ługowania rudy Moroshkovoe Lake po aglomeracji

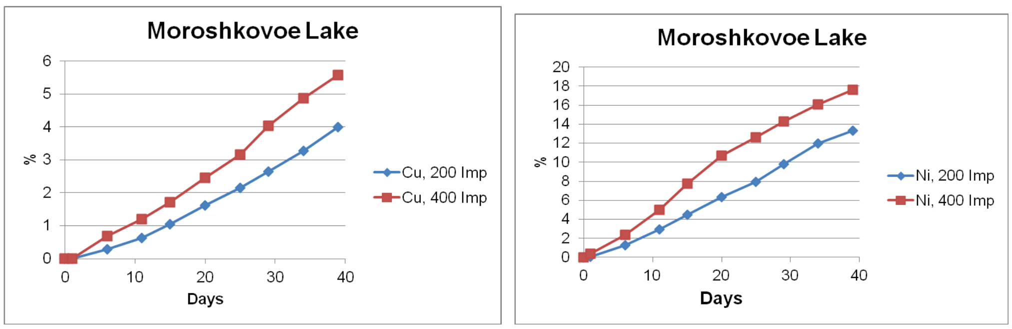

Fig. 2. Presents the metal leaching kinetics from Moroshkovoe Lake ore samples after EPD

Rys. 2. Kinetyka ługowania rudy Moroshkovoe Lake po wzbogacaniu eklektrycznym EPD

distilled water was supplied in an amount of 300 ml (two 150 ml steps). Then, after 3 days, the sulfuric acid leaching was started with 2% solution of acid, which was supplied in an amount of 25 ml every 3 days. The total duration of the experiments was 32 days. The contents of nickel and copper in the ore samples used for agglomeration are given in table 2. Output solutions were analyzed for nickel and copper by spectrophotometry ("SF-2000").

Results

The heap leaching. The Moroshkovoe Lake deposit. The intensity of Ni is much better then Cu. Copper is leached out slowly. Apparently, this is connected to electrochemical properties of sulfide minerals. The metal recovery was as follows, %: nickel 22.5, and copper 2.3. The Nud II. Copper was leached out poorly. After 41 days, the metal leaching was as follows, %: nickel 6.4, copper 2.5. According to XRD, there was no qualitative difference between the output and input ore substances. There was observed a decrease in intensity of pyrrhotite reflexes relatively the silicate reflexes especially evident in the upper layer of the column. At the same time, the column walls acquired a thin green coating which composition was analyzed and found to be, for the most part, a newly formed sulphate belonging to the group of halotrichite $FeAl_2(SO_4)_4.22H_2O$ (pickeringite $MgAl_2(SO_4)_4.22H_2O$, and wupatkiite $(Co,Mg,Ni)Al_2(SO_4)_4.22H_2O$).

Agglomeration. Based on the results of the experiments, it was found out that pellets obtained from ore with a size of -1, -0.5 and -0.25 mm during aqueous leaching significantly lost their strength and partially collapsed. Fractions -0.1 and -0.05 mm showed stability in the process of aqueous and subsequent acid leaching. As an example, Fig. 1 shows the concentration of metals in the productive solutions of ore leaching in the Moroshkovoe Lake deposit. As can be seen, nickel concentrations are quite high, copper is much lower.

The most intensive nickel is leached from the ore deposits of the Moroshkovoe Lake. For 32 days, the recovery was more than 60%, while almost 20% of nickel passed to the solution in the aqueous leaching stage for 1 day (Fig. 4a).

Significantly worse, nickel was leached from the ore deposit Nud Terrasa. The extraction of Ni over the same period was only about 10%. Obviously, this is due to the fact that the pulverized impregnation of sulphides prevails for this ore. Therefore, after dissolution of larger minerals in the aqueous leaching stage, the subsequent increase in nickel extraction before the end of the experiment was less than 2%.

As expected, copper is leached much more slowly than nickel, which is due to its presence in the "per-

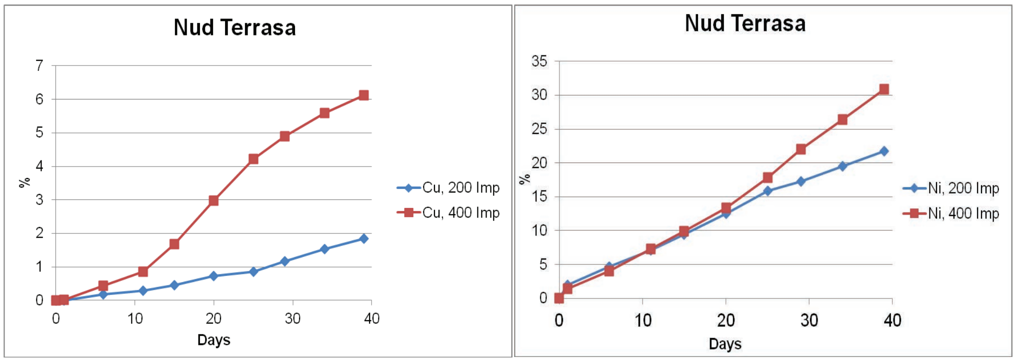

Fig. 3. Presents the metal leaching kinetics from Nud Terrasa ore samples after EPD
Rys. 3. Kinetyka ługowania rudy Nud Terrasa po wzbogacaniu eklektrycznym EPD

sistent" chalcopyrite. The lowest Cu extracts, as in the case of nickel, at the Nude Terrasa ore deposit are 1.9%. Leaching rates of non-ferrous metals per day were, %:

- Ore deposit Moroshkovoe Lake: nickel 1.87, and copper 0.13;
- Ore deposit Nud Terrasa: nickel 0.32, copper 0.06.

Thus, the sulfuric acid agglomeration of the crushed ores leads to a significant improvement in the leaching performance. Thus, in the leaching of the ore of the Moroshkovoe Lake with a particle size of -3+2 mm, the recovery rates for the solution were 0.48 for nickel, 0.08% for copper, which is lower by 3.9 and 1.6 times for ore in pellets.

Electric pulse destruction (EPD). The Moroshkovoe Lake deposit. Maximal leaching rates of non-ferrous ore were, %: nickel 17.6, copper 5.6, and these was got after 400 impulses (Fig. 2). Most of the nickel passed into the solution in the first 20 days of the experiment (10.7%) with ore, processed by 400 impulses, while most of the copper was recovered in the second half of the experiment. The leaching kinetics at 200 pulses differed, nickel passed into the solution stability throughout the entire experiment, and copper mainly in the second half of the experiment (2,39%).

The Nud Terrasa. The leaching of the ore from the Nud Terrasa deposit, processed by EPD, showed a higher recovery rates at 400 impulses (fig. 3). Maximum recovery of nickel and copper by the end of the experiment, %: nickel 30.9, copper 6.12. The extraction of nickel in the first half of the experiment was approximately equal, whereas in the second half of the experiment, nickel from ore processed by 400 pulse was extracted more actively. A characteristic of the ore leaching of the Nud Terrasa deposit is a strong difference in copper recovery between 200 and 400 impulses. When the ore was processed with 400 impulses, the extraction was three times higher – 1.85% (200 impulses) and 6.12% (400 impulses).

The most intensive is leached nickel from the Nude Terrasa ore, whereas copper extractions differed depending on the impulses. At 200 pulses, the level of copper recovery was higher from the Moroshkovoe Lake ore (4%), while at 400 pulses the copper recovery level was higher from the Nud Terrasa ore (6.12%).

Conclusion

The work shows that heap leaching allows to achieve a qualitative transition of nickel into the solution, but copper is leached out slowly. The following results were achieved:

- The Moroshkovoe Lake deposit: nickel 22.5%, and copper 2.3%;
- The Nud II: 6.4% nickel and 2.5% copper.

The metal recovery on the Moroshkovoe Lake deposit during agglomeration experiment was as follows, %: nickel 63.6, and copper 4.1. The Nud Terrasa deposit had demonstrated following result, %: nickel 10.3, and copper 2. It is necessary to optimize the agglomeration process.

Using the preliminary agglomeration of the ore, it was possible to achieve a much higher extraction of metals.

When ore is processed by EPD an increase in copper recovery was observed compared to heap leaching. The recovery of copper achieved 6%, whereas with heap leaching it was 2%.

The obtained results show that acid agglomeration and EPD allow to increase the extraction of nickel and copper from the low-grade copper-nickel ores. Thus, the studied methods for intensifying heap leaching are promising and further study is needed.

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Metody zwiększenia odzysku metali nieżelaznych z niskiej jakości rudy miedziowo niklowej przed ługowaniem na hałdzie

W pracy omówiono dwie metody wstępnej przeróbki rudy o niskiej zawartości miedzi i niklu. W pierwszym wariancie zastosowano przygotowanie rudy przy użyciu kwasu siarkowego i kolejno ługowanie na hałdzie. Drugi wariant polegał na obróbce wstępnie rozdrobnionej rudy w separatorze elektrycznym a następnie ługowanie na hałdzie.

Słowa kluczowe: surowce naturalne i antropogeniczne zawierające siarczki, metale nieżelazne, rozdrabnianie impulsami elektrycznymi