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# INFLUENCE OF GRINDING EXTENT OF NICKEL-CONTAINING ORE RAW MATERIALS ON EXTRACTION OF METALS AT HYDROCHLORIC ACID LEACHING

**Abstract.** This paper presents the characteristics of ore raw materials with the application of modern methods of physical and chemical analysis, technological features of preliminary preparation of raw materials in the process of nickel leaching and the choice of the optimum degree of grinding the ore for a hydrochloric acid leaching of specified raw material.

**Keywords:** oxidized nickel-containing ore, ore preparation, grain-size class, leaching, solvent.

**Introduction.** In Kazakhstan, nickel-containing raw materials are mainly presented by the poor oxidized ore materials (for example, Kempirsay deposit) and iron-containing ore materials and concentrates (Sokolovskoye and Sarbaiskoye deposits). Low concentration of nickel in ore materials, the complexity of the mineralogical composition and intergrowth of minerals require special preparation of crude ores for metallurgical processing.

Taking into account the high demand of nickel in the global markets, as well as stocks of raw materials in Kazakhstan, the study of the preparation of nickel-containing ores to metallurgical processing is an urgent task.

Pyrometallurgical and hydrometallurgical methods are used for the processing of nickel-containing raw materials. But because of the low quality of Kazakhstani nickel-containing raw materials, pyrometallurgical methods are generally unsuitable for processing ores in Kazakhstan. Therefore, combined and hydrometallurgical methods are widely used [1, 2].

The most energy intensive and time taking processes in the production technology of dispersed materials are operations on reducing the size of the piece goods, because the costs of these processes in prime cost of mining and processing stage is 30-50%. The combination of the ore processing by a variety of methods for obtaining coarseness of grading and material composition, determined by the requirements of the process stage or regulations for finished products, is called the process of ore preparation. In general, in mining plants on processing ores of non-ferrous and ferrous metals, also in chemical production this stage precedes the stage of ore concentration [3, 4].

As Figure 1 shows, ore preparation stage comprises the following steps:

1) ore breaking involving mechanical processes, as a result, extracted massive rock is crushed to a size suitable for further size reduction by milling. Devices that crush raw materials are considered as primary crusher; roll-jaw and cone-shaped crushers are basic ones;

2) preliminary grinding of ore is a preliminary step of obtaining the required size material. Usually performed in an aqueous medium by means of machines, in which the rock is grinded by means of cobble boulders produced from solid parts of ore and enclosing rocks;

3) primary ore grinding is the final stage of size reduction of the piece goods. Generally, at this stage grinding is performed in an aqueous medium by means of machines in which the rock is grinded with the help of cast iron or steel balls. As a result, a fine pulp with a high concentration of particles of grain-size class – 0.074 mm (about 70-80% of the total weight of the fine pulp) will be formed;

4) the classification of the ore which is necessary for the preparation of a specific dimension material for concentration. As a result, a large fraction of the fine pulp, which is returned to the regrinding process, will be extracted.

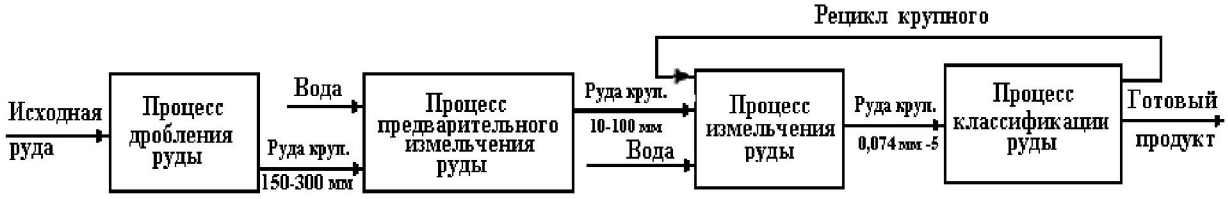


Figure 1 – The structure of the ore preparation stage

**Characteristics of the initial nickel raw materials.** In order to perform the experiments there was used oxidized nickel and cobalt containing ore, which is represented by green gray wizened claypans with light colored impregnations. The ore was grinded to 0.2 mm minus class.

After homogenization of the whole ore mass based on a "cone-ring" method and the consistent reduction of quartering method there were taken samples to determine the material composition of the ore using mineralogical, X-ray diffractometric, spectral and chemical analysis methods.

Technological sample consists of small fragments of rocks of various compositions, with domination of metamorphically altered serpentines from green gray to a dark green color, sometimes pigmented in brown with iron hydroxides. The structure of debris is uneven – from grainy to colloformic-zoned with replacement signs of the cerpentin-chrysotile formations nontronite montmorillonite (smectite) with finely divided (0.005-0.01 mm) grains of magnetite and colloformic-zonal formations of clay material [5, 6].

X-ray diffractometric analysis is performed on a DRON-2 diffractometer with Cu-radiation, beta-filter. Diffractogram survey was performed under the following conditions: U = 35 kV; 1 = 20 mA; Scale - 2000 imp; time constant – 2 seconds; survey – 2 theta; detector – 2 °C/min. X-ray diffraction analysis on the basis of semi-quantitative determination of the proportion of crystalline phases was carried out by diffractograms of powder samples using method of equal test charge and artificial mixtures.

For the interpretation of diffractograms we used ASTM Powder diffraction file data diffractograms of pure minerals. For the main phase we conducted contents calculation. Possible impurities, which identification cannot be valued because of the small content and the presence of only 1-2 diffraction reflections or poor crystallinity are given in diffractogram (Figure 2). The identification of mineral phases by X-ray analysis is given in Table 1.

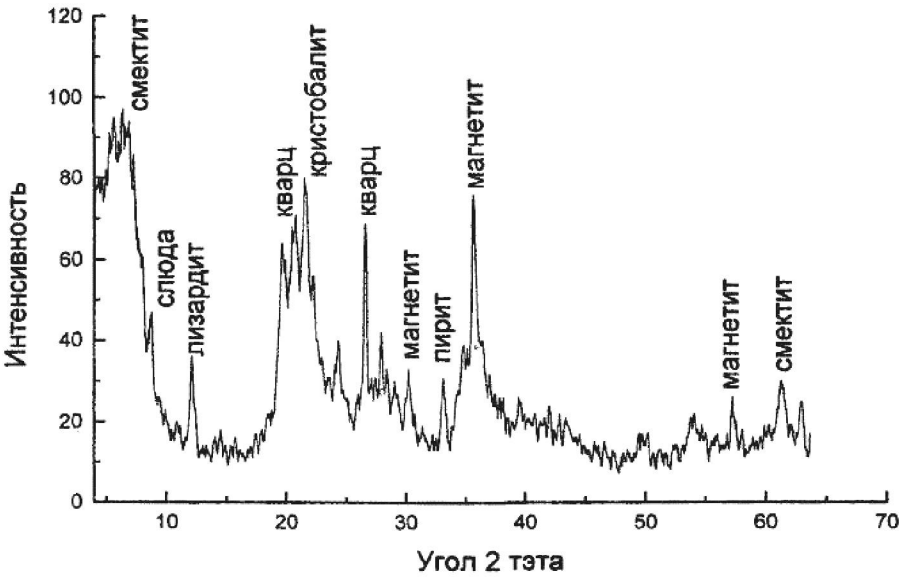


Figure 2 – Diffractogram of oxidised nickel-cobalt ore

According to the results of the physical and chemical studies of ore, mineral composition of technological sample was calculated, masses %: smectite 60-62; serpentine group 8-10; quartz 2-4; cristobalite 10-11; mica 3-5; feldspar 1-2; magnetite 12-13; pyrite 2-3.

Rock-forming minerals are presented by smectite (SMS), the serpentine group minerals (antigorite, lizardite), cristobalite (opal), quartz, in a subordinate amount – by feldspar and mica.

In the sample materials, ore minerals are represented by magnetite, less often by hematite and goethite; sulfide minerals have symbolic values they are presented by pyrite and marcasite. 0,007-0,04 mm size barrel-copper is rarely met.

Table 1 – The interplanar spacings and the phase identification of oxidized nickel-cobalt ores

| 2 Theta | DA | Intensity Count | Intensity, % | Phase |
|---|---|---|---|---|
| 6,403 | 13,79193 | 98,2 | 100,0 | Smectite |
| 8,764 | 10,08180 | 46,9 | 47,8 | Hydromica |
| 12,115 | 7,29930 | 39,5 | 40,3 | |
| 12,421 | 7,12036 | 24,5 | 25,0 | Chlorite |
| 19,651 | 4,51392 | 65,9 | 67,1 | Smectite |
| 20,846 | 4,25784 | 68,5 | 69,8 | Quartz |
| 21,606 | 4,10969 | 80,4 | 81,9 | Cristobalite |
| 22,225 | 3,99658 | 57,5 | 58,6 | |
| 24,378 | 3,64828 | 41,2 | 42,0 | Serpentine / n |
| 26,615 | 3,34654 | 76,8 | 78,2 | Quartz |
| 27,925 | 3,19248 | 43,4 | 44,2 | Pyrite middlings |
| 28,449 | 3,13481 | 34,0 | 34,7 | Sphalerite |
| 30,206 | 2,95633 | 32,9 | 33,6 | Magnetite |
| 33,155 | 2,69985 | 31,5 | 32,1 | Pyrite, sphalerite |
| 34,779 | 2,57740 | 40,8 | 41,6 | Smectite |
| 35.657 | 2.51595 | 79.5 | 81.0 | Magnetite |
| 42,012 | 214889 | 25,8 | 26,2 | Lizardite |
| 57,192 | 1,60939 | 26,6 | 27,1 | Magnetite |
| 58,025 | 1,58825 | 19,9 | 20,2 | |
| 61,288 | 1,51128 | 30,5 | 31,1 | Smectite |
| 62,974 | 1,47481 | 25,3 | 25,8 | Magnetite |

Smectite and minerals of the serpentine group are in close intergrowth, forming natural inseparable mixtures with pseudomorphs of clay minerals on serpentine and small dense impregnations of magnetite. Cristobalite and quartz present in the form of individual crystals.

Magnetite and hematite present in 0.3-1.0 mm sized grains; hematite circumferentially replaces magnetite grains, forming structures of margin flanges. Larger extractions of iron oxide apparently formed through natural oxidation of iron sulfides (pyrite, marcasite).

To complete the characteristics of the material composition and the identification of mineral impurities spectral semi-quantitative analysis of the sample on a diffraction spectrograph DFS – 425 was made, its results are given in Table 2.

Table 2 – Spectral analysis of the oxidized nickel-cobalt ore

| Elements | Concentration, % | Elements | Concentration, % | Elements | Concentration, % |
|---|---|---|---|---|---|
| Cu | 0,001 | Cr | ≥1,0 | Fe | – |
| Pb | 0,003 | Ni | >1,0 | Au | – |
| As | <0,005 | Co | 0,05 | Mg | >1,0 |
| V | 0,003 | Mo | 0,0003 | Si | >>1,0 |
| Sb | <0,005 | Zn | 0,05 | Ca | – |
| Mn | 0,2 | Ag | 0,0005 | Ge | – |
| Ti | 0,002 | Sn | 0,001 | Bi | – |