Investigation into the release of gravity-recoverable gold particles in products of a dynamic-impact mill

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Abstract. The experimental data on assessment of the gravity-recoverable gold release in disintegration of lumpy gold-bearing geomaterials at dynamic-effect crushers DKD-300, designed at the Mineral Processing Laboratory at the Institute of Mining of the North, SB RAS, Yakutsk. The tests on gold-bearing ore originated from Gurbey deposit, made it possible to establish experimentally that the multiple-dynamic-effect facility enabled to release up to 47% gravity-recoverable gold of -1 mm in size.

1. Introduction

At the mineral ore processing plants the grade and amount of final concentrates and recovery of valuable components depend on the efficiency of ore pre-concentration and a degree of chalks release. Experimental and theoretical studies as well as many-years practical experience enable to conclude that the disintegration selectivity constitutes the physical grounds for the efficiency of crushing and grinding pre-concentration of a mineral ore. Selective release of ores mainly depends on efficiency of preliminary weakening of ore-rock intergrowth boundaries. When analyzing the conventional crushing and grinding processes at the ore preparation stage, it was concluded that the percussion crushing is a most suitable technique in terms of physical arrangement of the selective disintegration process [1–3].

Considering the integration of a solid body by a percussion technique it is important to point out that the percussion moment gives a rise of a complex stress-strain field favorable for development of selective disintegration. The dynamic character of loading under high-speed percussion provides a possibility of free disintegration of single lumps, therewith the simultaneous removal of disintegrated products from the working zone predetermines a rational arrangement of percussion disintegration. However the available impact crushers, hammer mills, in particular, are not capable to provide high impact velocity. In view of the above the centrifugal impact crushers and rotor impact crushers are ranked as the most promising facilities. They can provide high performance in a single apparatus and reduction in feed coarseness in the follow-on grinding operations. The application of this crusher type can improve technological and engineering-and-economic performance of a concentrator [4].

The more popular and cheaper mineral processing technique is the separation of minerals by density, namely, gravity concentration. Combination of gravity concentration and impact crushing promotes higher economic parameters of mineral processing. However, the feed coarseness is of rather high importance in gravity concentration of gold-bearing geomaterials. Fine and dust-size gold particles are difficult to recover and discharged with wastes. In order to eliminate the
overgrinding of gold particles, let consider a variant involving gravity concentration of the product obtained in impact ore crushing with the grinding stage omitted.

2. Features of the gold ore processing
The gravity concentration of products produced at the dynamic-impact crusher was studied on Gurbey gold-bearing quartz ore. Gurbey ore is represented by metamorphic shale rock of different compositions with dominating biotite-quartz containing disseminated sulfide mineralization. Texture of rocks is shaly and laminated. The study ore specimen is classified as gold-quartz-sulfide low-sulfide ore type and as a primary ore in terms of 20.1 % oxidation degree calculated versus iron. The ore specimen mainly consists of lithophyous components (86.0 %), silicon oxide (59.08 %) prevailing. The main ore-forming components are iron and sulfur. Iron is present chiefly as oxide forms (6.06 %); and sulfide iron (2.26 %). Sulfur is generally present in sulfide form. The principal rock-forming minerals are quartz (22.8 %), chlorite (21.7 %), and feldspars (20.7 %). Sulfides in the study ore specimen are represented with pyrrhotine – 2.3 % and pyrite 1.8 %, rare grains of chalcopyrite and marcasite. The specific density is 2.90 g/cm$^3$, bulk specific density is 1.64 g/cm$^3$, calculated porosity is 0.43, hardness factor on Protodyakovon scale of 6.16 allows ore category IIIa, being “rather hard rocks”.

First the granulometric composition of the original ore specimen was assayed. Then the original ore was screened into size fractions of +12 mm and – 12 mm. Ore fraction of + 12 mm in size was processed according to the experimental flowsheet (Figure 1). The dynamic-impact crusher DKD-300 developed at IGDS SB RAS was employed as a facility to crush + 12 mm fraction, involving fractions returned after rough crushing according to the load circulation scheme [5]. In the course of the tests it was found that two cycles at DKD-300 crusher are quite enough for the experimental ore amount (Table1).

As it is obvious in Table 1, the greatest crushing degree of 8.40 in magnitude is gained in the first cycle. The feed of the second cycle is fractions of -20+10 mm and -40+20 mm (the uncrushed product after the first cycle being the basic circulation load), it constitutes 19.85 % and 10.78 % of the total mass of the crushed product. Thereto, the crushing ratio for the second cycle falls down to 2.28, but herewith granulometric compositions of crushed products of the first and second cycles are rather close thus indicating that the crushing efficiency at DKD-300 remains practically at the same level.

**Table 1. Granulometric compositions of crushed products of DKD-300**

| Size fractions, mm | Yield % | Original ore | 1 cycle | 2 cycle |
|-------------------|---------|--------------|---------|---------|
| -0.063            | 5.98    | 2.93         | 2.25    |
| -0.1 +0.063       | 2.64    | 2.27         | 2.21    |
| -0.315+0.1        | 5.76    | 7.35         | 6.03    |
| -0.5+0.315        | 1.88    | 3.71         | 2.58    |
| -1+0.5            | 3.19    | 7.46         | 5.46    |
| -2+1              | 4.00    | 9.67         | 8.00    |
| -5+2              | 7.53    | 20.73        | 20.46   |
| -10+5             | 5.09    | 15.25        | 15.47   |
| -20+10            | 10.91   | 19.85        | 29.6    |
| -40+20            | 16.16   | 10.78        | 7.94    |
| -100+40           | 21.42   | -            | -       |
| +100              | 15.44   | -            | -       |
| Crushing ratio    | -       | 8.40         | 2.28    |

Further investigation on Gurbey gold-bearing ore concerned the assessment of release and recovery of the valuable component (gold) in crushed products of DKD-300. Earlier studies on
formation of the granulometric composition and release of monomineral phases under disintegration of gold-quartz ores at DKD-300 showed a high release degree for components at the monomineral level [6]. According to the experimental ore processing flowsheet in Figure 1, the products of gold ore crushing cycle are separated into two size fractions of -12+3 mm and -3 mm.

DKD-300 crushed products of -12+3 mm in size were reground at a centrifugal mill. The ground product is fed to the pneumatic separator with the yield of two products: a concentrate and tailings. Pneumoseparator tailings were scavenged at SKO-0.5 concentration table. SKO-0.5 concentrate was recleaned at Moseley concentration table. The final recleaning of Moseley concentrate was performed by heavy-medium separation with extraction of gold particles. The pneumoseparator concentrate was separated into two size fractions: +1 mm and -1 mm. The pneumoseparator concentrate of -1 mm in size was re-cleaned at SKO-0.5 table. The resultant concentrate was subjected to recleaning at Moseley table. Moseley concentrate was finally re-cleaned at heavy-medium separation cycle with extraction of free gold. The pneumoseparator concentrate of +1 mm in size was reground in order to provide additional release of the valuable component with the follow-on processing according to the above described scheme. In total, 4 grinding cycles were practiced with follow-on respective processing operations.

DKD-300 crushed products of -3 mm in size were fed directly to pneumatic separation omitting the reground cycle, thereby eliminating overgrinding of the valuable component. Follow-on processing was carried out by the proposed ore processing flowsheet, described above.

![Flowsheet to process DKD-300 crushed products.](image)

The gold ore processing with extraction of free gold at re-cleaning cycles (table concentration: scavenger, re-cleaning, processing at Moseley mineral analyzer, magnetic separation, heavy-medium
separation on bromoform) and the analysis of granulometric composition of extracted gold (Table 2) enabled to establish that in the course of releasing of gold at crushing and grinding cycles the amount of the released free gold tends to descend notably. This statement justifies that the selective release of gold mainly depends on coarseness and the character of gold dissemination in the ore (location of gold in the texture of ore matrix). As it is obvious from the Table, the coarser gold fractions are extracted from DKD-300 crushed product without additional grinding stage. The size of extracted gold grains tends to diminish versus greater gold release in crushing and grinding cycles. The marginal size of practically releasable gold is 0.1 mm.

Table 2. Granulometric composition of recovered gold

| Products | Yield, % | Size, mm |
|----------|---------|---------|
|          | -1+0.5  | -0.5+0.315 | -0.315+0.2 | -0.2+0.1 | -0.1+0 | Total |
| Crushed product | 7.72 | 6.73 | 7.83 | 4.30 | 1.65 | 28.22 |
| Crushed product -12+ 3 mm 1 cycle | 1.32 | 1.32 | 1.76 | 0.77 | 0.44 | 5.62 |
| Crushed product -12+ 3 mm 2 cycle | 0.55 | 0.66 | 0.88 | 0.44 | 0.22 | 2.76 |
| Crushed product -12+ 3 mm 3 cycle | - | - | 0.11 | 0.22 | 0.22 | 0.55 |
| Crushed product -12+ 3 mm 4 cycle | - | - | | | | |
| Crushed product of DKD-300 | 15.21 | 11.03 | 12.35 | 6.95 | 1.65 | 47.19 |
| -1 mm | 4.85 | 2.98 | 3.64 | 1.87 | 1.21 | 14.55 |
| Grinding product of CMVU of crushed products at DKD-300 +1mm | - | - | - | | | |
| Tailings of pneumoseparation of grinding product -12+3mm | - | - | - | - | 0.33 | 0.33 |
| Tailings of pneumoseparation of grinding product -3 mm | - | - | - | - | 0.77 | 0.77 |

3. Conclusions
The present research made it possible to find that a single crushing operation applied to Gurbey gold-bearing ore at DKD-300 dynamic impacts crusher enables to release of 47.19 % of gravity-recoverable gold of -1 mm in size.

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