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EFFECT OF PARTICLE SIZE AND LIBERATION ON FLOTATION OF A LOW GRADE PORPHYRY COPPER ORE

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Abstract

This paper presents some investigation results about connection between degree of minerals liberation and flotation, responding to flotation plant "Veliki Krivelj". There are two main degrees of liberation among the sulphide minerals and gangue, and copper minerals and pyrite. Both of two liberation degrees strongly affect on flotation recovery of copper minerals as well as on copper concentrate grade. This paper deals with figures which give some dependence among the degree of liberation, copper recovery and concentrate grade.

Key words: *minerals, copper, porphyry ore, particle size, liberation, flotation.*

1. Introduction

Particle size distribution plays a great role in minerals flotation. Regarding to flotation plant praxis, metals recovery and selectivity among the minerals, is a strong function of mineral particle size and particle size distribution in flotation feed [1, 2, 3]. The fastest flotation rate and maximal metal recovery are associated with middle particle size region, while out of this region, the results usually diminished [1, 4]. Also, an upper and lower particle size limit exist beyond there is no flotation. For sulphide minerals of non ferrous metals these limits were found to be different for each species [5]. In the other hand, degree of liberation among the certain minerals may be considered as another factor which affect on flotation

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recovery especially on concentrate grade [6, 7, 8]. Degree of liberation among valuable minerals and gangue strongly affect on flotation results in coarse particle region, and decrease with particles increase in case of porphiry cooper ores.

Flotation plant "Veliki Krivelj" commissioned in 1983, with selective rougher flotation of copper minerals from pyrite and gangue. In the rougher flotation stage three parallel lines of Denver DR 500 flotation cells were installed, and each row consists of 21 cells in order 5+4+4+4+4. The rougher flotation stage gives three products: bulk copper and pyrite concentrate and final tailings. The selective flotation of copper minerals is performed in the second flotation stage, while the next stages are used for copper and pyrite concentrates cleaning. As the rougher flotation stage directly affect metal recovery, an investigation was conducted in order to improve its performance, and degree of minerals liberation was taken into consideration among others.

2. Experimental

2.1. Sampling procedure

Several sampling campaigns were conducted in the rough flotation section. Surveys lasted for 4 hour times each, under plant normal operation. The same reagent regimes was maintained: collector potassium ethyl xanthate 70 g/t, sodium isopropyl xanthate 15 g/t, D-250 5 g/t. Pulp density and pH were maintained on 1190 kg/m^3 and 9,6, respectively. The chemical composition of the feed ore was as follows: 0,36 % Cu and 2,8 % S.

2.2. Sample analysis

After each sampling campaign samples were wet sieved on Tyler's standard sieve series from 418 μm down to 38 μm, and on two Fritch's micro sieves of 15 μm and 5 μm. Based on sample mass and copper content in each particular size fraction the mass flow and copper distribution along the flotation bank was calculated [9]. Mass yield in rougher concentrate was 6,9 % regarding to feed of 100 %. Copper recovery of sulphide copper minerals in that concentrate was 89,9 %, while the recovery of nonsulphide copper minerals was not taken into consideration in this paper. Total copper recovery, from sulphide and nonsulphide copper minerals, in rougher concentrate was about 86 %, because of lower recovery of nonsulphide copper minerals.

One amount of particular grain size fractions of feed, concentrate and tailings were used for mineralogical analyses. Each size fraction, quoted in Table 1 and 2, was preparing for microscope assay by briqueting in resin and polished its upper surface. The results from mineralogical assays were presented in Table 1 and 2. Table 1, gives degrees of liberation along the particle size fractions, as well as, percents of non liberated particles in form of middling containing two, three and poly minerals, among the sulphide minerals: chalcopyrite, chalcocite and pyrite and gangue mineral quartz. Table 2, presents copper distribution in each particular size fraction and these distribution in liberated and non liberated particles.

The overall degree of liberation of chalcopyrite in flotation feed was 84,38 %, but this degree in rougher concentrate was slightly higher with value of 91,13 %.

3. Results and discussion

3.1. Degree of liberation

Degree of liberation of chalcopyrite has value 100 % for fine particle below 38 μm, slightly decreases down to value of 89,14 % for size fraction (-74+53) μm and rapidly drop down in coarse particle region Figure 1. From the same figure it can be seen that copper contents in liberated particles decrease with increase-ing particle size in the middle region and varies in coarse particle region, while the copper contents in non liberation particle slightly increasing from middle towards to coarse particle size region. Figure 2, presents behaviour of type of middling in non liberated particles along the particle size. The main middling particles are between chalcopyrite and quartz which rapidly arise in coarse particle region and reach value over 30 %, while in middle particle region these contents are small. Middling between chalcopyrite and pyrite uniformly increase along the particle size and reach value of about 15 % in coarse particle size region. Middling between chalcopyrite and chal-cocite are very low about 2 %. Also, in Figure 3, it can be seen copper distribution into mentioned type of middling along the particle size. The coarsest particles contain the highest amount of copper, particularly middling chalcopyrite-quartz and then chalcopyrite-pyrite.

Table 1. Degree of liberation for chalcopyrite (measured values) in flotation feed

Particle size fraction d mm	Mass M %	Cu_{sulph} %	Copper Distrib D_{Cu} %	Measured Liberation values		$MxCuxL_m$
				Liberated L_m %	Non liber. $NL=100-L_m$ %	
-0,208+0,147	32,33	0,213	17,68	34,60	65,40	238,27
-0,147+0,104	1,08	0,280	0,77	42,16	57,84	12,75
-0,104+0,074	8,89	0,449	10,24	74,02	25,98	295,46
-0,074+0,053	5,69	0,571	8,34	89,14	10,86	289,61
-0,053+0,038	0,33	0,760	0,64	92,14	7,86	23,11
-0,038+0,000	51,68	0,470	62,33	100,00	-	2428,96
Total	100,00	0,390	100,00	84,38	15,62	3288,16

Particle size fraction d mm	Type of middling						Sums
	Two minerals			Three minerals		Poly minerals	
	$CuFeS_2$ + SiO_2	$CuFeS_2$ + FeS_2	$CuFeS_2$ + Cu_2S	$CuFeS_2$ + FeS_2+ SiO_2	$CuFeS_2$ + FeS_2+Cu_2S	$CuFeS_2$ + poly	
-0,208+0,147	33,14	18,72	2,89	6,45	0,58	3,62	64,40
-0,147+0,104	35,44	11,21	3,11	5,98	-	2,10	57,84
-0,104+0,074	10,81	9,71	-	3,64	-	1,82	25,98
-0,074+0,053	8,33	1,76	0,77	-	-	-	10,86
-0,053+0,038	5,16	2,00	0,70	-	-	-	7,86
-0,038+0,000	-	-	-	-	-	-	
Total							

Table 2. Sulphide copper distribution according to degree of liberation and particle size fractions with type of middling

Particle size fraction d mm	Mass M %	Cu_{sulph} %	Copper Distrib D_{Cu} %	Degree of liberation L_m %	Copper distrib.	
					In liberated particles %	In middl-ings %
-0,208+0,147	32,33	0,213	17,68	34,60	6,12	11,56
-0,147+0,104	1,08	0,280	0,77	42,16	0,32	0,45
-0,104+0,074	8,89	0,449	10,24	74,02	7,58	2,66
-0,074+0,053	5,69	0,571	8,34	89,14	7,43	0,91
-0,053+0,038	0,33	0,760	0,64	92,14	0,59	0,05
-0,038+0,000	51,68	0,470	62,33	100,00	62,33	-
Total	100,00	0,390	100,00	84,38	0,33	0,06

Particle size fraction d mm	Type of middling						Sums
	Two minerals			Three minerals		Poly minerals	
	$CuFeS_2$ + SiO_2	$CuFeS_2$ + FeS_2	$CuFeS_2$ + CuS	$CuFeS_2$ + FeS_2+ SiO_2	$CuFeS_2$ + FeS_2+CuS	$CuFeS_2$ + poly	
-0,208+0,147	5,86	3,31	0,51	1,14	1,10	0,64	11,56
-0,147+0,104	0,27	0,09	0,02	0,05	-	0,02	0,45
-0,104+0,074	1,11	0,99	-	0,37	-	0,19	2,66
-0,074+0,053	0,70	0,15	0,06	-	-	-	0,91
-0,053+0,038	0,03	0,01	0,01	-	-	-	0,05
-0,038+0,000	-	-	-	-	-	-	-
Total	7,97	4,55	0,60	1,56	1,10	0,85	15,63

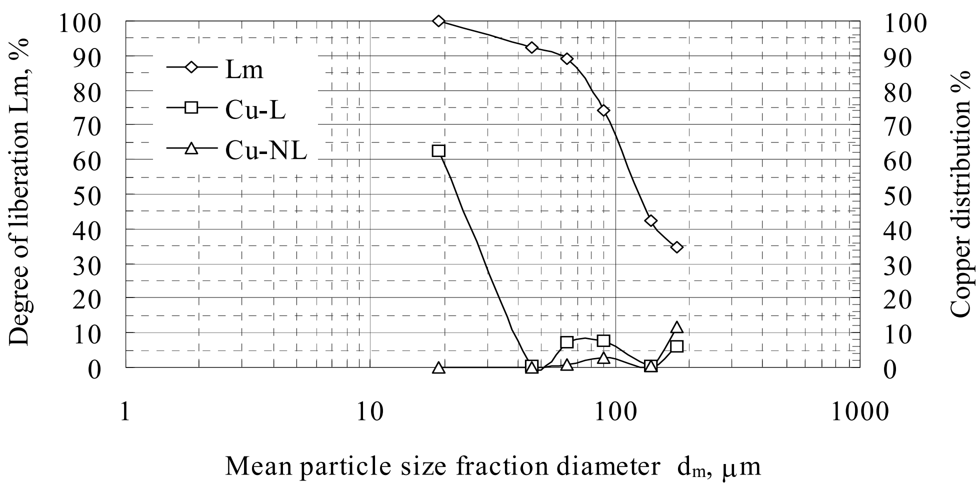

Fig. 1. Degree of liberation (Lm) and copper distribution vs. mean particle size diameter d_m, Cu-L copper in liberated particles, Cu-NL copper in non liberated particle

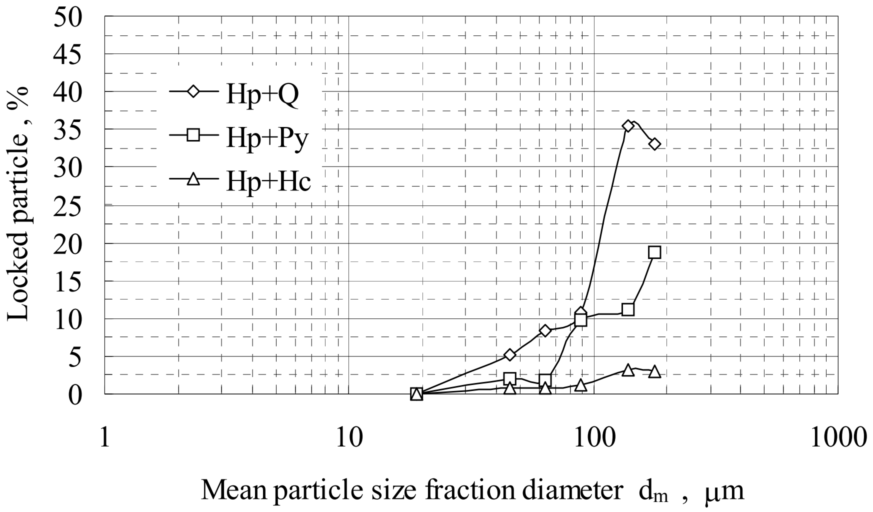

Fig. 2. Locked particle (middlings) vs. mean size fraction diameter d_m
Hp - chalcopyrite, Q - quartz, Py - pyrite, Hc - chalcocite

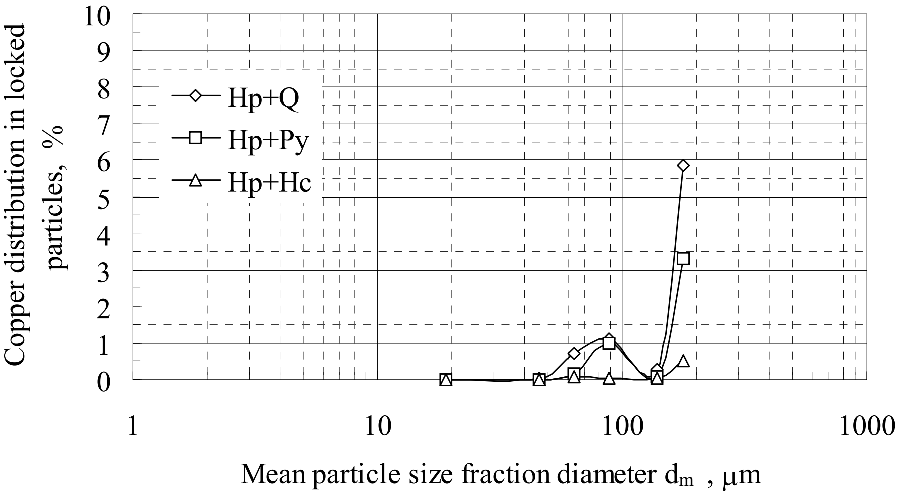

Fig. 3. Copper distribution in locked particle vs. mean size fraction diameter d_m
Hp - chalcopyrite, Q - quartz, Py - pyrite, Hc - chalcocite

3.2. Degree of liberation and flotation

Comparing of rougher flotation results with degree of liberation along the particle size were presented in Figure 4 and 5. Figure 4, presents degree of liberation and flotation recovery in particular size fractions. From this Figure it can be seen that degree of liberation and flotation recovery has the same behaviours in the middle particle size region, while little differ in fine and coarse particle size regions. Figure 5, presents degree of liberation and rougher copper concentrate grade in particular size fractions. Copper concentrate grade increases from fine to middle particle size region and reaches value over 6 % Cu and then rapidly drops down to coarse particle size region, while the degree of liberation shows only decreasing in coarse particle size region. These two parameters have the same trend only in coarse particle size region.

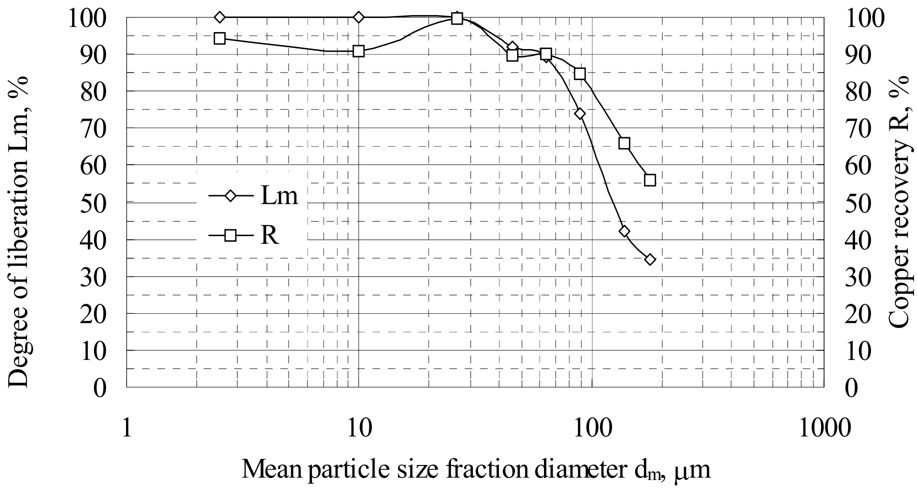

Fig. 4. Degree of liberation (Lm) and copper recovery (R) vs. mean size fraction diameter d_m

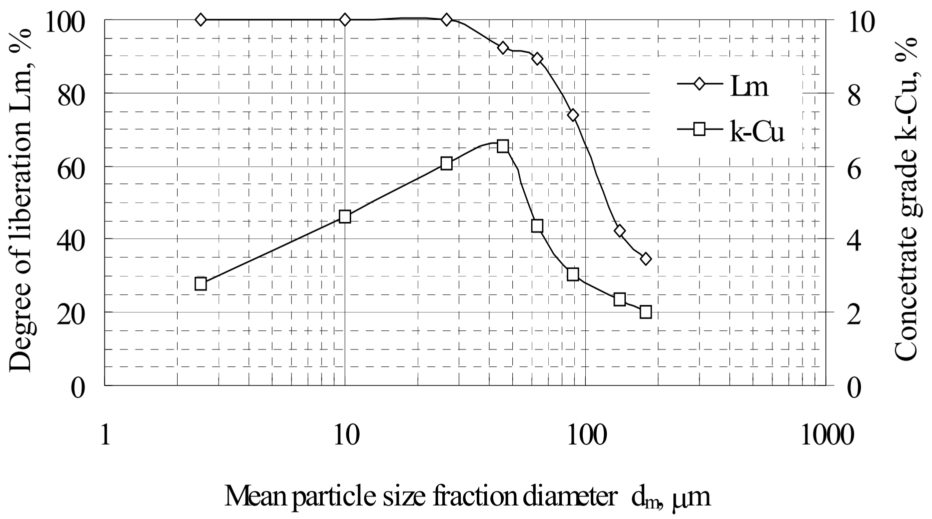

Fig. 5. Degree of liberation (Lm) and copper concentrate grade (k-Cu) vs. mean size fraction diameter d_m

4. Conclusions

Based on results presented above following conclusions can be drawn:

1. Flotation feed contains free copper mineral particles in fraction (-38+0) μm, small amount of locked particles was appeared in fractions from 38 up to 74 μm, while the rapid increase of locked particles in coarse size region over 74 μm.
2. Copper was distributed mainly in liberated particles in size fraction (-38+0) μm.
3. The main middling types are chalcopyrite-quartz and chalcopyrite-pyrite. Also, the copper contents are dominated in this type of middling.
4. Flotation recovery of copper minerals and degree of its liberation have the same trends in middle size region, while beyond this region they slightly differ and have similar trends towards coarse particles. In the fine particle size region degree of liberation is maximal so the flotation recovery depends rather on other factors, but in coarse particle region evidently depends on degree of liberation, besides of other factors in flotation system.
5. Rougher copper concentrate grade depends on degree of liberation in coarser particle size region. After regrinding of rougher concentrate and its refinery by flotation it can be achieved better copper grade due to increasing of degree of liberation in coarse particle region.

5. References

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