

Depletion of Slag from Almalyk Copper Plant with Aluminum Containing Waste



Sh.T. Khojiev, A.A. Yusupkhodjaev, D.Y. Aribjonova, G.B. Beknazarova, D.N. Abdullaev

Abstract: The article discusses the method of depletion of copper slag using local secondary technogenic formations. When performing this study, slag of secondary aluminum production was used as a reducing agent. It has been established that the developed and widely used in industry technologies for slag decontamination only partially solve the problem and lead to significant irretrievable losses of metal with dump slag. The main factors affecting the magnitude of the losses are established and suggestions for reducing their negative impact are recommended. The use of melting units in laboratory conditions is recommended, as in this case, it is possible to achieve a maximum reduction in the residual concentration of copper in the waste slag. Together, it is possible to achieve an increase in the complexity of the use of raw materials with the organization and implementation of low-waste technology.

Key words: copper production, loss of copper with slag, slag processing, depletion, slags of secondary aluminum production.

I. INTRODUCTION

The use of screenings of aluminum shavings and enrichment of slags for depletion of copper-rich slags, in particular, autogenous processes of smelting copper concentrates in OFF (Oxygen-Flare Furnace), may also correspond to solving the problem of waste-free production of aluminum alloys from scrap and waste [1-5].

When Oxygen-Flare smelting Almalyk's copper concentrate with slag is lost 2.5 - 3.0% of the copper contained in the charge. Of all known methods of copper slag depletion, depletion using aluminum-containing waste is the best [6-7]. According to the results of experimental smelting in a semi-industrial ore-thermal furnace (hearth area is 4.6 m²), copper content after decontamination is reduced from 2.8% to 0.15% when the copper content in the formed matte is 19.4% at screenings of casting slag.

The use of aluminum for the reduction of iron oxides of liquid slag is economically feasible to use waste aluminum containing waste [8-10].

A priori, it can be confidently stated that the above indicators of depletion of slag OFF (Oxygen-Flare Furnace) with the addition of aluminum-containing waste will be obtained by depletion of converter slag (containing copper in both slags is approximately the same) with conventional reflective smelting [9-13].

Thus, the joint processing of waste from the Tashkent Aluminum Alloy Plant and the Almalyk Copper Smelting Plant may become the main direction for further production improvement, due to:

- proximity to the location of enterprises;
- simplicity of mutual settlements;
- successful, simple, cheap resolution of the most difficult technical problems that do not require large capital investments to be implemented;
- coincidence of the needs of the copper plant in aluminum-containing waste and waste output at the aluminum alloy plant [14-17].

The Almalyk plant will finally overcome the eternal problem in the pyrometallurgy of copper and will remove converter slags from the matte formation and conversion cycle and will produce actual waste slag similar in copper content to off-balance ores in copper, and a scrap and aluminum alloy smelting plant [18-21].

II. OBJECTS AND METHODS OF RESEARCH

At the beginning, the depletion process of OFF (Oxygen-Flare Furnace) slag was carried out in laboratory-scaled laboratory conditions: screenings of foundry slag and shavings and cakes for water leaching of salt slag from the Almalyk non-ferrous metal plant [22-28]. Salt slag, ground up to + 10 mm, was leached out with hot water 4-5 times by stirring, settling and decanting, after which it was dried accordingly. Fractions of 0.315, + 0.24, and 0.14 mm were used in a ratio of 4:3:1, which ensures uniformity of salt slag. OFF slags were taken with a high content of copper and magnetite. The chemical composition of the charge components is carried out in table 1.

As follows from the above composition, when OFF slag is depleted in aluminum containing waste, copper is simultaneously extracted from the latter. Pyrite concentrate is introduced for matte formation [29].

Melting was carried out in a silica furnace in an argon atmosphere at 1573 K. Slag weights were finely ground. Slags with additives of depleting agents (200 - 250 g) were heated for 120 minutes,

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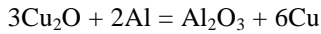
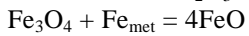
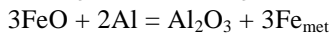
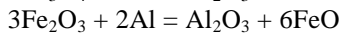
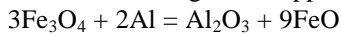
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and settled for 60 minutes. Smelting products (slag and matte) were subjected to chemical analysis for copper and other components of the magnetite content in the slag were determined by mineralogical and chemical methods [30-33].

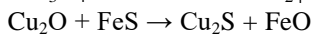
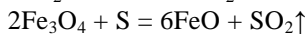
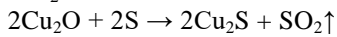
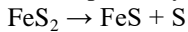
III. THE RESULTS AND DISCUSSION

Three series of experiments with various secondary aluminum production wastes were carried out. In the first series of experiments, slag depletion was studied by 2 screenings of cast alloys, pyrite concentrate, and their mixture. After melt at 1573 K of slag and settling without additives, the copper content decreases to 1.1% (this copper content in the slag is taken as the initial one when determining the efficiency of the depletion process) [34-39].

The addition of 2.4 and 6% of screenings leads to the restoration of magnetite copper (I) oxide:



In this case, the magnetite concentration decreases to 12.9 and 5%, respectively. The copper content is also reduced:



As a result of the reaction, the resulting copper sulfide added with iron sulfide forms a new matte phase [40-42]. But the date with the addition of 6% of screenings it remains quite significant (0.63%), despite a fairly deep recovery of magnetite (from 16 to 5%) and an increase in the acidity of the slag (SiO₂ content increases to 31.1, Al₂O₃ to 7.3 %).

The insufficient efficiency of depletion of aluminum slag containing wastes, apparently, is associated with the fine dispersion of the sulfide mixture formed during the reduction of magnetite, and its coalescence is insufficiently favorable (the viscosity of the slag melt increases) [43-44].

The addition of pyrite concentrate to the slag (Fig. 1, curve 2) also reduces the magnetite content in it, but the degree of recovery is low even with a more than twofold excess of FeS₂ (pyrite) versus the stoichiometric amount (at 6%) of the concentrate. This leads to the fact that a significant part of the iron sulfide goes into matte, reducing its copper content. When 6% pyrite concentrate is added to slag, the amount of copper decreases to 0.6%, and the conditional distribution coefficient $K_{\text{conditional distribution}}$:

$$K_{\text{conditional distribution}} = \frac{(\text{Cu})}{[\text{Cu}]} = 0.023$$

where: (Cu) is the concentration of copper in the slag, %; [Cu] is the concentration of copper in matte, %.

Significant depletion of slag is achieved by a mixture of aluminum containing screenings and pyrite concentrate. With the addition of 6% screenings and 6% concentrate, the copper content in the slag decreases to 0.2% (Fig. 1, curve 3). When the slag is depleted in the mixture, the screenings play the role of a magnetite reductant, and the iron sulfide formed during thermal dissociation of pyrite mainly rinses the slag and precipitates a copper-containing fine suspension, this is indicated by a significant decrease in the amount of copper in matte (Fig. 2):

$$K_{\text{conditional distribution}} = 0.02 - 0.033$$

In the second series of experiments (Figs. 3 - 4), slag (2.4 % Cu) was depleted in a mixture of screenings of chips and pyrite concentrate. With the introduction of 6 % screenings into the slag, the copper content decreased to 0.64 %. The addition to screenings of 2% concentrate reduced the copper content to 0.36 %, and the addition of 6 % concentrate to 0.25 %. Matte contained 16 – 26 % Cu, $K_{\text{conditional distribution}} = 0.014 - 0.016$.

One of the most important conditions for the economic feasibility of slag depletion methods along with the residual copper content in slags is the production of mattes with a rather high content (15 - 20%), since poor mattes complicate metallurgical production, increase the yield of dump slag, which reduces copper extraction into blister copper .

Comparing the data shown in Fig. 3 and 4, we see that when casting slag screenings (15.1% Al_{met}) are used for lean slag and mattes are obtained with 15 - 20% Cu, 2% pyrite concentrate must be added. At the same time, 0.35% copper is present in the slag. If you use chip screenings (12.7% Al_{met}), then 0.27% Cu will be in lean slag. With such average consumption of pyrite concentrate, the depth of copper slag depletion depends on the amount of screenings added to it. It was found that the best results on slag depletion when matte contains 15–20% Cu were obtained when 4–10% of casting slag screenings are depleted in slag as 5.5–9.0% of chip screenings (on average 7.5% aluminum containing waste regardless of their types).

In the third series of experiments, slag was depleted in a mixture of cakes and pyrite concentrate. Slag (2.0% Cu) after settling contained 1.25% Cu. Considering that there is almost as much aluminum in cakes as in screenings in foundry slag, the addition of pyrite concentrate was taken equal to 5%.

The addition of only pyrite concentrate (5%) to the slag reduces the copper content in it from 1.25 to 0.7%. As the proportion of cakes increases in the mixture, the copper content further decreases to 0.37% (10% cakes and 5% concentrate). The copper content in matte practically does not change at the same time it is higher than in previous experiments with the same amount of pyrite concentrate. This is due to the high copper content in the original slag.

$$K_{\text{conditional distribution}} = 0.014 - 0.016.$$

Thus, laboratory experiments established the possibility of a fairly deep depletion of copper slag at a flow rate of aluminum containing screenings of 7.5% for the matte content of 15 - 20% copper.

Mineralogical studies have shown that a significant amount of finely dispersed sulfide suspension is present in depleted slags. Therefore, a deep depletion of slag can be achieved by intensifying the process of coalescence matte-sulfide mixture. For this, the slag melt is purged with inert or natural gas, with which aluminum containing waste and pyrite concentrate can be introduced into the melt. Verification of this method on a laboratory scale is difficult.

Large-scale laboratory experiments were carried out in a two-electrode electric furnace with a capacity of 150 kg. Grinded to a particle size of 10 mm slag (2% Cu) was loaded into the furnace. After melting the slag, its surface was covered with a layer of coke (1% of the mass of slag) to prevent oxidation of the slag.



Upon reaching the melt temperature of 1623–1673 K, salt slag cake (13.1% Al_{met}) and pyrite concentrate were blown into the bath, for which a special installation was used, operating on the principle of an aerofoil with a dispenser [6]. Technical nitrogen (96.4% N_2) was used as a gas carrier. The duration of the melts, including loading, melting, purging and draining the melts was 7-8 hours, melting 3-4 hours, purging 10-15 minutes. The exit speed of the mixture of nitrogen and materials from the immersed tip (steel tube with a diameter of 12.5 mm) was 25-30 m/s. The experimental results are shown in Fig. 5.

The introduction of 5% pyrite concentrate into the slag melt reduces the copper content in the slag to an average of 0.41%, and 7.5% cakes to 0.36%. With successive injection of cake and then pyrite concentrate into the melt, the amount of copper in the slag decreases to 0.31%. The best conditions for coalescence of finely dispersed suspension are achieved by

blowing a mixture of cakes and pyrite concentrate - the copper content in the slag decreases to 0.15 - 0.2% (on average for a series of smelting - to 0.18%). With an average copper content in matte of 19%, the distribution coefficient is $K_{conditional\ distribution} = 0,0095$. With almost the same consumption of aluminum waste and pyrite concentrate per 1 ton of slag, the copper content in lean slag during larger laboratory melting is lower than for laboratory smelting. This is explained by an additional (1 - 2%) reduction of magnetite with carbon electrodes, as well as a more intense movement of the melt in the electric furnace, which contributes to the coalescence of finely dispersed sulfide suspension. The optimal slag depletion occurs at 1673 K. With a further increase in the temperature of the melt, the copper content in it practically does not change.

Table 1: The chemical composition of the components of the charge

Name of material	Components									
	Cu	SiO ₂	Al _{met}	Al ₂ O ₃	CaO	MgO	Fe	FeO	Fe ₃ O ₄	S
OFF slag 1	2,0	28,4	-	3,3	3,5	1,3	-	33,7	17,3	1,5
OFF slag 2	1,4	30,8	-	3,4	4,2	1,7	-	34,7	16,0	0,9
Casting slag screenings	0,8	26,7	15,1	45,9	2,9	2,0	-	5,8	-	-
Screening Chips	2,7	31,1	12,7	34,5	4,2	2,8	9,2	-	-	-
Cakes	1,1	8,5	13,1	48,8	1,6	-	-	3,6	-	0,4
Pyrite Concentrate	0,3	1,6	-	0,1	1,9	0,6	44,6	-	-	48,4

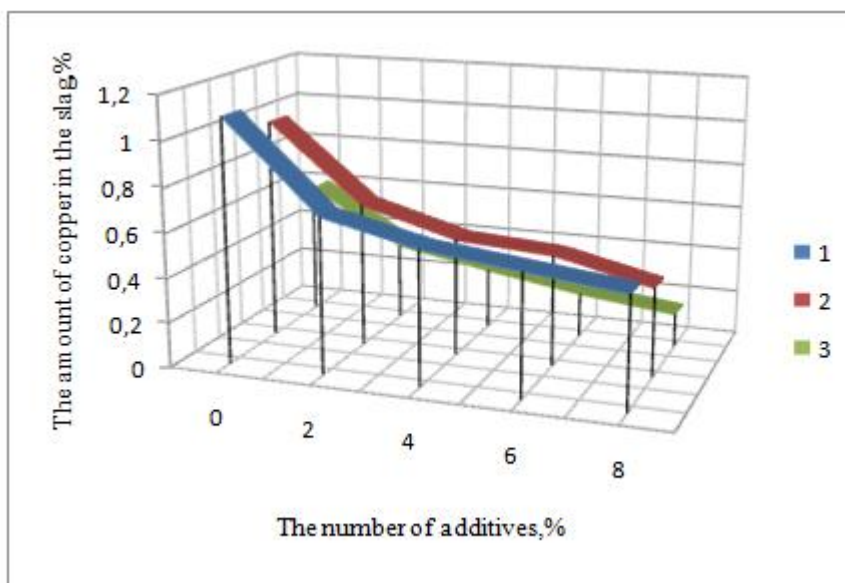


Fig. 1. The change in the copper content in the slag during the addition: 1 - screenings of casting slag; 2 - pyrite concentrate; 3 - mixtures of screenings of foundry slag and pyrite concentrate (equally each)

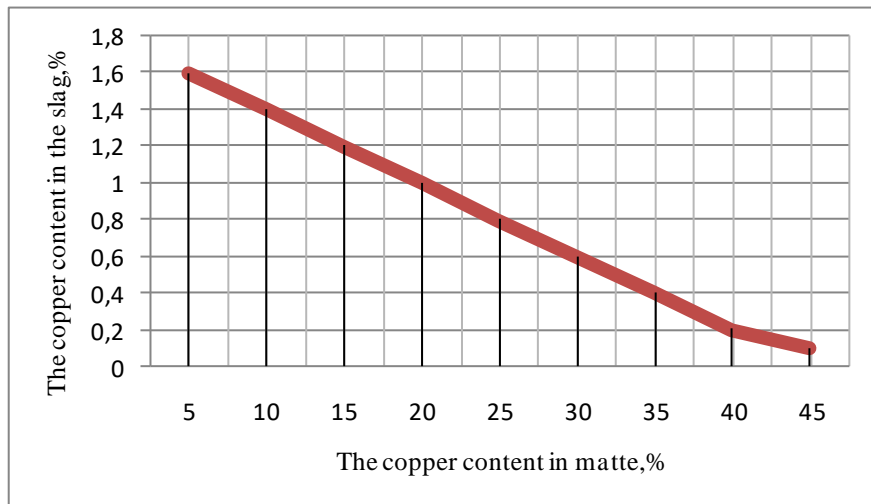


Fig. 2. The change in the copper content in matte with the addition of screenings of casting slag, pyrite concentrate and a mixture of screenings of casting slag and pyrite concentrate (equally each)

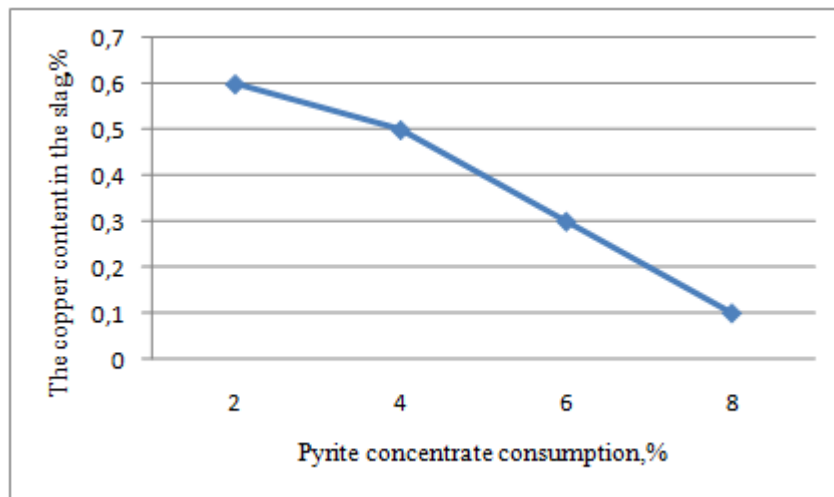


Fig. 3. The change in the copper content in the slag when added to the slag 6% screenings of chips and pyrite concentrate

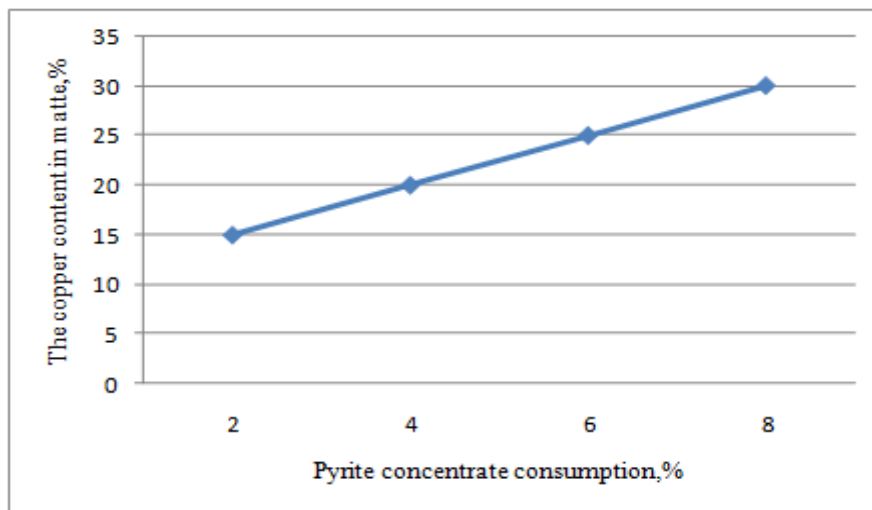


Fig. 4. The change in the matte copper content when adding to slag 6% screenings of chips and pyrite concentrate

Table 2: The results of depletion of aluminum slag containing waste

Indicators		Waste		
		Slag Screenings	Chip Screenings	Cakes
Pyrite concentrate consumption,%		2	5	5
The content in the slag,%:	In source	1,4	1,4	2,0
	After settling	1,1	1,1	1,25
	After impoverishment	0,35	0,36	0,4
The copper content in matte,%		16,2	17,2	18,0
$K_{\text{conditional distribution}}$		0,0216	0,0209	0,0222
Extraction of copper in matte,%		73,1	72,4	65,6

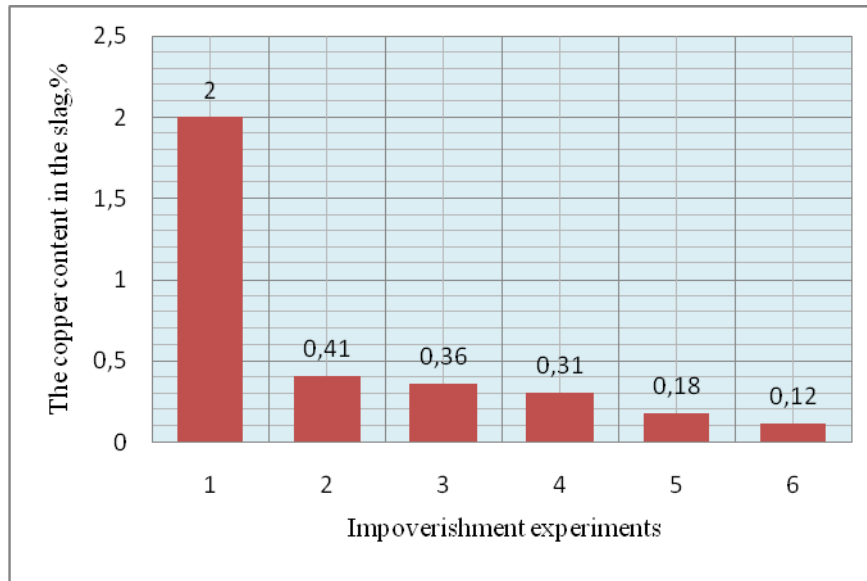


Fig. 5. The change in the copper content in the slag during the depletion of aluminum containing waste and pyrite concentrates at $T = 1623 - 1673 \text{ K}$, the duration of injection 10 - 15 min: 1 - the original slag; 2 - 5% concentrate; 3 - 7.5% of salt slag cakes; 4 - separate administration of 7.5% cake and 5% concentrate; 5 - introduction of a mixture of 7.5% cakes + 5% concentrate; 6 - 7.5% cakes + 5% concentrate + 10% SiO_2

IV. CONCLUSION

The reduction of copper content in the slag to 0.12 - 0.17% is achieved by blowing the lean mixture and adding silica sand (94% SiO_2) to the slag.

The addition of 10% sand to slag increases the silica content in it to 35% and reduces the copper content to 0.12%. In this case, $K_{\text{conditional distribution}} = 0.007$, the extraction of copper in matte is 95%. With an increase in the flow of quartz sand over 10%, there is some increase in copper in the slag, which is associated with an increase in the viscosity of the slag melt. The addition of lime (77.2% CaO) in an amount of 5-15% not only does not reduce the copper content in the slag, but, on the contrary, increases it.

Thus, enlarged by laboratory studies, the possibility of deep depletion of OFF aluminum slag containing waste mixed with pyrite concentrate is confirmed. Slag depletion conditions are also defined:

- composition and consumption of depletion mixture;
- feed rate;
- temperature of the slag melt;
- the content of silica in it.

In addition, the installation for injecting the depletion mixture with nitrogen into the melt was tested.

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