Original Article

Research and Development of Technology for the Extraction Copper, Iron and Other Precious Metals from Copper Slag

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DOI: 10.47750/pnr.2022.13.S08.313

Abstract

Copper slag was subjected to in-depth mineralogical characterization by integrated instrumental techniques and evaluated for the efficacy of physical beneficiation. In this study, a new technology has been developed to improve the enrichment of copper and iron components from copper slag, which promotes the mineralization of valuable minerals by modifying molten slag and promotes the growth of mineral grains. The results show that under appropriate conditions, the copper content of copper concentrate increased from 6.43% to 11.04%, the iron recovery of magnetic separation increased significantly from 32.40% to 63.26%, and other evaluation indicators slightly modified relative to unaltered copper slag.

Keywords: Copper Slag, Characterization, Microscope, Copper Matte, Fayalite, Magnetic Separation, Sulfuric Acid, Copper Compounds, Non-magnetic Fraction, Magnetic Fraction.

INTRODUCTION

World practice shows that today many metallurgical plants are engaged in the processing of secondary raw materials. This is due to the lack of ore reserves and emissions from metallurgical enterprises, which cause environmental problems. Almalyk MMC is one of the largest industrial enterprises in the Republic of Uzbekistan, which has been producing precious metals for many years. Depending on the properties of copper concentrates and the operating conditions in the pyrometallurgical process, about 2.0-3.0 tons of copper slag is produced per ton of copper production. About 12 million tons of copper slag is produced annually. Typically, copper slag contains about 35-45% iron and 0.5-1.5% copper indicates that it is a valuable secondary source for recycling. An analysis of the current state of slag processing technology shows that the technology of extracting all valuable components such as Cu, Fe, Ag and Au is the most optimal to involve slag in processing and to extract iron from them. Metallurgical and mineral processing industries generate a huge amount of wastes in the form of fines, slimes, slag, sludge etc., thereby creating environmental problems with ecological imbalances. Over decades, the primary aim has been directed towards the development of a zero waste technology by the utilization of such by-products or other industrial wastes. Simultaneous extraction of valuable metals by means of an ecofriendly technology is highly emphasized to bring in additional revenues to the producing industries. Industrial wastes such as blast furnace slag from steel plants and fly ash from thermal power plant have earned huge applicability as an additive in cement making. Transformation of such solid wastes from one form to another in view of its valorization either by the same production unit or by a different industrial installation has thus become very essential not only for conserving metal and mineral resources but also for protecting the environment. Copper ore globally at an average contains ~1% copper and the rest being silica, alumina, calcium, iron and magnesium. The cost of production of copper is very high due to the involvement of complicated steps right from ore processing to metal production. Although, the entire crush-grind-float treatment process to recover metal value is cost effective, recovery of any additional metal values from the generated wastes by a cost effective technique is highly desirable to earn additional revenue for the copper industry. One such material to be considered is the copper slag which is being produced during smelting and converting steps of copper matte production. It has been roughly estimated that for every ton of copper metal produced, about 2.2tons of slag is generated causing several environmental and space/land (dumping) problems. The common management options for copper slag are recycling, recovering of metal, production of value added products such as abrasive tools, roofing granules, cutting tools, abrasive, tiles, glass, road-base construction, railroad ballast, asphalt pavements etc. One of the greatest potential applications for reusing copper slag is in cement and concrete production. Some investigation on slag has indicated that an appreciable amount of Cu, Co, Ni can be recovered by hydrometallurgical and flotation techniques. However, hydrometallurgical applications for recovery of metal values from slags are not encouraging. For example, high concentration acid leaching has shown problems of the formation of silica gel, which induces an increase of leach liquor viscosity, difficult pulp filtration and crud formation during solvent extraction.

MATERIALS AND METHODS

Two slag samples and 2 briquettes were prepared from the slag samples, the composition of which was studied, and the following minerals were found.

From rare elements; like gold.

Minerals; pyrite, chalcopyrite, bornite, covellin and so on.

Table 1: Mineralogical composition of slags in copper production

Heavy fraction	
Mineralogical composition.	**Density, g / cm3**
FeO	5,74
Fe_3O_4	5,17
FeS	4,84
Cu_2O	6
FeS_2	4,9-5,2
Cu_2S	5,6
CuO	6,31
$CuFeS_2$	4,1-4,3
ZnO	5,61
Fe_2O_3	5,24
Light fraction	
SiO_2	2,65
CaO	3,34
Al_2O_3	3,95
MgO	3,58

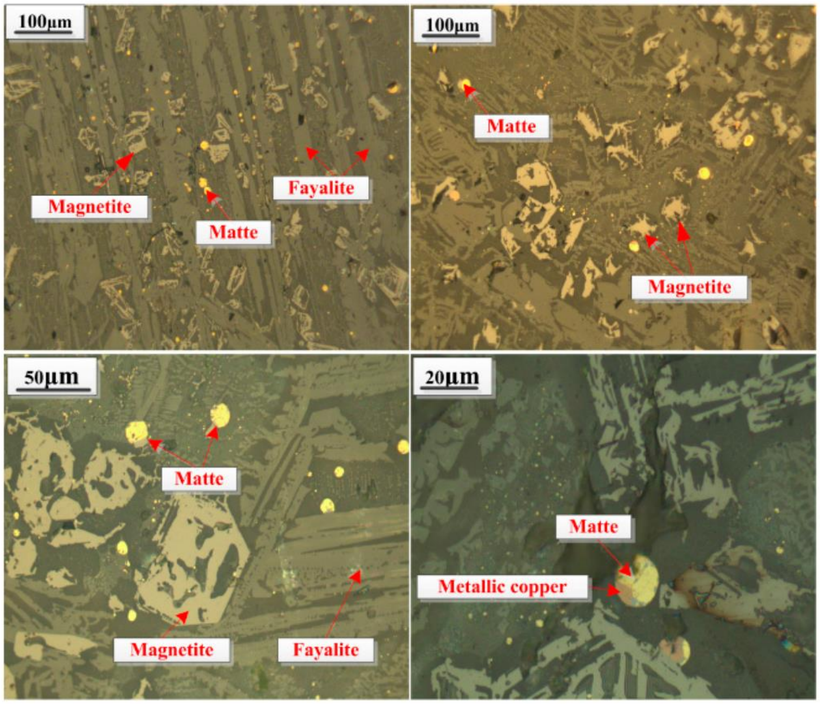
Table 2: Chemical composition of copper slag of AMMC

	Chemical content%							
Elements	Fe	Cu	SiO_2	Zn	Pb	Al_2O_3	CaO	MgO
Amount%	35-45	0.6-1.2	33 - 38	1.2	0.8	6-7	3-6	2-3

After studying the overall composition of the slag, the main task of the study was to separate Fe and Cu from the slag, so each metal was studied separately and the microstructure of the slag was examined to determine which minerals it encountered, and enrichment methods are selected based on these minerals the obtained results are presented in the table.

Table 3: The state of Fe in copper slag

Chemical content%						
Elements	$FeSO_4$	Fe_3O_4	FeS	Fe_2O_3	Fe_2SiO_4	All
Amount%	0,41	12,85	0,01	5,75	22,08	43



Picture 1. Microstructure of copper slag

As you can see in the picture, Fe has different looks and different sizes. Most of the iron combines with SiO_2 to form iron silicates, which can be seen in the hematite and magnetite states. Copper metal, on the other hand, is present in very small amounts in the oxide (CuO) and natural copper (Cu) states, while the rest is in the sulfide and mixed state.

Table 4: The state of Cu ni in copper slag

	Chemical content%			
Elements	CuO	Cu	CuS	Mixed
Amount%	0,02	0,18	0,46	0,55

METHODS OF RESEARCH

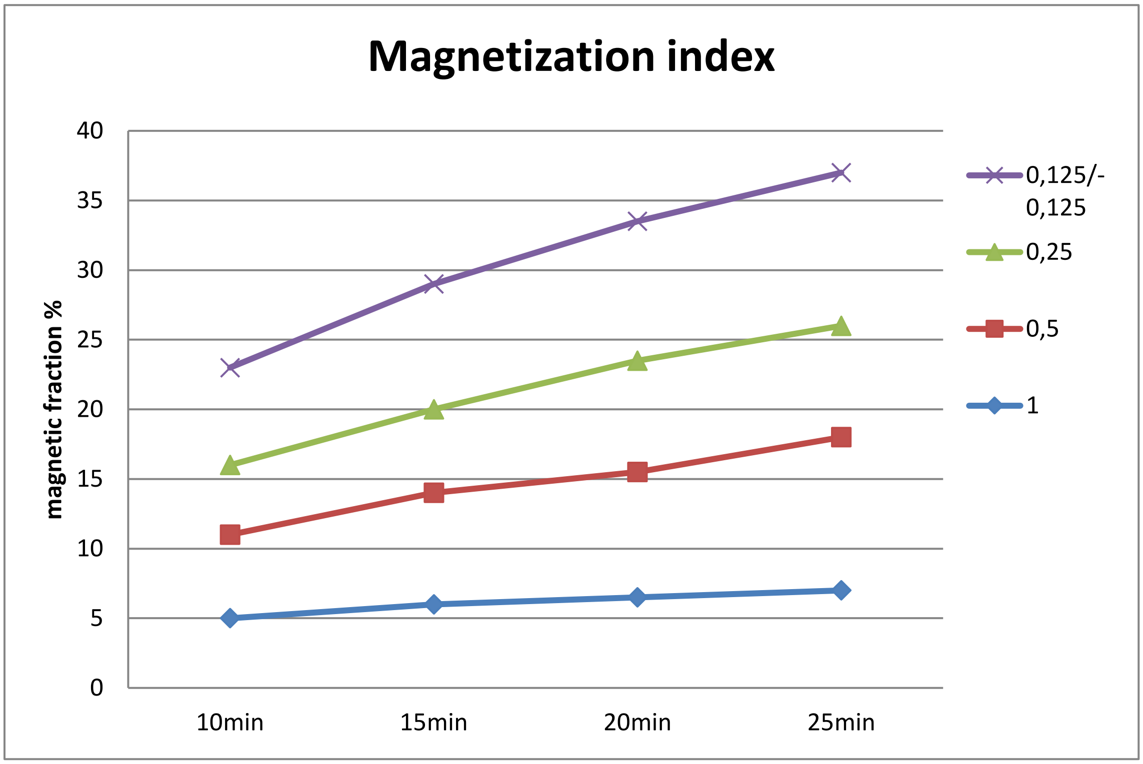
In the laboratory, a number of experiments were conducted on the preparation of AMMC copper slag. The purpose of these experiments is to determine the effective mode of the proposed technological scheme. Initially, 1067.9 g of copper slag was weighed on an analytical balance. The slag is a very solid substance with a density of 3-6 g / cm3 depending on the Fe content. Jaw crushers were used to reduce their volume. The grinding process was carried out in two stages to achieve the specified size. After grinding in two stages, the size of the product reached 6-9 mm, followed by a grinding process to send the product from the mill to the sieve, several products of different classes were obtained from the sieve process, the results of which are given in the table. Each product was magnetically separated. The purpose of these experiments was to determine the magnetization properties of the ore, depending on the size of the ore. Each product was weighed separately after screening. According to him, the mass of the product with a size of + 1 mm is 486 g, which is 48% of the total mass, and +0.5 mm is equal to 16% of the total mass. Products from +025 mm to -0.1 mm had almost the same mass.

Table 5: Classification of ore particles

Slag	**Size, mm**	**Grinding results, gr**	**Grinding results,%**
	+1	486,72	48
	+0,5	166,74	16
	+0,25	108,16	10
	+0,125	142,345	13
	-0,1	146,52	13
Disappearance		0	0
All		1067.9	100

Table 6: The magnetization of ore particles

Slag	Size, mm	Weight, gr	Magnetic fraction	Non-magnetic fraction	%
	+1	486,72	139.54	347.18	28
	+0,5	166,74	57.15	109.59	34
	+0,25	108,16	29.54	78.62	27
	+0,125 -0,125	288	106.90	181.1	37



200 g of product was weighed for magnetic separation. As a result of enrichment two different products were separated magnetic and non-magnetic fraction, in particular the magnetic fraction 53 gr non-magnetic fraction 147 gr.

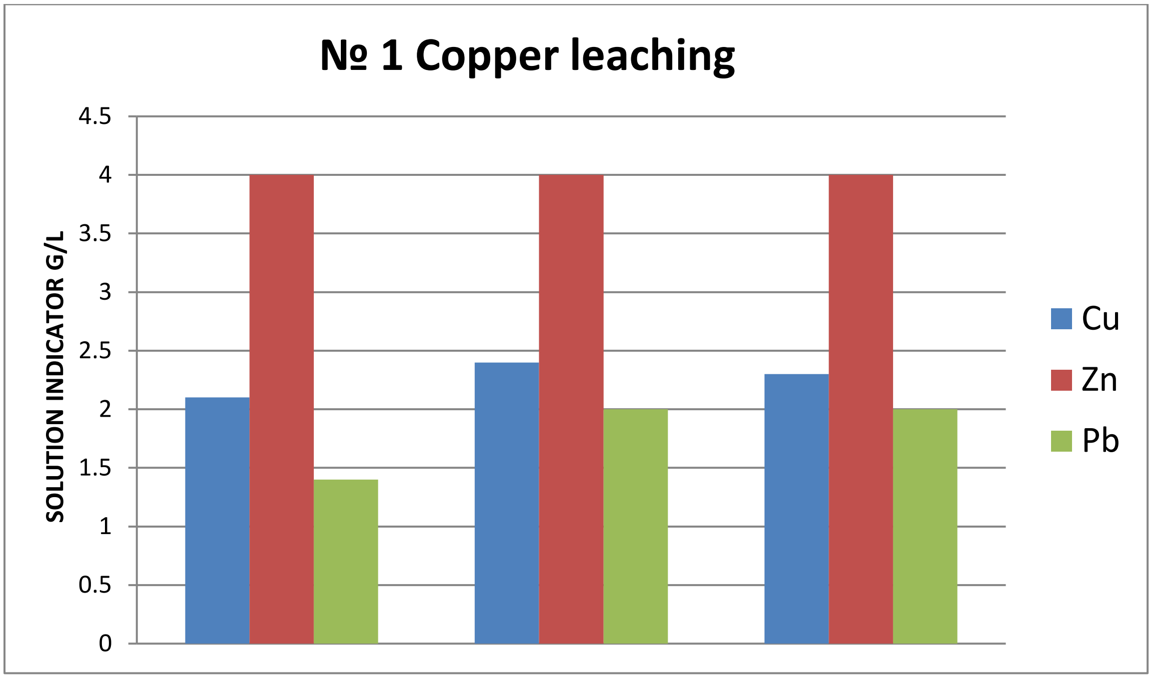
Copper Extraction Research

The above is the work done to separate Fe and its compounds from copper slag. Magnetic and non-magnetic fractions were obtained by magnetic separation of the product. The weight of the non-magnetic fraction was 147 g, which was determined by the presence of Cu, Zn, Pb, Au and silver in the product. For laboratory studies, KMP slag was obtained, which was divided into 3 samples, each of which used a different time, temperature, and acid concentration. H_2SO_4 was selected as the acid. (150gr H:L = 1: 5)

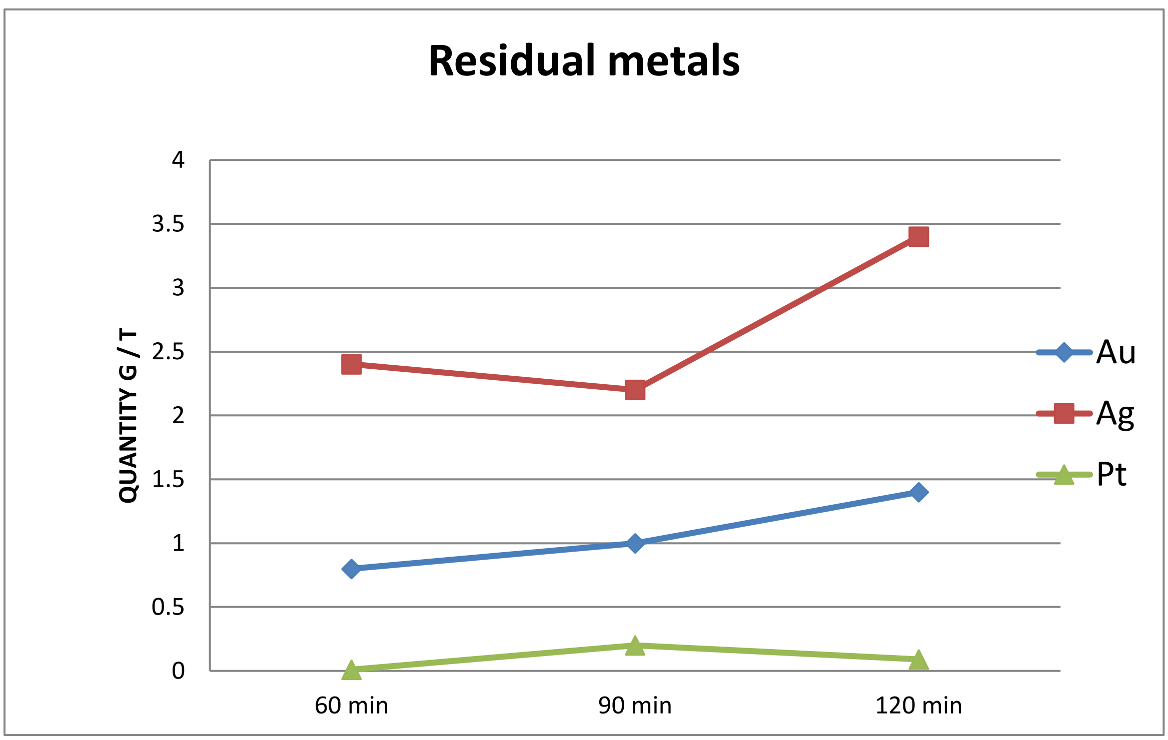
Sample № 1: selective melting, time 60 min, H_2SO_4 70 g/l, Temperature 50-55°C

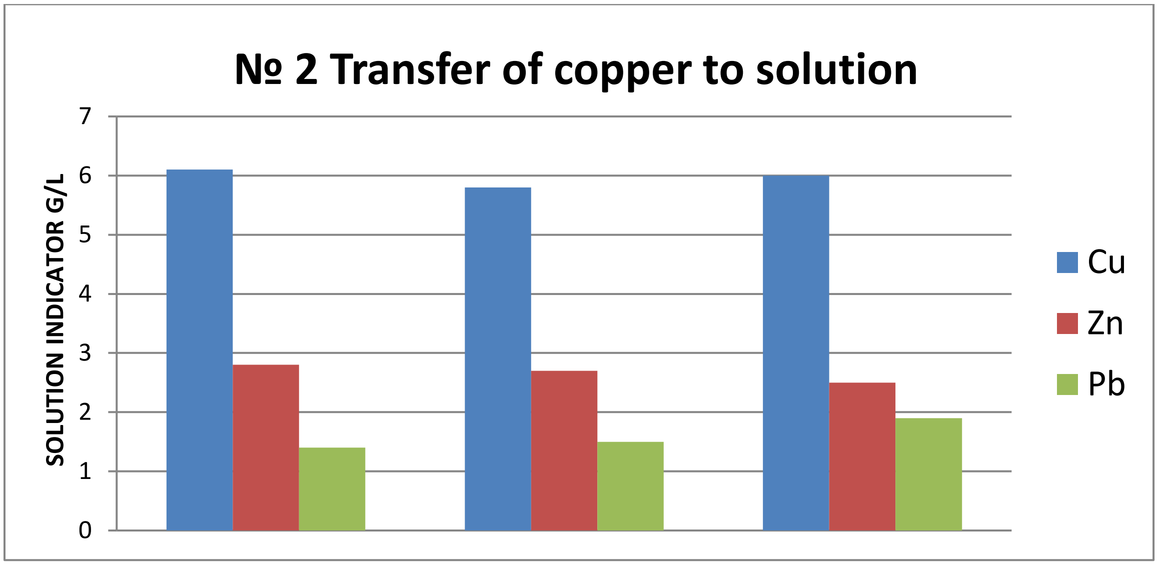
Sample № 2: selective melting, time 90 daq, H_2SO_4 74 g/l, Temperature 60-65°C

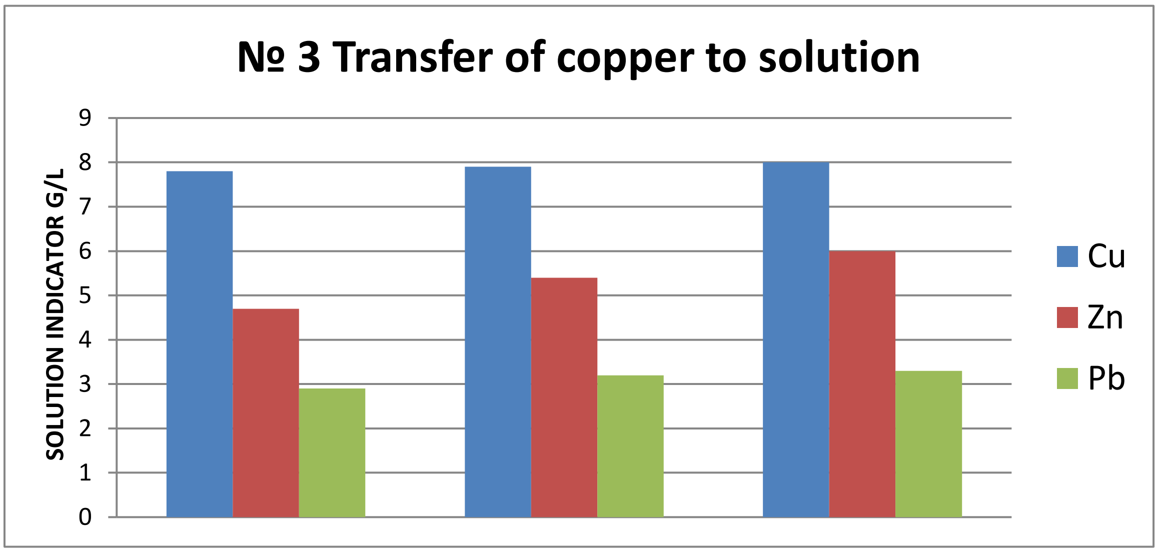
Sample № 3: selective melting, time 120 daq, H_2SO_4 78 g/l, Temperature 70-75°C

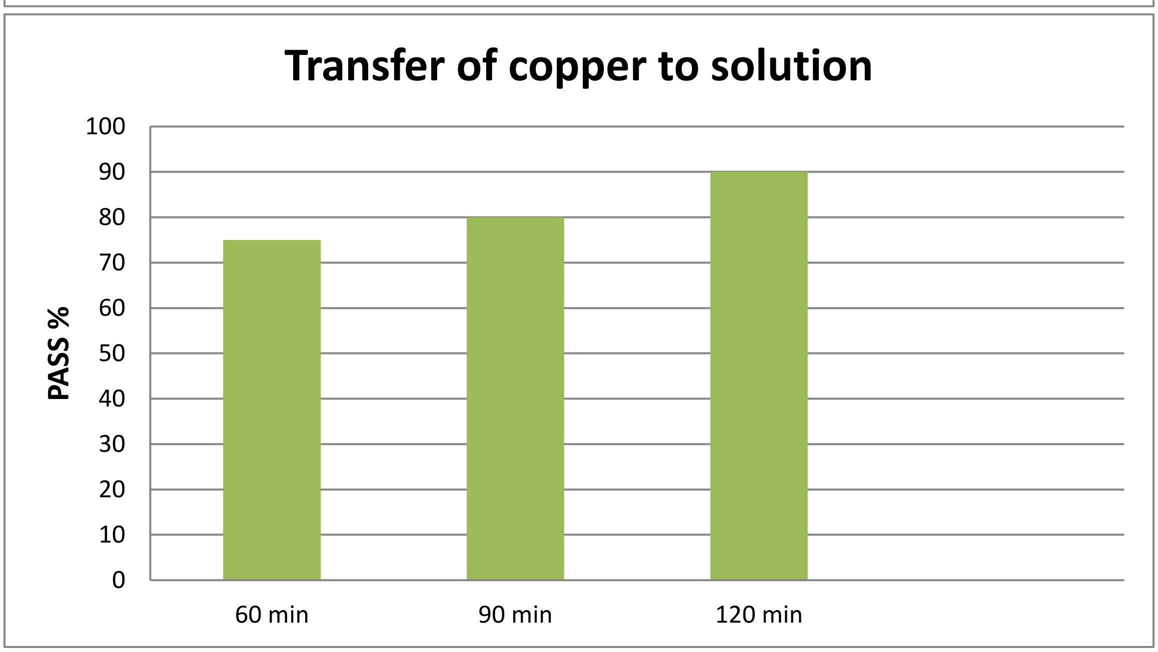


The diagram shows the melting of metals, the temperature of which was controlled during the process in the range of 50-55 ° C. At the end of the process, it was slightly cooled and two different products (solution and residue) were obtained using the filtration process.




№ 2 Transfer of copper to solution
SOLUTION INDICATOR G/L
7
6
5
4
3
2
1
0
Cu
Zn
Pb


№ 3 Transfer of copper to solution
SOLUTION INDICATOR G/L
9
8
7
6
5
4
3
2
1
0
Cu
Zn
Pb


Transfer of copper to solution
PASS %
100
90
80
70
60
50
40
30
20
10
0
60 min
90 min
120 min

CONCLUSION

Aimed at recovering iron from high-iron copper slag, the study introduced a combination of deep reduction and magnetic enrichment technology, studied the efficiency of extraction of iron, copper and other useful components, and optimized specifications. When carbon coke powder was used as a flux in the iron recovery process, iron was successfully separated from copper slag. In this study, a technology for processing copper slag was developed, the useful components of which were gradually separated. Initially, the composition and physicochemical properties of copper slag were studied and a technological scheme was developed. According to the developed technology, the processes were carried out in two stages, the crushing was carried out in two stages, and the ore particles were crushed and classified under laboratory conditions. The product of five different sizes was taken separately and each was magnetically separated. The purpose of this experiment was to determine the parameters of ore particles with high magnetization. Will have. Upon completion of the magnetization, a pyrometallurgical process using CaO and C was performed to restore the Fe oxides to the iron state. Calculations show that the Fe enrichment rate is 90%, which is a good estimate from an economic point of view. In addition, several studies on copper extraction have been selected as the most effective. Copper slag was found to be 90% leached by selective leaching. In conclusion, this study developed a slag processing technology that has been developed over the years by AMMC's copper smelter, from which the parameters for extracting the most efficient useful components of each process have been selected and listed above.

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