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# STUDYING THE CHEMICAL COMPOSITION OF SLAG FORMED WHEN SMELTING COPPER CHARGE

Samadov A. U.
Director, Doctor of Technical Sciences, Professor
Almalyk Branch of TSTU Named After. I. Karimova,
a.samadov@tdtuof.uz

Akhmedova N. E.
Senior Teacher Almalyk Branch of TSTU Named After. I. Karimova,
nigora071118@gmail.com

Jalolov B. A.
Doctoral Student Almalyk Branch of TSTU Named After. I. Karimova,
jalolovbaxtiyorjon319@gmail.com

**ABSTRACT**

In this article, the chemical composition of slags formed during high-temperature melting in copper-smelting furnaces (Vanyukov furnace, oxygen-flare melting furnace and reverberatory furnace) was studied in order to recover magnetite (Fe3O4) from slags formed during melting.

**Keywords**: Charge, melting, melting furnaces, Vanyukov furnace, oxygen-flare melting furnace, reverberatory furnace, slag, grinding, magnetite, recovery.

## INTRODUCTION

The Almalyk Mining and Metallurgical Plant intends to increase copper production to 170 thousand tons in 2024 in exchange for the short-term commissioning of the 3rd copper processing plant and the preparation of an additional 21.5 thousand tons of copper concentrate.

As a result of the commissioning of new capacities of the 4th Copper Processing Plant and the Copper Smelter, by 2030 the annual production of copper will reach 500 thousand tons, gold - 50 tons and silver - 270 tons, sulfuric acid - 4.1 million tons [6].

Enterprises of the republic for the extraction of raw materials annually generate about 180 million tons of technologically related production waste, represented by waste rock, enrichment waste, slag and sludge obtained during the opening of the surface of minerals.

Slag from copper smelters takes decades to form, and its content of useful components is higher than in currently mined ores. Slag contains useful components that are not extracted during primary processing, but can be extracted during recycling [1].

## MATERIAL AND METHODS

JSC Almalyk Mining and Metallurgical Plant collected more than 7 million tons of slag from the slag dump. Up to 350-400 thousand tons of copper slag are produced annually from the Vanyukov furnace, oxygen-flare smelting and reverberatory furnace, containing 38-45% iron, up to 1% copper, 0.4-0.6 g/t gold and other valuable components [1].

Researchers are studying mainly cooled slags, since various physical and chemical processes occur when cooling slags; indirect data results may be unreliable, since liquid slags are studied with great difficulty in aggressive environments at high temperatures.
A study conducted by an Uzbek scientist showed that the average proportion of magnetite and iron in converter slag is 20.26% and 48.32%, respectively [2].
Based on practical data, it has been determined that the magnetite content in the slag and matte obtained after melting the Vanyukov furnace averages 8.2% and 9.4% magnetite.
The chemical composition of slag from an oxygen-flare smelting furnace and a reverberatory furnace is given in table 1 [1].

Table 1. **Chemical composition of dump slag of Almalyk MMC JSC**

| | Type of slag | Content, % | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cu | Fe (gener.) | $SiO_2$ | $Al_2O_3$ | CdO | Zn | Pb | $Fe_3O_4$ | S | MgO | Ag g/t | Au g/t |
| 1. | OFM | 0,83 | 31,6 | 32,6 | 6,9 | 0,5 | 1,2 | 0,3 | 15,1 | 2,1 | 0,8 | 0,57 | 0,21 |
| 2. | RF | 0,61 | 34,7 | 34,6 | 2,8 | 3,6 | 1,8 | 0,1 | 17,2 | 0,2-7 | 1,6 | 0,34 | 0,07 |

## RESULTS

The slags generated from smelting furnaces were crushed using a laboratory mill MSHL-1 to analyze their chemical composition.

**Figure 1. Laboratory mill MSHL-1.**

An analysis of the composition of the slag was carried out in order to restore magnetite ($Fe_3O_4$) from the composition of the slag formed during the melting of copper charges in smelting furnaces (Vanyukov furnace, oxygen-torch smelting furnace and reverberatory smelting furnace) at high temperatures.

*a* *b*

**Figure 2. Type of slag formed from the Vanyukov furnace, before grinding (*a*) and after grinding (*b*).**

Table 2. **Chemical composition of the slag formed from the Vanyukov furnace**

| № | Formula | Element | Concentration, % |
|---|---|---|---|
| 1. | $Fe_2O_3$ | Iron (III) oxide | 49,58 |
| 2. | $SiO_2$ | Silicon dioxide | 20,98 |
| 3. | $Al_2O_3$ | Aluminium oxide | 5,702 |
| 4. | CaO | Calcium oxide | 3,954 |
| 5. | Zn | Zinc | 1,053 |
| 6. | Cu | Copper | 0,4677 |
| 7. | Pb | Lead | 0,3062 |
| 8. | MnO | Manganese (II) oxide | 0,2296 |
| 9. | Ti | Titanium | 0,1924 |
| 10. | Mo | Molybdenum | 0,1712 |

*a* *b*

**Figure 3. Type of slag formed from the OFM, before grinding (*a*) and after grinding (*b*).**

Table 3. **Chemical composition of the slag formed from the OFM**

| № | Formula | Element | Concentration, % |
|---|---|---|---|
| 1. | $Fe_2O_3$ | Iron (III) oxide | 43,06 |
| 2. | $SiO_2$ | Silicon dioxide | 23,47 |
| 3. | $Al_2O_3$ | Aluminium oxide | 6,515 |
| 4. | CaO | Calcium oxide | 3,562 |
| 5. | Zn | Zinc | 0,8037 |
| 6. | Cu | Copper | 0,4792 |
| 7. | Pb | Lead | 0,3217 |
| 8. | Ti | Titanium | 0,2918 |
| 9. | MnO | Manganese (II) oxide | 0,1995 |
| 10. | W | Tungsten | 116,1 (мг/г) |
| 11. | Mo | Molybdenum | 0,1474 |

**Figure 4. Type of slag produced from a reverberatory smelting furnace, before grinding (*a*) and after grinding (*b*).**

Table 4. **Chemical composition of slag formed from a reverberatory smelting furnace**

| № | Formula | Element | Concentration, % |
|---|---|---|---|
| 1. | $Fe_2O_3$ | Iron (III) oxide | 44,31 |
| 2. | $SiO_2$ | Silicon dioxide | 25,43 |
| 3. | $Al_2O_3$ | Aluminium oxide | 6,748 |
| 4. | CaO | Calcium oxide | 3,313 |
| 5. | Zn | Zinc | 0,7294 |
| 6. | Cu | Copper | 0,4025 |
| 7. | MnO | Manganese (II) oxide | 0,2605 |
| 8. | Ti | Titanium | 0,2009 |
| 9. | Pb | Lead | 0,1563 |
| 10. | Mo | Molybdenum | 0,09756 |
| 11. | W | Tungsten | 93,6 (мг/г) |

## CONCLUSION

Literature review and analysis results showed that slags formed from Vanyukov furnaces (VFF), oxygen-flare smelting (OFM) and reverberatory melting furnace were studied for the

presence of 45.65% $Fe_2O_3$, 32.3% $Fe_3O_4$ and 23.3% $SiO_2$. The average proportion of magnetite and iron in the composition of converter slags is 20.26% and 48.32%.

Together with the slags of the Vanyukov furnaces (VFF), oxygen-flare smelting (OFM) and reverberatory melting furnaces, it is advisable to carry out research work on the restoration of magnetite contained in the converter slag.

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