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Determination and Calculation of Components Cargo (Slag) During Smelting of Copper Ores

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Abstract: After smelting the copper ores in flame furnace crated matte that is smelting Cu_2S and FeS. The amount of copper in Matte determined amount of Cu_2S while rest is while FeS. In reallity matte contains less sulfur and other metals such as: PbS, ZnS, Fe_3O_4 and noble metals but their amount is small and does not affect the calculation. Processes of smelting in furnace and also in the converter is conditional on the fact that sulfur (S) is greater affinity to copper (Cu) than to iron (Fe). The percentage of copper in Matte depends on the amount of sulfur in cargo. Copper associated with assigned amount of sulfur and forms Cu_2S while the rest non-oxidized sulfur forms FeS. It follows that, much more have sulfur much more will be formed with FeS with that reduced the amount of copper in Matte. The amount of sulfur to oxidize the whole amount of sulfur in cargo ranges from 13-30% and passes in the form of SO_2 in gases. From the amount of iron in cargo an part passes Matte in form of FeS while the rest in slag in form of FeO. Losses of copper in slag are less than 0.9% of the amount of slag that with more precise definition of cargo and control of technological parameters of the process can be reduced.

Keywords: Cargo, Smelting, Matte, Slag

1. Theoretical Basis of the Process of Smelting and the Main Chemical Reactions

About 80 % of primary copper production comes from low-grade or poor sulfide ores. After enrichment steps, the copper concentrates are usually treated by pyrometallurgical methods.

Generally, copper extraction follows the sequence (see Figure below):

1. Beneficiation by froth flotation of ore to give copper concentrate
   (Optional partial roasting to obtain oxidized material or calcines)
2. Two-stage pyrometallurgical extraction
   1. smelting concentrates to matte
   2. converting matte by oxidation to crude (converter or blister) copper
3. Refining the crude copper, usually in two steps
   1. pyrometallurgically to fire-refined copper
   2. electrolytially to high-purity electrolytic copper

The melting process develop due to the heat that is released by burning the fuel, so that the combustion process is one of the basic conditions and normal economic functioning furnace. As fuel used coal powder which after burning must ensure:

- The maximum benefit amount of heat and its use as the best
- smelting temperature sufficient to fully cargo

To achieve the maximum temperature in the furnace, namely to ensure a better functioning of the furnace must be provided:

- Fuel qualitative
- Appropriate cartridge furnace and its elements
- Better control of the combustion process
- Careful adjustment of the capacity of the furnace etc.

Smelting chemical reactions consist of diffraction sulfur reactions and in the formation of slag reactions:

$$2CuFeS_2 \rightarrow Cu_2S+2FeS+S$$

$$FeS_2 \rightarrow FeS+S$$

$$2CuS \rightarrow Cu_2S + S$$

$$3Fe_2O_3 \rightarrow 2Fe_3O_4 + 0.5O_2$$

$$Cu_2O + FeS \rightarrow Cu_2S + FeO$$

$$2Fe_3O_4 + 3SiO_2 = 3[(FeO)_2xSiO_2] + O_2$$

$$CaO + SiO_2 \rightarrow CaOxSiO_2$$

$$3Fe_3O_4 + FeS + 5SiO_2 = 5[(FeO)_2xSiO_2] + SO_2$$

$$2FeS + 6Fe_2O_3 + 7SiO_2 = 7[(FeO)_2xSiO_2] + 2SO_2$$

If Mette considered as a three-component system of copper, iron, and sulfur without considering other filth, then its properties can be studied with the analysis of three-component diagram Cu-Fe-S.

The main properties of smelting slag as a system dependent on the chemical composition. Physical properties of the slag with particular importance are:

- Smelting temperature
- Viscosity and
- Specific density

Slag mainly composed of three main oxides: SiO_2, FeO and CaO.

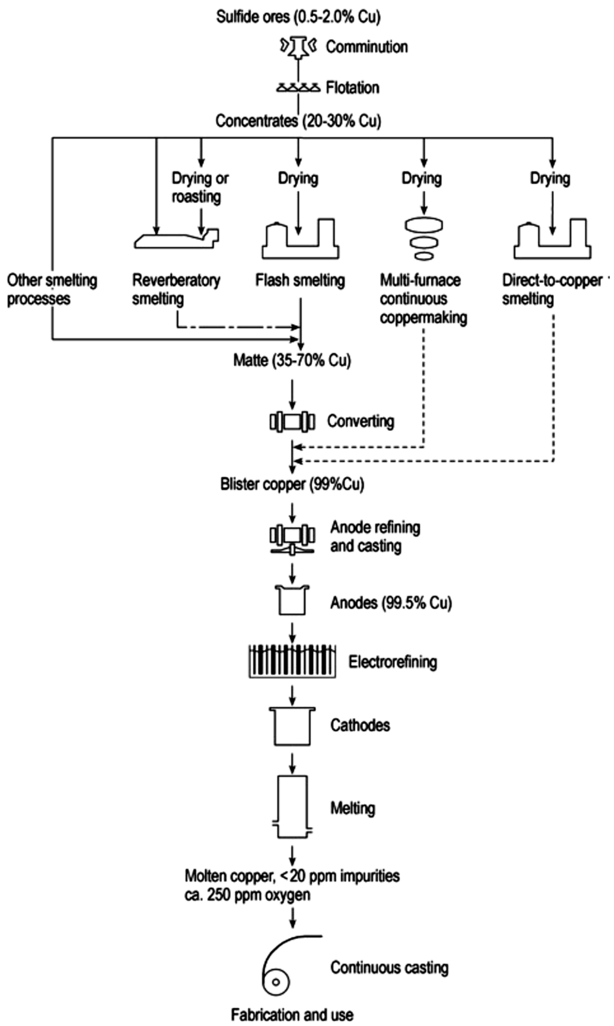

Figure 1. *Overview of copper production.*

Combustion process gases during their passage through the furnace, draw away a significant amount of ash and fine particles cargo, therefore it should be noted that we do not need to own furnace on the gas pressure. The temperature of the furnace gases found in the range of 1300-1350^{o}C and depends on the smelting temperature of the slag. Mainly containing gases: CO_2, SO_2, CO and O_2.

The capacity of the furnace, namely the amount of cargo to be processed per unit of time and the surface of the furnace depends on these factors:

- Temperatures with which enters the furnace and cargo
- Heat to dissolve the amount of cargo which is obtained by burning fuel (taking into account heat losses)
- Determining accurate as cargo elements for smelting
- Better control of the working process (mode of operation of the furnace better), which provides minimal loss of copper slag.

2. Determination of Cargo Components

Determination of cargo to gain assigned composition of matte and slag done in this way:

• First determined to taken 100 part of drying ore concnetrating which will be the main ingredient of cargo

• Then assigned the amounts of the other components needed to mix

Concentrating ore usually have no sulfur to obtain the requested matte. It meets next ore of non-concentrating. Non-concentrating ore it contains an amount of copper which is associated with copper ore that conentrating.

After this by the ratio of slag determined amount of iron ore and amount of limestone (CaO) under given conditions.

3. Data from Experimental Work

The composition of ores that are prepared for smelting in flame furnace and limestone, according to laboratory analysis are given in the table:

Table 1. *Composition of ores that are prepared for smelting.*

Ore of concentration A Composition in %		Ore of Non-concentration B Composition in %		Ore of Iron C Composition in %		Limestone D Composition in %	
Cu_2S	14%	$CuFeS_2$	30%	Fe_2O_3	80%	Fe_2O_3	80%
FeS	10%	FeS_2	20%	SiO_2	12%	SiO_2	15%
Fe_2O_3	31%	SiO_2	50%	Al_2O_3	3%	Al_2O_3	3%
SiO_2	36%			$CaCO_3$	5%	$CaCO_3$	2%
Al_2O_3	9%						

As combustibles, furnace use coal powder in amounts of 13 parts coal powder to 100 parts cargo. Coal powder containing 15% ashes with composition: 90% SiO_2 and 10% FeO.

From practical experience obtained that an amount of ashes (approximately half) remain in cargo while the rest leave with gases.

Also from practical experience obtained by the amount of

20% sulfur of cargo goes with gases (this amount is taken from the process gas analysis)

In this paper determined and calculated cargo of 1000 kg (composed by mixing the three ore, limestone and combustibles) to gain the Matte with 42% copper and slag ratio:

SiO_2, CaO, FeO = 40:15:45 since wheras MgO calculated as CaO in equivalent ratio.

It is worth mentioning that the amounts mattes having copper (40-45%) Cu and slag with high iron ratio to enable an optimal work (with suitable parameters such as viscosity, tepmperatura etc.) of furnace for smelting.

4. Analytical Calculations

Knowing that matte ($m=Cu_2S+FeS$) contains 42 % Cu

$$\% Cu_2S^m = \% Cu \times Cu_2S/2Cu = 42 \times 160/2 \times 64 = 52.5 \%$$

$$\%FeS=100-52.5= 47.5 \% FeS$$

$$\%Fe^m{}_{FeS}=47.5 \times Fe/FeS=30.2 \% Fe$$

$$\% S_{FeS}= 47.5-30.2=17.3 \% S$$

$$\% S_{Cu_2S}=52.5-42=10.5 \% S_{Cu_2S}$$

$$\% S^m=17.3+10.5=27.8 \% S$$

These data calculated ratio obtained mattes

$$Cu:Fe:S = 42:30.2:27.8$$

For 100 kg of ore cocnentration (A) has:

$$Cu^A = 100 \times 0.14 \times 2Cu/Cu_2S = 11.2 \text{ kg Cu}$$

$$42 \text{ kg Cu}: 27.8 \text{ kg S} = 11.2 \text{ kg Cu}:x$$

$$x=7.41 \text{kg S}$$

$$S^A=100(0.14 \times S/Cu_2S+0.10 \times S/FeS) \times (1-0.2)=5.15 \text{ kg S}$$

Explanation: (1-0.2) taken that amount of S 20 % that passes in gases.

Amount of sulfur (S) from ore B should be:

$$S^B=7.41-5.15=2.26 \text{ kg S}$$

For 1kg of ore B:

$$S^B{}_{1kg} = 1x(0.3 \times 2S/CuFeS_2+0.2x2S/FeS_2) \times 0.8=0.169 \text{ kgS / kgB}$$

$$Cu/1 \text{ kgB}=0.3 \times Cu/CuFeS_2=0.3 \times 64/184=0.1043 \text{ kgCu / kgB}$$

$$42 \text{ kgCu}:27.8 \text{ kgS}=0.1043:y$$

$$y=0.1043 \times 27.8/42=0.069 \text{ kgS}$$

$$S^{B\rightarrow A}=0.169-0,069=0.1 \text{ kgS / kgB}$$

$$1 \text{ kgB}:0.1 \text{ kgS}=B:2.26 \text{ kgS}$$

$$B=1 \times 226/0.1=22.6 \text{ kgB/100 kgA}$$

100 kgA+22.6 kgB

$$SiO_2{}^{A+B}=36+22.6 \times 0.5=47.3 \text{ kg}SiO_2$$

$$Fe^A=10 \times Fe/FeS+31 \times 2Fe/Fe_2O_3=28.10 \text{ kg Fe}$$

$$Fe^B=22.6(0.3 \times Fe/Fe_2O_3+0.2 \times Fe/FeS_2)=4.4 \text{ kgFe}$$

$$\sum Fe=28.10+4.4=32.5 \text{ kgFe}$$

$$Cu^{A+B}=11.2+22.6 \times 0.1043=13.56 \text{ kgCu}$$

$$Fe^m=13.56 \times 30.2/42=9.8 \text{ kgFe}$$

$$Fe^z=Fe^{A+B} - Fe^m=32.5-9.8=22.7 \text{ kgFe from A+B}$$

$$FeO=22.7 \times FeO/Fe=29.2 \text{ kgFeO}$$

From report of slag has:

$$40 \text{ kg}SiO_2:45 \text{ kgFeO}=47.3 \text{ kg}SiO_2{}^{A+B} : x$$

Explanation: from 100 kg A+22.6 kgB=100 x 0.36+22.6 x 0.5=36+11.3=47.3

$$x=53.2 \text{ kgFeO}^z$$

$$FeO^c=53.2-29.2=24 \text{ kgFeO}$$

From fraction: $Fe2O_3 \rightarrow 2FeO+1/2O_2$

Ore C contain 80 % $Fe2O_3$:

$$1 \text{ kgCxFeO / kgC}=0.8 \times 2FeO/Fe_2O_3=0.72 \text{ kg C}$$

Ore C contain SiO_2, that amount of FeO for SiO_2 own smelting is:

$$40 \text{ kg } SiO_2:45 \text{ kgFeO}=0.12 \text{ kg} : x$$

$$x=45 \times 0.12/40=0.135 \text{ kgFeO}$$

$$FeO^{C\rightarrow(A+B)} = 0.72-0.135 = 0.585 \text{ kgFeO / kgC}$$

$$1 \text{ kgC}:0.585 \text{ kgFeO}=C:24 \text{ kg}$$

C=41 kg ore C

$$SiO_2{}^{A+B+C}=47.3+41 \times 0.12=52.2 \text{ kg}SiO_2$$

$$40 \text{ kg}SiO_2:15 \text{ kgCaO}=52.2 \text{ kg}SiO_2:x$$

$$x=15 \times 52.2/40=19.6 \text{ kgCaO}$$

$$CaO^C=41 \text{ kg} \times 0,05 \times CaO/CaCO_3=1.1 \text{ kgCaO}$$

$$CaO^D=19.6-1.1=18.5 \text{ kg}$$

$$CaO+MgO/kgD=1 \times 0.8 \times CaO/CaCO_3+0.15 \times MgO/MgCO_3 \times CaO/MgO=0.548 \text{ kgCaO}$$

Calculate amount of CaO for SiO_2 of own limestone:

$$40:15:0,02:y$$

$$y=0,008 \text{ kgCaO}/0,02 \text{ kg}SiO_2$$

Amount of $CaO^{D\rightarrow(A+B+C+D)}$=0.548-0,008=0.54 kgCaO/kgD

$$1\ kgD:0.54\ kgCaO=D:18.5\ kg$$

$$D=18.5x1/0.54=34.3\ kg\ D$$

$$D=34.3\ kg$$

Now should calculate and amount of FeO and CaO for SiO_2 that comes from coal ash:
Amount of coal ash uses (q) is:

$$q=13/100(A+B+C+D)=0.13(100+22.6+41+34.3)$$

$$q=25.7\ kg$$

Amount of ashes (H) that falls in cargo is:

$$H=1/2\ x\ 25.7\ x\ 0.15=1.93\ kg\ ashes$$

Kg ash contain:

$$SiO_2^{H}=1.93\ x\ 0.90=1.74\ kg\ SiO_2$$

$$40kgSiO_2:45\ kgFeO=1.74SiO_2:a$$

$$a=45\ x\ 1.74/40=1.96\ kgFeO$$

$$FeO^{H}=1.93\ x\ 0.10=0.19\ kgFeO$$

a'=1.96-0.19=1.77kgFeO- amount of FeO in ash shold be added

$$1\ kgC:0.585\ kgFeO=C':1.77\ kgFeO$$

$$C'=1.77/0.585=3.0\ kg$$

C'-amount of added from C

$$40\ kgSiO_2:15\ kgCaO=1.74\ kgSiO_2:b$$

$$b=15\ x\ 1.74/40=0.65\ kgCaO$$

Amount of CaO that should added in limestone D is:

$$b'=0.65-0.08=0.57\ kgCaO$$

$$1\ kgD:0.54\ kgCaO=D':0.57$$

$$D'=1.1\ kg$$

Cargo is:

$$A=100$$

$$B=22.6$$

$$\sum C=41+3=44$$

$$\sum D=34.3+1.1=35.4$$

$$\sum=202\ kg$$

Calculation for 1000 kg =1t of cargo:

$$202\ kg:100A=1000:x=100/202\ x\ 100=495\ kgA$$

$$22.6\ x\ 1000/202=112\ kgB$$

$$44\ x\ 100/202=218\ kgC$$

$$35.4\ x\ 1000/202=175\ kgD$$

$$\sum(A+B+C+D)=1000\ kg$$

5. Discus of Results

The results obtained by calculations analysis for the base are obtained 100 kg of ore that concentrating (A). Per 100 kg of ore that concentrating (A) are calculated quantities of components: ore non-concentrating (B), ore iron (C) and limestone (D), based on the chemical reactions that take place in the area reactive and from the balance material of the process.

The composition of full OF CARGO presented in the table for the quantity of 1000 kg = 1t cargo

Table 2. *Quantitaive compositon of cargo for 1000 kg=1t.*

A	B	C	D	Cargo
495	112	218	175	∑1000 kg

Table 3. *Percentage of cargo components.*

A	B	C	D	Cargo
49.5	11.2	21.8	17.5	∑100 %

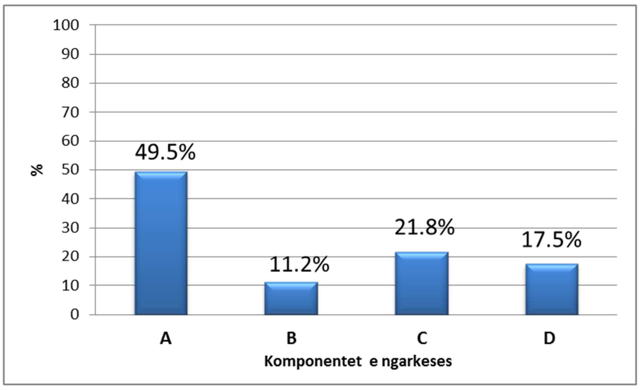

Figure.2. *Percentage of cargo components.*

6. Conclusions

Technological main indicators characterizing the operation of the furnace for smelting are:

- Quantity of cargo to melt expressed in t / 24h
- Consume of fuel expressed as a percentage of the mass of the cargo molten
- Copper ladder crossing in matte (minimum copper losses).

The results achieved and their practical application to fuse the copper ores can be concluded that during the work will have suitable parameters that enable continual good job of merging such as:

- The composition of mattes that Cu
- Viscosity of mattes that Cu
- The composition of slag
- Viscosity of slag
- Minimal loss of Cu

To achieve optimal values of main parameters working during smelting of the cargo, the main factors is the calculation and determination of the amount of cargo elements, which can value that is achieved in this paper.

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