УДК 621.01; 622.279

MAXIMISATION OF EXTRACTION EFFICIENCYIN COPPER METALLURGY

Viorel POP , Nicolae BĂNCILĂ, Cezar TOADER, Anamaria DĂSCĂLESCU, Radu COTEȚIU
North University of Baia Mare, Romania, Baia Mare 4800, st.Dr.Victor Babes NR 62A

The copper production is made in two essential stages: melt for matte and convertizing, confronted with big losses of copper. The separate onset of efficiency maximisation at those two work stages doesn't have lead until present at good results. This paper proposes a new approach of this problem: maximisation of efficiency with treating of melt for matte and convertizing as a unitary process, through methods of mathematical analyse, being necessary the utilisation of mathematical models especially elaborated for this purpose.

Медное производство состоит из двух основных стадий: плавления материала и превращения, сопровождающихся большими потерями меди. Отдельные исследования увеличения продуктивности на этих двух стадиях не дали хороших результатов до настоящего времени. Эта работа предлагает новый подход к проблеме повышения продуктивности производства меди. Процесс рассматривается как единый. Используются методы математического анализа и математических моделей, специально разработанных для этой цели.

Copper production through pirometallurgical processes, having as base stages melt for matte, convertizing and thermal refinement, is also accompanied by the appearance of sterile phase (slag) every time, which determines mainly lost of metal and extraction efficiency. Growing the copper content in matte cause the diminution of fes content in this, implicit diminution of matte capacity to sulphurate the metal oxides, with the retaining of those in the util phase, copper matte. The role of fes is well put in evidence at matte convertizing, where the non-ferrous metal concentrations in slag, including copper, raise very much, beginning with percent factions, and become 5-8 % at the end of convertizing process [1], more then mattes have much more cu_2s, respective by less fes.

In these conditions, we do *not* recommend at convertizing, a single slag elimination at the end of the process, of the entire quantity of slag (a slag with a higher copper content), but functioning with periodical evacuation of slags, as these are formed, having at the beginning smaller copper content and determine, as total media resulted slag, small metal looses, improving in this way the efficiency [2], [3].

Extraction efficiency at melt for matte and convertizing, treated according to the copper quantity in matte, are in opposition, meaning: at melt for matte efficiency is bigger as the produced matte is poorer in copper, and at convertizing, contra, the efficiency is bigger as the matte is richer in copper - see figure 3.

COPPER LOSSES WHIT SLAG

The slag quantity resulted, respectively, losses of copper at convertizing are according to the initial content of copper (y_i) of matte which is processed [3], getting smaller once with growing y_i . So, if we consider 100 tons resulted slag at processed matte with 40 % cu, for mattes with: 45, 50, 55 and 60 % cu, the resulted quantities of slag are: 86,76; 73,69; 60,53 and 47,38 tons (see figure 1), at convertizing being better processing of rich mattes.

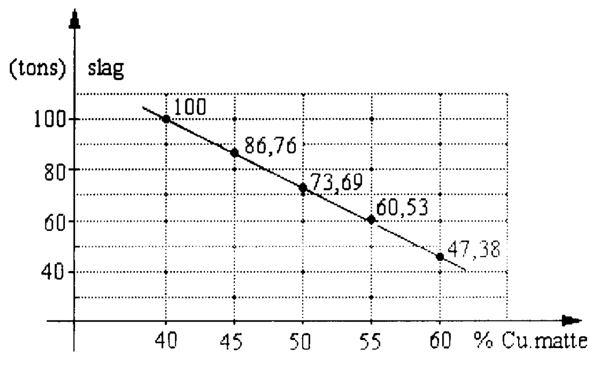

Fig. 1 - Slag quantity resulted at convertizing according to the percentual content of copper from matte

In figure 2, the copper content (% and tons) in resulted slag at convertizing through work systems, is presented with one, or two intermediary slag evacuation, according to the initial content in percent of copper of processed matte.

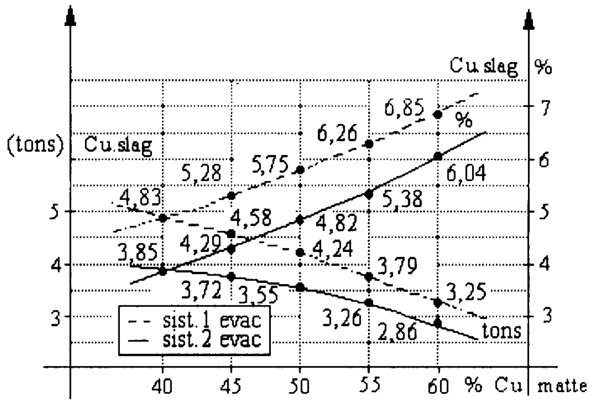

Fig. 2 - Copper content from convertizing slag according to the percentual content of copper from matte

The converter slag quantity and the copper in this, are calculated with mathematical models as [3]:

$$Q_{slag}= Q_{matte}\times \frac{6053-232{,}89y+2{,}9867y^2-0{,}01277y^3}{(80-y)(48-0{,}625y)\left[1+(1-0{,}0125y)\left(\frac{48{,}8-0{,}63y}{80-y}\right)\right]} \quad (1)$$

$$m_{Cu.sl}=Q_{matte}\times \frac{533-6y-0{,}08(51-y)^2}{1+(1-0{,}0125y)\left(\frac{48{,}8-0{,}63y}{80-y}\right)}\cdot 10^{-4} \quad (2)$$

$$z= \frac{(80-y)(48-0{,}625y)\left[533-6y-0{,}08(51-y)^2\right]}{100\left(6053-232{,}89y+2{,}9867y^2-0{,}01277y^3\right)}\,\% \quad (3)$$

in which: Q_{slag} - is the slag quantity resulted in the convertizing process ,*tons;* Q_{matte} - the matte quantity processed at convertizing ,*tons;* $m_{Cu.\,sl}$ - the copper quantity from the slag resulted at convertizing , *tons; y*-the percentual content of copper from matte; *z* - the percentual content of copper from slag.

Analysing figures 1 and 2, these are the results:

a) the slag quantity resulted in the convertizing process, gets smaller together with the increasing of the initial copper content y_i of the matte processed

b) together with the increasing of the initial content of copper y_i of the matte processed, the copper quantity (tons) from resulted slag diminishes, with all the increase of copper percent in these. The explanation is at the point 1 and it is the smaller quantity of slag, implicit the loss of copper with this.

. Thus, the diminution of the slag quantity formed at convertizing on the composition interval of matte processed (y_i = 40…60 % Cu) is over 2, comparative with approximate 1,5 that is the increasing of the copper content in percent in the resulted slag - figure 2.

c) the advantage of the work system with two intermediary slag evacuations, comparative with the classical system with one intermediary evacuation of slag, the losses of copper being smaller, assuring bigger extraction efficiency in this way.

MAXIMIZATION OF EXTRACTION EFFICIENCY

In figures 1 and 4 the curves representing the extraction efficiency at melt for matte and convertizing are presented. Thus, we notice, that the efficiency is increased with copper enrichment in the processed matte, but in exchange, at the precedent technological phase, at melt for matte the efficiency is bigger as matte is poorer.

It results that to maximise the extraction efficiency at copper processing, the melt processes for matte and convertizing *can't* be treated separate, by these representing two interconditionate stages of a unitary process.

For the calculation of extraction efficiency at convertizing omographic equations and regression equations were used [2], [3]. For the work system with one elimination intermediary of slag,

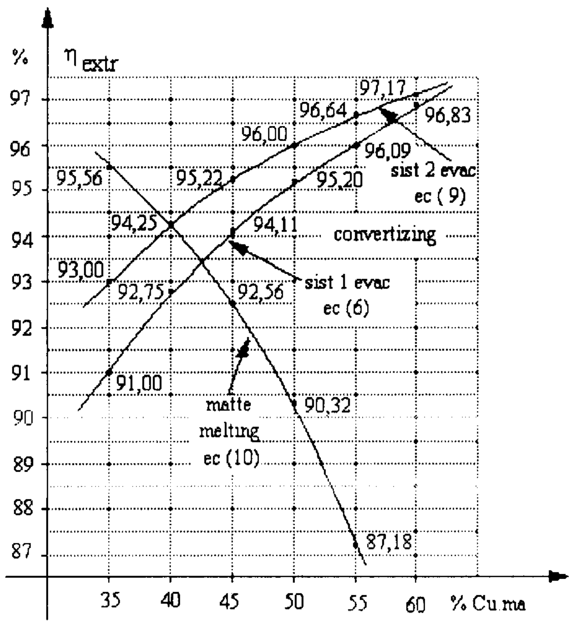

Fig.3- Efficiency extraction at matte melting and convertizing: work systems with one, respective two intermediary eliminations of slag

the equations are:

$$\eta_{extr.\,1} = 84{,}772 \cdot 1{,}0022^{\,y} \qquad (4)$$

and

$$\eta_{extr.\,1} = 100 - \left(\frac{400-3y}{1{,}3y} + \frac{64-y}{20-0{,}2y} \right) \qquad (5)$$

or

$$\eta_{extr.\,1} = 100 - \frac{490-5y}{y} \qquad (6)$$

and for the work system with two intermediary evacuations of slag:

$$\eta_{extr.\,2} = 88{,}294 \cdot 1{,}0016^{\,y}. \qquad (7)$$

$$\eta_{extr.2} = 100 - \left(\frac{117-y}{5+0{,}2y} - \frac{y-40}{270-3{,}6y} \right). \qquad (8)$$

$$\eta_{extr.\,2} = 100 - \frac{350-3y}{y}. \qquad (9)$$

At melting for matte, we propose the equations:

$$\eta_{extr.\,(m.m.)} = 100 - \frac{x-1{,}9}{13{,}24-0{,}1654y} \ (\%). \qquad (10)$$

$$\eta_{extr.\,(m.m.)} = \frac{5600x-(70x+1{,}72\cdot Fe_{ch})y}{(0{,}0116-0{,}7x)y+56x-0{,}9632} \ (\%) \qquad (11)$$

in which: x - represent the percentual content of copper from charge; y - the percentual content of copper from matte; Fe_{ch} - the percentual content of iron from charge

The presented equations allow treatment through methods of mathematical analyses of the problem of maximisation extraction efficiency cumulated (at melt for matte and convertizing).

The cumulate efficiency, is calculated as the product of those two efficiencies taken individually:

$$\eta_{extr.\,cumulate} = \eta_{m.m} \cdot \eta_{conv.} \qquad (12)$$

Maximisation of cumulate efficiency extraction, is obtained through the evaluation with zero of the first degree derived from the cumulated efficiency equations and solving the resulted equation. The obtained solution is according to the variable "y" showing which is the copper content from matte resulted at melt and convertizing, that the efficiency beeing maxim.

$$\text{So: } \eta'_{cumulat} = \eta'_{m.m.} \cdot \eta_{conv.} + \eta_{m.m.} \cdot \eta'_{conv.} \qquad (13)$$

Using equations (9) and (11) for efficiency at convertizing and melt for matte we have:

$$\eta_{cumulat} = \frac{103y-350}{y} \cdot \frac{5600x-(70x+1{,}72Fe_{ch})y}{(0{,}0116-0{,}7x)y+56x-0{,}9632} \qquad (14)$$

and the first derived is:

$$\eta'_{cumulat} = \frac{2{,}6x-(96{,}32x-1{,}657)Fe_{ch}}{56x-0{,}9632-(0{,}7x-0{,}116)y} \cdot \frac{103y-350}{y} + \frac{5600x-(70x+1{,}72Fe_{ch})y}{(0{,}0116-0{,}7x)y+56x-0{,}9632} \cdot \frac{350}{y} \qquad (15)$$

from where the result equation, by variable "y":

$$\eta'_{cumulat} = y^2\,(17\,150 - 15{,}736\,x - 9\,499{,}56\,F \cdot x - 586{,}815\,F) - y\,(2744000 - 45376{,}35\,x + 33712\,F \cdot x - 33\,712\,F) + 109\,760\,000 - 1\,887{,}87x = 0 \qquad (16)$$

By solving the equation (16), for known values of copper content (x) and iron (f) from charge, we obtain percentual content of copper (y) of matte that must be obtained at melt, such as the cumulated efficiency (melt-convertizing) to be maxim.

For charge having copper content between 12 - 14 % and iron between 28 - 30 % characteristically at melt for matte in Romania factory [5], the equation (16) becomes:

- for charges containing 12 %Cu and 30 %Fe

$$x^2 + 419{,}113\,y - 16\,327{,}3 = 0$$

with positive solution $y \approx 36\ \%\ Cu_{matte}$

- for charges containing 14 %Cu and 28 %Fe

$$x^2 + 1\,449{,}46\,y - 57\,750{,}6 = 0$$

with positive solution $y \approx 38\ \%\ Cu_{matte}$

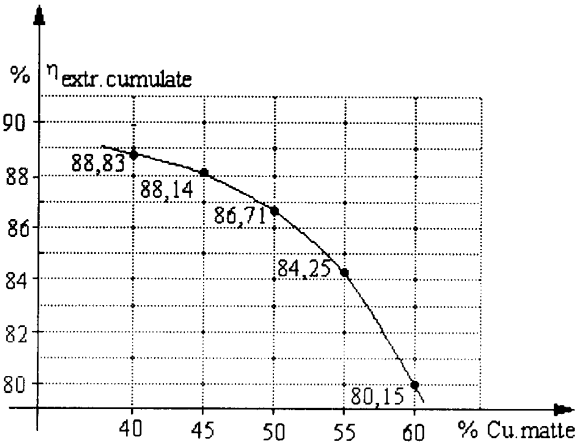

Fig. 4 - Extraction efficiency cumulate: melt for matte and convertizing according to the percentual content of copper from matte

It has to the noticed that the very small values (under 40 %) for copper content in matte, resulted at maximisation of extraction cumulated efficiency, at processing of some charges containing 10 - 15 %Cu , although in factories where matte is obtained through flash melting there is the opinion (tendency), to produce and use matte more enriched, with a content of 50 - 60 %Cu without considering the drastically diminution of global efficiency, which has on interval 40 - 60 %Cu in matte for convertizing, is getting lower with over 8 % - see figure 4.

CONCLUSIONS AND RECOMANDATIONS

- The loss of copper with slag, at melt and at convertizing as well is growing together with the enrichment of copper in matte, at convertizing reaching from 2-3 % at the beginning of the process, to 5-8 % at the end of the convertizing process
- In this conditions we do *not* recommend at convertizing a single evacuation of the entire slag quantity at the end of the process, according to the periodical eliminations of slags as this is formated, considering that the first formed slag are poor, diminishing, in that way, per global, the loss of metal (copper).
- For the effectuation of the calculation for copper losses with slag and of the efficiency, it is necessary the elaboration of mathematical models which allow the application of mathematical methods in squaring maximisation extraction efficiency
- The squaring in this way of the maximisation efficiency shows that we *can not* treat separately by these technological phases, from this point of view, melt for matte and convertizing, representing two tightly interconditionated stages of a unitary process
- Pursuant to the calculation in this paper, we notice the surprising small values, around 40 % for copper content in matte produced at melt and processed at con-vertizing, in the maximisation of extraction efficiency conditions, contrary to the actual tendency to produce at melt in suspension of matte richer with contents going to 60 %Cu.

REFERENCES

1. Oprea, Fl., Taloi, D., Constantin, I., *Echilibrul fazic în sistemele sulfuroase la topirea şi convert. continuă*, Revista Metalurgia, 2 şi 3 (1980), pag. 93-98 şi 148-152

The phasic equilibrium at copper melting and convertizing, Journal of Metallurgy, Bucharest, 2 and 3 (1980), pp. 93-98 and 148-152

2. Viorel POP, *Conducerea optimală a procesului de convertizare*, Revista Metalurgia, Bucureşti, 3 (1987), pag. 127-132

Optimal coordination of copper convertizing, Journal of Metallurgy, Bucharest, 3 (1987), pp. 127-132

3. Viorel POP, *Mathematical models at copper mattes convertizing*, Miskolc University - Hungary, "micro CAD 1996" vol. B, pp. 79-83

4. Spira, P., Themelis, N.J., Journal of Metals, vol. 21, 4 (1969), pp. 35-39

5. Viorel POP, Cezar TOADER, *The suspension melting of copper concentrates*, *under computer coordination*, Miskolc University - Hungary, "micro CAD 1995" vol. B, pp. 22-27