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ANALYSIS OF THE EAF METAL CHARGE STRUCTURE

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Abstract: *The steelmaking process and the steel quality are greatly influenced by the metal charge used, both in terms of assortment and quality. Regarding steelmaking, in the current stage people are interested in the oxygen converters and electric arc furnaces. In case of oxygen converters, the metal charge consists of about 80% liquid pig-iron, the balance of 20% being scrap, and in case of electric arc furnaces, the charge is 100% solid and consists of scrap. The paper presents the results of analyzing the structure of the charge intended for ultra-high power EAFs, with eccentric bottom tapping (E.B.T.), 100 tonnes capacity. In the cases we have studied, the charge consisted of scrap (types: E1, E2, E5, and E100), internal & purchased ferrous skulls, and ferrous materials from internal recycling & disposal. We monitored 98 heats, analysing the structure of the metal charge, the additives introduced directly in the metal charge throughout the steelmaking process, the propellant materials and the oxygen blown into the metal bath. The results are shown in graphical form, based on which we made a technological analysis, presented in this paper.*

Keywords: *ultra-high power EAFs, steelmaking process, steel quality, metal charges, technological analysis*

INTRODUCTION

The technical revolution of the human society requires increasingly resistant materials, safe in operation, which can be obtained in qualitatively and economically competitive conditions.

Among the materials used in the construction of machinery, equipment, vehicles, etc., the steel still occupies the predominant place, being materials which, in addition to the wide variety and high value properties, have the advantages to be obtained at lower costs, have a long life operation and can be recycled 100% [1,2,3,4].

To reduce the weight of constructions (industrial buildings, equipment, machinery, vehicles, etc.) and to immobilize smaller quantities of steel in the long life operation constructions, the unalloyed steels tend to be increasingly replaced by quality carbon steel, low and medium alloyed.

But, the technical development entailed the growth to a great extent of the scrap sources, by decommissioning of the machinery, equipment, plants, steel construction, vehicles, etc., obsolete and worn out, and by obtaining larger amounts of manufacturing debris (due to increased production), determining the steel to be largely made from scrap. By reintroducing the scrap in the manufacturing process, not only the iron is recycled, but also the alloying and harmful elements. Therefore in steel, besides the prescribed elements, which are designed to ensure the required quality of steel, can be also found foreign elements, usually known as tramp elements. Any chemical element can be either alloying element in some steel grades (except for manganese and silicon, which in the carbon steels are found as accompanying elements, at a concentration of less than 0.80% Mn and less than 0.50% Si, respectively), or trace element in others, according to the influence on the steel properties [1,2,3,4].

The limits on the percentage of elements contained in steel are presented in Table 1.

Table 1. *Minimum limits for alloying elements [2].*

Element	% min	Element	% min
Al	0.10	Co	0.10
Bi	0.10	Cu*	0.40
B	0.008	Mn	0.80
Cr*	0.30	Mo*	0.08
Ni*	0.30	Si	0.50
Nb**	0.05	Te	0.10
Pb	0.40	Ti**	0.05
Se	0.10	W	0.10
V**	0.10	La	0.05
Zr**	0.050	Others***	0.05

** If the elements are in combination with one or more elements found in the respective steel heat, it is required to assess the percentage of each element and the total content, which must be 70% of the sum of the limits specified for each element.*

*** The rules above apply also to the combinations of these elements.*

**** Without taking into account: C, P, S, N, O.*

Currently, the oxygen converters and electric arc furnaces are of interest for the steelmaking process. The development of high productivity equipment for steelmaking, i.e. oxygen converter and ultra-high power electric arc furnace, enabled us to prove that some steelmaking phases, as deoxidation and alloying, hinder or cancel the economic effect of the intensive processes of melting and refining, which take place in the high productivity metallurgical units, by means of oxygen [1,2].

To obtain competitive economic effects, the transfer outside the metallurgical equipment of these technological operations was a great technological solution, especially since it was associated with the continuous casting technology.

In these new technological conditions, a particular importance has the structure and quality of the metal charge, in terms of chemical composition, origin and charge preparation.

STUDY OF THE PROBLEM

Given the above, for the analysis of the charge structure we monitored 98 steel heats made at an electric furnace steel plant equipped with an electric arc furnace of EBT type and a continuous casting plant with 5 strands, the semi-finished products obtained being blooms, billets and round profiles.

The parameters monitored at those 98 steel heats, intended to produce steel tubes, were:

- *components of the metal charge: scrap (types: E1, E2, E5, E100), internal and purchased ferrous skulls, scrap from internal recycling or disposal;*
- *auxiliary materials for slag formation: dolomite, foaming material, coke, Topex Ca, Topex;*
- *additives for the refining process: lime, graphite, carbon (injectors), oxygen (injectors), oxygen (lance), gas (injectors);*
- *additives for the deoxidation process: ferro-manganese, ferro-silicon and ferro-silico-manganese;*
- *duration of the technological stages until tapping (included);*
- *electrical energy consumption;*
- *limits of variation and average values for the monitored parameters;*
- *content of trace elements unusable as alloying elements at the end of the melting stage;*
- *content of trace elements that can be used as alloying elements at the end of the melting stage;*

During the steelmaking process, the charge structure was carefully monitored, along with its dimensional appearance and slag content, either concerning the internal steel skulls (collected from the slag dumps) or purchased. Also, we visually appreciated the quality of the prepared scrap (E1, E2, E5, and E100) and the scrap originated from disposals, concerning the content of rust, nonferrous metals, soil, sand, etc.

Below, we graphically presented the obtained results, based on which we performed a technological analysis of the conducted research.

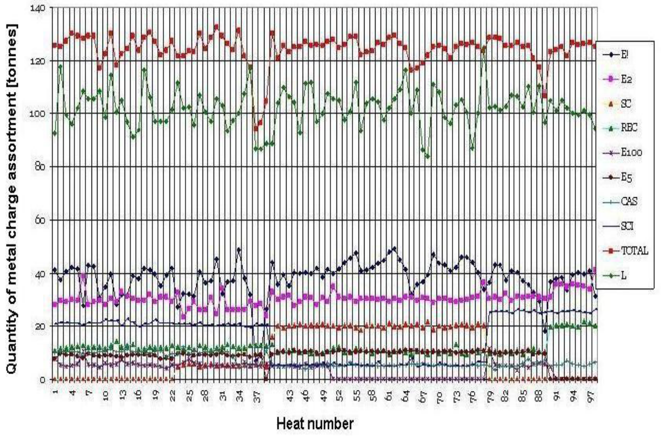

***Figure 1**. Variation of the EAF charge composition (EBT type)*

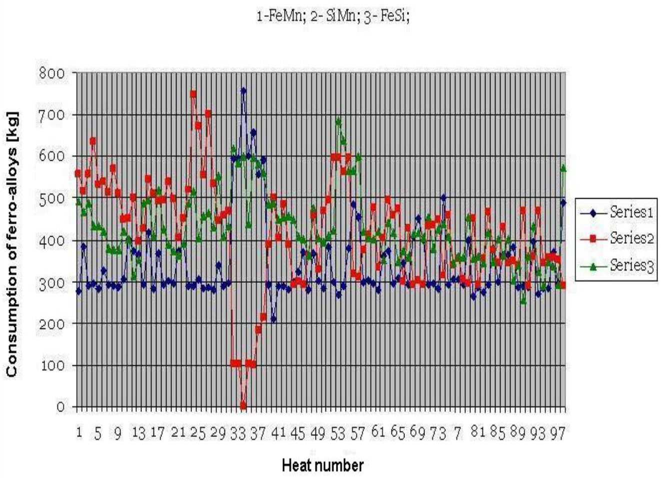

***Figure 2**. Variation of the ferroalloy amounts at tapping*

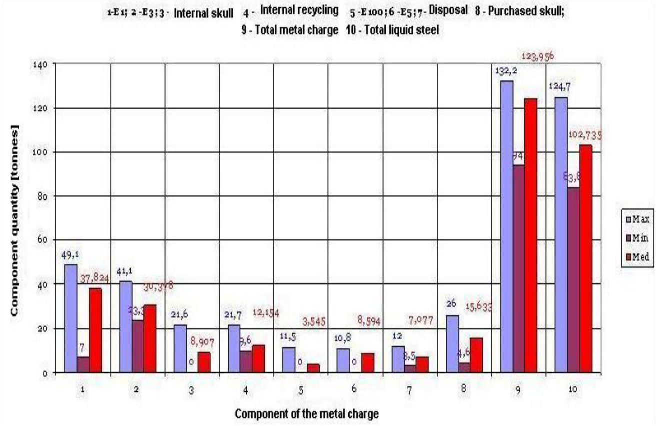

***Figure 3**. Variation limits of the metal charge components*

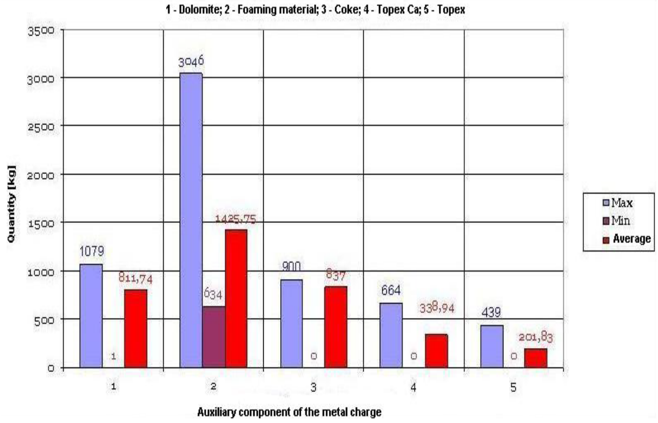

***Figure 4** . Variation limits of the auxiliary components in the metal charge*

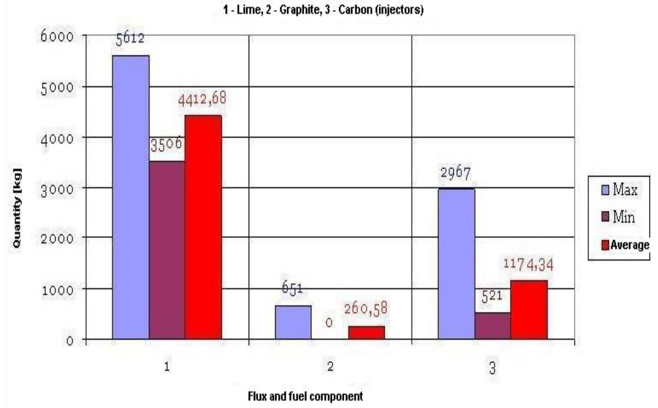

***Figure 5**. Variation limits of the non-metal components added during the steelmaking process*

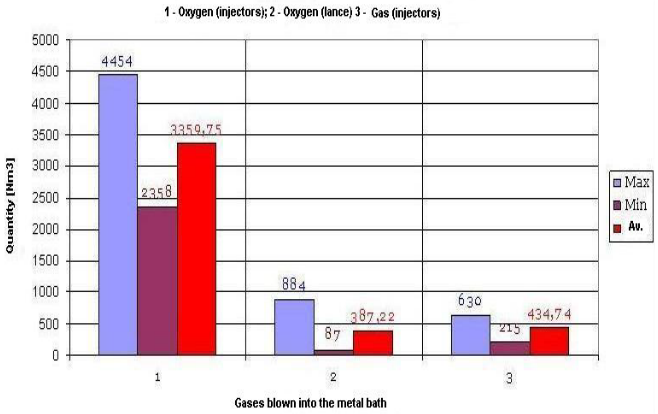

Figure 6 . *Variation limits of the gases injected into the liquid bath*

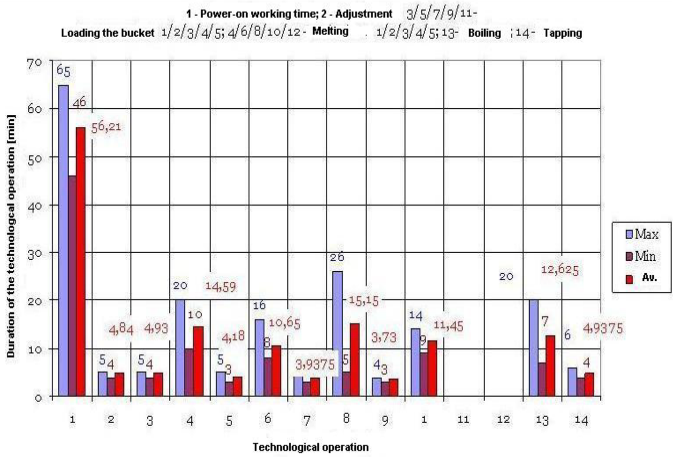

Figure 7. *Variation limits of the technological stages*

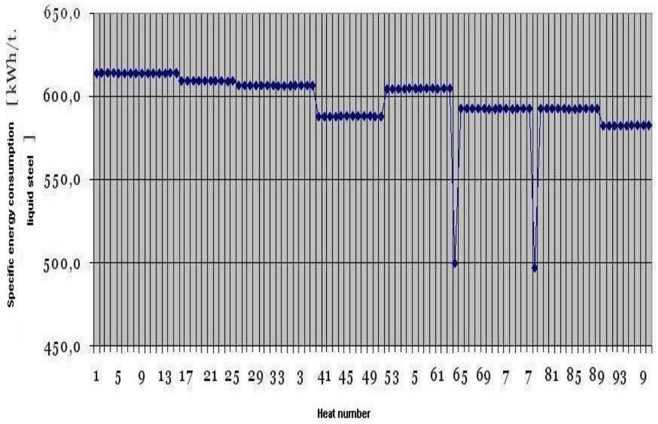

Figure 8 . *Variation of the specific consumption of electrical energy - distribution plot*

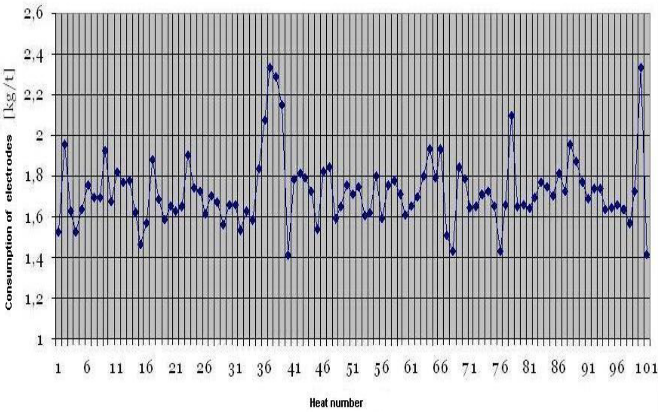

Figure 9. *Variation of the electrode consumption*

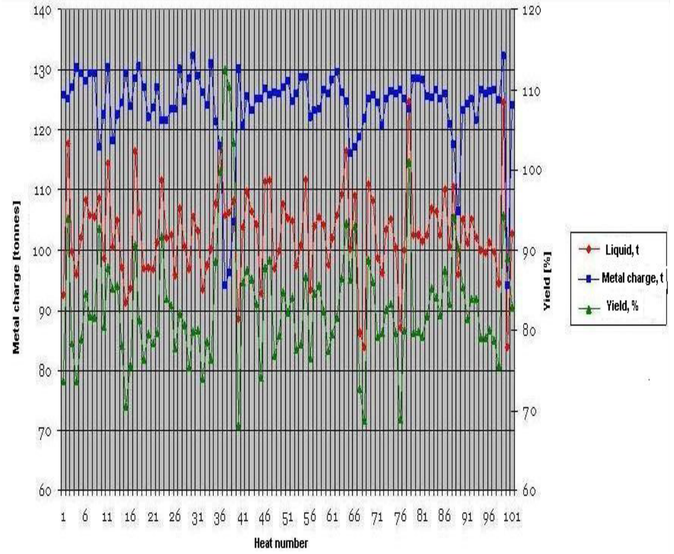

Figure 10. *Variation of the metal charge weight, liquid steel weight and yield*

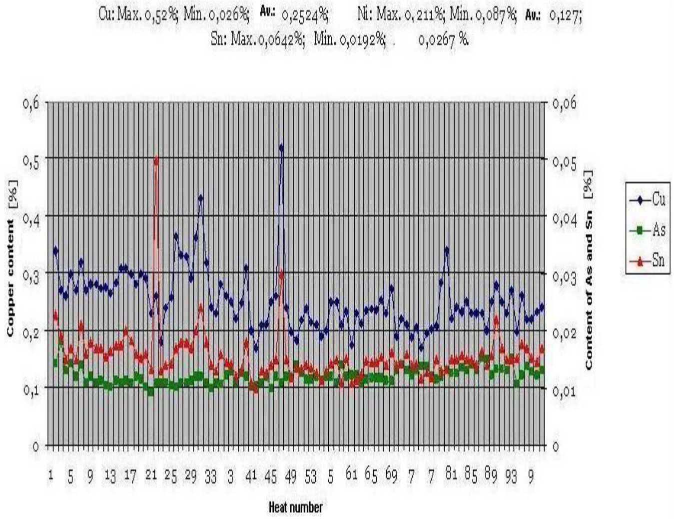
Cu: Max. 0,52%; Min. 0,026%; Av.: 0,2524%; Ni: Max. 0, 211%; Min. 0,087%; Av.: 0,127;
Sn: Max. 0,0642%; Min. 0,0192%; . 0,0267 %.

Figure 11. *Variation of trace elements (Cu, As, Sn)*

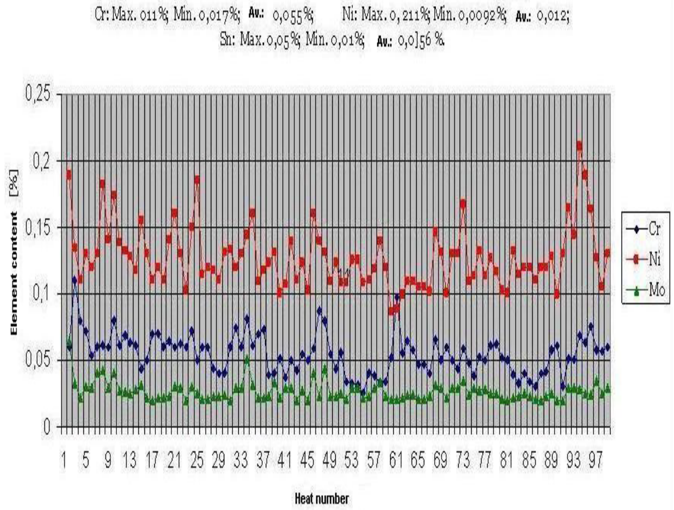
Cr: Max. 011%; Min. 0,017%; Av.: 0,055%; Ni: Max. 0, 211%; Min. 0,0092%; Av.: 0,012;
Sn: Max. 0,05%; Min. 0,01%; Av.: 0,0]56 %.

Figure 12. *Variation of trace elements (Cr, Ni, Mo)*

TECHNOLOGICAL ANALYSIS

The following technological aspects resulted from the technological analysis of the graphical charts presented in the figures 1-12:

- *Regarding the metal charge composition, the types of scrap E1 and E2 have the largest share in total metal charge (Figure 1 and*

Figure 2), their average being 38% and 30%, respectively; the variation of the scrap quantities, especially E1 and, to some extent, E2, is reflected in the variation of the total charge and yield;

- *Having in view the high level of scrap preparation, it is advisable that the quantity of these assortments to not fall below the average value (or their sum to not fall below the sum of their averages) - Figure 3;*
- *Regarding the internal skull consumption, it reached 21.6 tonnes/heat, with the remark that at some heats this was not a charge component, the average value being 8.91; in several cases, the skulls had high slag content, reason why this assortment have been rejected in some cases;*
- *Also, the consumption of purchased skulls (external) varied from 1.6 tonnes to 26 tonnes/heat, the average value being 15.63 tonnes/heat; in terms of quality, these skulls did not raise special problems;*
- *The scrap arising from internal recycling varied within wide limits, from 9.6 to 21.7 tonne/heat, its average value being 12.16 tonne/heat; this scrap assortment has a good quality, it is advanced prepared and comes from the whole technological process; when using this type of scrap, the chemical composition of the heat can be predicted within narrow limits;*
- *Regarding the scrap arising from disposals, its quantity did not exceed 12 tonne/heat, fact that is correct in principle, because the origin of the scrap is not precisely known and, therefore, it can bring Cr, Ni, and Mo in the analysed steel; these elements are considered tramp elements, and their percentage in steel should be limited;*
- *A particular attention should be paid to the components E5 and E100, because this assortment can bring non-ferrous materials (can be turnings mixed with non-ferrous alloys);*
- *The materials introduced in the metal charge (in bucket) varied within pretty wide limits, the only component present in every metal charge being the foaming material; the metal charges of some heats did not contain dolomites or other materials (Figure 4);*
- *The data presented in figures 5 and 6 show that the material additions made during the steelmaking process, although varied within wide limits, were well correlated with the metal bath composition;*
- *By analysing the data presented in Figure 7, we can see that there are real possibilities to reduce the period when the furnace is power supplied, the maximum duration being 65 min, minimum: 46 min, and average: 56 min; the reduction of the power supply duration leads to the reduction of electricity and electrodes consumption;*
- *Also, the analysis of the main technological stages durations (Figure 7) shows clearly the possibility of shortening the technological operations; by increasing the scrap processing level, we can achieve these requirements;*
- *Regarding the consumption of ferroalloys (Figure 2), we can see a wide variation, but the ferroalloys consumption is correlated with the metal charge and the liquid steel quantity; the ferro-manganese and ferro-silicon consumptions increase with the reduction of silico-manganese consumption;*
- *The electric energy consumption (Figure 8) varied from 582 to 614 kWh/tonne of liquid steel; if we take into account the yield, this can be considered a normal variation; an advance preparation of the metal charge leads to the reduction of the specific energy consumption;*
- *At 2 heats, the energy consumption was 497 and 503 kWh/tonne of liquid steel, respectively, explained by the fact that the furnace was completely emptied for repairing the hearth, and thus the quantity of liquid steel was larger;*
- *A significant variation was obtained at the specific consumption of electrodes (Figure 9), which varied within wide limits, from 1,41 to 2,36 kg/tonne of metal charge; this variation is due to the metal charge quality and the yield, whose values were sometimes low;*
- *From the data presented in Figure 10, are resulting very wide variations of the metal charge weight, liquid steel weight and yield, the main cause being the metal charge quality, i.e. the share of the non-metallic components in the assortment of the metal charge;*
- *the metal charge weight varied from 94 to 132.2 tonnes, the average being 124.18 tonnes; the liquid steel weight varied from 83.8 to 124.7 tonnes, the average being 102.70 tonnes; regarding the yield, the minimum value was 68.10 and the average was 82,95%;*
- *From the presentations shown in Figure 11, we can see that the trace elements Cu and Sn had wide variations, due to the use of light scrap containing food packaging and copper from various electrical equipments, the maximum limits being exceeded at 3 heats (at one heat the contents of Cu and Sn were exceeded, and at one heat only the content of Sn was exceeded), while the arsenic varied within quite narrow limits and did not exceed the maximum limit;*
- *Regarding the trace elements Cr, Ni, and Mo, which are alloying elements for the alloy steels, although the Cr and Ni contents had wide variations (especially the Ni content), the maximum limits were not exceeded.*

The analysis performed showed the influence of the metal charge structure and quality on the steelmaking process, and the justification for extending the results throughout the manufacturing process.

CONCLUSIONS

Synthesizing the research results, we can conclude the followings:

- *the electric arc furnace of EBT type is the most appropriate unit for processing scrap in order to obtain steel, both in terms of charge* quality and the number of scrap assortments introduced in the charge;

- the charge structure may vary within wide limits in terms of assortment, provided to be advanced prepared;
- the metal charge weight varied within wide limits due to the variation in the share of different assortments of scrap;
- the scrap assortment structure did not result in exceeding the content of trace elements that could lead to heat downgrading;
- the quality of scrap and skull is reflected in the yield;
- in practice, the charge quality is also determined by economic considerations, who are depending on the steel grade, which obviously varies from one steel plant to another.

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