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Influence of the steel scrap classes on the liquid steel output molten in electric steel processes

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Analysis and modelling

ABSTRACT

Purpose: This is why we have analysed in the paper, using statistical analysing methods, the influence of use in the electric arc furnace charges of steel scrap of different qualities on the index of liquid steel output from a melt.

Design/methodology/approach: The used research methodology consists in analytical simulation of variations in mass of liquid steel obtained from melts differing in steel scrap content in the metallic charge and statistical analyses of industrial results acquired from the corresponding process documentation (so called melt cards).

Findings: Basing on the analytical and statistical analyses carried out we have determine resulting variations in the liquid steel per melt ratios depending on the content of steel scrap in the metallic charge.

Research limitations/implications: The research results obtained can be utilized in each steelmaking facility, which employs the Electric Steelmaking process, in order to "design" the metallic charge compositions, having in view the quality and economic aspects.

Practical implications: The research results presented in the paper can be used for steel production of high purity steels.

Originality/value: The results presented in this paper are directed to the steelmakers employing the Electric Steelmaking process and constitute the authors' original study.

Keywords: Metallurgy; Liquid steel; Ferrous scrap; Electric arc furnace

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1. Introduction

The modern arc furnace used in steel production is, next to the oxygen converter, primary metallurgical aggregate. For the production of steel in the electric steel process are used pre-sorted steel and iron scraps. In the electric furnace it constitutes 100% mass of the metallic charge [1-9]. Due to a variety of the factors most commonly used is called post-amortized scrap, consisting of a very different form. Assignment to a particular class of metal scrap is extremely important, because of the need for appropriate collation of the charge, thus guaranteeing the best conditions for melting the scrap in the electric arc furnace and it's faultless service.

2. Characteristics of the charge for electric steel processes

Currently in Poland dominate two steel making technologies. The first technology realized in the so-called integrated steel works, consists in melting of pig iron in blast furnaces and reworking it in oxygen converters into steel with the participation of ferrous scrap. The second steel-making technology is carried out entirely based on ferrous scrap, in steelworks equipped with electric arc furnaces. Charge constitutes ferrous scrap, mainly post-amortized (often in steel industry referred to as trading ferrous scrap), circulating scrap arising at different stages of steel production and metallurgical steel self products (from individual departments of the steelwork) and post-production scrap (ferrous scrap, which arise in the steelwork processing of steel products). Thanks to this process is much less energy consuming compared to steel's manufacturing process in integrated steelworks in the blast furnace system – basic oxygen furnace, simultaneously playing an important role in the recycling of scrap metal [9]. In the electric steel process different grades of steel are produced, from the "normal" carbonic to the high alloyed. In case of carbon steel production used post-amortized ferrous scrap with chemical composition containing very little alloy additions. In such processes the selection of the charge in terms of chemical composition of materials is not as significant, but the choice of form and scrap's lumpiness determine the effectiveness of the process. In the manufacture of alloy steels collation of the input materials in chemical composition is as important as it's lumpiness. The production of such steels can be carried out with the use of mild-alloy metal scrap and additions in the form of ferro-alloys and technically pure metals or using the alloy scrap with small additions of needed metal. Determined by economic factors. Scrap used in the electric steel process must be pre-prepared and sorted. Deploy: scissor press' cutting, burning, shredding, binding and packing. Preparation of ferrous scrap in terms of chemical composition is carried out according to the Polish Standard [PN-85/H-15000] [10]. It applies to alloyed and unalloyed ferrous scrap, production waste, post-amortized scrap, post production waste and defines batch and non-batch waste.

3. Determination of yield of liquid steel from melting in an electric arc furnace indicator

Metallic charge in the smelting of steel in electric arc furnace constitute completely ferrous scrap, which initially will be classified according to classes.

The mandatory procedure in the final stage of the technological process of steel making is the preliminary deoxidation of the metal bath – made mostly during tapping by appropriate ferroalloys.

Iron from the ferroalloys increase the mass of liquid steel in each smelting.

That is why the charge should also include metallic ferroalloys used and to determine the yield indicator of liquid steel from smelting, the "iron-giving" part of ferroalloys.

Examined indicators: the yield of liquid steel WU (%) and participation in the charge of scrap grades smelting (%) will be defined by the formula [11, 12]:

$$W_U = \frac{M_{CS}}{M_{W1} + M_{W2} + M_{W5} + M_{W14} + \frac{1}{3} M_{FS}} \cdot 100\% \tag{1}$$

$$Z_{W_1} = \frac{M_{W1}}{M_{W1} + M_{W2} + M_{W5} + M_{W14} + \frac{1}{3} M_{FS}} \cdot 100\% \tag{2}$$

$$Z_{W_2} = \frac{M_{W2}}{M_{W1} + M_{W2} + M_{W5} + M_{W14} + \frac{1}{3} M_{FS}} \cdot 100\% \tag{3}$$

$$Z_{W_5} = \frac{M_{W5}}{M_{W1} + M_{W2} + M_{W5} + M_{W14} + \frac{1}{3} M_{FS}} \cdot 100\% \tag{4}$$

$$Z_{W_{14}} = \frac{M_{W14}}{M_{W1} + M_{W2} + M_{W5} + M_{W14} + \frac{1}{3} M_{FS}} \cdot 100\% \tag{5}$$

$$Z_{FS} = \frac{M_{FS}}{M_{W1} + M_{W2} + M_{W5} + M_{W14} + \frac{1}{3} M_{FS}} \cdot 100\% \tag{6}$$

where: W_U – yield of liquid steel from smelting , %;
M_{CS} – mass of liquid steel from smelting, Mg;
M_{W1} –share of W_1 class scrap in the metal charge , %;
M_{W2} – share of W_2 class scrap in the metal charge , %;
M_{W5} – share of W_5 class scrap in the metal charge , %;
M_{W14} – share of W_{14} class scrap in the metal charge , %;
M_{FS} – ferroalloys' mass (FeMn, FeSi), Mg.

The tests were performed in March 2009 in one of the domestic mills that had electrical steel-melting shop on a group of 400 randomly selected heats on the basis of heats' technical documentation. The documentation contains detailed data on the heats made in electric arc furnace with a capacity of 30 Mg. The analysis aims to identify correlation between the charge (unalloyed batch scrap and ferroalloys) and the yield of liquid steel from the smelting. The analysis was performed for 7 classes of ferrous scrap, and in this case study were presented as an example the influence of four classes of scrap W_1, W_2, W_5, W_{14}, and ferroalloys (introduced as a deoxidizers).

To research the impact of W_1 class scrap analysed data of 29 heats, which had above named scrap class. These have been analysed using regression and linear correlation method. Directional indicator of the direct regression of a = 0.4438 means that the higher the weight of W_1 unalloyed batch scrap in the charge with yield of the steel indicator of 1% will grow and change it's value by ~ 0.44%. Analysis results are presented in graphical form in

Figure 1, where the determined theoretical values form a line with an upward trend. Analysing the R factor and taking into account the n sample quantity can be concluded that the relationship between the yield of liquid steel and mass of W_1 class ferrous scrap is the largest among the researched classes of scrap. In this case, the entire sample of 29 casts, 43%, or about 12 casts meet accepted linear relationship. Taking into consideration that the directional coefficient and correlation coefficient have the same positive sign should be noted that with the increase of the W_1 class ferrous scrap share in an electric arc furnace's metallic charge the yield of liquid steel from smelting increases. To study the influence of W_2 class scrap analysed data of 390 heats, which had above named scrap class. Directional indicator of the direct regression of a = 0.0212 means that the higher the weight of W_2 unalloyed batch scrap in the charge with yield of the steel indicator of 1% will grow and change its value by ~ 0.02%. Results of the analysis are presented in graphical form in Figure 2, where the determined theoretical values form a line with an upward trend.

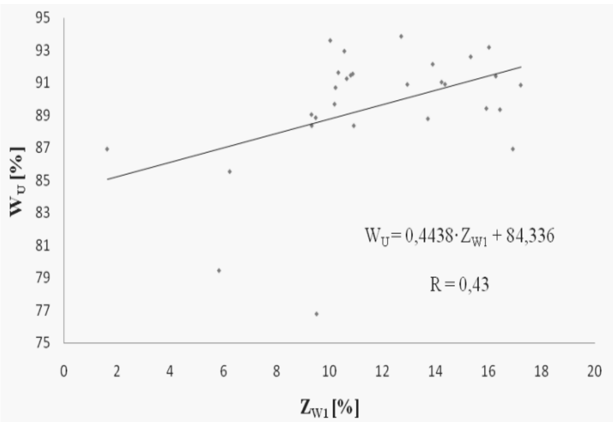

Fig. 1. The dependence of the liquid steel output obtained from a melt on the W_1 quality scrap share in a furnace metallic charge

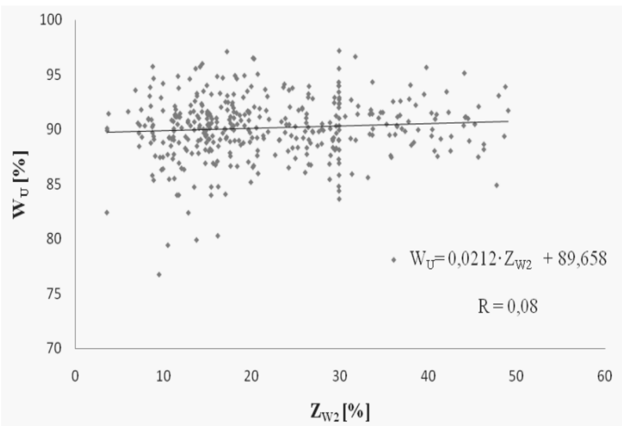

Fig. 2. The dependence of the liquid steel output obtained from a melt on the W_2 quality scrap share in a furnace metallic charge

Analysing the R factor, taking into account the sample quantity can be stated that the relationship between the analysed features that is yield of liquid steel from the smelting, and the mass of the W_2 class ferrous scrap is very weak. In the analysed case from total number of casts – 390 only, 8%, or about 31 casts meet accepted linear relationship. Taking into consideration that the directional coefficient and correlation coefficient have the same positive sign should be also noted that the increase of the W_2 class ferrous scrap share in charge the yield of liquid steel from smelting increases.

To test the influence of W_5 class scrap analysed data of 326 heats, which had above named scrap class. Directional indicator of the direct regression of a = 0.0258 means that the higher the weight of W_5 unalloyed batch scrap in the charge with yield of the steel indicator of 1% will grow and change its value by ~ 0.03%. Results of the analysis are presented in graphical form in Figure 3.

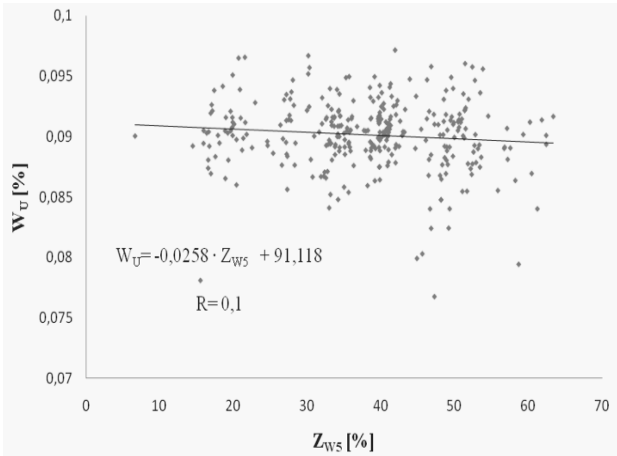

Fig. 3. The dependence of the liquid steel output obtained from a melt on the W_5 quality scrap share in a furnace metallic charge

The determined theoretical values have an downward trend. Analysing the R factor and taking into account the sample quantity can be stated that the relationship between the analysed features that is yield of liquid steel from the smelting, and the mass of the W_5 class ferrous scrap is very weak. In the analysed case from total number of casts – 326 only, 10%, or about 32 casts meet accepted linear relationship. Based on the analysis can be concluded that the growth in the share of W_5 class ferrous scrap in the metallic charge tends to slightly decrease the yield of steel smelting. To test the influence of W_{14} class scrap analysed data of 198 heats, which had above named scrap class. Directional indicator of the direct regression of a = 0.0119 means that the higher the weight of untypical W_5 batch scrap in the charge with yield of the steel indicator of 1% will grow and change its value by ~ 0.01%. Results of the analysis are presented in graphical form in Figure 4.

The determined theoretical values form a line and have an upward trend. Taking into account the sample quantity can be stated that the relationship between the analysed features that is yield of liquid steel from the smelting, and the mass of the W_{14} class ferrous scrap is quite strong. In the analysed case from total number of casts – 198 only, 1%, or about 2 casts meet accepted linear relationship. Taking into consideration that the directional coefficient and correlation coefficient have the same positive sign should be also noted that the increase of the W_{14} class ferrous scrap share in metallic charge the yield of liquid steel from smelting increases, but this increase is small enough to tell rather only about the upward trend.

The impact of the mass of ferroalloys in the metallic charge for yield of liquid steel from smelting analysed data of 396 heats, which were introduced as a deoxidizer ferroalloys. Directional indicator of the direct regression of a = 0.9003 means that the higher the weight of W_{FS} ferroalloys in the metallic charge, the yield of the steel indicator will grow and change its value by ~ 0.9%. Results of the analysis are presented in graphical form in Figure 5. The determined theoretical values form a line and have an upward trend. Analysing the R factor, taking into account the n sample quantity can be stated that the relationship between the analysed features that is yield of liquid steel, and the mass of the W_{FS} ferroalloys is quite strong. In the analysed case from total number of casts - 396 only, 5%, or about 20 casts meet accepted linear relationship.

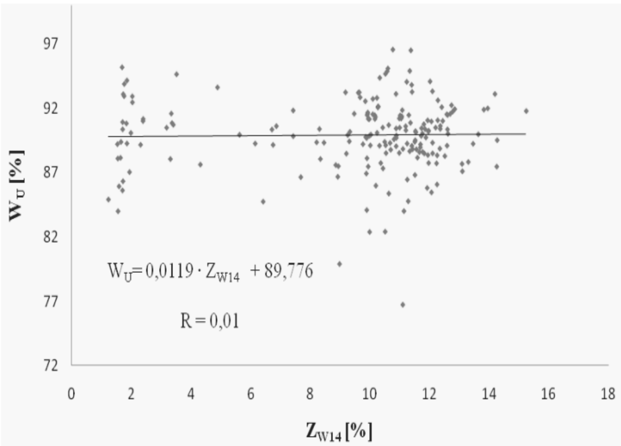

Fig. 4. The dependence of the liquid steel output obtained from a melt on the W_{14} quality scrap share in a furnace metallic charge

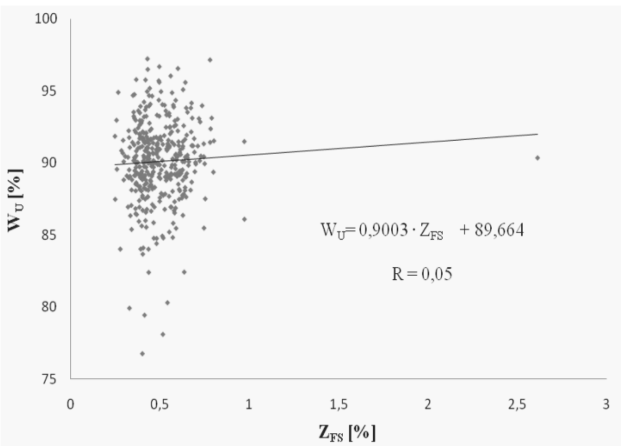

Fig. 5. The dependence of the liquid steel output obtained from a melt on the ferroalloys – deoxidizers in a furnace metallic charge

Taking into consideration that the directional coefficient and correlation coefficient have the same positive sign should be noted that the increase of the ferroalloys share in metallic charge the yield of liquid steel increases.

4. Summary and conclusions

Improvements and modernization of the steel making process inteoduced in the last decades caused that at the present time, electric arc furnaces are treated as high performance units for melting metal and ladle furnaces treated as the steel unit satisfying a number of metallurgical purposes, among others, modification of non-metallic inclusions, regulation of temperature, chemical composition, which combined with the line for continuous casting is the production system of specific semi0finished steel with no surface and internal defects, and treated with pre0forming operations. These solutions have led to significant improvement in process efficiency, increase productivity and reduce the cost of steel production. Based on the analysis of ferrous scrap class effect on the yield of molten steel in electric arc furnace the following conclusion can be formulate:

1. the use of non-alloy scrap input (W) in the electric process in technological terms of analysed steelwork has no significant effect on the formation of the yield of liquid steel from the melt indicator,
2. the greatest impact on the yield of liquid steel from melting of the analysed scrap classes has W_1 scrap class,
3. the only one having a negative effect on the yield of liquid steel from melting in electric arc furnace is W_5 class scrap, the result is puzzling, because the quality of the scrap should affect the increase of the yield,
4. ferroalloys added at the end of the process, used as a deoxidizers and to complement the chemical composition of the melt, which goes without saying, have the greatest impact on the yield of liquid steel from melting indicator of all the metallic components of the charge, because they contain in their composition 30% of Fe (it does not happen to oxidize).

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