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THE INFLUENCE OF FERROUS SCRAP'S GRADE ON THE YIELD OF STEEL SMELTED IN AN ELECTRIC-ARC FURNACE (EAF)

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In the paper there is presented a statistical analysis of the influence of various quality classes and the amount of scrap in steel charges on the rate of liquid steel yield from the electric arc furnace (EAF). The research methodology involved the analytical simulation of changes in the liquid mass of steel acquired from melts with different scrap content and statistical analysis of data obtained from the correlating process documentation (so-called melting sheets) under industrial conditions. The attained results may be employed in any steel mill that uses electrical steelmaking processes, to design the composition of a metal charge while bearing in mind the qualitative and economic aspects.

Keywords: steel, EAF, ferrous scrap, ferroalloys, statistical analysis

INTRODUCTION

The modern arc furnace is, alongside the converter, the primary metallurgical aggregate used in steelmaking. The EAF process uses only pre-sorted steel and iron scrap as the metallic charge [1-3]. Mostly only the post-production scrap is used. Scrap is classified into different classes which is particularly important for the appropriate collation of the charge that guarantees best conditions of melting in the EAF and its faultless operation.

Because of the mandatory deoxidation procedure in the final stage of the EAF process the appropriate ferroalloys are added (mostly during tapping) to the liquid metal. Iron in the ferroalloys increase the effective mass of steel produced in the process. Because of that the addition of ferroalloys to the charge should be taken into consideration during determination of the yield indicator of liquid steel from melting as the „iron-giving" constituent of ferroalloys. The yield indicator Y_L and the indicators of participation in the charge for different grades of scrap Z_{Wi} and ferroalloys Z_{FS} are calculated using the formulae [4-8]:

$$Y_L = \frac{M_{LS}}{M_{W2} + M_{W4} + M_{W8} + M_{WZE1} + \frac{1}{3}M_{FS}} \cdot 100\ \% \quad (1)$$

$$Z_{Wi} = \frac{M_{Wi}}{M_{W2} + M_{W4} + M_{W8} + M_{WZE1} + \frac{1}{3}M_{FS}} \cdot 100\ \% \quad (2)$$

$$Z_{FS} = \frac{M_{FS}}{M_{W2} + M_{W4} + M_{W8} + M_{WZE1} + \frac{1}{3}M_{FS}} \cdot 100\ \% \quad (3)$$

where: Y_L – yield of liquid steel from melting / %
M_{LS} – mass of liquid steel from melting / Mg
M_{Wi} – share of W_i class scrap in the metal charge / %
M_{ZE1} – mass of scrap iron / Mg
M_{FS} – ferroalloys mass (FeMn, FeSi) / Mg
W_2, W_4, W_8, W_{ZE1} – class of scrap.

ANALYSIS OF INDUSTRIAL DATA

The analysis was performed on the group of 200 randomly chosen heats from the domestic steel mill which use the electric arc process. The data was acquired from technical documentation of selected heats manufactured in the EAF of the 150 Mg capacity. The main aim of the examination was to identify the correlation between the charge composition (unalloyed scrap and ferroalloys) and the yield of liquid steel from the melting. This paper presents the study of influence of four classes of scrap W_2, W_4, W_8, W_{ZE1} (scrap iron), and ferroalloys (introduced as a deoxidizers).

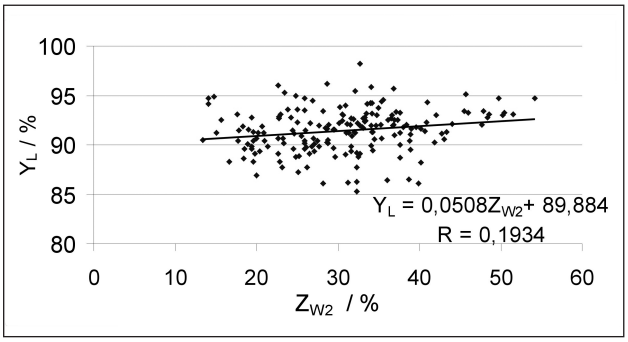

Figure 1 The impact of the share of W_2 scrap on the liquid steel output

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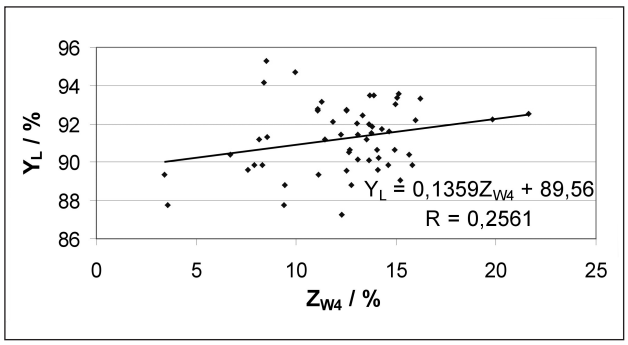

Figure 2 The impact of the share of W4 scrap on the liquid steel output

To assess the impact of W_2 class scrap the melt cards of 188 heats were analyzed using regression and linear correlation method. The directional indicator of the direct regression of a = 0,0508 means that when the weight of W_2 unalloyed batch scrap in the charge is higher the yield of the steel indicator of 1 % will increase and change its value by ~ 0,05 %. The study of the R factor which also takes into account the n sample quantity shows that the relationship between the yield of liquid steel and mass of W_2 class ferrous scrap is the strongest among examined classes of scrap. From the group of 188 heats up to 19 % met accepted linear relationship (approx. 36 melts). Taking into account the positive sign of both directional coefficient and correlation coefficient, it can be stated that with the increase of the W_2 class ferrous scrap share in the charge the yield of liquid steel from melting will increase.

For the assessment of the impact of W4 class scrap the data of 55 heats was analyzed using regression and linear correlation method. The directional indicator of the direct regression of a = 0,135 means that when the weight of W_4 unalloyed batch scrap in the charge is higher the yield of the steel indicator of 1 % will increase and change its value by ~ 0,14 %. Analysis of the R factor which also takes into account the n sample quantity shows that the relationship between the yield of liquid steel and mass of W_4 class ferrous scrap is very weak. From group of 55 heats only 26 % met accepted linear relationship (approx. 14 melts). As in case of W_2 class scrap, the indicators show that the yield will increase with the rise of W_4 share. The results of the assessment of influence of W_2 and W_4 scrap are presented in Figures 1 and 2 with the increasing trend marked by the straight line.

To assess the impact of W_8 class scrap the melt cards of 95 heats were analyzed. The directional indicator of the direct regression of a = 0,0539 means that when the weight of W_2 unalloyed batch scrap in the charge is higher the yield of the steel indicator of 1 % will rise and change its value by ~ 0,05 %. The obtained values show the decreasing trend. The analysis also shows that the relationship between the yield of liquid steel and mass of W_8 class ferrous scrap is very weak – from the total of 95 heats only 15 % met accepted linear relationship (approx. 14 melts). Results show that the increase in the share of W_8 scrap tends to slightly decrease the yield.

In case of W_{ZE1} scraps iron the data of 156 heats was analyzed. Indicator a = 0,4168 shows that with the increase in share of untypical W_{ZE1} batch scrap in the charge the yield of the steel indicator of 1 % will be also higher and change its value by ~ 0,40 %. The theoretical values in both cases form a line and show an upward trend. Taking into consideration the size of test sample it can be concluded that relationship between the share of W_{ZE1} and the yield is fairly weak. From group of 156 heats only 26 % met accepted linear relationship (approx. 41 melts).

The positive signs of directional and correlation coefficients show that with the growth in share of W_{ZE1} scrap the yield will also increase, but this rise is so small that it only indicates an upward trend.

Graphical representation of results for W_8 and W_{ZE1} scrap classes with the relevant trend lines are shown in Figures 3 and 4.

To examine the impact of the ferroalloys the data of 190 heats in which ferroalloys were introduced as a deoxidizer, were analyzed.

Directional indicator of the direct regression of a = 1,1711 means that with the increase of W_{FS} ferroalloys mass in the charge, the yield of the steel indicator will grow and change its value by ~ 1,17 %. The determined theoretical values form a line with an upward trend.

Analyzing the R factor, taking into account the n sample quantity, it can be stated that the relationship between the examined features, that is yield of liquid

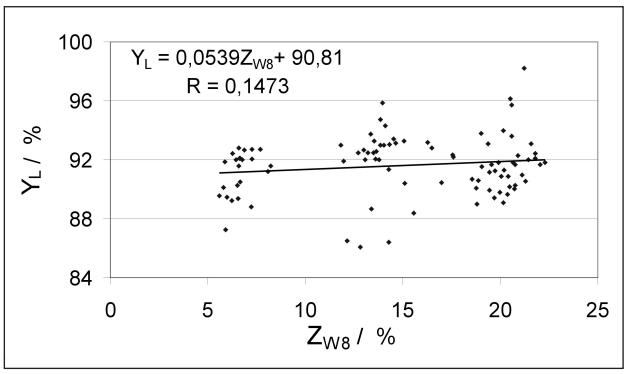

Figure 3 The impact of the share of W8 scrap on the liquid steel output

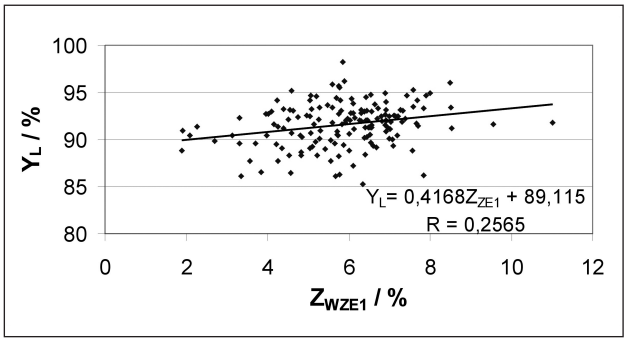

Figure 4 The impact of the share of WZE1 scrap on the liquid steel output

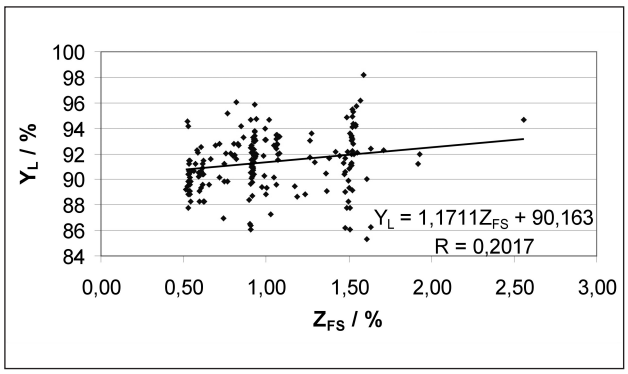

Figure 5 The impact of the ferroalloy deoxidizers on the liquid steel output

steel from the melting and the mass of the W_{FS} class ferrous scrap, is very high. From total number of casts – 190, 20 % met the accepted linear relationship (approx. 38 melts). Taking into account that the directional and correlation coefficients have the same positive sign, it can be stated that the addition of the ferroalloys increase the yield of liquid steel.

Results of the analysis considering the addition of ferroalloys to the liquid steel are presented graphically in Figure 5 with an upward trend indicated by the straight line.

SUMMARY AND CONCLUSIONS

Presented analytical data enables to conclude the following:

– among the different scrap classes the greatest impact was observed for the W_4 and W_{ZE1} classes,
– usage of non-alloyed scrap in the electric process has no significant impact on the yield of liquid steel from the melt;
– ferroalloys (used as deoxidizers and to supplement the chemical composition of the melt) added at the end of the process have very strong impact on the yield of liquid steel because they contain 30 % non-oxidized Fe.

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Note: The responsible translator for English language is M. Mitas, Katowice, Poland