Contributions to steel semi-finished parts quality improvements

A Socalici¹, E Popa¹, T Heput¹ and V Puţan¹

¹Engineering and Management Department, Polytechnic University of Timisoara, 5 Revolutiei Street, Hunedoara, 331128, Romania

E-mail: virginia.socalici@fih.upt.ro

Abstract. The quality of finite steel products depends on steel content of hydrogen. On steel elaboration, in order to remove the dissolved hydrogen, at least one ladle secondary treatment is needed. The paper introduces the results obtained in the increase of hydrogen removal output, during steel secondary treatment inside the LF installation. Correlations were established between the hydrogen removal rate and the parameters of the secondary treatment (bubbling flow, bubbling time and bubbling pressures).

1. Introduction

Practically, during the usual elaboration, the hydrogen content of steel frequently varies between 1.8 – 10 ppm, and if the steel is the subject of the secondary treatment and vacuum casting metallurgy, the content of hydrogen is of maximum 1.8 – 2.2 ppm [1].

The main sources from which the hydrogen can turn into steel in liquid condition are: the metallic load and all the other materials used in the elaboration and casting, refractory materials, cooled elements of the oven and of installations for the treatment of liquid steel, humidity of the atmosphere in which one works, etc. The content of hydrogen must be limited in steel because it has negative effects on the semi-finished or on the finished products [4].

The negative influence of the hydrogen in steel can be observed in the following [2]:
- is one of the causes of breaths in steel ingots and castings of calm steels;
- contributes to the defect called "flakes" (tiny cracks) in steels alloyed with chromium and nickel, which substantially reduce the fatigue strength of steel parts;
- reduces the plasticity and tenacity of steel;
- affects the electrical and magnetic properties of the steels.

2. Experimental Research

The industrial experimentations regarding the influence of the slag characteristics on the hydrogen removal efficiency were performed on a technological flow of processing the steel made of an electric arc furnace, EBT type of 100 t capacity, LF installation and continuous cast installation with 5 wires.

At the secondary treatment of the steel in the LF installation the argon bubbling of the metallic bath takes place and also the addition for correcting the chemical composition and for deoxidation and desulphuration as well as the additions for reducing slag formation (lime, bauxite). The duration of the secondary treatment of the steel is 50-90 minutes, required by the timing with the continuous cast installation [3, 4]. To determine the hydrogen removal efficiency, samples of hydrogen were taken, before the insertion of the steel ladle in the LF installation and at the end of the treatment.
To underline a multiple influence of the technological agents on the hydrogen removal efficiency, I processed the data in the MATLAB programme and the results obtained are presented in a graphical manner. The surface regression equation (1st and 2nd degree) regarding the hydrogen removal efficiency ($\eta_H$), bubbling pressures ($P_b$), bubbling flow ($D_b$) and bubbling time ($T_b$) is:

$$\eta_H = -0.05D_b + 12.43P_b + 20.02$$  \hspace{1cm} (1)

Correlation coefficient: $R = 0.38$. Deviation from the regression surface: $S = 7.76$.  

$$\eta_H = -0.005D_b^2 + 0.02D_bP_b - 80.02P_b^2 + 5.59D_b + 699.44P_b - 3081.35$$   \hspace{1cm} (2)

Correlation coefficient $R = 0.92$. Deviation from the regression surface: $S = 3.25$. Point of maximum: $P_b = 4.48$; $D_b = 555.39$; $\eta_H = 55.39$.

$$\eta_H = 13.7818P_b + 0.11301T_b - 24.3727$$ \hspace{1cm} (3)

Correlation coefficient: $R = 0.92$. Deviation from the regression surface: $S = 7.76$.  

$$\eta_H = -0.005P_b^2 + 0.02P_bT_b - 0.009T_b^2 + 589.37P_b + 1.31T_b - 1324.45$$ \hspace{1cm} (4)

Correlation coefficient: $R = 0.92$. Deviation from the regression surface: $S = 2.49$. Point of maximum: $P_b = 4.49$; $T_b = 88.12$; $\eta_H = 55.06$.

$$\eta_H = 0.09 \cdot T_b - 0.05 \cdot D_b + 68.11$$ \hspace{1cm} (5)

Correlation coefficient: $R = 0.25$. Deviation from the regression surface: $S = 8.12$.  

$$\eta_H = -0.004T_b^2 - 0.002T_bD_b - 0.008D_b^2 + 2.32T_b + 9.41D_b - 2688.05$$ \hspace{1cm} (6)

Correlation coefficient: $R = 0.92$. Deviation from the regression surface $S = 3.25$. Point of maximum: $T_b = 86.12$; $D_b = 560.42$; $\eta_H = 56.17$.

The surface regression is presented in Fig.1-6.

---

**Figure 1.** $\eta_H = f(D_b, P_b)$ – correlation of grade 1

**Figure 2.** $\eta_H = f(D_b, P_b)$ – correlation of grade 2
Figure 3. $\eta_{hi} = f(T_b, P_b)$ – correlation of grade 1

Figure 4. $\eta_{hi} = f(T_b, P_b)$ – correlation of grade 2

Figure 5. $\eta_{hi} = f(T_b, D_b)$ – correlation of grade 1
3. Conclusions

The analysis of the double correlations expressed analytically and graphically leads to the following conclusions:

- The variation of the independent parameters within technological limits determines for the dependent parameter a variation that also ranges within the technological parameters, which places it on a regression surface or in its vicinity, considering the standard dispersion, deviation and error;

- By intersecting the correlation surfaces with level planes, level curves were obtained, which allowed the determination of the variation limits for the independent parameters, in order to obtain a certain value for the dependent parameter. For each graphical representation, the sub-domains were shown (hatched A, B) for which the values for the dependent parameter should be found, which determines in fact the variation limits for the independent parameters;

- The analysis of the diagrams allows the establishment of the values for bubbling duration, argon flow rate and pressure on bubbling, so that the projection of the correlation surfaces should range within the hatched surface A, thus obtaining almost maximum values for the output of hydrogen removal.

References

[1] Nica G, Socalici A, Ardelean E and Hepuț T 2003 Technologies to improve the quality of steel (Timisoara: Mirton) p 48

[2] Hepuț T, Ardelean E and Kiss I 2005 Some influence of the chemical composition upon the viscosity of synthetic slags used in continuous steel casting Rev. Metal. Madrid 41 220

[3] Dragoi F, Socalici A, Hepuț T and Popa E 2012 Researches on the influence of the slags formed in the instalation on the hydrogen removal efficiency Rev. Metal. Madrid 47 477

[4] Dragoi F 2012 Researches regarding the reduction of the gas content from the steels produced and treated on the EBT-LF technological flow (Timisoara: PhD Thesis, Politehnica University of Timisoara) pp 85