ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering

Tome XII [2014] – Fascicule 4 [November]
ISSN: 1584-2673 [CD-Rom, online]

a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara

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THE INFLUENCE OF RESIDUAL ELEMENTS UPON THE HARDNESS OF THE BRAKE SHOES MADE OF SULFUROUS CAST IRON

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Abstract: The paper introduces the influence of the residual chemical elements in the structure of phosphorous cast iron used in making brake shoes meant for the tractive or trailing rolling stock, upon its hardness. The results express the dependency residual elements - hardness and allow the determination of the optimal variation domains of the parameters under question so that they should meet as closely al possible the quality requirements for the brake shoes meant for the rolling stock.
Keywords: elaboration, cast, pig iron, braking shoes, rolling stock

1. INTRODUCTION

The criteria of assessing the rail braking shoes are the following [1]: the stability of the braking paths; lowest possible specific wear; highest possible thermal load capacity; lowest possible break sensitivity; low sparking tendency.

Brake blocks (Figure 1) are made of cast iron second fusion. The iron casting process is carried out as required clogs provider must comply with the specifications nr.1/SFMR/SDT/2000 [1].

The molten (second fusion) pig iron used in casting brake shoes can be elaborated in three types of facilities: cupola furnaces, electric arc furnaces and electric induction furnaces.

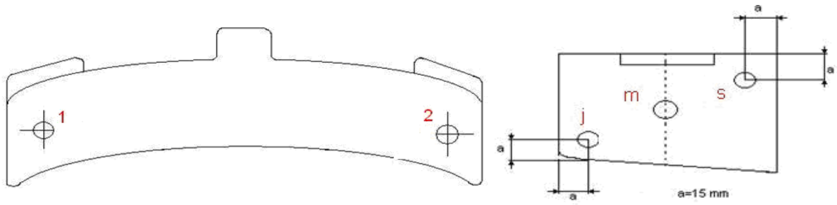
Figure 1. Phosphorous cast iron brake blocks [2]

The facility is chosen according to economical and environmental criteria. The facilities most frequently used in casting brake shoes are the electric induction furnaces that have the advantage of a swift charge melting and the possibility of controlling the composition of the pig iron. Besides, the energy consumption of an induction furnace is about 450 KWh/tone of molten pig iron [3-5].

2. SCIENTIFICAL RESEARCH

The charge for pig iron elaboration can be structured as follows [3,4]: 5-25% first fusion pig iron; 30-60% pig iron scrap; 40…70% steel scrap. The dimensional preparation of the charge plays a particular role in the elaboration in induction furnaces, namely the charge has to be ground into pieces whose size depends on the dimension and capacity of the furnace. The furnace is charged periodically, with the help of cups, which grants continuous melting and minimum consumption of energy. In the case small size metal scrap is used (lathe chips and splinters) they have to briquetted (pressed) or ground, which grants a continuous loading, by means of a conveyor. In order to avoid the appearance of gas during the charge melting process, it has to be previously washed with degreasing chemical solutions.

By increasing the content of phosphorous in the pig iron, the phosphorous eutectic P – Fe_3P – Fe_3C (steadite) is formed in its structure [6,7]. This eutectic melts at the high temperatures generated by braking and occupies the space formed at the limit of austenite grains, favoring a better contact wheel-braking shoe and a higher friction coefficient, which increases the efficiency of the braking.
The chemical elements existing in the structure of the material can have a different impact upon the crystallizing.
The researches that are being done are going to establish the influence of the chemical elements in the structure upon the physical and mechanical characteristics of the braking shoe material. In order to achieve this, the chemical structure and the physical and mechanical characteristics were analyzed for 25 charges of P10 phosphorous pig iron, elaborated in a trading company.
An important characteristic with a significant influence upon the useful life of brake shoes if hardness. Hardness is tested according to SR EN ISO 6506-1:2006. Hardness is measured at the extreme points of the brake shoe (1 and 2 – Fig.2.a), on its front and at three points located diagonally (s, m and j – Fig.2.b). The brake shoe must have on its lateral surface, as well as on the cross section, a Brinell hardness ranging within 197-225HB [2].



a. shoe b. sample
Figure 2. Sampling areas hardness shoe [2]

The experimental data related to the influence of the chemical structure upon the mechanical hardness characteristics have been processed in Matlab and the results are given in graphical and analytical form in figure 3 – figure 9.

3. EXPERIMENTS AND RESULTS

The processed data resulted in 2nd degree correlation equations between hardness (HB_1, HB_2, HB_s, HB_m, HB_j respectively the means for the shoe surface $(HB_1+HB_2)/2$ and for its cross section $(HB_s+HB_m+HB_j)/3$ – dependent parameters) and the elements present in the chemical composition (P and residual elements – independents parameters). Residual elements present in the chemical composition of pig iron are: Cr, Mo, Ni, Nb, V, W. The amount of residual elements is denoted by R. Correlation equations for hardness variation (HB_1) depending on the content of phosphorus and residual elements are:

$$HB_1 = -671.3 \cdot P^2 - 308.6 \cdot R^2 + 611.5 \cdot P \cdot R + 1082.4 \cdot P - 437.1 \cdot R - 216.2 \quad (1)$$

Correlation coefficient: $R^2 = 0.66$.
Point of maximum: P= 0.88%; R=0.16%, HB_1=224.74HB

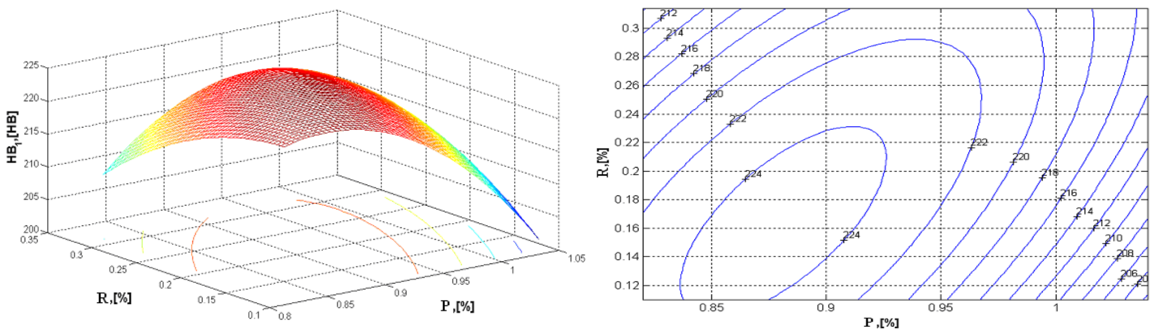


Figure 3. HB_1= f (P, R)

Correlation equations for hardness variation (HB_2) depending on the content of phosphorus and residual elements are:

$$HB_2 = -667.1 \cdot P^2 + 152.9 \cdot R^2 - 172.8 \cdot P \cdot R + 1259.6 \cdot P - 67.4 \cdot R - 355.2 \quad (2)$$

Correlation coefficient: $R^2 = 0.59$.
Inflection point: P= 0.90 %; R=0.29%, HB_2=225.36HB

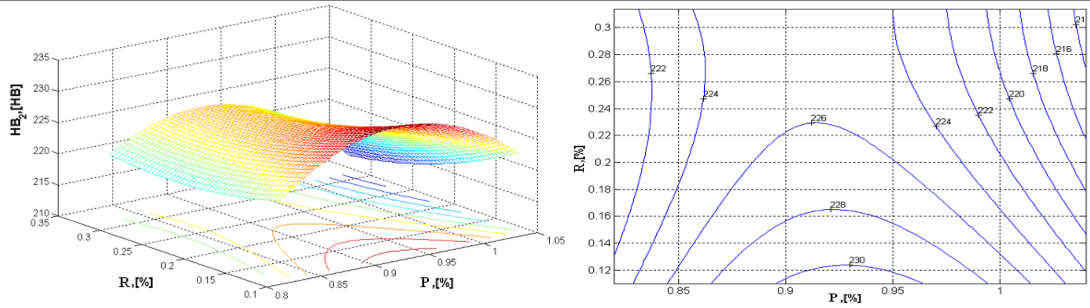


Figure 4.B2= f (P, R)

Correlation equations for hardness variation (HB_s) depending on the content of phosphorus and residual elements are:

$$HB_s = -443.70 \cdot P^2 - 162.98 \cdot R^2 + 49.32 \cdot P \cdot R + 829.91 \cdot P + 11.88 \cdot R - 168.54 \quad (3)$$

Correlation coefficient: $R^2 = 0.47$. Point of maximum: P=0.94%; R=0.17%, HB_s=224.73HB

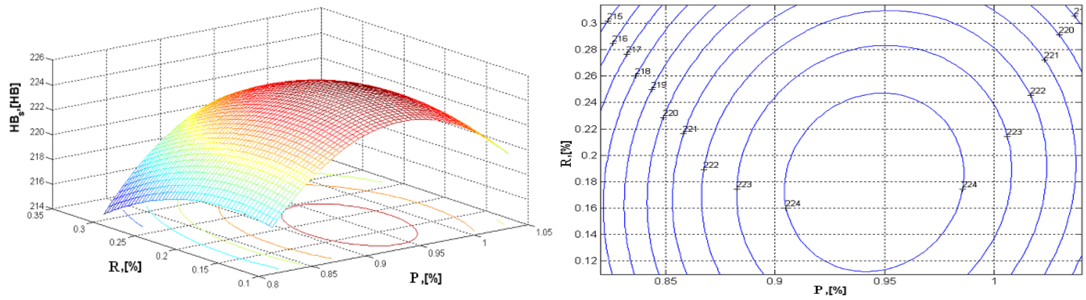


Figure 5. HB_s= f (P, R)

Correlation equations for hardness variation (HB_m) depending on the content of phosphorus and residual elements are:

$$HB_m = -337.96 \cdot P^2 + 563.57 R^2 - 450.61 \cdot P \cdot R + 705.28 \cdot P + 161.61 \cdot R - 127.70 \quad (4)$$

Correlation coefficient: $R^2 = 0.46$. Inflection point: P=0.89%; R=0.21%, HB_m=206.90HB

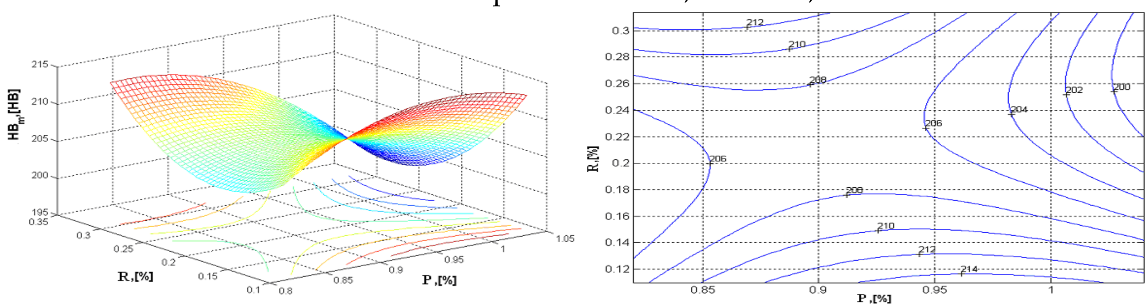


Figure 6. HB_m= f (P, R)

Correlation equations for hardness variation (HB_j) depending on the content of phosphorus and residual elements are:

$$HB_j = -496.12 \cdot P^2 - 40.04 \cdot R^2 + 218.79 \cdot P \cdot R + 874.01 \cdot P - 171.23 \cdot R - 164.26 \quad (5)$$

Correlation coefficient: $R^2 = 0.38$. Point of maximum: P=1.02%; R=0.67%, HB_j=227.93HB

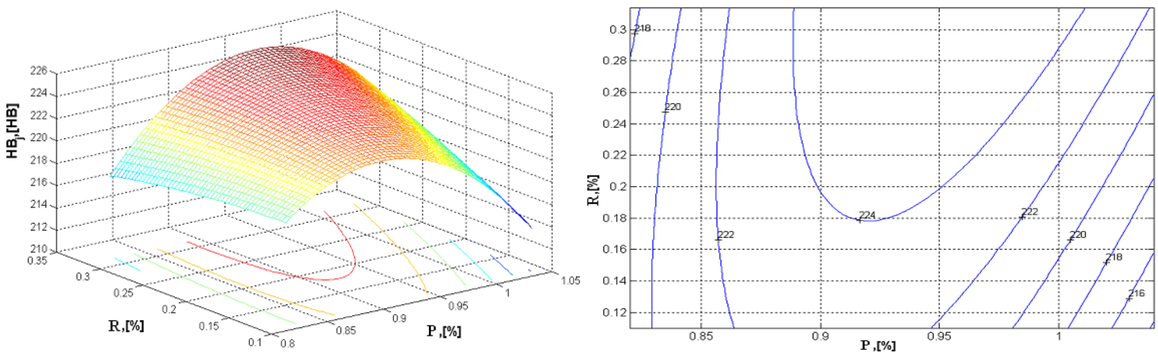


Figure 7. HB_j= f (P, R)

Correlation equations for averange hardness variation ($(HB_1+HB_2)/2$) depending on the content of phosphorus and residual elements are:

$$(HB_1 + HB_2)/2 = 450.09 \cdot P^2 - 373.74 \cdot R^2 - 350.40 \cdot P \cdot R - 744.30 \cdot P + 503.32 \cdot R + 501.25 \quad (6)$$

Correlation coefficient: $R^2 = 0.54$. Inflection point: P=0.92%; R=0.24%, $(HB_1+HB_2)/2$=219.35HB

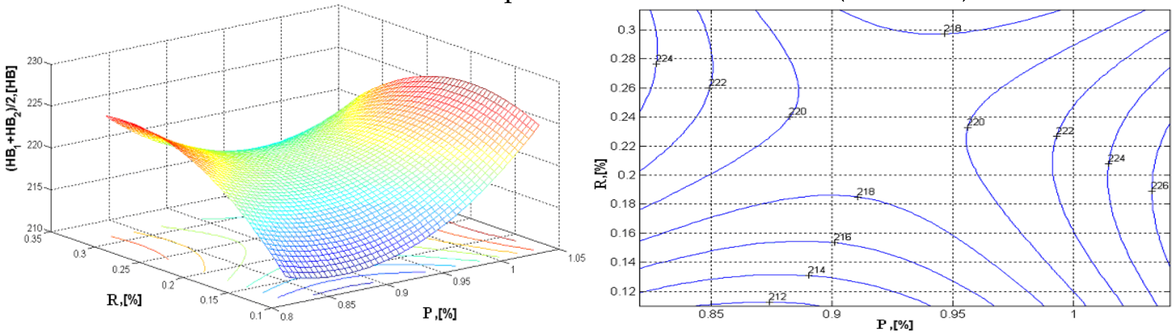


Figure 8. $(HB_1+HB_2)/2$ = f (P, R)

Correlation equations for averange hardness variation ($(HB_s+HB_m+HBj)/3$) depending on the content of phosphorus and residual elements are:

$$(HB_s + HB_m + HB_j)/3 = -851.4 \cdot P^2 - 162 \cdot R^2 + 414.9 \cdot P \cdot R + 1503.1 \cdot P - 355.6 \cdot R - 440.7 \quad (7)$$

Correlation coefficient: $R^2 = 0.63$.

Point of maximum: P=0.89%; R=0.04%, $(HB_s+HB_m+HB_j)/3$=222.97HB

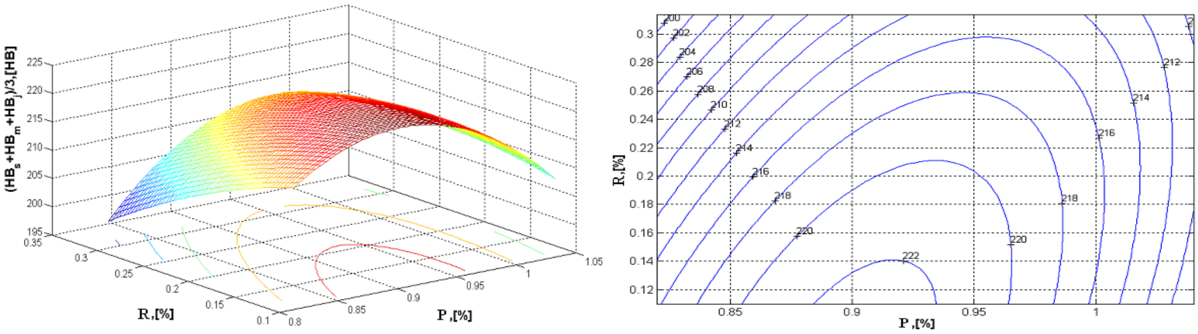


Figure 9. $(HB_s+HB_m+HB_j)/3$ = f (P, R)

4. CONCLUSIONS

The analysis of the research results leads to the following conclusions:

- ✓ the chemical composition of the cast iron used in making brake shoes grants the ranging of hardness within standard limits;
- ✓ there is a hardness difference between the cross section extremities and the centre of its cross section, which is explained by the solidification conditions;
- ✓ the level curves obtained in the graphical representation allow the choice of the independent parameters (P, Cr, Mo, Ni, Nb, V, W) so as to obtain the desired value for hardness.

ACKNOWLEDGMENTS

This work was partially supported by the strategic grant POSDRU/159/1.5/S/137070 (2014) of the Ministry of National Education, Romania, co-financed by the European Social Fund – Investing in People, within the Sectoral Operational Programme Human Resources Development 2007-2013.

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