

Industrial research on the quality of brake shoes meant for rolling stock

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Abstract. Brake shoes wear appears as a normal exploitation process and depends both on the braking force and on the material the shoe is made of. Brake shoes are made of molded sulfurous cast iron. The industrial research and experiments aim at determining the specific characteristics of the phosphorous cast iron (chemical and structural homogeneity, hardness) and their optimization in view of improving the quality of the brake shoes meant for the 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.

During braking, the superficial area of the shoe can reach temperatures of 800 – 900°C, and therefore, some structural constituents can melt. On cooling, structural modifications may arise, which increases the hardness.

On manufacturing brake shoes meant for the rolling stock, phosphorous pig irons are largely used. Their use is limited, their friction coefficient diminishing dramatically on braking at high speeds, while their wear, due to the seizing up tendency, is growing when the temperature in the braking coupling goes up [2]. The chemical structure of the braking shoes for railway vehicles running at speeds of up to 120km/h is the following: C=2,9-3,2 %; Si=1-2 %; Mn=0,3-0,7 %; S<0,2 %; P=0,2-1,3 %. Their structure has to be a pearlitic one, without free ferrite.

The high content of phosphor improves the friction – wear behavior of such cast iron. The higher concentration of phosphor grants the formation of phosphorous ternary eutectic, also called Steadite (Fe₃C + Fe₃P + P), hard (650 HB), brittle and with a low melting temperature (950 °C). The structure of the cast iron made of perlite, graphite and phosphorous eutectic makes for its wear resistance and high fluidity.

The alloying element Ni, Cr, Mo, Cu, etc., influence the basic metallic mass, leading to a finer structure of the graphite.

The brake shoe must have on its lateral surface, as well as on the cross section, a Brinell hardness ranging within 197-225HB [3], [4].



The resulting experimental data pertaining to the influence of chemical composition on hardness have been processed in Matlab and the results are given both in analytical and graphical form.

2. Experimental researches

The researches that are being done are going to establish the influence of the chemical elements (content of carbon and residuals 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 is 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 – Figure 1.a), on its front and at three points located diagonally (s, m and j – Figure 1.b). The brake shoe must have on its lateral surface, as well as on the cross section, a Brinell hardness ranging within 197-225HB [5-8].

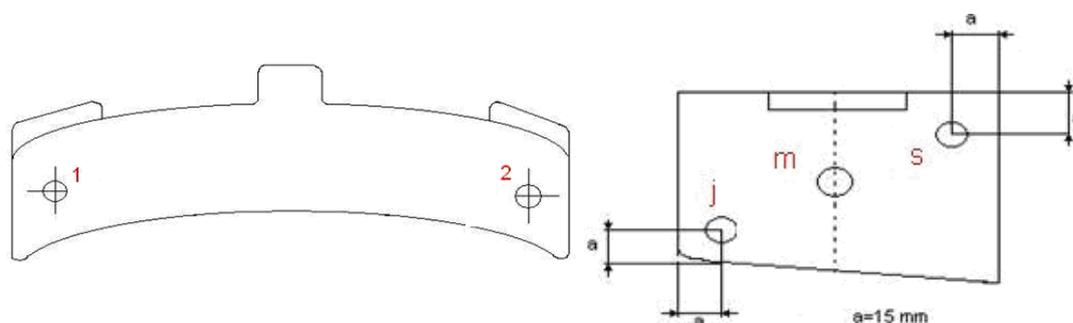


Figure 1. Sampling areas hardness shoe [5]

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 2 - Figure 8.

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 (C 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 depending on the content of carbon (C) and residuals elements (R) are:

$$HB_1 = 90.5 \cdot C^2 + 90.4 \cdot R^2 + 85 \cdot C \cdot R - 556 \cdot C - 294.2 \cdot R + 1074.6 \quad (1)$$

Correlation coefficient: $R^2 = 0.65$

Point of minimum: $C = 2.96\%$; $R = 0.23\%$, $HB_1 = 217.17\text{HB}$

$$HB_2 = -41 \cdot C^2 - 333.4 \cdot R^2 - 302.2 \cdot C \cdot R + 355.9 \cdot C + 1095.2 \cdot R - 503.8 \quad (2)$$

Correlation coefficient: $R^2 = 0.79$

Inflection point: $C = 2.55\%$; $R = 0.48\%$, $HB_2 = 216.15\text{HB}$

$$HB_s = 134.4 \cdot C^2 - 157.5 \cdot R^2 - 120.1 \cdot C \cdot R - 799.6 \cdot C + 450.1 \cdot R + 1397.9 \quad (3)$$

Correlation coefficient: $R^2 = 0.59$

Inflection point: $C = 3.08\%$; $R = 0.25\%$, $HB_s = 220.28\text{HB}$

$$HB_j = 45.58 \cdot C^2 + 133.96 \cdot R^2 + 274.64 \cdot C \cdot R - 329.72 \cdot C - 896.8 \cdot R + 809.44 \quad (4)$$

Correlation coefficient: $R^2 = 0.44$

Inflection point: $C = 3.09\%$; $R = 0.17\%$, $HB_j = 221.52\text{HB}$

$$HB_m = -124.9 \cdot C^2 + 43.2 \cdot R^2 + 56.7 \cdot C \cdot R + 783.4 \cdot C - 199.9 \cdot R - 1016.7 \quad (5)$$

Correlation coefficient: $R^2 = 0.50$

Inflection point: $C = 3.18\%$; $R = 0.22\%$, $HB_m = 209.11\text{HB}$

$$(HB_s + HB)/2 = -2.33 \cdot C^2 - 561.13 \cdot R^2 - 4.68 \cdot C \cdot R + 8.0 \cdot C + 269.16 \cdot R + 189.96 \quad (6)$$

Correlation coefficient: $R^2 = 0.43$

Point of maximum: $C = 1.49\%$; $R = 0.23\%$, $(HB_s + HB_2)/2 = 227.44\text{HB}$

$$(HB_s + HB_m + HB_j)/3 = 284.2 \cdot C^2 + 328.8 \cdot R^2 + 229 \cdot C \cdot R - 1805.8 \cdot C - 883.3 \cdot R + 3100.5 \quad (7)$$

Correlation coefficient: $R^2 = 0.72$

Point of minimum: $C = 3.06\%$; $R = 0.27\%$, $(HB_s + HB_m + HB_j)/3 = 210.24\text{HB}$

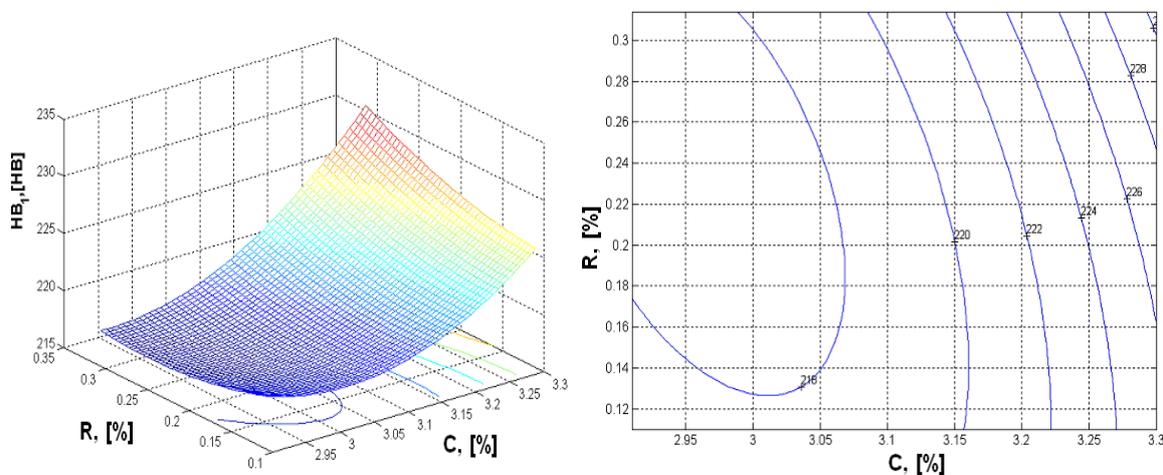


Figure 2. $HB_1 = f(C,R)$ -correlation 2nd degree a-surface regression; b-level lines

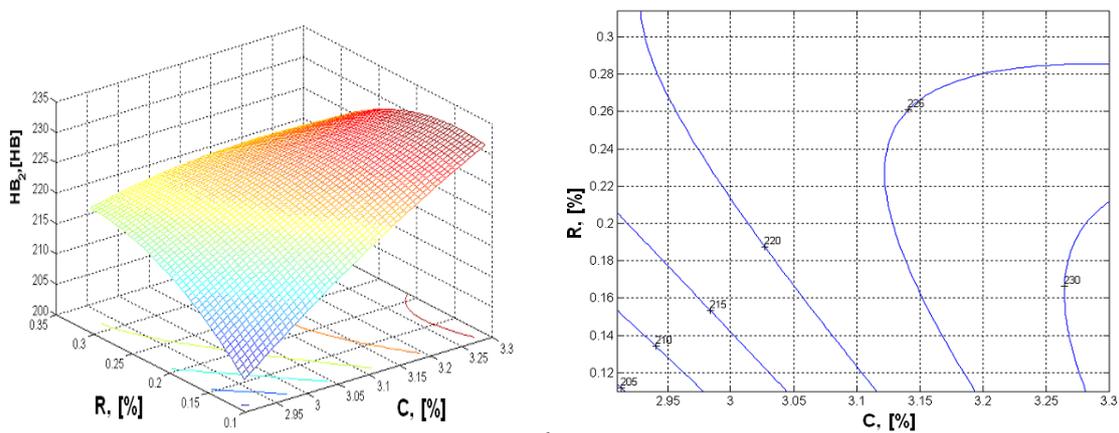


Figure 3. $HB_2 = f(C,R)$ -correlation 2nd degree a-surface regression; b-level lines

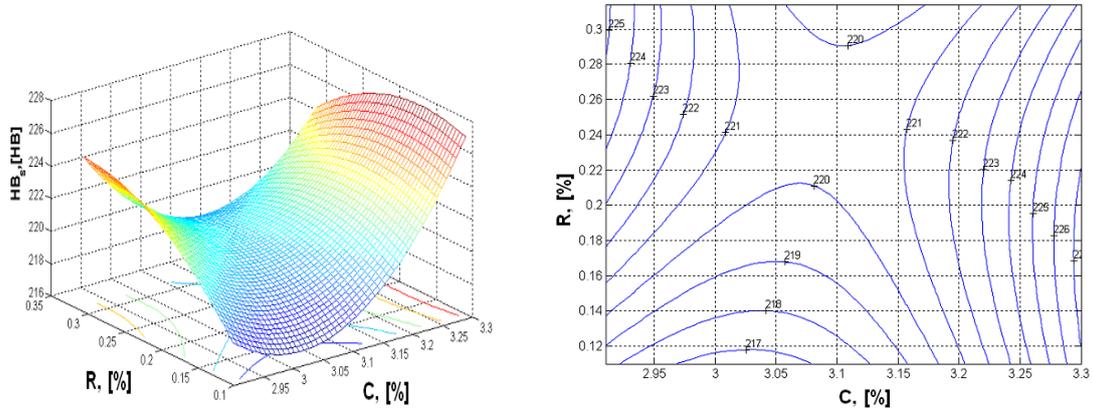


Figure 4. $HB_s = f(C,R)$ -correlation 2nd degree a-surface regression; b-level lines

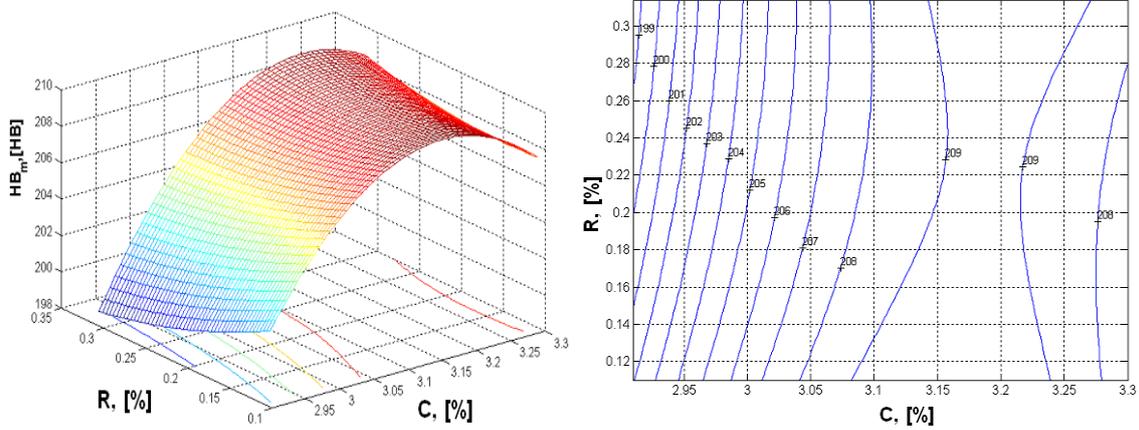


Figure 5. $HB_m = f(C,R)$ -correlation 2nd degree a-surface regression; b-level lines

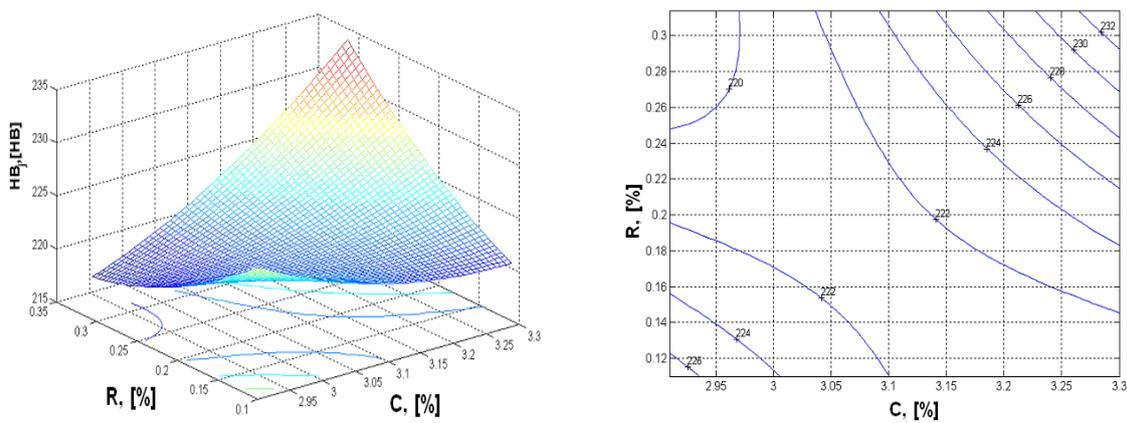


Figure 6. $HB_l = f(C,R)$ -correlation 2nd degree a-surface regression; b-level lines

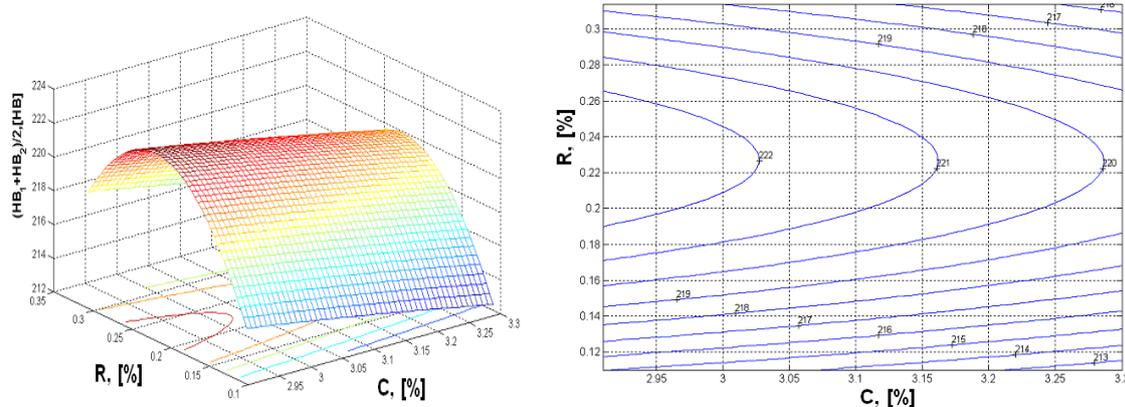


Figure 7. $(HB_1+HB_2)/2=f(C, R)$ -correlation 2nd degree a-surface regression; b-level lines

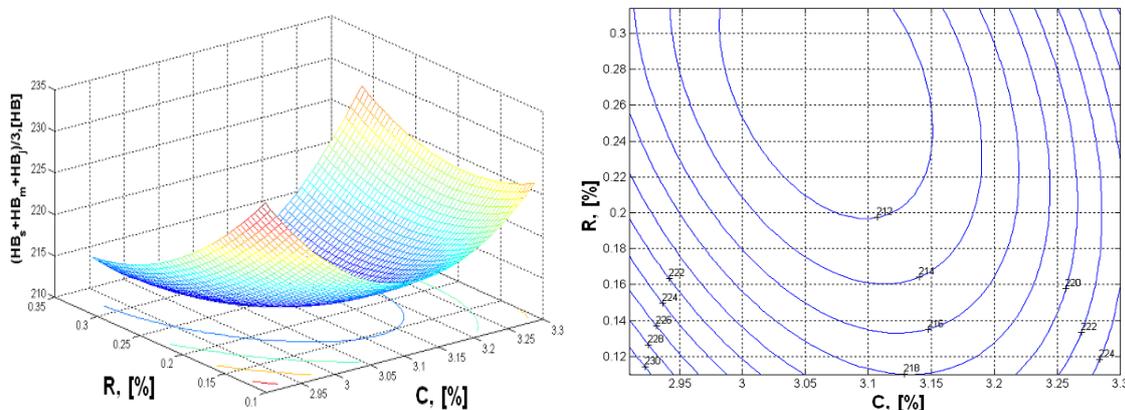


Figure 8. $(HB_s+HB_m+HB_i)/3=f(C,R)$ -correlation 2nd degree a-surface regression; b-level lines

3. 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

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