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# THE INFLUENCE OF THE ELEMENTS C, Ni AND Mo UPON THE HARDNESS OF THE BIMETALLIC CASTED IRON PIG MILLING ROLLS

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**ABSTRACT**

The bimetallic hard-crusted iron rolls casting, for decrease of the hardness and the wear resistance destine the hard iron, alloyed with Ni and Mo. This paper suggests a mathematical shaping of the influence of the main alloy elements upon the mechanical features of this iron type, for 50 industrial batch, resulting the average values and average square aberration of the variables HSh, Ni and Mo, the equations of the hyper surface in the four dimensional space, they appealed to the successive replacement of each independent variable with the average value, resulting the equations that belong to the tree dimensional space, which are graphically represented and easy to interpret by technologists. Knowing the level curbs allows the correlations of the values of the two independent variables so that the hardness value (HSh) can be obtain in the requested boundaries.

**KEYWORDS**

bimetallic milling rolls, alloy elements, hardness, wear resistance

## 1. INTRODUCTION

Technical conditions imposed to the milling rolls are very different and often contradictory. Thus, raised hardness from the crust correlated with mechanical resistance and raised high temperature, as well as with the raiser resilience of the alloys from the middle and journals, are enough difficult to obtain. For this reasons, the realization of the rolling mills is complexes enough, being necessary the obtaining mechanical-physical properties different in diverse points of the one and the same casted piece. Because the properties of each casted piece from de steel and pig irons are determined by the microstructure which is formed during the solidification and cooling of this, the base criterion, which determine the physical and mechanical properties of the milling rolls, is this structure.

In casted milling rolls from the pig iron are found all the carbon-iron alloys structures. One of the base factor which determine the given structure of the rolls is the chemical composition of the alloy and his speed cooling besides of the iron and the usually elements: carbon, silicon, manganese, phosphor, sulphur there are found also: chromium, cerium, nickel, calcium, molybdenum, copper, magnesium and aluminum. For the whiten degree correction of the liquid pig iron, purposed to crusting rolls with white crust, are utilized at large action of the tellurium. Besides of those previous showed, in any alloy for the milling rolls there also found gases: oxygen (almost entirely on shape of oxides), hydrogen and nitrogen. The exposed elements exert up to the alloy a carburide or graphiting action (figure 1) [1].

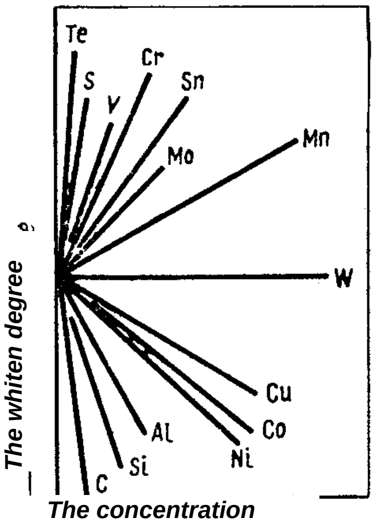


Fig.1. The carburide action of chemical elements over the alloyments fated to the rolls casting

**Nickel**. From the point of view of nickel influence in liquid pig iron, this belongs to the graphite elements groups, but this influence of his, it is not taken in deeming in the rolls casting manufacture. In this last case it is more important the fact that the nickel, having a unlimited solubility in pig iron, allows the improvement of properties series of harnesser of casted piece: brings the extension ferrite resistance from perrlite, magnify the mechanical resistance and at the pig iron rolls. Her bases property consists in the fact that, in certainness limits, exact brought, magnify the base metallic volume mass hardness, as a result of dwindle of critique point of eutectoids transformation.

Because this property, even in piece so unwieldy how there are the rolling mill rolls, in usual conditions cooling, it may obtain, not only the hard crust, but on their entire section, the entire gamut of transition structure of (depending on the nickel content), from fine lamellar perlite, until the martensite with are of uncomposed austenite and, as consequence, conformably to this, a harnesses large gamut 68 … 88 HSh. Martensite structure of base metallic mass it is brought by the content over 3,4 … 3,6%Ni, for small rolls and over 3,8%Ni, for the big one.

The extension of nickel content over 4,5% brings the appearance in rolls structure a some important quantity of residual austenite. This fact provokes the increase of resistance properties of the hard crust and in the same time, a somehow a lower of her hardness. The study of this rolls shows that the work surface hardness, during rolling process, may even increase as a result of transformation martenasite-austenite of residual austenite. It seems that, it is possible the deploy of the one and the same transformation at law temperature processing of the rolls [1].

The nickel it is used to the rolls manufacture for profiles of all types. Almost all this rolls it is cast in alloyed pig iron with chromium and nickel. The nickel neutralize the carburide influence of chromium and the resistance increase obtained on the nickel, it is double at the report Ni/Cr 2 : 1.

**The molybdenum** belongs the carburides elements group but her influence it is evince only to the contents over 0,6 % Mo. To the lower contents 0,6% Mo in reports kept conditions from structural elements, it is obtain thick structure with fine granulation on the entire section of the rolls, event in the hard rust, and also in her center, also in journals trifles. In this way it is obtain the resistance increase at usuance and at height temperatures of the hard crust, of the mechanical resistance and the dur5abulity in harnesser of the rolls resistance. Even to the low content of molybdenum, this dissolving in perrlite-ferrite, provokes the increasing of the base metallic mass resistance and, as consequence, of the total resistance of the rolls. The content over 0,4% Mo, dispersion metallic mass of base increase in a visible way.

In alloyed height bimetallic rolls with the contents over 3,8%Ni and 0,8%Cr, in hard crust appear frugal contents of silicon and height in chromium, can not stop the graphite process from alloyed pig iron with nickel in a long time maintaining conditions of pieces in temperature plane 900 … 950$^{o}$C. Linked with the reduction the carbon content in the austenite arias, being in the neighborhood of the graphite, the iron uncompose it is deploy faster. The presence of an enough quantity of molybdenum induce the stopping of this uncomposing. Because of this, the rolls with alloyed lamellar graphite with chromium, nickel and molybdenum are distinguished by higher hardness and, as a result, they have a higher resistance to usance.

At the contents of 1%Mo, when it is develop her carburide action, the depth of the crossing area on the entire section of the roll. Therefore, at the rolls for table rolling, the content of molybdenum is limit at 0,3 … 0,6%. The rolls casting with molybdenum under 0,25%, it is not reasonable, because it not conduct to the visible improvement of their structure.

The pig iron alloyment for rolls casting wit molybdenum, which it is solidifing with frugal speeds, it is needful the assurance of some frugal contents of phosphor (under 0,15%), because the formation of the complexes eutectoids of molybdenum and phosphor it is followed by the molybdenum diffusion from the base metallic mass, fact which increases the roll alloyment with molybdenum. In the fast solidification case of the whit area (so as this take place at the casting in chill, mold) eutectoid of Mo-P it not succeed to form and, therefore the properties influence of molybdenum in crust it is maintain even to the raiser contents of phosphor.

The adding molybdenum in pig iron for rolls presents one of the safe method of increasing of the resistance to usance and high temperature, also the all-out resistance of those [1] .

## 2. The results of the experiments

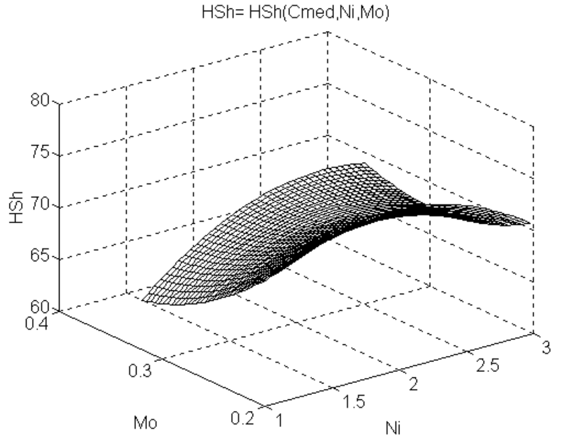
In this paper we suggest a mathematical shaping of the influence of the main alloy elements over the mechanical characteristics of this type iron pigs, resulting the average values and average square aberration of the variables HSh, Cr and Mo, the equations of the hyper surface in the four dimensional space.

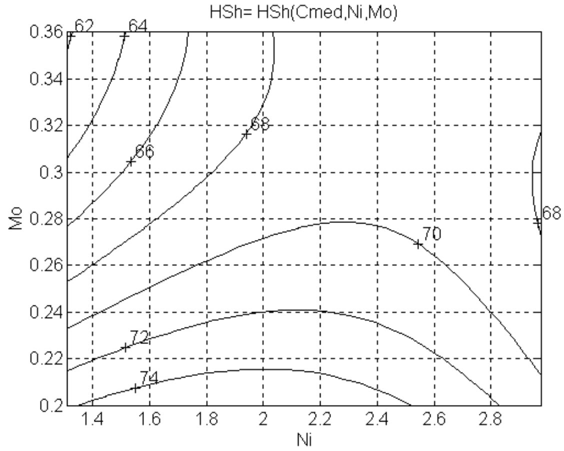
For the statistical and mathematical analysis, there were used 50 industrial batches.

The average values and the average square aberration of the variables are:

| | | |
|---|---|---|
| **C** | 3.2152 | 0.049 |
| **Ni** | 2.6278 | 0.53185 |
| **Mo** | 0.2946 | 0.039152 |
| **HSh** | 69.58 | 3.8808 |

Next, there are shown the results of the multidimensional processing of experimental data. For that purpose, we searched for a method of molding the dependent variables depending on the independent variables x, y, z:

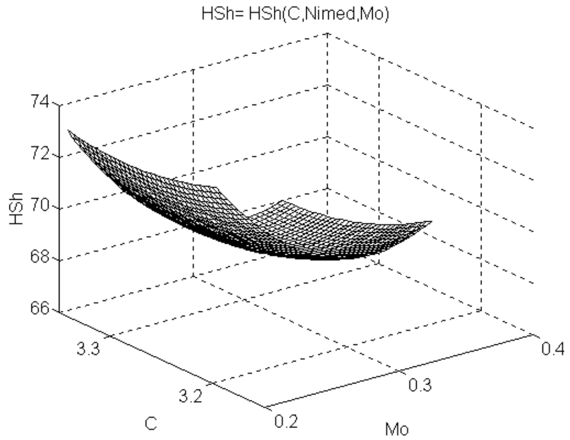



$$u = c_1 \cdot x^2 + c_2 \cdot y^2 + c_3 \cdot z^2 + c_4 \cdot x \cdot y + c_5 \cdot y \cdot z + c_6 \cdot z \cdot x + c_7 \cdot x + c_8 \cdot y + c_9 \cdot z + c_{10} \quad (1)$$

*Fig.2. The surface $HSh = HSh(C_{med}, Ni, Mo)$*

*Fig.3. The level curves of distribution $HSh = HSh(C_{med}, Ni, Mo)$*



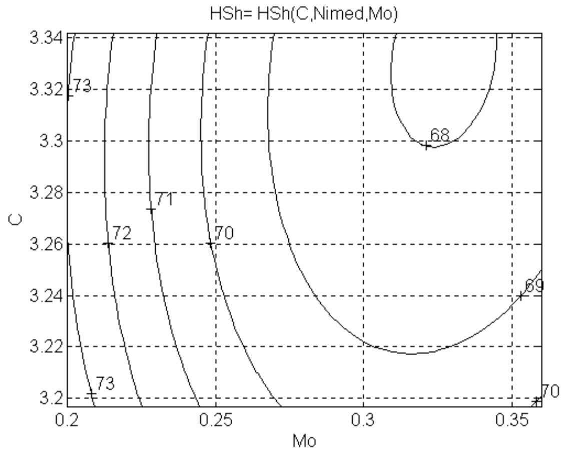
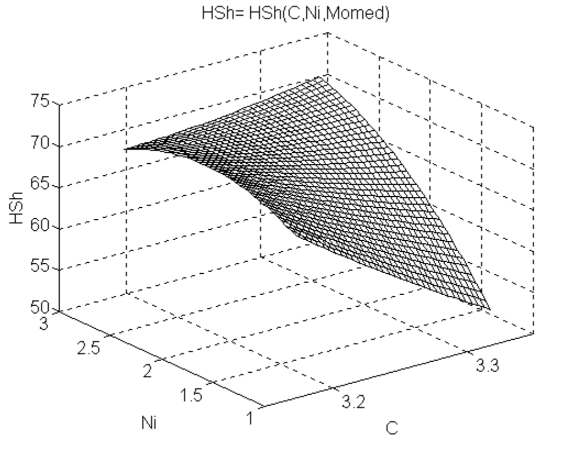




*Fig.4. The surface $HSh = HSh(C, Ni_{med}, Mo)$*

*Fig.5. The level curves of distribution $HSh = HSh(C, Ni_{med}, Mo)$*



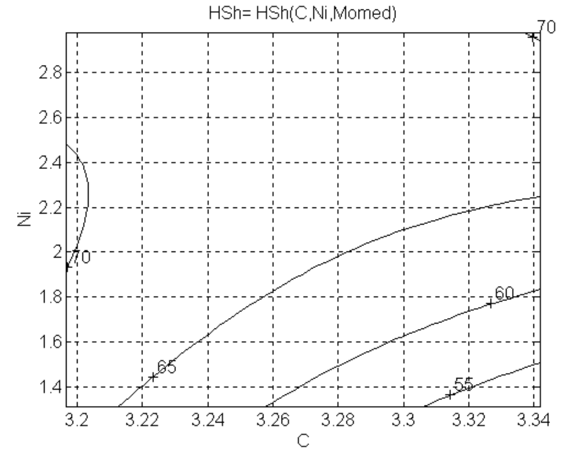




*Fig.6. The surface $HSh = HSh(C, Ni, Mo_{med})$*

*Fig.7. The level curves of distribution $HSh = HSh(C, Ni, Mo_{med})$*

The optimal form of molding, studied on a sample of 50 batches is given by the equations:

$$HSh = 85.68 \cdot C^2 - 4.378 \cdot Ni^2 + 324.2 \cdot Mo^2 + 73.41 \cdot C \cdot Ni + 39.36 \cdot Ni \cdot Mo - 60.47 \cdot Mo \cdot C - 744.2 \cdot C - 227 \cdot Ni - 113.8 \cdot Mo + 1615, \quad (2)$$

where the correlation coefficients are:

$$r = 0.44722511771627 , \quad (3)$$

and the aberrations from the regression surface are:

$$s = 3.47104664168859 . \quad (4)$$

These surfaces from the four dimensional space allow a saddle point, having the following co-ordinates:

$$C_ş = 3.258$$
$$Ni_ş = 2.788$$
$$Mo_ş = 0.3103$$
$$HSh_ş = 68.5 \quad (5)$$

## 3. Conclusions

The chemical, physical and mechanical properties of alloyed reach pig iron are induced, in first place, by their chemical composition (nature and content of alloy elements) and the way of thermic manufacture, but the big importance is the casting and elaboration method, so as to obtain a pure pig iron regarding of the gases content (oxygen, hydrogen, nitrogen) and nonmetallic inclusions, wit chemical homogeneous and advanced structural.

The hard pig iron, alloyed with Cr, Ni and Mo, it is fated to casting the bimetallic rolls crust, in purpose of their hardness in creasing and of the usuance resistance.

In the technological field, the behavior of these hyper surfaces in the vicinity of the saddle point, or of the point where three independent variables take their average value, can be studied only tabular, which means that the independent variables are attributed values on spheres concentric to the studied point.

Because these surfaces cannot be represented in the three-dimensional space, the independent variables were successively replaced with their average values. This is how the following equations were obtained.

$$HSh(C_{med}) = - 4.378 \cdot Ni^2 + 324.2 \cdot Mo^2 + 39.36 \cdot Ni \cdot Mo + 9.052 \cdot Ni - 308.3 \cdot Mo + 107.8 \quad (6)$$

$$HSh(Ni_{med}) = 324.2 \cdot Mo^2 + 85.68 \cdot C^2 - 60.47 \cdot Mo \cdot C - 10.42 \cdot Mo - 551.3 \cdot C + 988.2 \quad (7)$$

$$HSh(Mo_{med}) = 85.68 \cdot C^2 - 4.378 \cdot Ni^2 + 73.41 \cdot C \cdot Ni - 762 \cdot C - 215.4 \cdot Ni + 1609 \quad (8)$$

These surfaces, belonging to the three-dimensional space, can be represented and, therefore, interpreted by technologists. The surfaces are represented in figures 2, 4 and 6. For a more correct quantitative analysis, in figures 3, 5 and 7 there were represented the corresponding level lines, resulting the following conclusions: in the case of $C = C_{med}$, the hardness HSh allows a maximum for Ni of maximum value and Mo = 0,2% and a minimum for Mo of maximum value and Ni = 1,5%; in the case of

Mo = $Mo_{med}$ it can be observed a maximum values in the Ni arya of the maximum value and C = 3,35%, the minimum value being touched for Ni of minimum value and for C = 3,35%; in the case of Ni = $Ni_{med}$ the surface allows a minimum point for Mo = 0,325% and C =3,33%, therefore has a great importance because they offer stability to the process in the vicinity of this point, stability that should be either preferred or avoided. In our case, it is preferred.

Knowing these level curves allows the correlation of the values of the twos independent variables so that HSh can be obtained in between the requested limits.

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