Researches on the Influence of Alloying Elements on the Adamit Steel Type

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***Abstract*—** Chemical composition of the alloy from which the cylinders are made by rolling is one of the main factors that determine macro and micro structure. This paper presents a method of optimizing the chemical composition of rolling cylinders made of carbon steel with high concentration. Based on industry to study the influence of alloying elements on steel rolling mill cylinders cast for the determination of correlation between surface hardness cylinders and alloying elements. Optimization of chemical composition of the cylinder was made by mathematical modeling of real experimental data obtained from production using specialized computer program Excel and Matlab. Correlations obtained were plotted in this way being able to determine optimal areas between hardness and hold various alloying elements.

***Keywords*—** Adamit, Quality, Mechanical, Rolling, Rolling mill cylinders.

I. INTRODUCTION

LAMINATION is the processing of plastic performed (hot or cold) between mill rollers that rotate in the opposite direction (longitudinal rolling) or in the same direction and tilted axis (rolling helix), thereby rendering, the friction material metal in the area in which the deformation [1,2].

Also in this context can talk about cross-rolling mill as a process characterized by rolling the material to the longitudinal axis perpendicular to the direction of rolling, the length of product material resulting from the initial widening and widening of its elongation.

About 90% of rolled products are achieved by longitudinal rolling. (Fig. 1) [2]. In the process of rolling, metal form is obtained by plastic deformation that occurs between two parallel cylinders and axes rotating in opposite directions.

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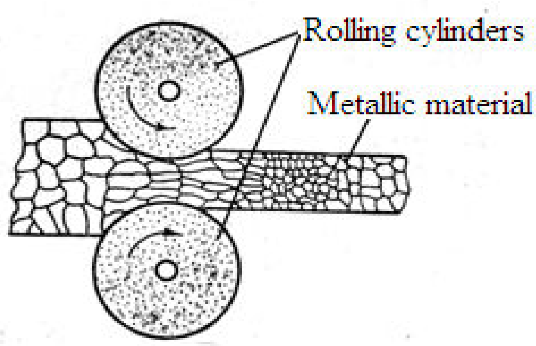

Fig. 1. Longitudinal rolling schedule

A big variety of laminates and different working conditions have led to the creation of a wide variety of cylinders.

In addition to technical and operational conditions take particular account of sustainability in operating cylinders (resistance to wear and tear). Rolling cylinders is one of the most important components (tools) used in the rolling of metallic materials.

To obtain maximum durability of rolling cylinders is necessary to determine the optimal correlation between operating conditions and quality.

Consumption of rolling cylinders has a great influence on the cost of laminates and therefore decrease its economic efficiency increases rolling sections.

Of industrial data that the values recorded for sustainability are low enough that induce critical analysis requirement to remove the causes leading to the exploitation of the results less satisfactory in terms of operational behavior of rolling cylinders.

For this purpose it is necessary to know the precise nature of stress as a request, materials, accurate evaluation of their characteristics to determine the service life and comparing them with certain values required in advance.

They are designed for proper operation executions of deformation, giving shape and dimensions required laminate.

During the rolling process, working cylinder pressures are those that support deformed material and temperature stresses that occur especially in hot lamination.

Economic efficiency of production of laminates depends largely on the quality of rolling cylinders, whose durability is determined by the characteristics operating material they are manufactured, operating conditions, characteristics and condition of materials are laminated. To obtain maximum durability of rolling cylinders is necessary to establish the relationship between the optimal operating conditions and quality. Research in the production of rolling cylinders is oriented in two directions: improvement of existing materials for rolling cylinders and their manufacturing technology and development processes of perspective, to substantially improve the quality of the cylinders. Rolling cylinders can be classified according to the material it is running, the user, working surface hardness, metallographic structure, and size and hardware technology. Fig. 2 shows a breakdown of rolling cylinders according to the material it is running. Because data are presented in this real data obtained from industry, in fig.3 presents rolling cylinders in use in a mill of a steel mill in Romania, in Fig. 4 presents the laminate deformation when passing, and in Fig. 5 presents the scheme rolling cylinders.

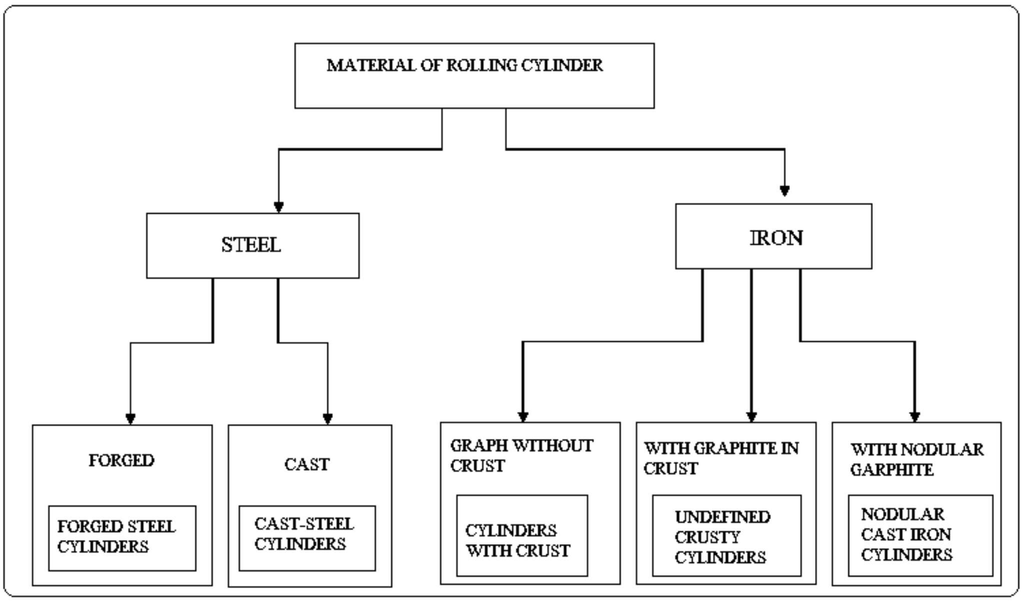

Fig. 2. Classification of cylinders, depending on the material running


Fig. 3 Rolling cylinders in exploitation

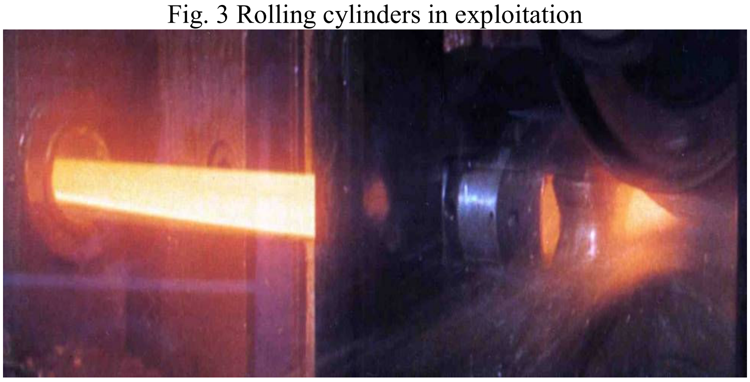
Fig. 4 Rolling deformation zone

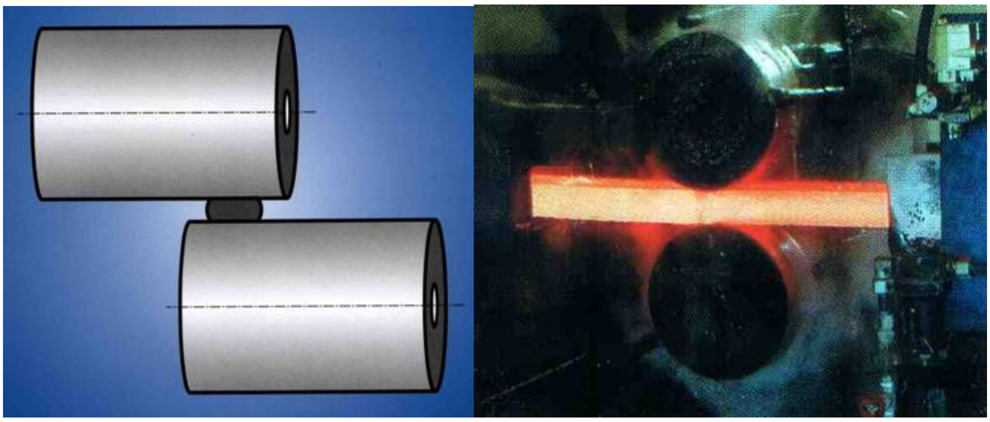

Fig. 5 Rolling cylinders

II. PROBLEM FORMULATION

A special category is cast steel cylinder with a high content of C (1.2 to 2.2%) type ADAMIT. As a material, they fall in terms of chemical in hypereutectoid steel, alloyed with Ni, Cr, Mo, and as such should be applied and heat treatment operations. The technical conditions imposed rolling cylinders are very different and often contradictory way, crust hardness coupled with high mechanical resistance at high temperature and often with higher resilience of the metal core, zones and clubs are difficult to obtain. Therefore particular attention should be given chemical composition, which has a decisive role in achieving the desired structure. For the same reasons, the assimilation of new types of cylinders and alloys with high operating properties led to wide application, thermal treatment. The chemical composition of the alloy is poured from the rolling cylinders is one of the main factors that contribute to user properties. This leads to macro and microstructure, possibly after processing liquid amendment directed solidification and cooling conditions and, in some cases after heat treatment. zone depth, reducing thereby the mechanical and thermal resistance of the cylinders [4]. Nickel and chromium increases. Steel cylinders (as compared with those of iron) have high resistance and resilience, and mills that are used to working with heavy loads and an appreciable reduction. Since the cylinders were after re-turning to minimum diameter allowed it is still a very large amount of metallic material, the more encompassing their labor and are heavy losses re-melting were looking for different ways to extend the durability of cylinders work of the mills. A method widely used in cutting mills is the loading cylinders welded panels on a surface thickness ranging between 1 and 40 mm. This method lends itself well to the steel cylinder and a C content below 0.6% and cylinders steel alloyed with Cr and Mn content of not too high. Another method used to decrease cylinder wear, namely to increase their sustainability, is the increase in hardness by hardening cylinder shallow panels with high frequency equipment. Hardness hardened layer, which is around 3 mm thick, generally exceeding 600-700 HB. Thus, during the operation can double cylinders. A current problem remains optimizing the chemical composition of the alloy for the manufacture of In cylinder cast iron and steel, and iron out common elements (carbon, silicon, manganese, phosphorus, sulfur) are also found: chromium, cerium, nickel, calcium, molybdenum, copper, magnesium, aluminum, boron, titanium. In conditions of rapid cooling, carbon Fe-C alloys form iron carbide (cementte) and slow cooling under a separate form of free carbon (graphite). The molybdenum belongs to carburigene elements group, but its influence is manifested only in content over 0.6% [6]. Almost all cylinders are allied with Mo, 0,3-0,5% in a rate [3]. Casting cylinders of molybdenum content less than 0,25% is not reasonable, because not lead to visible improvement of their structure. [4]. In the case of casting-rolling cylinder, nickel, having unlimited solubility in irons, allows increased resistance of perlite ferrite and increases the mechanical strength and wear of cast iron [5].

Chromium, in alloys for casting cylinder form stable carbides increases the hardness and the depth of the crust in the harsh conditions favoring the development and transition contents, fall within low and medium alloyed cast iron, by increasing the content of these cylinders and the hardness rolling cylinders. Given the above, the desired approach work in a original research and dynamic phenomena and processes of transfer between the cylinders, to increase hardness and hence the service life (durability). Working cylinder must have great strength and durability. These properties can be obtained by proper choice of material and manufacturing technology of cylinders in accordance with their destination. Thus, the working cylinders of the mills can be made by casting of gray cast iron, cast iron and alloyed hard crust, as well as by casting or forging of carbon steel or alloy steel, being made of sheet metal hardness between 150 and 800 HB. In case of cold rolling of sheets and bands, their quality depends largely on the state cylinders working unless hot rolling. For these reasons, the working cylinders of the table and strip mills cold conditions require a series of much more severe. Thus, the plate cylinder to be very smooth and free of any defects (cracks, flaking material, printing, inclusions, corrosion marks etc.) in case of a small defect leading to his removal from service.

III. PROBLEM SOLUTION

Chemical composition, which led to the best results in terms of physico-mechanical characteristics and operating cylinders, proved to be: 1.7 to 2.2% C, 0.6 to 1.5% and; 0.7 to 0.9% Mn, 1.0 to 2.0% Ni, 0.7 to 1.5% Cr, 0.3 to 0.5% Mo, 0.04% P; max.0, 02 % S [6]. In the research conducted was aimed at determining a correlation between the cylindrical surface hardness and chemical composition of some elements. The project is aimed to optimize the chemical composition of mill rolls and determination of correlations between hardness, depending on the chemical elements. Have been selected a total of 29 cylinders of a set of 92, because they have accomplished service campaigns. Among the chemical elements with significant influence on the hardness were chosen as follows: chromium, molybdenum, manganese, carbon and silicon. The data were processed in Excel spreadsheets and MATLAB programs, the paper presenting the results of the second great influence on the program parameters. During the experiment, followed by regression analysis to determine the mathematical form which binds teams dependent variables in our case hardness, the independent variables, the elements contained in the chemical. Mathematical expression of the form: HB = f (chemical composition elements) is called the regression equation and determining the real coefficients that enter into this equation is the method of least squares. Based on experimental results, we have two stages. In the first stage will be determined depending on mathematical models to optimize the parameters of technological parameters influence the process. As parameter was chosen to use the board Brinel working hardness, it is the most requested area to mill cylinders. Mathematical models are in the form:

HB table = f (chemical composition)
HB table = f (Mn, Si, Mo)
HB table = f (C, Si, Mn)

Phase II we can call OPTIMIZATION, involves finding the optimum multifactorial space, more specifically, determining the maximum and minimum extreme values of the parameter values optimized to get it. Data processing by Matlab functions are based on determining the highest values, lowest values of the calculation of average, the product of regression terms, sort items in ascending order, calculating the standard deviation (dispersion) or descending, and the coefficient of correlation. After determining these values, the MATLAB program to generate regression equations surfaces determined by equations of degree n 1.2....n and equations that describe the exact demarcation surfaces. Graphic representations areas of variation of the variables and the degree the determination of regression equations describing surfaces is higher with both graphic fields are correct. If the experiment we analyzed the multiple regression equations representing the order of 2 for which there is one correlation coefficient and a deviation from the regression surface. Small values of deviations in terms of mathematical precision means that the model conceptually corresponds to the average values from these values are calculated results. In point values for the variables corresponding to sea optimum hardness for the supported and recommended by the optimal technologies. Because this equation with four unknowns can not plot as working method I chose the path of imposing successive average values of some input parameters, leaving the free float of a number of 3 variables subject to optimization Regression equation hypersurfaces hardness variation depending on the content of manganese, silicon and molybdenum steel for manufacturing cylinders:

$$D = 2566{,}84 \cdot Mn^2 - 380{,}46 \cdot Si^2 + 3946{,}41 \cdot Mo^2 - 2950{,}83 \cdot Mn \cdot Si + 3260{,}11 \cdot Si \cdot Mo - 4558{,}75 \cdot Mo \cdot Mn - 672{,}56 \cdot Mn + 1921{,}49 \cdot Si - 907{,}84 \cdot Mo + 94{,}93 \quad (1)$$

R_f = 0.83 corelation coefficient. Deviation from regression surface S_F = 6.41. Average values and deviations of variables are:
D = 382.42, S_D= 11.603;
D_{Mn}= 0.81269; S_{Mn}= 0.040815;
D_{Si}= 0.68654; S_{Si}= 0.08403;
B_{MD}= 0.32231; S_{Mo} = 0.03320.
Saddle point coordinate are: D = 0.77603, Mn = 0.69645, and Si = 0.27558, Mo = 377.9887.
Since this can not be represented hypersupraface SPTI with 4 sizes, replacement was used successively, each an independent variable with its value on average. These areas, which belong to three space dimensions can be represented and interpreted by technology.

$$D(Si, Mo, Mn_{med}) = -380{,}46 \cdot Si^2 + 3946{,}41 \cdot Mo^2 + 3260{,}11 \cdot Si \cdot Mo - 476{,}62 \cdot Si - 4612{,}70 \cdot Mo + 1243{,}68 \quad (2)$$

$$D(Mn, Mo, Si_{med}) = 3946{,}41 \cdot Mo^2 + 2566{,}87 \cdot Mn^2 - 4558{,}75 \cdot Mo \cdot Mn + 1330{,}34 \cdot Mo - 2698{,}42 \cdot Mn + 1234{,}78 \quad (3)$$

$$D(Si, Mn, Mo_{med}) = 2566{,}87 \cdot Mn^2 - 380.46 \cdot Si^2 - 2950{,}83 \cdot Mn \cdot Si - 2141{,}88 \cdot Mn + 2972{,}25 \cdot Si + 212{,}28 \quad (4)$$

Regression equation hypersurfaces hardness variation depending on the content of silicon, chromium and molybdenum steel for manufacturing cylinders:

$$D = -337{,}77 \cdot Si^2 - 493{,}41 \cdot Cr^2 + 954{,}98 \cdot Mo^2 - 504{,}63 \cdot Si \cdot Cr + 261{,}76 \cdot Cr^2 \cdot Mo + 1376{,}75 \cdot Mo \cdot Si + 614{,}91 \cdot Si + 1456{,}85 \cdot Cr - 1717{,}59 \cdot Mo - 444{,}16 \quad (5)$$

R_f correlation coefficient = 0.8467.
Deviation from regression surface S_F = 6.1737.
Average values and deviations of variables:
D = 382, S_D = 11.603;
D_{Si} = 0.68654; S_{Si} = 0.08403;
D_{Cr} = 1.0927; S_{Cr} = 0.05537;
B_{MD} = 0.32231; S_{Mo} = 0.033202.
Saddle point coordinates are: D = 391.5153; Si = 0.58917; Cr = 1.2553; Mo = 0.30256.

$$D(Cr, Mo, Si_{med}) = -496{,}41 \cdot Cr^2 + 954{,}98 \cdot Mo^2 + 261{,}76 \cdot Cr \cdot Mo + 1110{,}40 \cdot Cr - 772{,}40 \cdot Mo - 181{,}20 \quad (6)$$

$$D(Cr_{med}, Mo, Si) = 954{,}98 \cdot Mo^2 - 337{,}77 \cdot Si^2 - 1376{,}75 \cdot Mo \cdot Si + 1431{,}56 \cdot Mo \cdot Si + 63{,}50 \cdot Si + 558{,}60 \quad (7)$$

$$D(Cr, Mo_{med}, Si) = -337{,}77 \cdot Si^2 - 493{,}41 \cdot Cr^2 - 504{,}63 \cdot Si \cdot Cr + 1058{,}65 \cdot Si + 1541{,}22 \cdot Cr - 898{,}55 \quad (8)$$

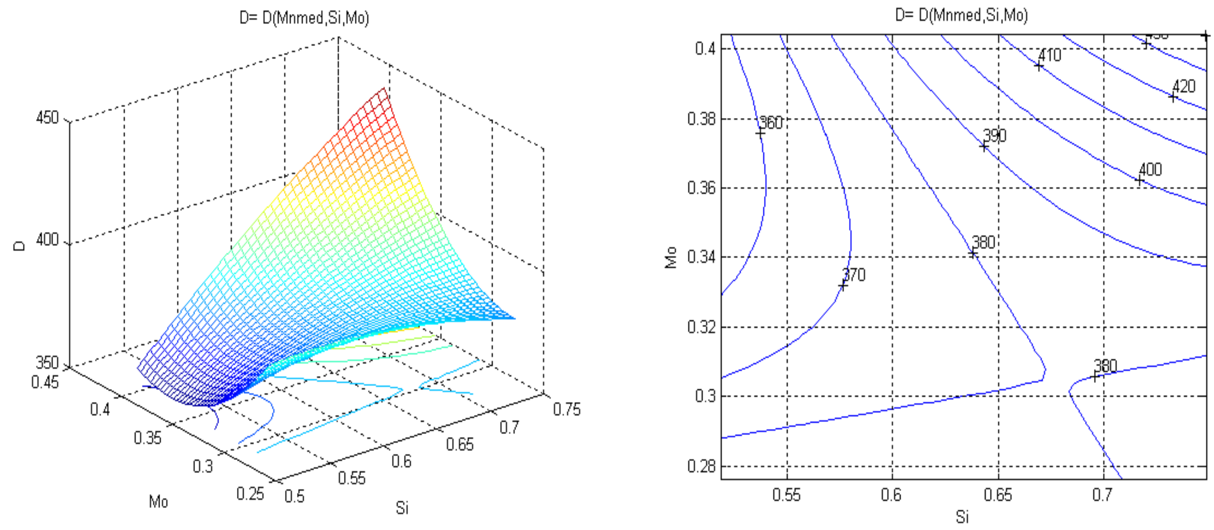

Fig. 3. Variation of hardness depending on the content of silicon and molybdenum steel cylinders for construction

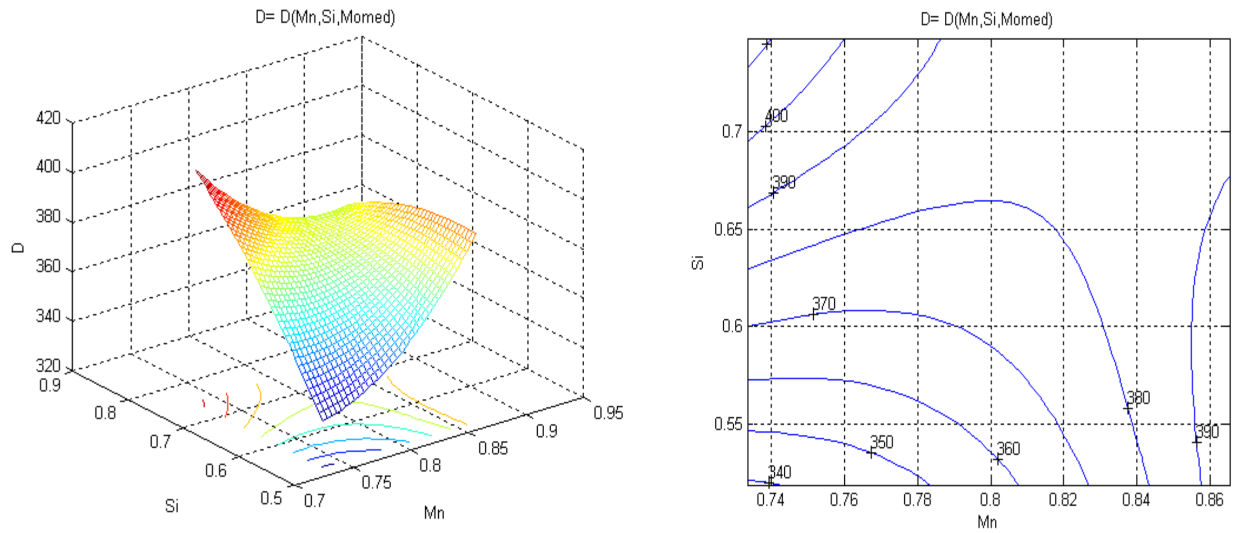

Fig. 4. Variation of hardness depending on the content of silicon and manganese steel cylinders for construction

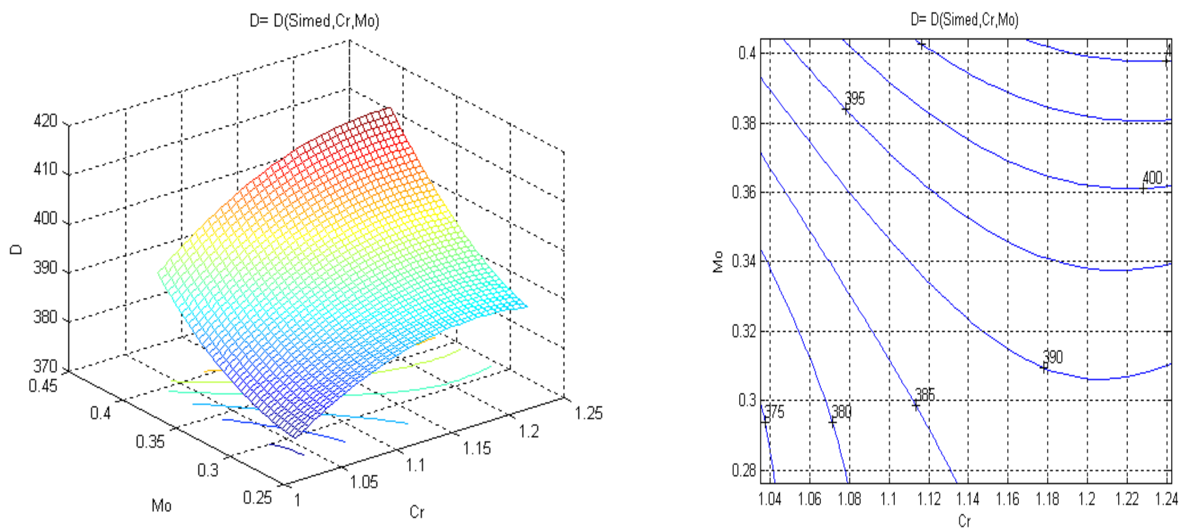

Fig. 5. Variation of hardness depending on the content of molybdenum and chromium steel cylinders for construction

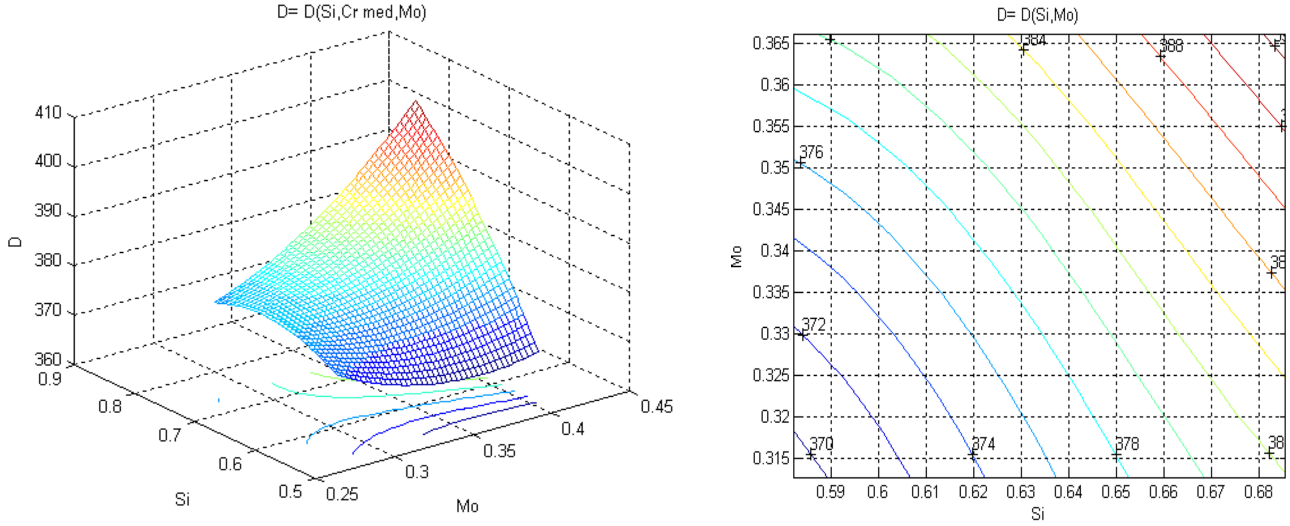

Fig. 6. Variation of hardness depending on the content of molybdenum and chromium steel cylinders for construction

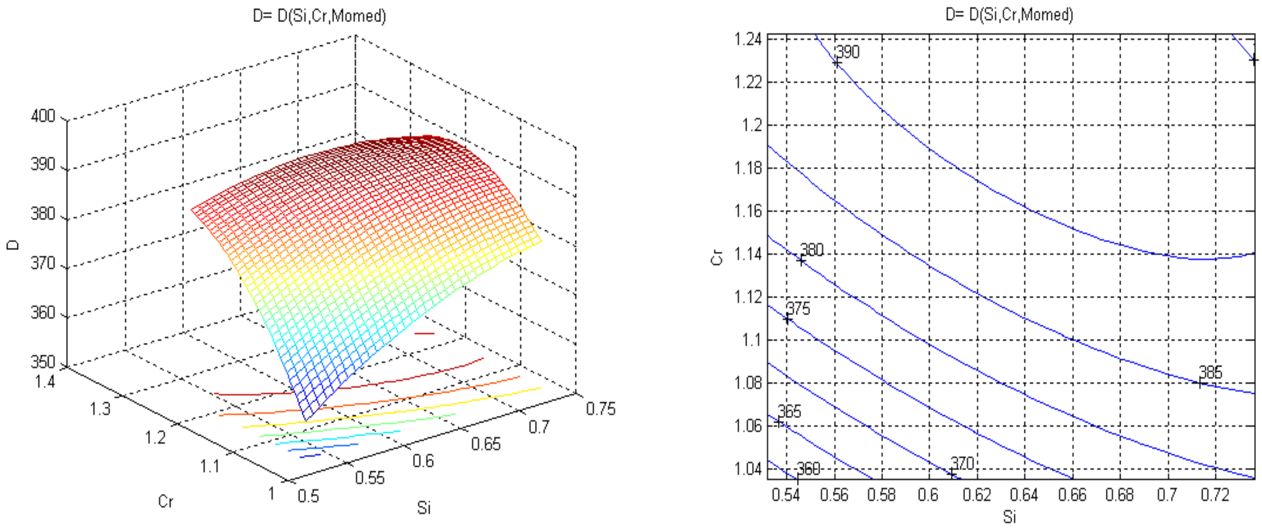

Fig. 7. Variation of hardness depending on the content of molybdenum and chromium steel cylinders for construction

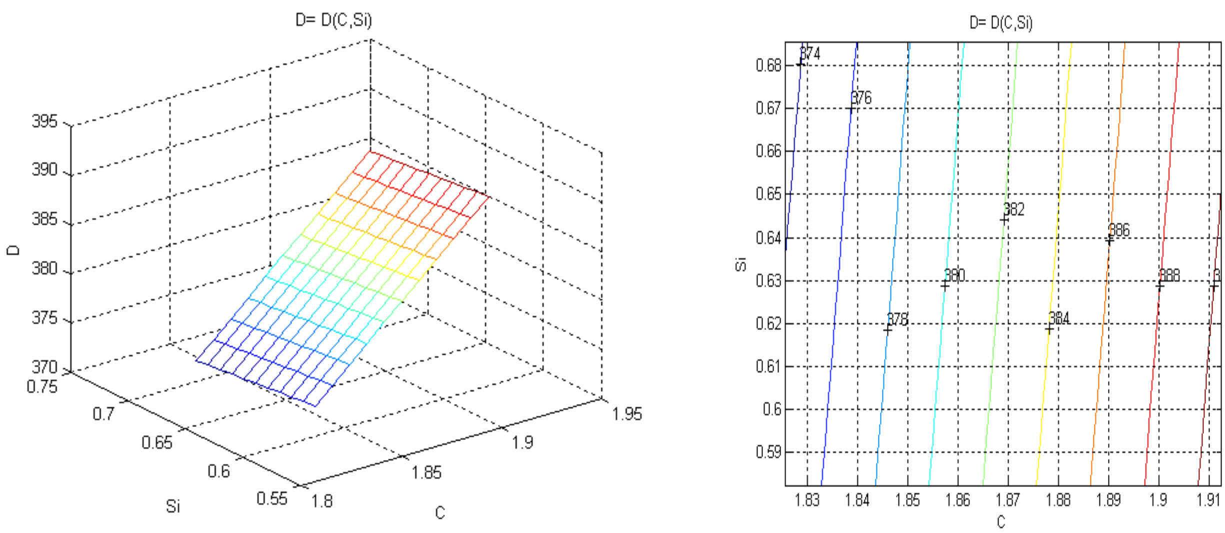

Fig. 8. Variation of hardness depending on the content of silicon and carbon steel cylinders for construction

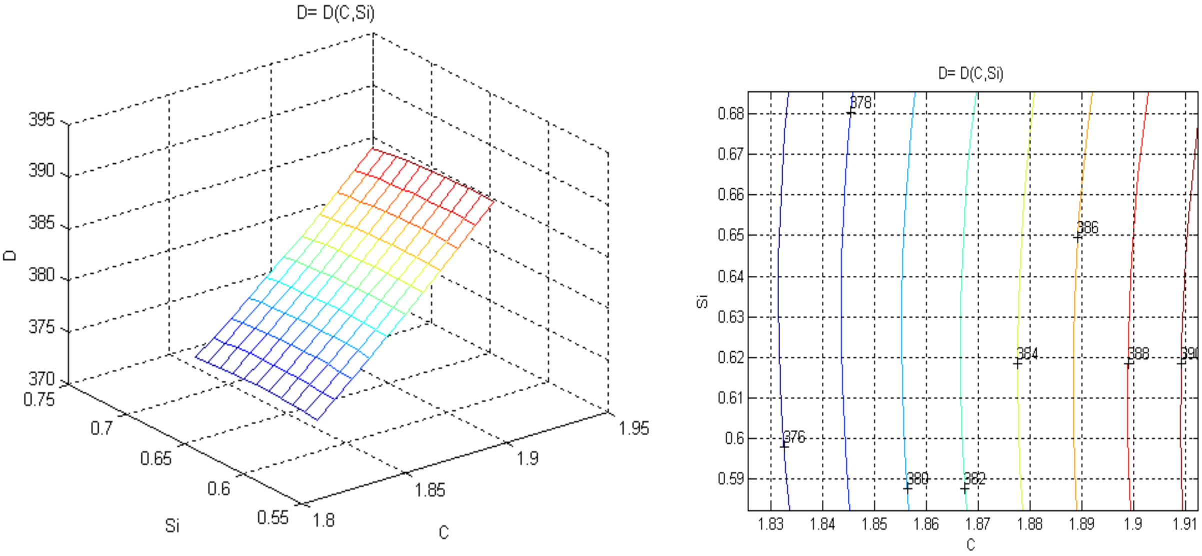

Fig.9. Variation of hardness depending on the content of silicon and carbon steel cylinders for construction

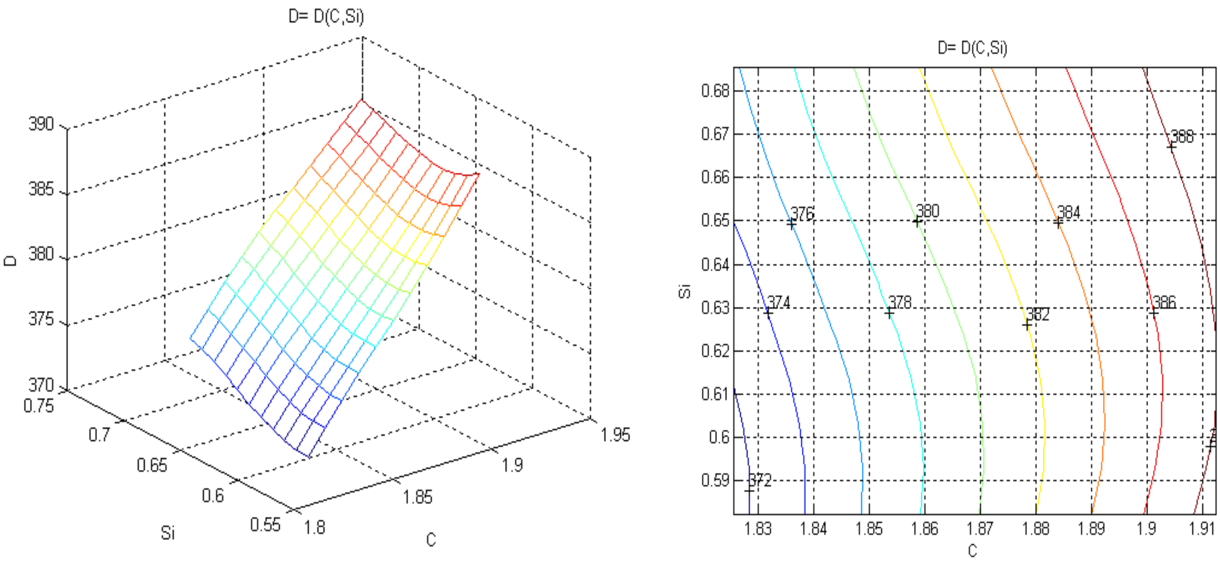

Fig.10. Variation of hardness depending on the content of silicon and carbon steel cylinders for construction

For better information on the influence of chemical composition of steel elements on its hardness, we processed the data to obtain the degree of correlation equations 1,2 and 3.

We chose as independent parameters C and Si, and the parameter dependent hardness (as in previous measurements).

Regression equation hyper-surfaces grade 1,2 and 3 of the hardness variation according to the carbon and silicon steel for the manufacture of cylinders is shown in the correlations.

$$D = 187.0275 \cdot C - 12.4629 \cdot Si + 40.4466 \quad (7)$$

$$D = 206.7015 \cdot C^2 - 96.6352 \cdot C \cdot Si - 126.6913 \cdot Si^2 - 532.5949 \cdot C + 338.1052 \cdot Si + 606.8563 \quad (8)$$

$$D = 6213.8513 \cdot C^3 - 5241.7784 \cdot C^2 \cdot S + 3295.203 \cdot C \cdot Si^2 - 5181.5404 \cdot Si^3 + 31616.915 \cdot C^2 + 15044.2627 \cdot C \cdot Si + 4035.776 \cdot Si^2 + 54788.5851 \cdot C - 16435.9629 \cdot Si - 30719.3143 \quad (9)$$

Correlation coefficients are:

R_{f1}= 0,9410;
R_{f2}= 0,9464;
R_{f3}= 0,9641.

Deviations from regression surface are:

S_{f1}= 3,9276;
S_{f2}= 3,7462;
S_{f3}= 3,0831.

The analysis equations and deviations of correlation coefficients, it clearly shows that the equation of degree 3 plays better dependence, confirmed and graphics.

IV. CONCLUSION

Based on industrial data studied influence of alloying elements Cr, Mn, Si, Mo on the hardness of steel for casting Adam rolled cylinders.

The analysis of correlations obtained by processing data in Matlab program that all elements studied have positive influence on the hardness which corresponds with the literature [7].

Cumulative influence of the elements Mn, Si, Mo is present in (a) and the elements So, Cr, Mo is shown in equation (5), and the influence of alloying elements on hardness is shown graphically in Fig.3- 7.

Graphical representations allow us to choose an area of variation and correlation strength in this area resulting in the limit of variation for the elements analyzed.

The fig.4 shows that the Mn content higher than 0.34% it significantly influences the hardness, especially if more than 0.60% and between 0.70 and 0.80% Mn.

Regarding Cr it has significant influence within the 1.00 to 1.25% when Mn, Si, Mo is contained in the above limit. The stated goal of this research was the demonstrations that ensure optimal chemical composition is a means to ensure the best technical properties of exploitation.

Diagrams can be used in establishing the technological parameters for that process to have the desired hardness. Regression surface variation of hardness HB produces domains according to combinations of chemical elements for this type of mathematical model aimed.

It was the best solution to determine the optimal chemical composition of hardness values. In most real problems, the process efficiency is considered not a single indicators but by many.

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