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TECHNOLOGICAL BEHAVIOUR AND INTERPRETATIONS IN SOME MULTIDISCIPLINARY APPROACHES

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ABSTRACT: In engineering and manufacturing, quality control and quality engineering are involved in developing systems to ensure products or services are designed and produced to meet or exceed customer requirements. These systems are often developed in conjunction with other business and engineering disciplines using a cross-functional approach. Quality assurance is the activity of providing evidence needed to establish quality in work, and that activities that require good quality are being performed effectively. All those planned actions necessary to provide enough confidence that a product or service will satisfy the given requirements for quality. Quality assurance covers all activities from design, development, production, installation, servicing and documentation. It includes the regulation of the quality of raw materials, assemblies, products and components, services related to production, and management, production, and inspection processes. This paper suggest a mathematical interpretation of the influence of the main alloy elements over the mechanical characteristics (the hardness of the rolls) of this nodular irons, resulting the average values and average square aberration of the variables HB, and the main alloying elements (Cr, Ni, Mo), the equations of the hyper surface in the four dimensional space, using a lot of industrial cases. The resulted surfaces, belonging to the three-dimensional space, can be represented and, therefore, interpreted by technologists. Knowing these level curves allows the correlation of the values of the twos independent variables so that the hardness can be obtained in between the requested limits.
KEYWORDS: multidisciplinary research, modeling, Matlab, correlations, level curves, rolls, alloying, hardness

INTRODUCTION

Through its nature, the quality assurance in the rolls manufacturing is a research with interdisciplinary character. It approaches, on aside, the technical area of manufacturing and exploitation of rolls, both in theory and practice, and on the other hand, the areas of the statistical mathematic analysis, of the algorithms and the numerical calculus methods, as well as the mathematically modeling and optimization area, applied to a product so simple from point of view of the geometry, but so complex, as structure, property and characteristics ensumed, as the rolling mills rolls are. In a typical scientific research process there is a stage that consists of the following activities: a review of literature, an exploration of existing theories, a review of theoretical background and a definition of the terminology used. The research activities devoted to materials relate to their production, characterization and use. These, mainly focused on ferrous and non-ferrous alloys, relate to:

- Optimization of the processes for developing new technologies in collaboration with industry;
- Production technologies;
- Research into solutions for management of products;
- Improvement of the quality of cast, rolled and powder metallurgy products;
- Development of statistical tools for quality control.
- Theoretical modeling and experimental study

The main objectives included in our preoccupations are:

- Study of the influence of chemical elements on iron properties;
- Modeling in order to optimize the production flows;
- Characterization of mechanical properties;
- Development of new technologies;
- Multivariate statistical analysis of industrial data;
- Analysis on various methods to improve the hardness and mechanical properties;
- Simulation of forming, casting and cooling;
- Optimization of production processes.

The final scope is the optimization of processes, that's equivalent to respond to new economic and environmental imperatives, designers must optimize the real behavior of the casting materials.

The *multidisciplinary point of view* relates to the use of various research methodologies. *Modeling* refers to the representation of knowledge through algorithms and tools. The resulting models are used both in applications that aim at scientific understanding and also in applications that aim at practical understanding. *Scientific and technological methodologies* refer to empirically-based and modeling-based approaches that draw upon advanced tools for measuring and processing information.

❖ RESEARCH AREA

The quality of rolls is determined through hardness and through wear resistance, last index having a special importance for all modern rolling mills with a growth production. Of major importance for the rolls exploitation is not merely growth resistance, but also the ability to oppose to different types of wear. Thus, rolling mill rolls considerable influence the specific production and the qualitative level of laminates, reason for which they are given a special attention, in manufacturing, as well as in usage. These requirements can not be completely fulfilled, compelling to the granting of priorities depending on the type of laminates, therefore to compromises. At large, the problem is reduced to the correct material choice, eased by the rich available experience in the current conditions of manufactured and burdened, in the same time, by the large diversity of material used.

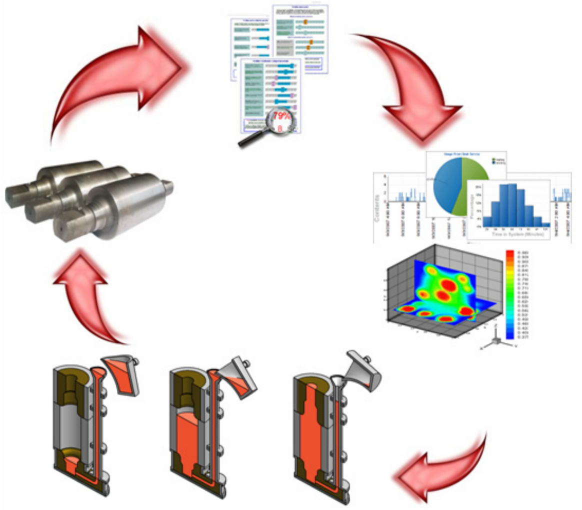

Figure 1. The optimization flowchart in the rolls manufacturing industry

Although the manufacture of rolls is in continuously perfecting, the requirements for superior quality rolls are not yet completely satisfied, in many cases, the absence of quality rolls preventing the realization of quality laminates or the realization of productivities of which rolling mills are capable. To the selection of materials is considered the type of rolling mill, the sizes of rolls (in specially this diameter), the speeds of lamination, the stands from the train of lamination for which is achieved rolls, the working temperature in the lamination process, the module of cooling during work, the size caliber, the pressure on rolls, the rolled material hardness, etc. The rolls must present high hardness at the crust of rolls and lower hardness in the core and on the necks, adequate with the mechanical resistance and in the high work temperatures. If in the crust the hardness is assured by the quantities of cementite from the structure of the irons, the core of the rolls must contain graphite to assure these properties.

The technological manufacturing process of the rolling mills rolls, as well as the quality of material used in manufacturing them, can have a different influence upon the quality and the safety in the exploitation. Our proposal approaches the issue of quality assurance of the rolling mills rolls, from the viewpoint of the quality of materials, which feature can cause duration and safety in exploitation. In these sense, our researches propose, on aside, to analyze the technological field of the rolling rolls manufacturing process – analysis materialized from prism of the foundry experiments, including the metallurgical and mechanical aspects (casting process, molding, iron melting, nodularization of graphite, hardness, durability and so others), and on another side, the optimization of the manufacturing technology of the cast rolls, especially those from cast-iron – using electronic calculus technique as the molding phenomenon and mathematical interpretation of the technological processes.

This study analyses iron rolls cast in the simplex procedure, in combined forms (iron chill, for the crust and moulding sand, for the necks of the rolls). The research included rolls from the half-hard class, with hardness, between 33…59 Shore units (219…347 Brinell units) for the 0 and 1 hardness class, measured on the crust, respectively 59…75 Shore units (347…550 Brinell units), for the class 2 of hardness. This study is required because of the numerous defects, which cause rejection, since the phase of elaboration of these irons, destined to cast rolls. According to the previous presentation, it results that one of the most important reject categories is due to the inadequate hardness of the rolls. The research includes half-hard cast rolls, from nodular graphite irons (type FNS), hardness class 1 and 2, with the half-hard crust of 40…150 mm depth. All these types of rolls have high strength, excellent thermal properties and resistance to accidents and there is very little hardness drops in the surface work layer.

❖ RESULTS AND DISCUSSIONS

The character of the metallurgical processes optimization is influenced by the complex peculiarities of these, which take place into a great number of variables (parameters) that operates independently or cumulate. For this reason, to analyze the metallurgical processes is used, mainly, the statistical fundamental methods that permit to drawn conclusions, from the observed values, about the repartition of the frequencies of various parameters, about their interaction, about verification validity of certain premises, and about the research of the dependencies among different parameters. However, the statistical methods of the metallurgical process analyses do not solve a series of aspects regarding the mode of establish the decisions for the management of the process. Thereof, parallel with the statistical methods it was developed optimization methods. Therefore, we suggest a mathematical interpretation of the influence of the main alloy elements over the hardness of these nodular cast iron rolls, resulting the average values and average square aberration of the variables HB, and the main alloying elements (Cr, Ni, Mo), the equations of the hyper surface in the four dimensional space. For the statistical and mathematical analysis, there were used a lot of industrial cases.

Figure 2. The multidimensional processing of experimental data

Next, there are shown the results of the multidimensional processing of experimental data (also presented in Figure 2). For that purpose, we searched for a method of molding the dependent variables depending on the independent variables x, y, z. The optimal form of molding, studied on a sample of the cases is given by the equation:

$$HB = -77.1259\,Ni^2 - 678.1307\,Cr^2 - 4915.8057\,Mo^2 + 384.4321\,Ni \cdot Cr - 1990.8226\,Cr \cdot Mo + 646.2006\,Mo \cdot Ni - 39.5771\,Ni + 471.3705\,Cr + 2131.6892\,Mo - 101.7176 \quad (1)$$

where the correlation coefficients is $rf_{HB = f(Ni,\ Cr,\ Mo)} = 0.7671$. The aberrations from the regression surface is $sf_{HB = f(Ni,\ Cr,\ Mo)} = 8.7376$.

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 (equations 2-4). These surfaces, belonging to the three-dimensional space, can be represented and, therefore, interpreted by technologists. Knowing these level curves allows the correlation of the values of the twos independent variables so that HB can be obtained in between the requested limits.

$$HB\ Ni_{med} = -678.1307\,Cr^2 - 4915.8057\,Mo^2 - 1990.8226\,Cr \cdot Mo + 1189.7571\,Cr + 3339.2414\,Mo - 445.0005 \quad (2)$$

$$HB\ Cr_{med} = -4915.8057\,Mo^2 - 77.1259\,Ni^2 + 646.2006\,Mo \cdot Ni + 1081.7467\,Mo + 163.1691\,Ni - 41.7373 \quad (3)$$

$$HB\ Mo_{med} = -77.1259\,Ni^2 - 678.1307\,Cr^2 + 384.4321\,Ni \cdot Cr + 114.9492\,Ni - 4.6957\,Cr + 126.9318 \quad (4)$$

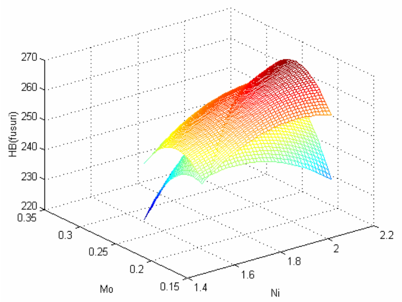

Figure 1. The volume variation of the regression surface HB for Cr = Cr_{med}

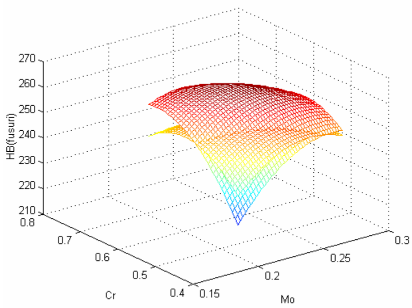

Figure 3. The volume variation of the regression surface HB for Ni = Ni_{med}

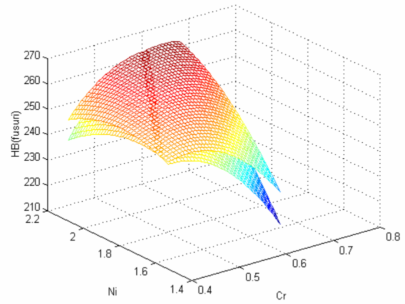

Figure 5. The volume variation of the regression surface HB for Mo = Mo_{med}

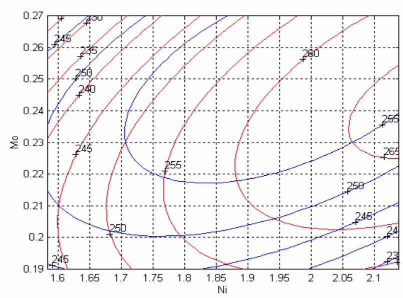

Figure 2. Level curves for the volume variation of the regression surface HB for Cr = Crmed

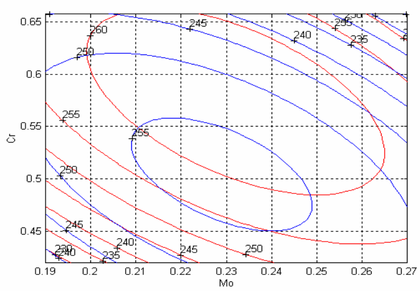

Figure 4. Level curves for the volume variation of the regression surface HB for Ni = Ni_{med}

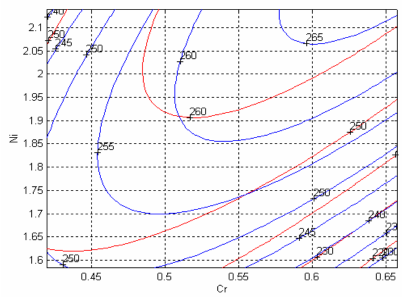

Figure 6. Level curves for the volume variation of the regression surface HB for Mo= Mo_{med}

❖ CONCLUSIONS

The performed research had in view to obtain correlations between the hardness of the cast iron rolls (on the necks) and the representative alloying elements. These results are immediate practical utility both the cast-iron rolling mills cylinders manufacturing industry, and the rolling sectors. In this sense, these researches results can be used in the collective framework of the foundries and the rolling mills sectors, for assurances quality of rolls as far back as phase of production, as well as in exploitation these, what lead to, inevitably, to the assurance quality of produced laminates.

The values processing were made using Matlab calculation program. Using this calculation program we determinate some mathematical correlation, correlation coefficient and the deviation from the regression surface. This surface in the four-dimensional space (described by the equations) admits a saddle point to which the corresponding value of hardness is an optimal alloying elements.

We can conclude the following technological aspects:

- the existence of a saddle point inside the technological domain has a particular importance as it ensures stability to the process in the vicinity of this point, stability which can be either preferable of avoidable.
- the behavior of this hyper surface in the vicinity of the stationary point (when this point belongs to the technological domain) or in the vicinity of the point where the three independent variables have their respective mean value, or in a point where the dependent function reaches its extreme value in the technological domain (but not being a saddle point) can be rendered only as a table, namely, assigning values to the independent variables on spheres which are concentrically to the point under study.
- as this surface cannot be represented in the three-dimensional space, we resorted to replacing successively one independent variable by its mean value. These surfaces (described by the equations), belonging to the three-dimensional space can be reproduced and therefore interpreted by technological engineers. Knowing these level curves allows the correlation of the values of the two independent variables so that we can obtain the hardness within the required limits.
- in the Figures 1, 3 and 5 the level curves for the volume variation of the regression surface HB (for the Ni_{med}, Cr_{med} and Mo_{med}) are presented. Also, the Figures 2, 4 and 6 presented the volume variation of the regression surface HB for one of the middle value of the analyzed chemical elements Ni, Cr, Mo.
- for a complete imagine upon the rolls quality assurance, we suggest a mathematical interpretation of the influence of the basic elements over the hardness, through the multi-component equations and the level curves for the volume variation of the regression surface HB (for the C_{med}, Si_{med} and Mn_{med}).

Therefore, the realization of an optimal chemical composition can constitute a technical efficient mode to assure the exploitation properties, the material from which the rolling mills rolls are manufactured having an important role in this sense. From this point of view is applied the mathematical modeling, witch is achieved starting from the differentiation on rolls component parts, taking into consideration the industrial data, as well as the national standards specifications, which recommends the hardness, for different chemical compositions.

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