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THE BASIC CHEMICAL COMPOSITION INFLUENCES UPON THE NODULAR CAST IRON ROLLS HARDNESS

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ABSTRACT

In our foundries, specialised in the cast iron rolls, in spite of trying the most accurate guidance of the iron melting processes, of the outside treatments melting aggregate, of the moulding and drying of moulds (the so-called casting process), of the cooling and the directional solidification of the castings in the moulds, as well as of the rapping, cleaning and the subsequent processing of the rolls, the performance factor remains relatively low.

This paper presents some considerations upon the mechanical properties, especially the hardness of the iron rolls, assured by the chemical composition and tries to draw some conclusions upon the optimal composition of this irons destined for rolls casting. Also, the paper presents the results of some researches regarding the chemical composition of the irons (with nodular graphite) destined for casting semihard rolls. It is presented, in graphical form, the influence of each chemical element, from the composition of these irons on the hardness, measured on the crust and the necks. Also, the hardness variation graphic is presented, with the carbon equivalent value.

KEYWORDS:
nodular semihard cast iron rolls, basic elements, hardness

1. INTRODUCTIVE NOTES AND PRESENTATION

The technical conditions, which are imposed to the cast iron rolls in the exploitation period, are very different and often contradictory. The obtaining of various physical and mechanical properties in the different points of the same foundry product meets difficult technological problems in the industrial condition. This supposes us to know many technological factors, which lead to this deformation equipment.

The rolls must present high exploitation qualities, which are determined from the hardness, resistance and high temperature stability. These qualities assure the high resistance at the wear in dried friction conditions, as well as the stability at unexpected temperature variations in the rolling operation, resistance at the thermal fatigue (because the rolls are heated at the contact of the laminate), high resistance at the thermal shock stress, as well as the bending strain. Also, the rolls must assure the clamping of materials, as well as the high quality of laminate surface.

The rolls must present high hardness at the crust of rolls and lower in the care and the neck's, adequate with mechanical resistance and in the high work temperature. If in the crust, the hardness is guarantied by the quantities of cementite in the structure of irons, the core of rolls must be content graphite, to assure this property.

One of the parameters, which are determined the structure of the irons destined for rolls casting, its is the chemical composition. If we do not respect this composition, which guaranties the exploitation properties of the each roll in the stand of rolling mill, leads to rejection. First, the hardness achievement of the crust of rolls, fixed strictly by the standards for each type in part, is conditioned by the achievement of the structure of iron (which contains pearlite, cementite and graphite). This structure is a result of the correct chemical composition, which is respected at elaboration, and the modification treatment of the graphite nodularity, in the case of irons with nodular graphite.

In our foundries, specialised in the cast iron rolls, in spite of trying the most accurate guidance of the iron melting processes, of the outside treatments melting aggregate, of the moulding and drying of moulds, the so-called casting process, of the cooling and the directional solidification of the castings in the moulds, as well as of the rapping, cleaning and the subsequent processing of the rolls, the performance factor remains relatively low.

The industrial analysis included charges of rolls from different hardness classes (semihard, hard), with definite and indefinite crust, in simplex or duplex cast processes. The main defects, which appear in the weight or on the surface of the rolls, are presented in their great variety on the figure 1, in graphical form.

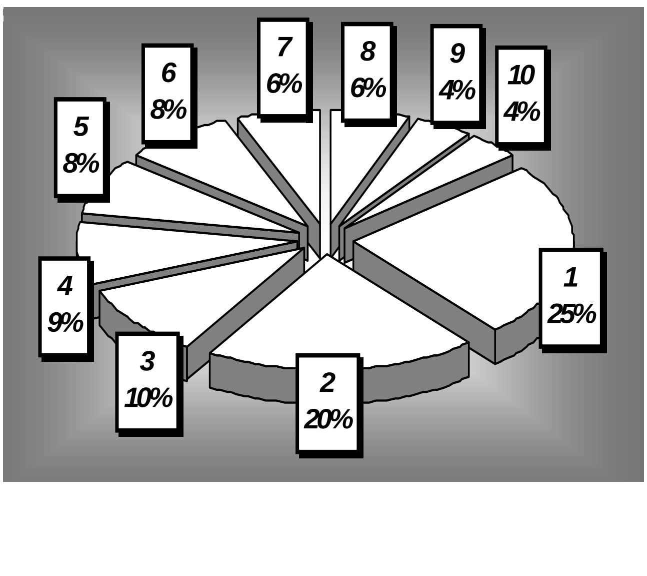

Figure 1.
The Repartition of the Cast Iron Rolls Rejection Forms
1. pockets (pipes);
2. cracks (longitudinal or transverse, at heat or at cold);
3. insufficient or extended depth of the roll's hard crust;
4. inadequate hardness at the necks and the body of roll;
5. inclusions and adherences;
6. shrinkages and porosities;
7. inadequate chemical composition;
8. texture defects;
9. inadequate base size;
10. other defects

From the total quantity of rejects, the pockets in the mass of the castings cause more than 25% and the causes for the presence of the pockets are various. The cracks (longitudinal or transverse) represent almost 20% from the total mass of rejects. Avoiding the occurrence of cracks is an extremely complex task, which requires an adequate respect of the rolls production technologies, especially in the preparation of the chill for casting.

Another group of defects, which lead to rejection, consists of inadequate depths of the hard crust of the rolls. These defects may consist of insufficient thickness of the crust, or of excessive thickness, instead of the specified ones by their subsequent destination. The uneven thickness on the height of the crust, on the rolling face, leads to rejection, too.

The rejected rolls quantity, caused by the inadequate hardness of the crust (the rolling surface), as well as of the necks and the core of rolls, is approximately 9% from the total reject forms. The insufficient or extended depth of the roll's hard or semihard crust is caused by the other 10% from the reject forms. In 6% of the situations, the rejection is caused by structural and texture defects.

2. TECHNICAL AREA OF ANALYSES

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 semihard 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 recommended hardness of these, on the crust, as well as on the necks and in the core of rolls, fixed by the standards, is presented in *table 1*. The recommended chemical composition for the semihard class rolls, cast from lamellar graphite iron (type FS) and nodular graphite iron (type FNS) is presented in *table 2*.

Table 1. *The Recommended Hardness of the Semihard Cast Iron Rolls*

Analysed Roll Types	*Class of Hardness*	***Recommended Hardness for these Rolls***			
		on the Crust (Surface) of Rolls		*on the Core and the Neck's of Rolls*	
		[Shore Hardness]	*[Brinell Hardness]*	*[Shore Hardness]*	*[Brinell Hardness]*
FNS	*0*	*33…42*	*218…286*	*30…40*	*195…271*
FNS	*1*	*43…59*	*294…347*	*30…40*	*195…271*
FS	*2*	*59…68*	*420…491*	*35…45*	*218…309*
FNS	*2*	*69…75*	*499…550*	*35…45*	*218…309*

Table 2. *The Recommended Chemical Composition of the Semihard Cast Iron Rolls*

Types of Rolls	Chemical Composition, [%]								
	C	Si	Mn	P	S	Ni	Cr	Mo	Mg
FS	2,9... 3,6	0,3... 1,2	max 0,6	max 0,15	max 0,1	max 0,6	max 0,5	0,3... 0,5	-
FNS	3,0... 3,5	1,2... 2,5	0,1... 0,7	max 0,15	max 0,02	1,5... 2,5	max 0,8	0,3... 0,5	0,02... 0,04

The chemical composition include both the basic elements (*C, Si, Mn, S, P*), and the alloying elements (*Cr, Ni, Mo*), as well as the magnesium content (in the case of nodular irons). In special cases, these irons can contain up to 0,15…0,2% vanadium. Also, in the case of elaboration of irons with nodular graphite, destined to casting rolls (type *FNS*), a higher content of phosphorus is accepted, because this chemical element participates at the hardening of the rolling surface of the rolls.

3. RESULTS OF ANALYSES

The research includes semihard cast rolls, from nodular graphite irons (type FNS), hardness class 1 and 2, with the semihard crust of 40…150 mm depth. The lot of analysed rolls is representative for the semihard category, the chemical composition and the measured hardness of that is presented in table 3. The hardness checking, both on the two necks of the rolls, and on the rolling surface, are made in equidistant points of the manufactured surfaces, according to the standard stipulation. The measured values of the hardnesses are presented in table 3.

The value of the equivalent carbon, calculated by the formula *I*, is recommended to be maximum 4,3%, for castings with the heavy thickness (in this case of rolls). Also, for the equivalent carbon value calculation, the formula *II* is accepted, too.

$$C_{ech} = C + 0,3\ (Si + P) - 0,03\ Mn + 0,4\ S + 0,07\ Ni + 0,05\ Cr\ [\%] \qquad (I.)$$

$$C_{ech} = C + 0,33\ Si + 0,1\ Ni\ [\%] \qquad (II.)$$

Table 3. *The Chemical Composition and the Measured Hardness of the Semihard Cast Iron Rolls*

Chemical Composition [%]					C_{ech} [%]	**Hardness** [Brinell units]	
C	**Si**	**Mn**	**P**	**S**		on the Necks	on the Crust
3,22…3,42	1,72…2,19	0,62…0,79	0,13…0,165	0,011…0,024	3,952 - 4,219	219…276	282…352
Ni	**Cr**	**Mo**	**Mg**				
1,49…2,22	0,36…0,72	0,18…0,28	0,021…0,029				

The main basic element of the irons composition is the carbon, which is influenced, both on the hardness, and on the strength of rolls. In this case of the semihard iron rolls, this chemical element varies between 3,0…3,5%, that assures the recommended hardness of the crust

(220…420 Brinell units) and of the core and of the necks (220…300 Brinell units). The chemical composition, analysed after the elaboration period, in the case of carbon content (3,22…3,42%), fits in the established values, while the hardness is between 219…276 Brinell units, measured on the different points of necks, respectively between 222…352 Brinell units (*table 3*).

The silicon percentage in these irons, destined to rolls casting, is in close dependence with the carbon content. With the growth of silicon and carbon content in the chemical composition of these irons, the semihard crust's thickness is narrowed, due to the growth of the graphite's quantity.

The separate effect of each of them is stronger when one of the elements is in a smaller or a larger proportion accordingly. But their action is similar. The silicon has influence upon the refinement of graphite, being one of the elements that have graphitesing effect and favours the presence of graphite in the core of rolls.

The hardness variation by the carbon and silicon content, on the crust and the necks, is presented in *figure 2*, respectively in *figure 3*. The chemical composition showed that the silicon varied between the values of 1,64…2,19%, which are accepted by the FNS types cast iron rolls standard (1,2…2,5%). *Figure 3* remarks the hardness diminution with the silicon content growth in the composition of these irons, the variation being similar with a carbon variation.

At a lower limit of manganese content, this element has a strong anti-graphitesing effect. Above the 0,7% in the manganese content of irons, the carbides are stabilised and the hardness is increasing. Above 1,0%, the manganese acts like alloying element, stabilises the cementite, and implicitly hardens the irons. The hardness variation with this chemical element is presented graphically in *figure 4*.

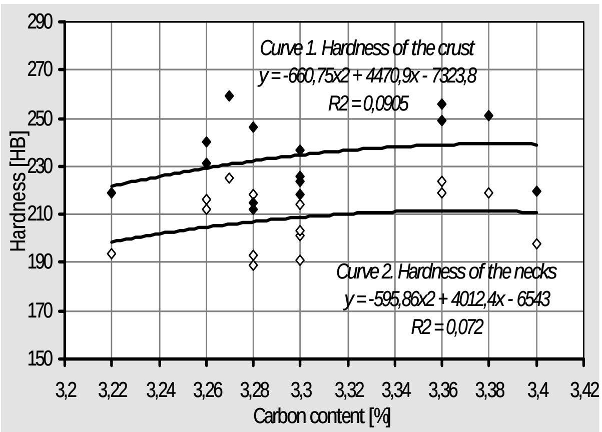

Figure 2.
The Hardness Dependence with the Carbon Content at the Semihard Cast Iron Rolls

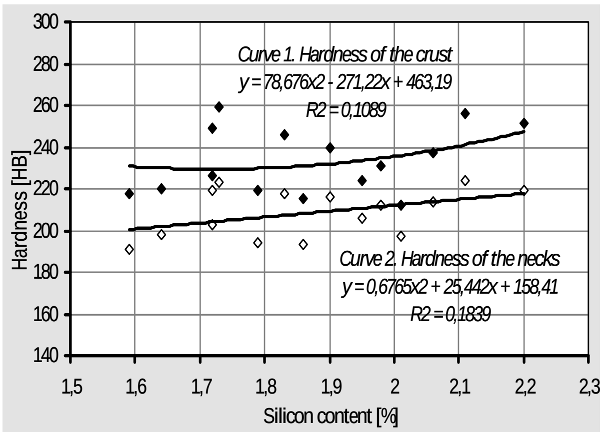

Figure 3.
The Hardness Dependence with the Silicon Content at the Semihard Cast Iron Rolls

The sulphur in these irons is recommended to be in minimal quantities, because this element has an unfavourable effect upon the mechanical properties; the hardness, as well as the strength decreases while the sulphur content grows. Also, the content of sulphur in the chemical composition affects the graphite nodularity, in case of nodular graphite irons, so there is a need to reduce it to the minimum. In this condition, the sulphur contents are strictly imposed and are recommended to be at maximum 0,02 %.

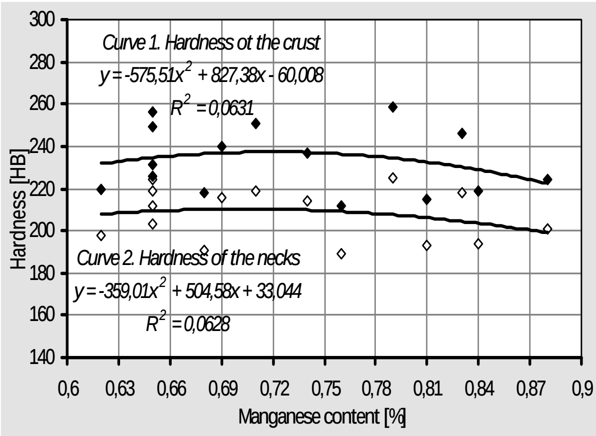

Figure 4.
The Hardness Dependence with the Manganese Content at the Semihard Cast Iron Rolls

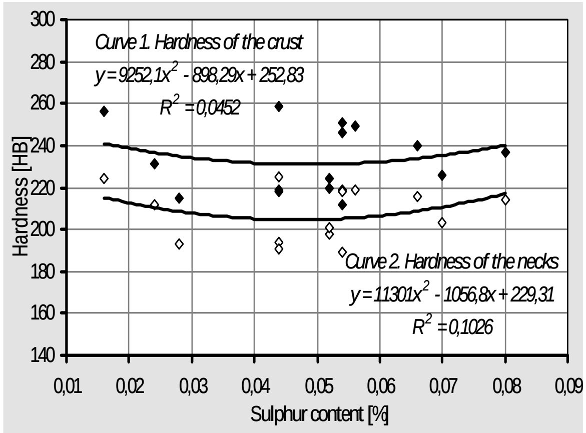

Figure 5.
The Hardness Dependence with the Sulphur Content at the Semihard Cast Iron Rolls

The graphical representation of hardness (*figure 5*) presents the optimal value of the hardness, on the crust and in the core of these rolls, for the analysed chemical composition. The graphic is made according to this data, and presents the hardness dependence with the sulphur content. In the conditions of the sulphur content limitation to the standard values, this element cannot prejudice the structure of the irons. Above this value, the sulphur has a negative value upon the irons' mechanical properties.

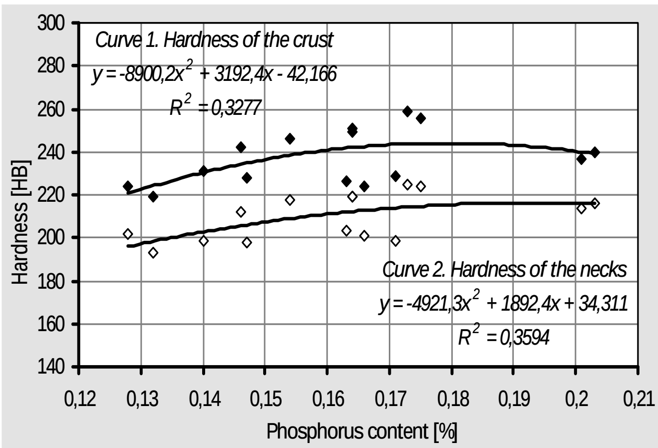

Figure 6.
The Hardness Dependence with the Phosphorus Content at the Semihard Cast Iron Rolls

In the case of semihard rolls, the phosphorus content is limited to a maximum of 0,2…0,3%. Because this chemical element shapes tough compounds, needed in the rolling surface, the phosphorus does not affect, if limited in the recommended intervals. The increase of hardness can be observed in the graphic of *figure 6*, together with the growth in the chemical composition of phosphorus percentage.

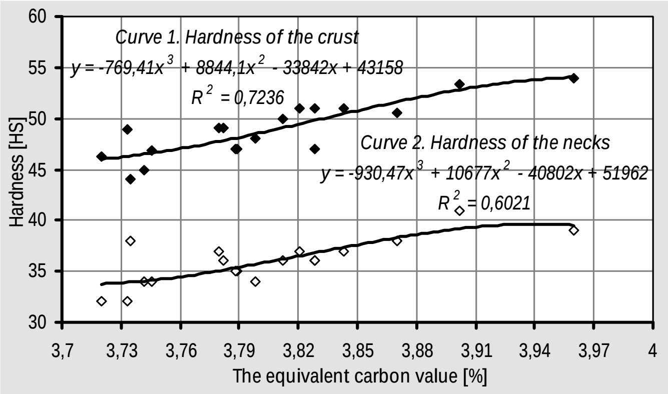

Figure 7. *The Hardness Dependence (on the Necks and on the Semihard Crust of Rolls) with the Value of Equivalent Carbon*

Figure 7. presents the hardness variation both on the crust and on the necks and in the core of the rolls according the equivalent carbon values, calculated for the each chemical composition in part. A smooth increase of the hardness is to be noticed at higher values of the equivalent carbon and also a concentration of the marks for hardnesses at values of approximately 3,7…3,8%. Having in view the considerable stress during the workings of the rolls, high mechanical properties (resistance to wear, resistance to abrasion, resistance to thermal shock, hardness on the rolling surface and in the core and on the necks, etc.) are imposed on them. Consequently the equivalent carbon content diminishes from 4,2% (its value stands between 3,8 ÷ 4,0%), as the irons are hypoeutectic.

4. CONCLUSIONS

- in the processing phase of the irons, the hardness is adjusted through the quality of the metallic charge and of the addition materials, as well as through a proper leading of the melting and of the processing; An optimal proportion between the silicon and the manganese contents is needed both from the basic metallic charges and from the ferro-alloy addition (FeSi, FeMn, SiMn);
- the optimal values of the chemical composition in the main elements (C, Si, Mn, S, P) of this irons destined to the cast of the semihard rolls are to be found on the diagrams on figures 3…7. According to them the optimal values in the concentration of each main element can be noticed, values that can assure the adequate hardness on different areas of the rolls; a special importance is needed to be given to the sulphur from this irons, as it can effect the nodularity;
- for a narrower semihard or hard crust on the rolling surface of the rolls, a supplementary addition of FeSi is made, which released the silicon, thus segregating supplementary quantities of graphite in the crust area and narrowing the crust; For crusts of increased depth a supplementary addition of carbides is made to heighten the quantity of the tough formation cementite;
- the main chemical composition must be correlated with further addition of alloying elements, respecting the adequate proportions between nickel and silicon, chrome and nickel, molybdenum and phosphorus, sulphur and magnesium, besides an optimal ratio of carbon and silicon.

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