ANNALS OF THE FACULTY OF ENGINEERING HUNEDOARA
2004, Tome II, Fascicole 1

SOME CONSIDERATIONS REGARDING THE MODIFICATION TREATMENT OF THE GRAPHITE NODULARITY AT THE CAST IRON ROLLS

IMRE KISS

UNIVERSITY "POLITECHNICA" of TIMIŞOARA,
ENGINEERING FACULTY of HUNEDOARA
5, REVOLUŢIEI, HUNEDOARA, 331128, ROMANIA

ABSTRACT

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.

One of the parameters, which determine the structure of the irons destined for rolls casting, is the chemical composition. If we not respect this composition, which guaranties the exploitation properties of the each roll in the stand of rolling mill, it will lead to rejection. Also, the inadequate treatment with magnesium for obtaining the nodular graphite's iron can produce one of the important forms of rejection in the case of cast iron rolls.

This paper presents an analysis of the main factors in the practical conditions of the foundry, factors that have influences on the durability of the magnesium treatment and on the later inoculation effect on irons destined to cast rolls, and presents also some graphical addenda.

KEY WORDS:

graphite nodularity, modification treatment, cast iron rolls,
chemical composition, mechanical properties, hardness

1. INTRODUCTION

Ductile iron belongs to the family of cast graphitic irons, which possess high strength, ductility and resistance to thermal shock. Its strength, toughness and ductility duplicate many grades of steel and far exceed those of standard grey irons. Yet it possesses the advantages of design flexibility and low cost casting procedures similar to grey iron. The difference between ductile iron and grey iron is in the graphite formation. Ordinary grey iron is characterised by a random flake graphite pattern in the metal. In ductile iron the addition of a few hundreds of 1% of magnesium or cerium causes the graphite to form in small spheroids rather than flakes. These create fewer discontinuities in the structure of the metal and produce a stronger, more ductile iron. It is this graphite formation, which accounts for the fact that ductile iron is also referred to as "nodular iron." The nodular graphite cast iron is considered as one of the most versatile roll materials nowadays. A small proportion of magnesium added to the melt as nickel-magnesium or alternative alloy, or as pure magnesium produces it. In the nodular graphite's iron roll, the free carbon takes the shape of spheroids or nodules, thereby eliminating the notch effect of flake graphite and improving upon the mechanical properties of the cast iron.

Nodular graphite cast iron rolls are so superior in wear resistance to that of cast steel rolls that they are specially adapted for roughing and intermediate plate mills and rod or bar mill roughers. As a result of the spherical form of the graphite, these iron rolls are much stronger than rolls of the clear-chill type and the gradual fall in hardness is an added advantage. As such, these rolls are particularly suitable for strip mills, also bar billet mills, and are being increasingly used for other applications.

The improved mechanical properties increase its resistance to breakage from physical load, or mechanical and thermal shock far above that of grey iron. The corrosion resistance of ductile iron is equal or superior to grey cast iron and to cast steel in many corrosives. Its wear resistance is comparable to some of the best grades of steel and superior to grey irons in heavy load or impact load situations. Because it can be cast with the same low cost procedures used for grey iron it is considerably less expensive than cast steel and only moderately more expensive than grey iron.

The structure of the nodular graphite cast iron rolls consists of transformed austenite (pearlite) eutectic carbide and nodular (or spherical) graphite. These rolls may have a pearlitic matrix or, if relatively large amount of alloy elements is present the structure may be acicular or martensitic. These are specifically good for small section and flat rolling. There is also some use of pearlitic structure's nodular graphite iron rolls in conditions in which the first essential is toughness, rather than wear-resistance. The rolls are destined for heavily loaded roughing stands.

The nodular cast iron rolls are characterised by the nodular shaped graphite in the microstructure. Through adjusting the alloy elements of nickel, chrome and molybdenum and heat treatment technique, the different type of rolls of popular nodular graphite cast iron. Large scale alloyed nodular graphite cast iron, pearlitic nodular graphite cast iron and acicular nodular graphite cast iron can be manufactured. All these types of rolls have high strength, excellent thermal properties and resistance to accidents and there is very little hardness drop in the surface work layer.

These type of material may be used to produce large scale rolls in double pouring process, the barrel of rolls has high hardness while the neck has high toughness, so these type of rolls exhibit the properties of high thermal stability and resistance to wear.

2. TECHNICAL AREA OF ANALYSES

As the characteristics of any casting are influenced by the microstruture that is formed during the solidification in the casting form, and under the influence of the cooling speed, the main criteria, which determines the mechanical properties of the rolls is the structure. All structural components can be found in cast iron rolls, each of the components having its own well-determined hardness.

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

This study continues the analyses of influence of the chemical composition upon the mechanical properties of roll (especially that of hardness). The analyses concern the influence of main alloying elements in the chemical composition of the irons, as well as the conditions under which the hardness is affected by the insufficient nodularity of the graphite. All FNS type rolls are alloyed especially with chrome, nickel and molybdenum, in different percentages. The irons destined to these cast rolls belong to the class of low-alloyed irons, with reduced content of these elements. The technological instructions firmly state the elements required to rise the quality of rolls. In this case, the contents of these elements stand between large limits. Also, the contents of these alloying elements can be reduced due to the strong effect of the magnesium from the nodulising agent, upon the structure and the form of the graphite.

3. RESULTS OF ANALYSES

Magnesium plays a special part, as it is the element with which the ladle inoculation has been made, either by itself or as a master alloy. The graphite’s nodularity in the irons destined to cast rolls (type FNS) assures higher mechanical properties, by eliminating a series of the inconveniences that are to be found at the rolls cast from irons with lamellar graphite. This aspect, concerning the nodularity of the graphite and the inoculation treatment with magnesium, is dealt with a special attention in this study. Just as in the case of the irons with lamellar graphite, after the ladle inoculation (treatment), in the case of irons with the nodular graphite there is a process of de-modification, due especially to the magnesium loss. This effect consists of powerful decrease of the nodule number and a higher whitening tendency. This last effect can be counteracted through a later postmodification of the irons, treated by strong inoculate agents.

A special importance is to be given to the influence of the time factor. Maintaining the treated irons in liquid state causes important structural changes. After approximately 5 minutes, the shape of the graphite begins to alter, and cementite appears in the metallic mass implicitly whitening the irons. After 20 minutes, graphite is to be found in the structure in an intermediate form, besides the ferrite. After 30 minutes, the structure is made up by graphite, exclusively under lamellar form, and by ferrite. These alterations of the graphite’s form are due to the losses of magnesium in time. The losses of magnesium at maintaining in liquid state depend also on the irons chemical composition.

Also, the higher the sulphur and oxygen contents in the melting bath are, the stronger the de-modifying effect will be. The magnesium from the irons may be consumed, due to the reaction with the oxygen and the nitrogen from the melting bath.

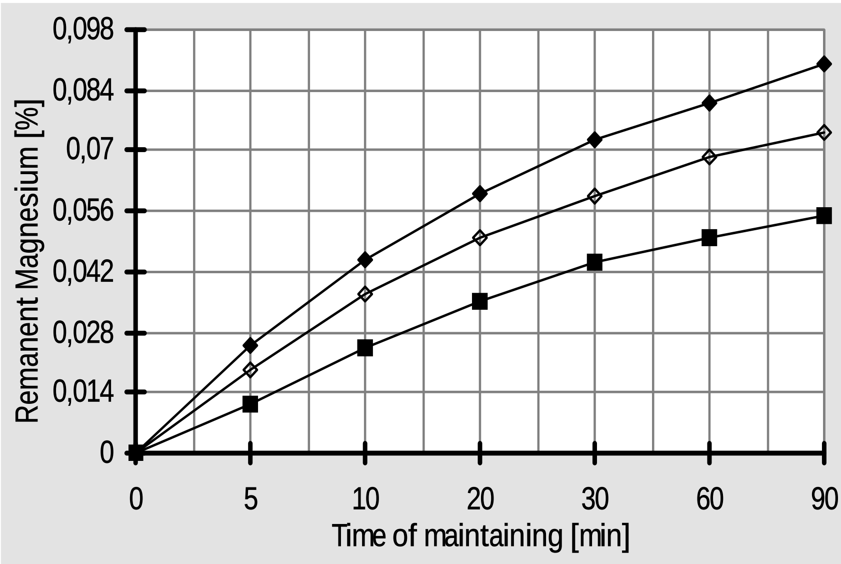

Figure 1.
The Influence of Maintaining at Heat ($1400\ ^0C$) of the Inoculated Irons upon the Residual Magnesium Content

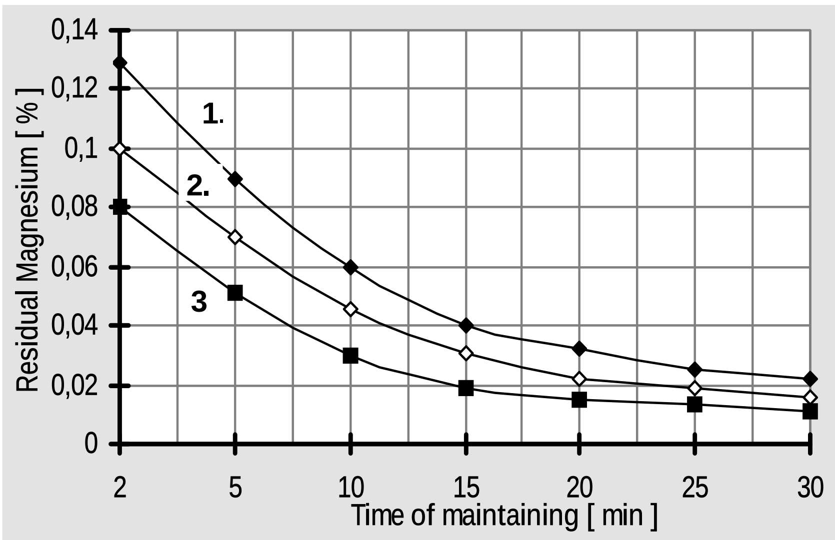

Figure 2.
The Influence of the Temperature of Maintaining upon the Magnesium Loss
1. at $1440\ ^0C$;
2. at $1420\ ^0C$;
3. at $1400\ ^0C$

Considering the magnesium losses, it is recommended for the casting to be executed at about 6 ÷ 10 minutes, after the magnesium treatment.

Thus, the risks of an iron de-modification will be minimal. As shown previously, the de-modification consists not only in the degeneration of the nodular form of the graphite, but also in the disappearance of the graphitesing post-modifier effect, after magnesium treatment. There is a considerable diminution of the number of graphite nodules, at maintaining in liquid state. This is due also to the chemical composition of the modifier used in this purpose. Also, the presence of free cementite in the structure at 5÷10 minutes after modification is another result due to the disappearance of the modifying effect. The loss of nodulising effect at maintains after the ladle inoculation, is characterized by the continuous decrease in time of the residual magnesium. This content, in the nodular graphite's iron, results from the following three sources:

- dissolved magnesium in the melting bath;
- magnesium in the microparticle;
- magnesium in the slags particle.

The sum of these three sources is equivalent with the value determined through analyses, respectively the content of the residual magnesium in the irons. When there is no certified analytical method to separate between the three contributions, then the magnesium determined in the analyses will be both the dissolved and the combined magnesium. In the ladle inoculation, both the number of nodules and the graphite's nodularity decrease simultaneously.

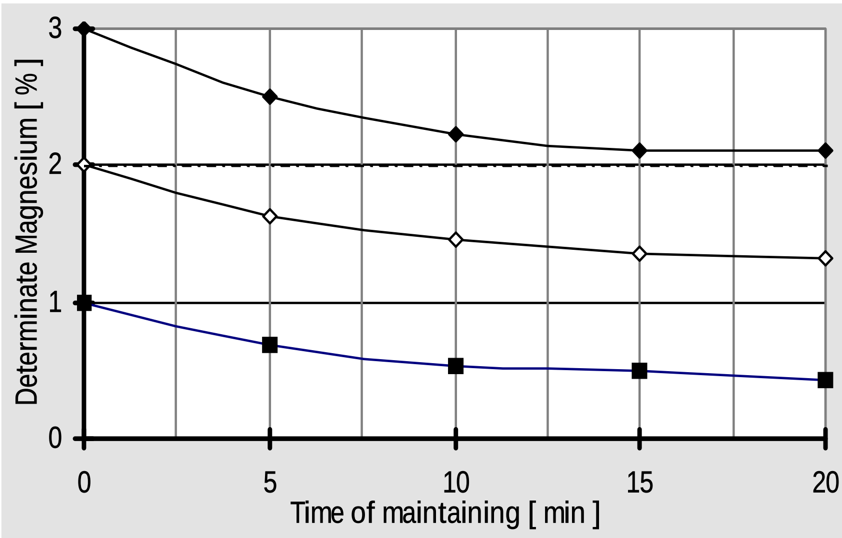

Figure 3. The Magnesium Losses at the Maintain, after Magnesium Treatment
height 1. the loss of the dissolved Mg in the melting bath;
height 2. the loss of the Mg in the microparticles;
height 3. the loss of the magnesium in the slag

These parameters are regained through a new addition of the inoculate agent. Thus, the maintaining of the magnesium treated irons for a few minutes before the addition of the inoculate agent can be an advantage, as the largest part of the undesirable elements (particles and slag microparticles), can be separated on the surface of the melting bath. Therefore, the inoculation must be done as close to the casting process as possible. The diminution of the maintaining period after the inoculation leads to avoiding the losses of nodularity.

In figure 3 the magnesium content decrease on the melting bath is presented, at maintaining after the nodulising treatment of the graphite. The decrease of the magnesium value in each of the component is to be noticed. The graphite's nodularity, as well as the magnesium loss in time, is presented in figure 4. The graphite's nodularity is rebuilt at the new addition of the inoculate agent, in two phases:

- phase I. - the ladle inoculation with magnesium (or master alloy with the magnesium content), followed by the first inoculate with FeSi;
- phase II. - the second FeSi addition

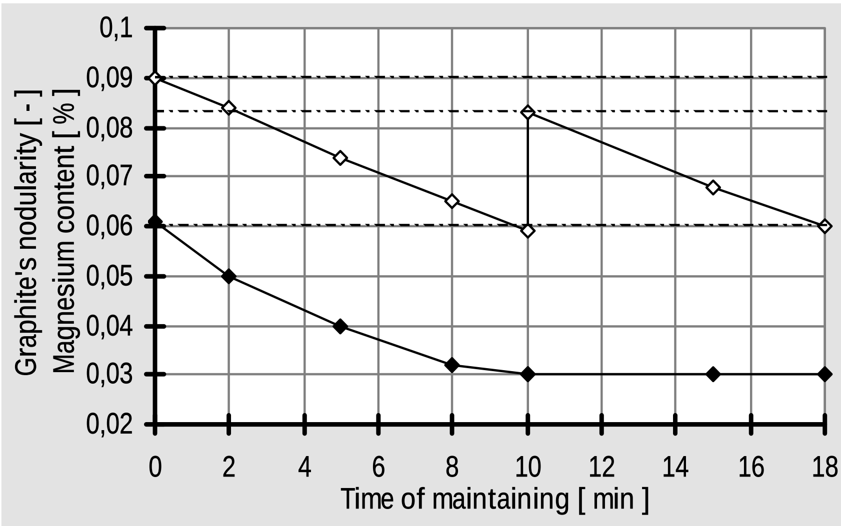

Figure 4. The Influence of the Post-modification at Irons upon the Rebuilt of the Graphite Nodularity
height 1. (at 0,06% Mg) – the curve of the magnesium loss in time;
height 2. (at 0,09% Mg) – the variation of the graphite's nodularity during the ladle inoculation and the second addition

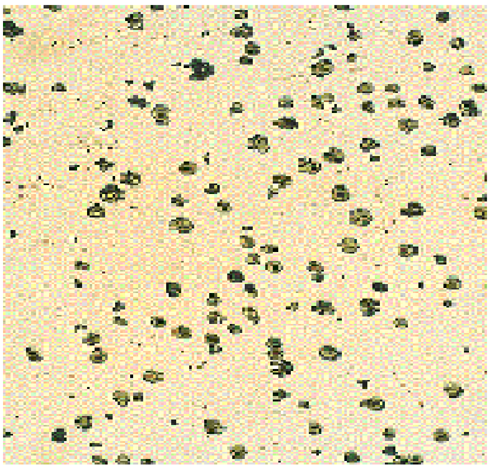

Figure
The Pearlitic Nodular Iron
X50

Figure
The Pearlitic Nodular Iron
X100

4. CONCLUSIONS

- the non-uniformity of the hardness of the crust is due to shape deformations, which cause hard marks on the surface of the rolls, disturbing further mechanical manufacturing;
- the non-uniformity of the crust can be technologically imposed, just as in the case of the passing area;
- the macrostructure is not imposed (except for the nodular graphite irons, where a spherical shape of the graphite is required), conditioned by the adequate quantities of cementite in the crust and graphite in the core and on the necks.
- the process of de-modification (the magnesium losses effect) can be counteracted through a post-modification of the irons, treated by strong inoculate agents or through a second addition, before the casting.

5. BIBLIOGRAPHY/REFERENCES

[1.] BUDAGHIANŢ, N.A., KARSSKI, V.E.: Cast Iron Rolls, Editura Tehnică, Bucureşti, 1984.
[2.] DIETER, G.E.: Mechanical Metallurgy, Editura Tehnică, Bucureşti, 1970
[3.] PIWOWARSKI, E.: High Quality Irons, Editura Tehnică, Bucureşti, 1967
[4.] SOFRONI, L., RIPOŞAN, I.: Iron Casting, Editura Tehnică, Bucureşti, 1985
[5.] SOFRONI, L., STEFANESCU, D.M.: Special Irons, Editura Tehnică, Bucureşti, 1974
[6.] SOFRONI, L., STEFANESCU, D.M.: Inoculate Irons with High Properties, Editura Tehnică, Bucureşti, 1971
[7.] SOFRONI, L., STEFANESCU, D.M.: Irons with Nodular Graphite, Editura Tehnică, Bucureşti, 1974
[8.] RIPOŞAN, I.: Nodular Graphite Iron for the Cast Iron Rolls, in: Buletin of University Politehnica Bucureşti, 1980/3
[9.] SOFRONI, L., RIPOŞAN, I.: Contribution for the Improvement of the Cast Iron Rolls Quality, in: Metalurgia, 1983/10
[10.] COJOCARU, V.: Mărimea suprafeţei reacţiei de modificare şi dirijarea vaporilor de magneziu în oala de turnare, in: Revista de turnătorie, no.2, 1997, pg. 29…32
[11.] COJOCARU, V.: O nouă concepţie asupra pierderii efectului modificator, in: Revista de turnătorie, No. 1 - 2, 1995
[12.] DINESCU, L., CRĂCIUN, ŞT., POPESCU, M.: Fabricarea fontelor cu grafit vermicular, cu controlul şi corectarea operativă a formei grafitului, in: Metalurgia, no.3, 1980, pg. 171…175
[13.] MARINICĂ, I.: Consideraţii privind eliminarea petelor negre din cilindrii turnaţi din fontă cu grafit nodular, in: Metalurgia, no.10, 1971, pg. 623…626
[14.] PERCHERON, J.C.: Contribution á l'étude de tratement des fontes a graphite spheroidal, in: Revue de Metallurgie, no.5, 1971, pg. 365…378
[15.] KISS, I.: Considerations upon the Reject Forms of the Cast Iron Rolls, at Scientific Conference, Bucureşti, 2000
[16.] KISS, I.: The Hardness of Cast Iron Rolls with Indefinite Structure, in: Symposium, Petroşani, 2001

[17.] KISS I., HEPUŢ T.: Mechanical properties of the cast iron rolls, assured by the chemical composition, Buletinul Ştiinţific al Universităţii Politehnica Timişoara – Mecanics series, 2002
[18.] KISS I., HEPUŢ T.: The hardness of the cast iron rolls, assured by the alloy elements and the modification treatment of the graphite nodularity, Buletinul Ştiinţific al Universităţii Politehnica Timişoara – Mecanics series, 2002
[19.] KISS I., RATIU S., VILCEANU L, ALEXA V.: Particularităţi ale proprietăţilor mecanice la cilindri de laminor turnaţi din fonte cu grafit nodular, Simpozion International Universitaria ROPET, Petroşani, 2002
[20.] A. JOSAN, D. PETRE, I. KISS.: Studies and researches on the influence of chemical composition of cast rolls made of hypereutectic steel, on their hardness in exploitation, Scientific Conference Research and Development of Mechanical Elements and Systems Jahorina – IRMES, Sarajevo, Bosnia & Hertegovina, 2002
[21.] KISS I.; RAŢIU S.; NICA Gh.: Some considerations regarding the mechanical properties of the cast iron rolls, assured by the chemical composition and the modification treatment of the graphite nodularity (I), Scientific Conference Research and Development of Mechanical Elements and Systems Jahorina – IRMES, Sarajevo, Bosnia & Hertegovina, 2002
[22.] KISS I.; JOSAN A; CIOATĂ V.: Some considerations regarding the mechanical properties of the cast iron rolls, assured by the chemical composition and the modification treatment of the graphite nodularity (II), Scientific Conference Research and Development of Mechanical Elements and Systems Jahorina – IRMES, Sarajevo, Bosnia & Hertegovina, 2002
[23.] KISS I., HEPUŢ T., RAŢIU S.: The Hardness Of The Cast Iron Rolls, Assured by the Alloyed Elements and the Modification Treatment of the Graphite Nodularity, in: Masinstvo – Journal of Mechanichal Engineering, No.1 / 2003, Zenica, Bosnia & Hertegovina
[24.] KISS I.: The Mechanical Properties of the Semihard Cast Iron Rolls Assured by the Basic Elements, in: Masinstvo – Journal of Mechanichal Engineering, No.4 / 2003, Zenica, Bosnia & Hertegovina