International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 13, Issue 2 (February 2017), PP.30-35

Some Results from the Investigation of Effects of Heat Treatment on Properties of Ni-Hard Cast Irons

Blagoj Lj. Rizov
"Sts. Cyril And Methodius" University In Skopje Faculty Of Technology And Metallurgy, 1000 Skopje, Republic Of Macedonia

Abstract:- The results of an investigation which was undertaken to reveal the differences in the mechanical properties and microstructural characteristics of two types of Ni-hard cast irons are presented in this study. The cast irons were obtained in a laboratory conditions and their compositions are in accordance with European standard EN 12513. One type of cast iron is EN GJN-HV520 (Ni-hard 2) containing 2.10% Cr and the second type EN GJN-HV600 (Ni-hard 4) with 9.04% Cr. The cast irons were evaluated in both as-cast and heat treated conditions. To improve mechanical properties specifically wear resistance, the samples of both types Ni-hard cast irons were subjected to different heat treatment processes. Annealing of Ni-hard 2 samples at 480°C during 4 hours caused increasing of hardness for about 13.5% due to additional precipitation of secondary carbides. On the other hand the heat treatment process consisting of annealing at 790°C during 4-8 hours of Ni-hard 4 samples, compared to the as-cast condition, improve the hardness for about 22.5%. In this case besides precipitation of secondary carbides, transformation of retained austenite to martensite occurs.
Keywords:- white cast iron, Ni-hard, abrasion resistance, heat treatment.

I. INTRODUCTION

For many years the cast irons are materials which are fulfilling the demands for economical production and offer good service properties. However, along with the economic development comes the need to use materials with higher durability and better properties; that`s why the use of alloyed cast irons has increased lately. Among the alloyed cast irons the abrasion resistant cast irons are really important. The European standard EN 12513 these irons differentiates in three classes of white, abrasion resistant cast iron: unalloyed or low-alloyed cast iron; chromium-nickel cast irons and cast irons with high chromium content [1]. Unlike other cast iron materials, the chemical composition is also included in the standards for alloyed white cast irons because it determines the microstructure, response to heat treatment and above all, the wear characteristics. In this study our interest was focused on the second class of cast irons.

The cast irons alloyed with Ni and Cr, that have wide use in the production of castings with high resistance to abrasion, are known as Ni-hard. Since they are highly resistant to wearing, these materials are particularly suitable for applications involving wear caused by minerals, for example in grinding tools, in reducing, mixing and conveying equipment and systems and pumps [1]. Ni-hard castings can be considered as economic substitute for the carbon and manganese steels and in every other case when there is need for abrasion resistance but only when they are not completely expose to impacts. Nickel and chromium are the main alloying elements, but also there are some other elements depending of the content of the main elements. Ni-hard castings can be divided in two main groups. The first one is with lower content of chromium (1.5 – 3 mass %) and the second one with higher content (8-10 mass % Cr). The first group Ni-hard castings is mostly used when there is need of high abrasion resistance at lower or moderate impacts. As a result of the high strength and toughness, the second group is used when there is need of increased wear and impact resistance. The usual criteria for evaluating Ni-hard castings in exploitation conditions is the hardness that on the other hand depends of the microstructure. We should have in mind that not only the chemical composition, but also the cooling rate and the heat treatment have influence on the microstructure. [2]

The nickel content is essential in order to obtain a martensitic-bainitic matrix structure without pearlite. The necessary nickel content depends on the casting section and the cooling rate. The hardness maximum providing best abrasion resistance corresponds to the nickel content producing the maximum amount of martensite. At lower nickel contents, hardenability is not sufficient to suppress pearlite formation, resulting in reduced hardness and abrasion resistance. An excessive nickel content will favour the formation of retained austenite, which will lower the hardness. The main goal of alloying the cast iron with nickel is to create a martensitic structure with high hardness. The hardness of metal matrix could be increased through formation of carbides in the structure. The amount of carbide particles as hard component is dependent on the amount of carbon and some carbide forming elements. For that reason, the chromium is also used for alloying. The presence of chromium increases the tendency for complex carbides with high level of hardness to be formed ([1],

[2], [3]). According to this, the alloying of cast iron with nickel and chromium leads to create hard metal matrix with chromium mixed-carbides distributed more evenly in the microstructure, causing high level of abrasion resistance.

Although Ni-hard was originally intended to use in as-cast condition, practically all Ni-hard iron castings are heat treated prior to their use in service. Heat treatment of these castings enhances their impact resistance and reduces stresses in the castings. Heat treatment results in significant improvement in strength and resistance to impact. No loss of hardness and abrasion resistance occur due to heat treatment ([4], [5]). There are three basic heat treatments which serve three purposes: 1) stress relief and improved toughness, and some improvement of repeated impact fatigue resistance, by tempering at 225-275°C (single-stage tempering); 2) improved repeated impact fatigue resistance by a duplex treatment at 450 + 275°C (double-heat treatment); 3) improved hardness and abrasion resistance by soaking at 750-850°C, slow cooling, and tempering (hardening) ([6], [7]).

II. EXPERIMENTAL PROCEDURE

Two types of Ni-hard cast irons were tested, type EN GJN-HV520 (Ni-hard 2) and type EN GJN-HV600 (Ni-hard 4) according to EN 12513. These types of cast irons were obtained in the laboratory for casting of metals in the Faculty of Technology and Metallurgy in Skopje. The charge materials for melting include gray cast iron, steel scraps, nickel, ferro-alloys and carburite. The melting was performed in a crucible middle frequency induction furnace. The temperature of casting was between 1450°C and 1470°C. The melt was poured into a sand molds For created with CO_2 method. For this investigation were prepared cylindrical probes with Ø30 mm and three-level probes with different thickness (28 mm, 14 mm and 8 mm) for both types of Ni-hard cast irons. For determination of the chemical composition, the microstructure and the hardness before and after the heat treatment, 4 cylindrical specimens and 3 three-level probes for both types were used. The heat treatment of the first type cast iron (Ni-hard 2) involves annealing at temperature of 480 ^{o}C during different holding times of 4, 8 and 12 hours and for second one (Ni-hard 4) the heat treatment process consisted of annealing at 790 ^{o}C during 4, 8 and 12 hours.

III. RESULTS AND DISCUSSION

The results from the examination of the chemical composition of both types Ni-hard cast irons using X-ray quantitative analysis are given in Table1. It's obvious that the composition of obtained cast irons is in accordance with standard EN 12513 for these types of white cast irons.

Table 1. Chemical composition of Ni-hard cast irons

Element wt %	Standard EN 12513	Ni-hard 2	Standard EN 12513	Ni-hard 4
C	2.5-3.0	2.80	2.5-3.5	3.20
Si	max. 0.8	0.60	1.5-2.5	1.95
Mn	max. 0.8	0.54	0.3-0.8	0.49
Ni	3.0-5.5	4.50	4.5-6.5	5.11
Cr	1.5-3.0	2.10	8.0-10.0	9.04
Mo	0-0.4	0.50	0-0.4	0.49

The microstructures of both types cast irons in as-cast condition are shown on the Figures 1 and 2. As can be observed in Fig. 1, the microstructure of Ni-hard 2 consists of primary austenite dendrities and carbide eutectic. The eutectic is a mixture of carbide plates, (probably M_3C), and austenitic-martensitic matrix. The microstructure of the second type (Ni-hard 4), Fig. 2, that contains 5.11% Ni, 9.04 % Cr and 3.2% C is different. In this case, the as-cast matrix structure consists of about equal amounts of martensite and austenite and some secondary carbides. The higher chromium content promotes formation of M_7C_3 carbides.

On the Fig 3 to 5 the microstructure of Ni-hard 2 is given, after heat treatment at temperature of 480 °C in different holding time (4, 8 and 12 hours). The microstructural comparison of the samples demonstrated that a minor microstructural variation is resulted from the increase in the holding time at that temperature and it means that the chosen intervals have insignificant effect on the transformation of the high-temperature phase austenite, in one of the low-temperature phases (martensite or bainite). The microstructures of the Ni-hard 4 after heat treatment at temperature of 790 °C in different holding times of 4, 8 and 12 hours are shown on the Fig. 6 to 8. It's obvious that the content of martensite is higher with more secondary carbides. This is a reason for increasing the hardness, shown in Table 2.

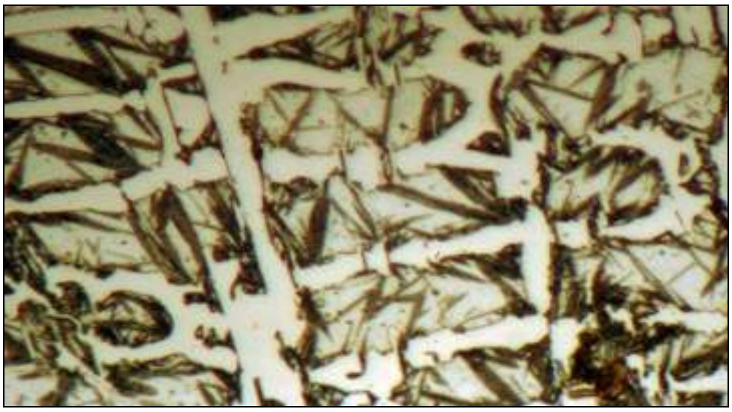

Fig. 1. Microstructure of Ni-hard 2, in the as-cast condition, X500; etched with Villela's

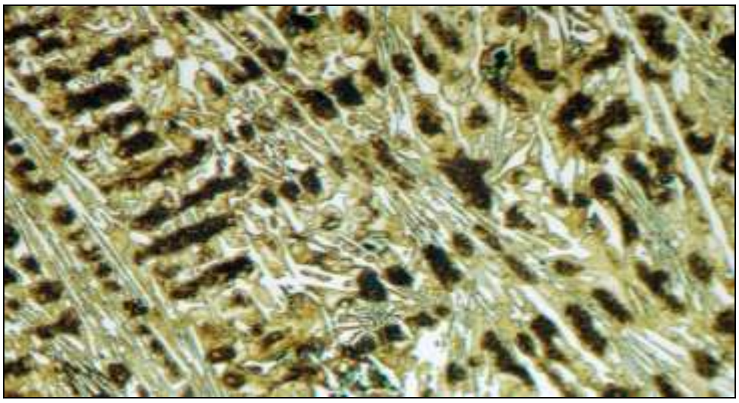

Fig. 2. Microstructure of Ni-hard 4, in the as-cast condition, X200; etched with Villela's

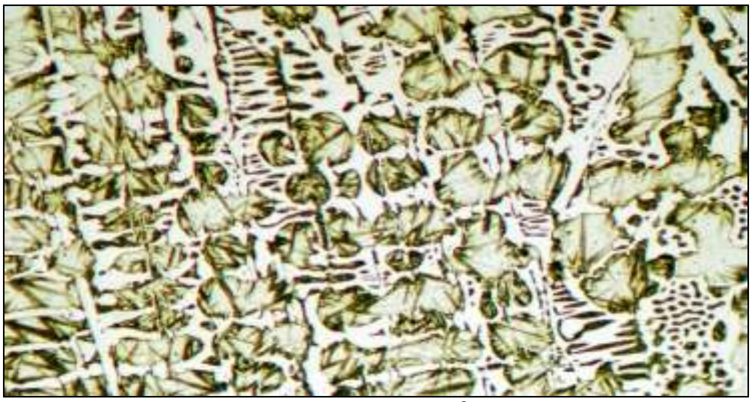

Fig. 3. Microstructure of Ni-hard 2, after annealing at 480^{o}C, during 4 h, X200; etched with Villela's

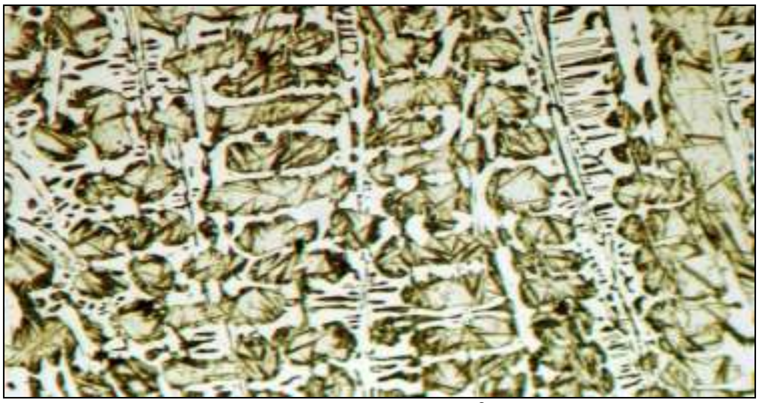

Fig. 4. Microstructure of Ni-hard 2, after annealing at 480^{o}C, during 8 h, X200; etched with Villela's

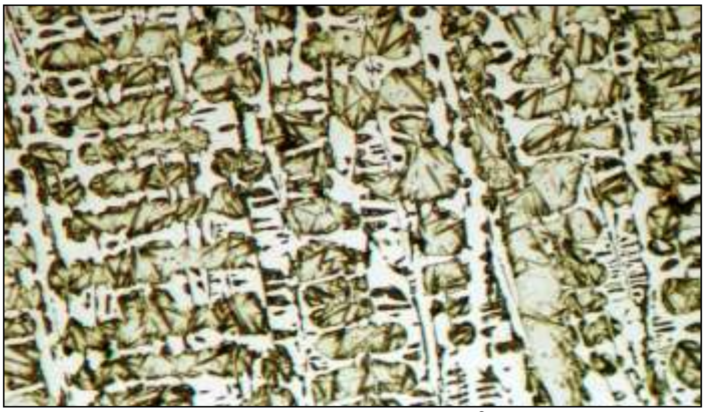

Fig. 5. Microstructure of Ni-hard 2, after annealing at 480^{o}C, during 12 h, X200; etched with Villela's

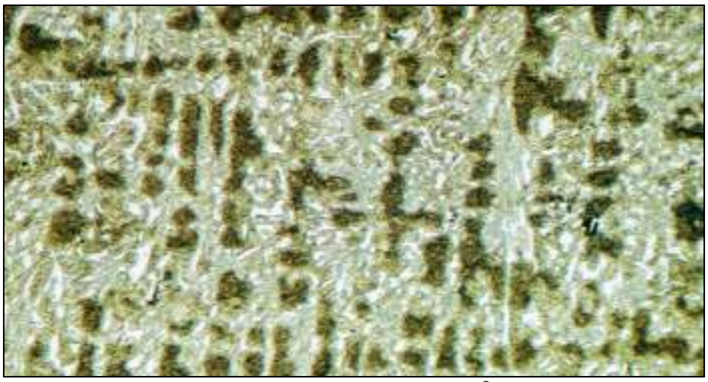

Fig.6. Microstructure of Ni-hard 4, after annealing at 790^{o}C, during 4 h, X200; etched with Villela's

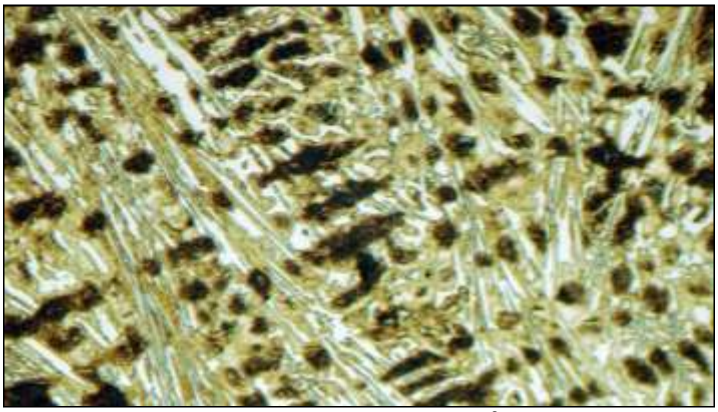

Fig. 7. Microstructure of Ni-hard 4, after annealing at 790^{o}C, during 8 h, X200; etched with Villela's

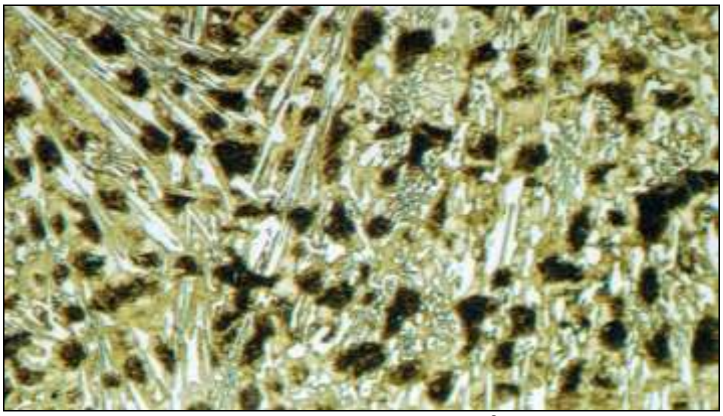

Fig. 8. Microstructure of Ni-hard 4, after annealing at 790^{o}C, during 12h, X200; etched with Villela's

The hardness was measured by the Rockwell C method on all cylindrical samples and on the three level probes of both types of Ni-hard iron castings. In the Table 2, the results of the hardness measuring of cylindrical samples for Ni-hard 2 and Ni-hard 4 are shown.

Table 2. Values of hardness for cylindrical samples

Sample	Conditions	HRC (Ni-hard 2)	Condition	HRC (Ni-hard 4)
1	As-cast	55.3	As-cast	49.5
2	Annealing at 480°C for 4 h	61.7	Annealing at 790°C for 4 h	61.4
3	Annealing at 480°C for 8 h	63.0	Annealing at 790°C for 8 h	60.1
4	Annealing at 480°C for 12 h	63.4	Annealing at 790°C for 12 h	60.0

The results of the hardness measuring on three level probes in as-cast condition and after heat treatment for type Ni-hard 2 and Ni-hard 4 are shown in the Table 3. At least three measurements for reporting each data point were made in all samples.

Table 3. Values of hardness for three-level probes of Ni-hard 2 and Ni-hard 4

Sample	Conditions	position 1 (28 mm)	position 2 (14 mm)	position 3 (8 mm)
Ni-hard 2, 1	As-cast	52.0	53.0	54.3
Ni-hard 2, 2	Annealing at 480 °C for 4h	63.0	64.2	64.3
Ni-hard 4, 3	As-cast	48.7	49.8	50.8
Ni-hard 4, 4	Annealing at 790°C for 8h	61.4	62.5	62.4

The hardness is usually regarded as an indication of abrasion resistance of material. As it is known the higher the hardness, the higher the abrasion resistance. From the obtained results for hardness (Table 2 and 3) it can be concluded that with applied heat treatment processes to both types of Ni-hard samples, the microstructure was changed and the level of hardness is increased for about 6 to 12 HRC compared to the as-cast ones. The increasing of the hardness can be interpreted by the transformation of retained austenite to martensite and additional precipitation of secondary carbides. As can be observed from Table 3, the difference in thickness of three-level probes caused a minor variation of hardness (1-2 HRC). Based on these results it can be concluded that the cooling rate does not significantly influence for such dimensions of probes.

IV. CONCLUSIONS

This study was carried out to investigate the effects of heat treatment on the performance of Ni-hard cast irons. Based on the obtained results presented previously, it can be concluded that the heat treatment caused some changes in microstructure and mechanical properties (hardness) at both types of cast irons.The difference in hardness in as-cast condition for two types of cast irons is due to more quantity of retained austenite in Ni-hard 4, (more alloying elements).During heat treatment, by increasing the holding time at appropriate constant temperature for both types of Ni-hard cast irons, very slight changes in mechanical properties (hardness) could be observed.The annealing of Ni-hard 2 cast iron at 480°C leads to increasing of the hardness for about 11.6-14.6% regarding to as-cast condition. Prolongation of the soaking time to 12 hours doesn’t influence on the values for hardness.

That means that 4 hours are quite sufficient time for desirable effects. This treatment promotes secondary carbides precipitation which reduces carbon content of austenite. The heat treatment of Ni-hard 4 samples at 790 °C leads to increasing of the hardness for about 21-24%. During soaking at this temperature, secondary carbides are precipitated from the austenite which increase the Ms temperature and facilitates transformation to martensite during cooling to room temperature.

REFERENCES

[1]. www.classguss.de, Claas Guss, Technical Information, No 11.

[2]. C.P. Sharma, Engineering Materials-Properties and Apllications of Metals and Alloys, Prentice Hall India, New Delhi, 2004.

[3]. T.V.Rajan, C.P. Sharma and A. Sharma, Heat Treatment Principles and Techniques, Prentice Hall India, New Delhi, 2011.

[4]. K. Rohrig, Ni-hard Material Data and Applications, Pennsylvania State University, 2010.

[5]. Ö.N. Doğan, J.A. Hawk, J. Rice, "Comparison of three Ni-Hard i alloys", Materials Science and Technology Conference, New Orleans, LA, 2004, pp. 26–29.
[6]. A. Kosowski, E. Syrala, "Wybrane Wlasciwosci Mechaniczne i Uzytkowe Zeliwa NI-hard 4", Archives of Foundry Engineering, (2004), Vol. 4, 11, pp. 266-273.
[7]. D. Kir, H. Öktem, M. Çöl, F. Gül Koç, F. Erzincanli, "Determination Of The Cutting-Tool Performance Of High-Alloyed White Cast Iron (Ni-Hard 4) Using The Taguchi Method", Materials and Technology, (2016), 50, 2, pp. 239–246.