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THE INFLUENCE OF HARDENING TREATMENT ON THE MECHANICAL AND TRIBOLOGICAL PROPERTIES OF NODULAR CAST IRON

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ABSTRACT
Heat treatment, and especially austempering on bainite structure, significantly expands the area of applicability of nodular cast iron.
The austempered ductile iron is applied increasingly for machine components exposed to high dynamic loads. In this way steel forgings and steel castings are substituted by austempered ductile iron ensuring adequate reduction of production costs.
In this paper the influence of austempering and conventional quenching and tempering treatments on mechanical and tribological properties of nodular cast iron NL 420 is examined.
Keywords: nodular cast iron, austempering, conventional quenching and tempering

1. INTRODUCTION

Nodular cast iron represents valuable material in mechanical engineering and its production is growing rapidly in all industrial countries. The production of nodular cast iron in the world is today around 17 mil. tonnes per year with an increase of about 7 to 8 % annually. This increase shows that nodular cast iron is a very economical cast material for the foundries as well as for the designers and users of this material [1].
By its mechanical and physical properties the nodular cast iron is between gray iron and cast steel. The heat treatment significantly increases application area of nodular cast iron.
Conventional quenching and tempering treatment of nodular cast iron consists of hardening and tempering, and after that, martensitic microstructure is obtained. Austempering of nodular cast iron consists of austenitizing, quenching to the isothermal transformation temperature, duration on this temperature and easy cooling to the room temperature. By the austempering of nodular cast iron bainite microstructure is obtained [3,4]. This paper examines the influence of austempering and conventional quenching and tempering of nodular cast iron NL420 on mechanical (tensile strength R_m, yield stress $R_{p0,2}$, elongation A and hardness HV) and tribological (abrasive wear resistance) properties compared to nodular cast iron NL 420 without heat treatment.

2. EXPERIMENTAL WORK

Samples made of nodular cast iron NL420 were used for this investigation. The results of chemical composition testing are represented in Table 1.

Table 1. Chemical Composition of NL420

%C	%Si	%Mn	%S	%Cr	%P	%Cu	%Mg
3,26	2,62	0,19	0,01	0,036	0,03	1,07	0,031

The following experiments have been planned and carried out:

I. Austempering and conventional quenching and tempering of nodular cast iron NL420.
II. After the heat treatment the samples were tested for hardness by Vickers method and tensile tests were carried out.
III. Tribological testings on abrasion wear resistance with wear subscripts calculated by the method of wear depth measurement ($i_{\Delta l}$) and the method of weight loss measurement ($i_{\Delta m}$).

2.1. Heat Treatment of the Nodular Cast Iron NL420

Figure 1. shows the process diagram of the austempering of nodular cast iron NL420 and Figure 2. shows the process diagram of conventional quenching and tempering of nodular cast iron NL420.

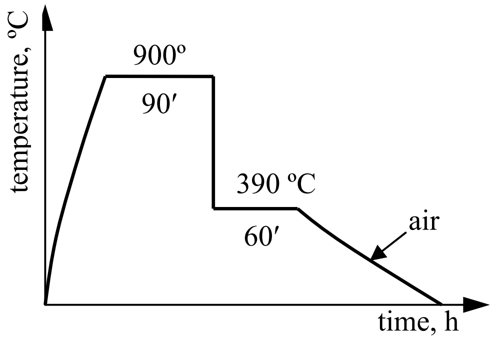

Figure 1. Diagram of Austempering of Nodular Cast Iron NL420

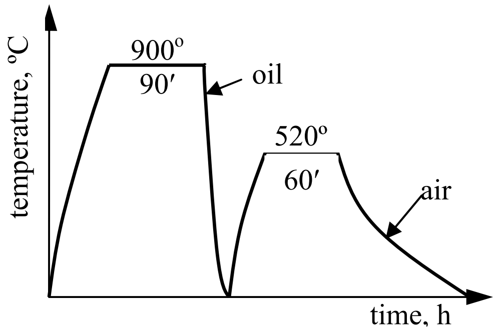

Figure 2. Diagram of Conventional Quenching and Tempering of Nodular Cast Iron NL420

2.2. The Results of Mechanical Testing

After the heat treatment the hardness has been tested by Vickers method HV5, three measurements for each sample, and after that the average value was calculated.

The values of hardness HV5 are given in Table 2. Figure 3. shows the histogram of hardness values HV5.

Table 2. The Results of Hardness Testing

Condition of material NL420	Sample mark	HV5			
		Ordinal number of measurement			Average value
		1	2	3	
No heat treatment	1.1	150	178	177	168
	1.2	162	160	175	166
Austempered ϑ_a=900°C/1.5h i ϑ_i=390°C/1h	2.1	332	336	313	327
	2.2	328	340	326	331
Quenched & tempered ϑ_a=900°C/1.5h i ϑ_p=520°C/12h	3.1	330	321	329	327
	3.2	333	320	337	330

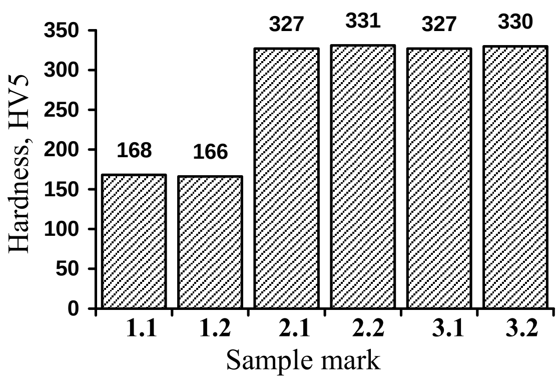

Figure 3. Histogram of Hardness Values HV5

The results of tension test are represented in Table 3, and Figures 4, 5 and 6 show histograms of mechanical properties (R_m, $R_{p0,2}$ and A) depending on the type of heat treatment process.

Table 3. The Results of Tension Testing

Condition of material NL420	Sample mark	R_m, N/mm^2	$R_{p0,2}$, N/mm^2	A, %
No heat treatment	1.1	417	299	18,0
	1.2	421	320	19,2
Austempered	2.1	985	862	6,3
ϑ_a=900^{o}C/1.5h i ϑ_i=390^{o}C/1h	2.2	975	856	7,2
Quenched & tempered	3.1	953	0	0
ϑ_a=900^{o}C/1.5h i ϑ_p=520^{o}C/12h	3.2	959	0	0

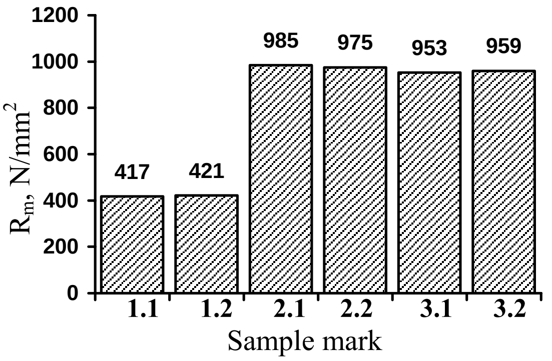

Figure 4. Histogram of Tensile Strength Values

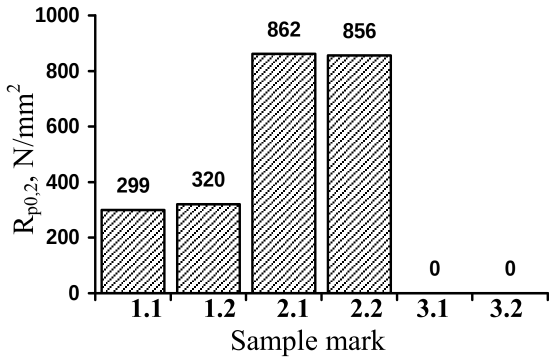

Figure 5. Histogram of Yield Stress Values

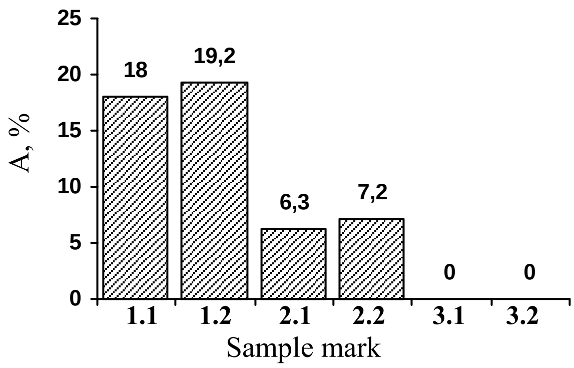

Figure 6. Histogram of Elongation Values

2.3. The Results of Tribological Testings

The wear resistance of NL420 on abrasion was conducted on Taber Abraser device model 503.

The abrasion resistance examination was carried out with the friction pair of the specimen (ϕ6x12mm) and the grinding plate B60K6V36 with grain size No. 8.

The results of tribological measuring of abrasion wear are expressed by wear index:

- method of wear depth measurement ($i_{\Delta l}$)

$$i_{\Delta l} = \frac{\Delta l \cdot 1000}{n} \tag{1}$$

where: Δl - wear depth in mm; n - number of revolutions

- method of weight loss measurement ($i_{\Delta m}$).

$$i_{\Delta m} = \frac{\Delta m \cdot 1000}{n} \tag{2}$$

where: Δm - wear mass in mg: n - number of revolutions

The results of tribological testing are represented in Table 4, and Figures 7 and 8 show histograms of wear index ($i_{\Delta l}$ and $i_{\Delta m}$) depending on the type of heat treatments process.

Table 4. The Results of Testing Represented by Wear Index

Condition of material NL420	Sample mark	$i_{\Delta l}$	$i_{\Delta m}$
No heat treatment	1.3	$19 \cdot 10^{-3}$	4
	1.4	$19{,}6 \cdot 10^{-3}$	3,9
Austempered ϑ_a=900°C/1.5h i ϑ_i=390°C/1h	2.3	$6{,}6 \cdot 10^{-3}$	1,34
	2.4	$7 \cdot 10^{-3}$	1,16
Quenched & tempered ϑ_a=900°C/1.5h i ϑ_p=520°C/12h	3.3	$5{,}8 \cdot 10^{-3}$	1
	3.4	$5 \cdot 10^{-3}$	0,9

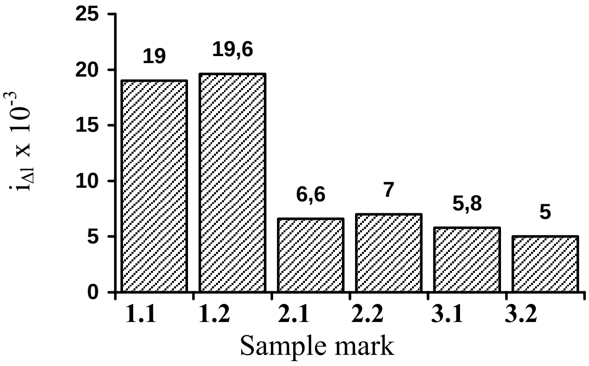

Figure 7. Histogram of Wear Index $i_{\Delta l}$

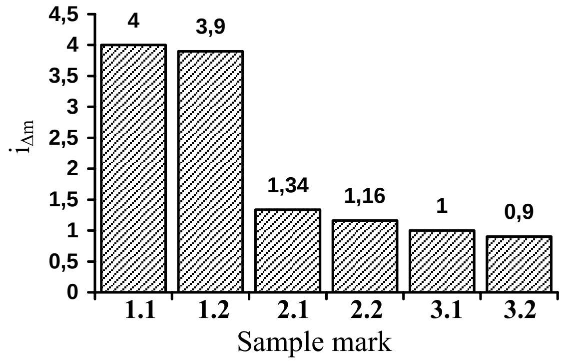

Figure 8. Histogram of Wear Index $i_{\Delta m}$

3. CONCLUSION

The represented results indicate significant influence of austempering and conventional quenching and tempering heat treatment on mechanical and tribological properties of nodular cast iron NL420.

The austempering of nodular cast iron increases hardness, tensile strength, yield stress and abrasion wear resistance and decreases elongation, compared to not heat treated nodular cast iron NL420.

The conventional quenching and tempering of nodular cast iron increase hardness, tensile strength, and abrasion wear resistance and significantly decrease yield stress and elongation, compared to not heat treated nodular cast iron NL420.

With conventional quenching and tempering, the same levels of hardness and tensile strength have been obtained as by austempering, but there were some differencs in abrasion wear resistance. The reason for difference in abrasion wear resistance is different microstructure condition.

The conventional quenched and tempered nodular cast iron with martensitic microstructure has higher abrasion wear resistance compared to austempered nodular cast iron with bainite microstructure, although their hardness values are the same.

4. REFERENCES

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