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THE EFFECT OF ISOTHERMAL AUSTEMPERING ON MECHANICAL AND TRIBOLOGICAL PROPERTIES OF NODULAR CASTING IRON

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ABSTRACT
In this paper, the effects of isothermal tempering on mechanical and tribological properties of ADI have been examined. Isothermal tempering of ADI significantly increase mechanical properties of hardness and tensile strength with simultaneous retention of ductility properties. Results of tribological research on abrasion and adhesion indicate considerably greater abrasive resistance of ADI regarding bainite structure in comparison with not austempered nodular iron.
Keywords: austempered ductile iron (ADI) pearlite nodular casting NC700, tribological properties, abrasion, adhesion

1. INTRODUCTION

Austempered Ductile Iron (ADI) represents the latest form of nodular casting which offers superior mechanical properties, even two times greater strength than standard quality nodular castings, retaining at the same time the same ductility and yield properties. Such material has got high dynamic toughness and is extremely resistant to abrasive wear. ADI is extensively used as substitution material for production of expensive components which are manufactured from the rolled, forged iron and steel castings, resulting in major production cost savings.
Its advantage lies in excellent machinability (cost savings for machine tools), increased speed of machine operations, better vibration damping, near net shape casting of the product, and reduction of the weight of the product, etc.
The paper presents some test results obtained after research of the influence of the baianite structure on mechanical and tribological properties of ADI.

2. TESTING PROCEDURE

Austempering has been carried out on pearlite nodular casting NC 700, obtained after austenitization at 900°C/90 minutes, quenching to temperatures of isothermal transformation (250°C, 300°C and 350°C), keeping at this temperature level for 180 minutes, and cooling on room temperature, as shown in Fig.1.

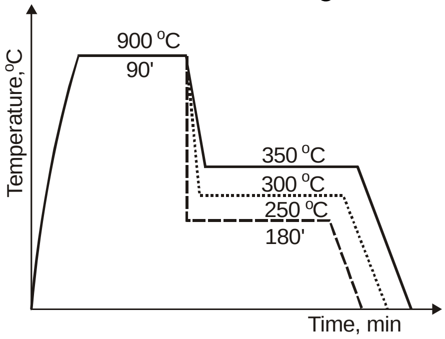

Figure 1. Time-temperature diagram, $\vartheta - t$, austempering on upper and lower baianite structure

Testing of mechanical properties: tensile strength R_m, yield $R_{p0.2}$ and elongation A, has been carried out with standard test samples on tear machine "Schenck" according to test procedure schedule shown in Table 1.

Table 1. Test schedule for mechanical testing of test samples

	Heat treatment of test sample			
	state at time of	austempering		
	delivery	250°C	300°C	350°C
Designation of test sample	1.1 1.2	2.1 2.2. 2.3 2.4	3.1 3.2 3.3 3.4	4.1 4.2 4.3 4.4

ADI abrasion tests have been performed on ASTM device *Taber Abrazer*, Model 503, keeping up strictly to the test schedule shown in Table 2:

Table 2. ADI abrasion test schedule

ϑ, °C	abrasive pair				
	test sample number			plate number	
350°C	1.1.	1.2	1.3	1 SP	GP
300°C	2.1	2.2	2.3	2 SP	GP
250°C	3.1	3.2	3.3	3 SP	GP
delivery sate	4.1	4.2	4.3	4 SP	GP

SP - steel plate
NC - nodular casting plate
GP - grinding plate

Adhesion testing has been performed by coupling of nodular casting against nodular casting plate (NC against NC), and nodular casting against quenched steel plate with hardness of 60 HRC.
During abrasion testing with test sample made of nodular casting, left plate has got designation B60 K6V36. It is grinding plate containing white corund and ceramic, ASTM grain size 8.

3. TEST RESULTS

Test results of mechanical properties of austempered nodular casting NC 700 are shown in Table 3:

Table 3. Results of mechanical testing of material NC 700

Austempering temp.	Test sample designation	R_m MPa	$R_{m\ sr.}$ MPa	$R_{p0,2}$ MPa	$R_{p0,2\ sr.}$ MPa	A %	$A_{sr.}$ %
delivery	1.1	753,5		-		-	
state	1.2	734,9	744,2	442,9	442,9	-	-
	2.1	1327		1157		6,68	
250	2.2	1375	1351	1088	1125	5,4	4,79
	2.3	1369		1127		3,4	
	2.4	1372		1128		3,68	
	3.1	1084		747		6,55	
300	3.2	1051	1062	838	821	6,74	6,39
	3.3	1055		803		6,83	
	3.4	1059		897		6,42	
	4.2	999		645		15,68	
350	4.2	1004	999	632	645	13,2	15,7
	4.3	1015		629		14,4	
	4.4	978		674		19,44	

Abrasion resistance is calculated by the following methods:

a) depth of abraded surface method
b) volume loss method

a) Results of measuring by volume loss method are represented by index of abrasion, in the following equation:

$$i_{\Delta l} = \frac{\Delta_l \cdot 1000}{n}$$ where we have:

$i_{\Delta l}$ - abrasive index obtained by measuring of depth of abraded surface

Δ_l - depth below abraded surface , mm

n - number of revolutions

Table 4 shows measured abrasion values obtained by method of measuring of depth of abraded surface $i_{\Delta l}$.

Table 4. Abrasion measure results expressed by abraded depth index $i_{\Delta l}$

Austempering temperature	Abrasion Index	Kind of tribologic test		
		adhesion		abrasion
350°C	$i_{\Delta l1}$	$2{,}047 \cdot 10^{-3}$	$1{,}761 \cdot 10^{-3}$	$5{,}810 \cdot 10^{-3}$
300°C	$i_{\Delta l2}$	$2{,}266 \cdot 10^{-3}$	$2{,}001 \cdot 10^{-3}$	$4{,}751 \cdot 10^{-3}$
250°C	$i_{\Delta l3}$	$2{,}381 \cdot 10^{-3}$	$1{,}667 \cdot 10^{-3}$	$4{,}320 \cdot 10^{-3}$
state at time of delivery	$i_{\Delta l4}$	$3{,}841 \cdot 10^{-3}$	$3{,}105 \cdot 10^{-3}$	$6{,}820 \cdot 10^{-3}$

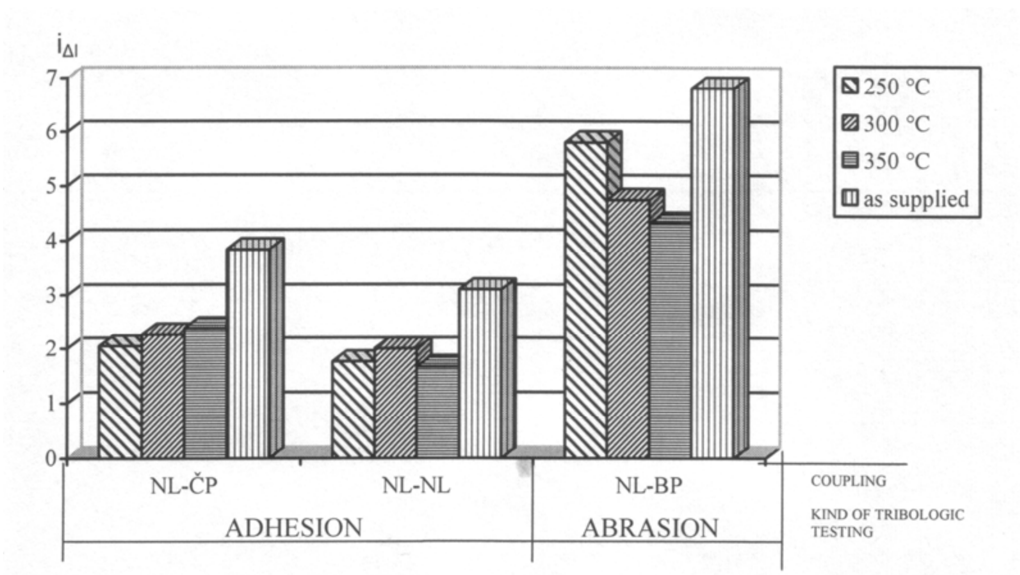

Figure 2. Graphic representation of the volume loss test results

Table 5. Volume loss test results

Austempering temperature	Abrasion index	Kind of tribologic testing		
		adhesion		abrasion
350°C	$i_{\Delta m1}$	0,1667	0,0619	1,1524
300°C	$i_{\Delta m2}$	0,1714	0,1143	1,1429
250°C	$i_{\Delta m3}$	0,1050	0,0810	1,0334
state at the time of delivery	$i_{\Delta m4}$	0,2013	0,1972	2,4651

$$i_{\Delta/m} = \frac{\Delta_m \cdot 1000}{n}$$ where we have:

$i_{\Delta m} =$ abrasion index obtained by volume loss method

$\Delta_m =$ volume loss, mm

$n =$ number of revolutions

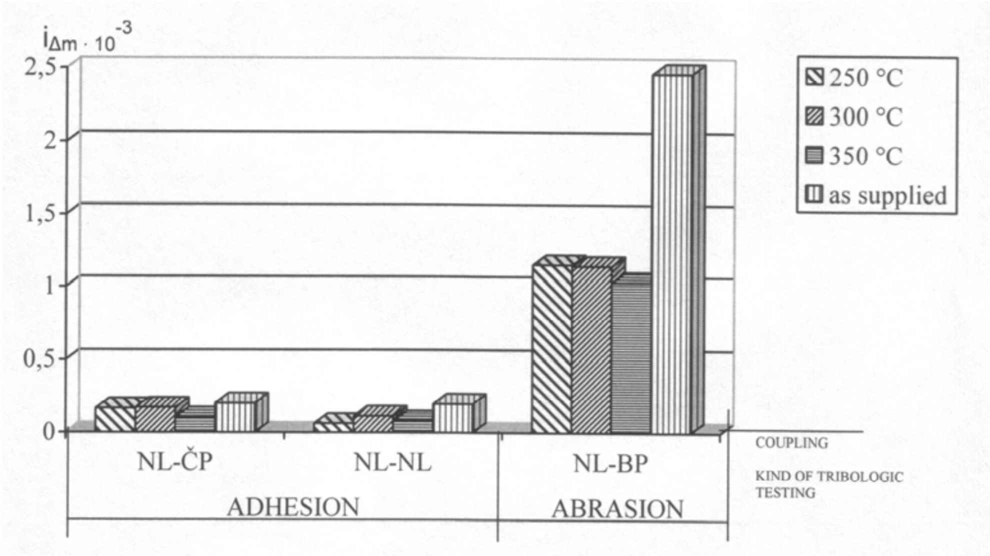

Figure 3. Graphic representation of test results and abraded depth measuring

4. CONCLUSION

Test results of mechanical properties (HV, R_{m1} , $R_{p0,2}$, A) of ADI in comparison with nodular casting NC 700 at the time of delivery show hardness HV increase, tensile strength R_m increase with satisfactory retention of other mechanical properties (elongation and yield). Tensile strength R_m and yield $R_{p0,2}$ display high values at lower transformation temperature (lower baianite) but with increase of austempering temperature these values deteriorate.

Tribologic test results on adhesion between test samples made of nodular casting NC and the steel plate (SP) in the first experiment, and NC plate in the second experiment indicate evident increase of adhesive resistance of ADI NC 700 in relation to situation at the time of delivery.

It has been proved that austempering temperatures do not exert essential influence on adhesive resistance of austempered NC. It has been noticed that better results might be expected when both abrasive couples are made of nodular casting (NC-NC). Among other things (i.e. improved mechanical properties), the content and the form of graphite in ADI exert beneficial influence by some sort of "lubrication" during testing.

Abrasion test results show that abrasion resistance depends in high degree upon hardness of the test sample which comes into contact with the abrasive device.

The best results have been found on test samples at austempering temperature of 250°C, which is characterized by the lower baianite structure.

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