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THE INFLUENCE OF THE HARDENING COOLANT AGENT ON THE PROPERTIES OF HOT ROLLED BARS OF THE STEEL 42CrMo4

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In the work the influence results of two different hardening coolant agents on the basic mechanical proprieties and microstructure of the round hot rolled bars were presented. The bars of 42CrMo4 steel were exposed to analysis, and for those bars in the hardening process, water and modern pro-ecological polymer cooling agents Aqua Quench MK were used.

Key words: 42CrMo4 steel, hot rolled bar, thermal treatment, mechanical properties, hardening cooling agents

INTRODUCTION

The metallurgical blanks in the form of hot rolled bars are often offered by industry in the hardening and tempering standard.

Water, as a hardening cooling agent has a lot of disadvantages which have a direct impact on the final proprieties of the product.

The most important of which is the high alteration of the cooling speed in the function of its temperature. In the processes of hardening and tempering, the synthetic cooling agents called polymers, are becoming more and more popular. These cooling agents are the alternative for water and the quenching oil and more often are the medium which replace water and quenching oil in the hardening process. The huge advantage of currently used polymeric cooling agents is the possibility of the exact control of the cooling speed in chosen phases of the hardening process. It is achieved by the controlled change of the polymer concentration, the temperature of the solution and the intensity of the centre movement in the bath [1].

The change of the hardening cooling agent is indispensably connected with the study of a new technology of heat treatment. The fundamental change is the necessity to monitor the precise concentration and temperature of the cooling agent. The final temperature of the heat is also very important, especially during drawing out it from the bath. The consequence of keeping the proper parameters of the hardening process in the polymer cooling agents in the product with high and repetitious strength properties.

In the work, the comparative analysis of the mechanical proprieties and microstructure of the hot rolled bars of 42CrMo4 steel after the heat treatment with the water and polymer cooling agent Aqua Quench MK hardening, will be presented.

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MATERIAL FOR RESEARCH

For the research, the randomly chosen hot rolled bars of 42CrMo4 steel of 130 mm diameter and 6 000 mm length were used. Each of the bar was exposed to the heat treatment process in the full production cycle. The bars were exposed to the process of hardening and tempering with the use of water (bar no. 1) and the polymer cooling agent Aqua Quench MK (bar no. 2). The chemical composition of the analysed bars is shown in the Table 1.

Table 1 **The chemical composition of the bars**

Chemical composition / %							
C	Mn	Si	P	S	Cu	Cr	Ni
0,44	0,73	0,24	0,022	0,023	0,03	1,00	0,02
Mo	V	Sn	As	Ti	Al	N	Fe
0,19	0,007	0,003	0,002	0,002	0,025	0,006	97,26

METHOD AND RANGE OF RESEARCH

The range of the research includes the structure analysis, the mechanical proprieties and the layout of hardness in the bar section.

The sample for the strength research was made according to the standard PN-EN 10083 (Figure 1).

The test of static tension was made according to PN-EN 10002-1/2002 on the testing machine AMSLER 60ZD 1368 with the modernized driving system and the measurement in the DUPS I system of the Zwick company [2,3]. The microscopic observation was made on the Axiovet 200MAT microscope, with the software 'Image Express', with the magnification of 1 000 x in the metallographic specimen digested by 'Nital' reagent. The structure was observed near the surface and in ½ radius of the bar.

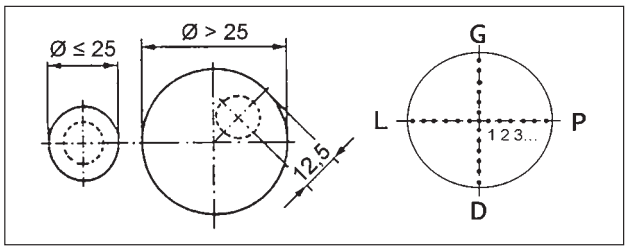

Figure 1 The place of taking the samples of the analysed bars according to PN-EN 10083 [2] and the direction of the strength measurement in the cross-section

PARAMETRES OF HEAT TREATMENT AND REQUIRED PROPRIETIES

In the research it was assumed that the bars which were hardened and tempered, should have mechanical proprieties compliant with PN-EN 10083-1 [2]. The mechanical proprieties are presented in the Table 2.

Table 2 **Required mechanical proprieties according to PN-EN 10083-1 [2]**

100 mm < d ≤ 160 mm				
R_e min.	R_m	*A* min.	*Z* min.	*KV* min.
/ MPa	/ MPa	/ %	/ %	/ J
550	800-950	13	50	35

According to the received foundings, the parameters of the heat treatment which take into consideration the type of used hardening cooling agent were selected. The parameters of the treatment were selected according to works [2,4-11] and are presented in Table 3.

Table 3 **Parameters of the heat treatment of bars dimension Ø 130 mm in the grade of steel 42CrMo4 [2,4-11]**

	Bar no. 1	Bar no. 2
HARDENING		
Hardening temp.	860 °C	860 °C
Heating time	2,0 h	2,0 h
Annealing time	0,5 h	0,5 h
Cooling agent	Water	Aqua Quench MK
Concentration	-	7 %
Cooling time	11 min.	12 min.
Cooling agent temp.	25 °C	25 °C
Agitation	1,6 m/s	1,6 m/s
TEMPERING		
Tempering temp.	620 °C	620 °C
Tempering time	4 h	4 h
Cooling	Air	Air

RESULTS AND DISCUSSION

On the basis of carried out researches, the diagrams of power to extension correlation was obtained. They are presented in Figures 2, 3. On their basis the fundamental mechanical proprieties were calculated and are presented in Table 4.

Analysing the results from Table 4 it was assumed that in both cases the mechanical proprieties of the bars receive the minimal levels stated in PN-EN 10083-1 standard (Table 2). In case of the bar hardened in water, the upper range for R_m was crossed for 21 - 39 MPa. For the bar hardened in polymer cooling agent all values are in standard ranges.

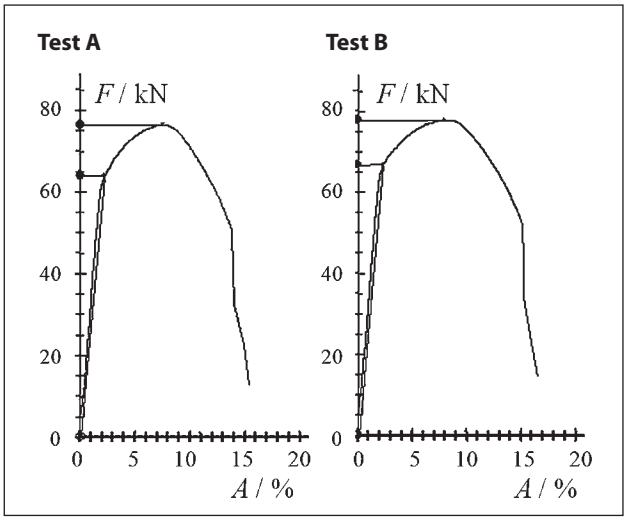

Figure 2 Power to extension correlation for bar 1 (hardened in water)

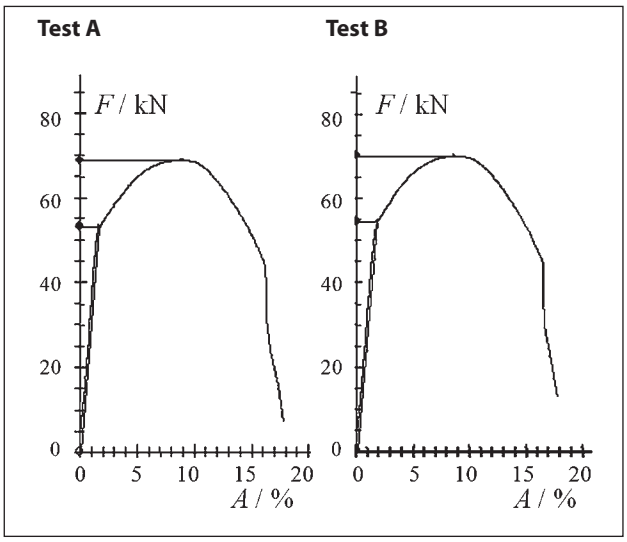

Figure 3 Power to extension correlation for bar 2 (hardened in polymer cooling agent)

Table 4 **Mechanical proprieties of the testing bars Ø 130 mm for 42CrMo4 steel**

		Bar no. 1		Bar no. 2	
		Test		Test	
		A	B	A	B
d_0	/ mm	10,0	10,0	10,0	10,0
S_0	/ mm²	78,5	78,5	78,5	78,5
$F_{0,2}$	/ kN	63,93	66,72	52,99	54,44
$R_{0,2}$	/ MPa	814	850	675	693
F_{max}	/ kN	76,30	77,67	68,80	69,99
R_m	/ MPa	971	989	876	891
Lu	/ mm	56,73	58,83	58,92	57,80
A_5	/ %	13,5	17,7	17,8	15,6
d_z	/ mm	6,44	6,57	6,60	6,27
Z	/ %	58,5	56,8	56,4	60,7

The analysis of impact strength showed minor differences in favor of the samples taken from the bar hardened in polymer cooling agent. The level of impact strength in both cases meets the requirements of PN-EN 10083-1 standard.

Table 5 **Results of measurements of impact strength of bars Ø 130 mm for 42CrMo4 steel**

Impact strength *KV* / J , temp. +20 °C				
Bar no. 1 (hardened in water)				
Test	Measurement			Approx. value
	1	2	3	
A	48	36	40	41,3
B	48	40	44	44,0
Bar no. 2 (hardened in polymer cooling agent)				
Test	Measurement			Approx. value
	1	2	3	
A	54	46	46	48,6
B	54	44	34	44,0

The measurement of the hardness in the tested bars section was made in two opposite directions (Figure 1) The results were averaged and are presented in Figure 4 in the symmetric lay-out of the hardness.

The layout of hardness in the section of tested bars is comparable and is held in the approximate range 32 - 33 HRC near the surface and about 27 - 28 HRC in the area of the bar core.

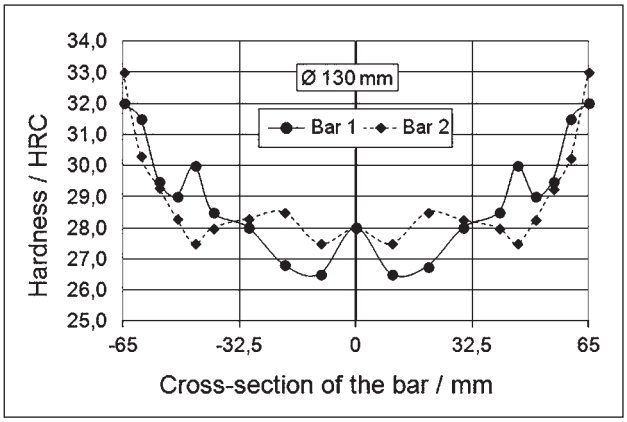

Figure 4 Layout of hardness in the section of tested bars

On Figures 5,6, the setting-up of chosen photos of the microstructure of the tested bars near the surface and ½ R are presented.

The microstructure observed in the metallographic specimen taken from the bars shown the accurate structure of fine acicular tempered martensite. In the deeper parts, the additional slight release of ferrite was recorded.

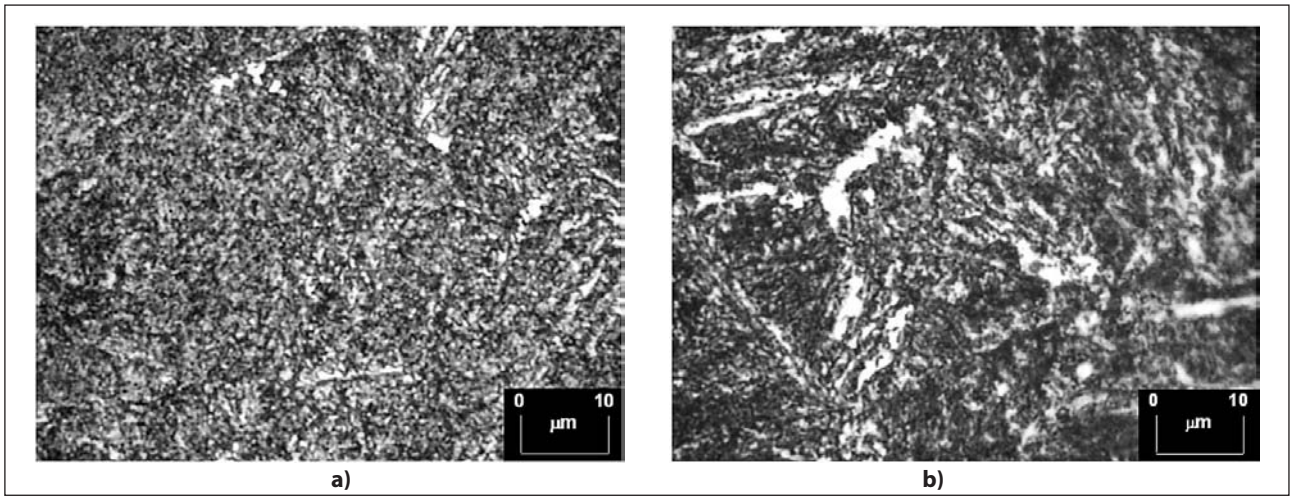

Figure 5 Microstructure for bar no. 1 - hardened in water, a) surface, b) ½ R, (magn. 1 000 x)

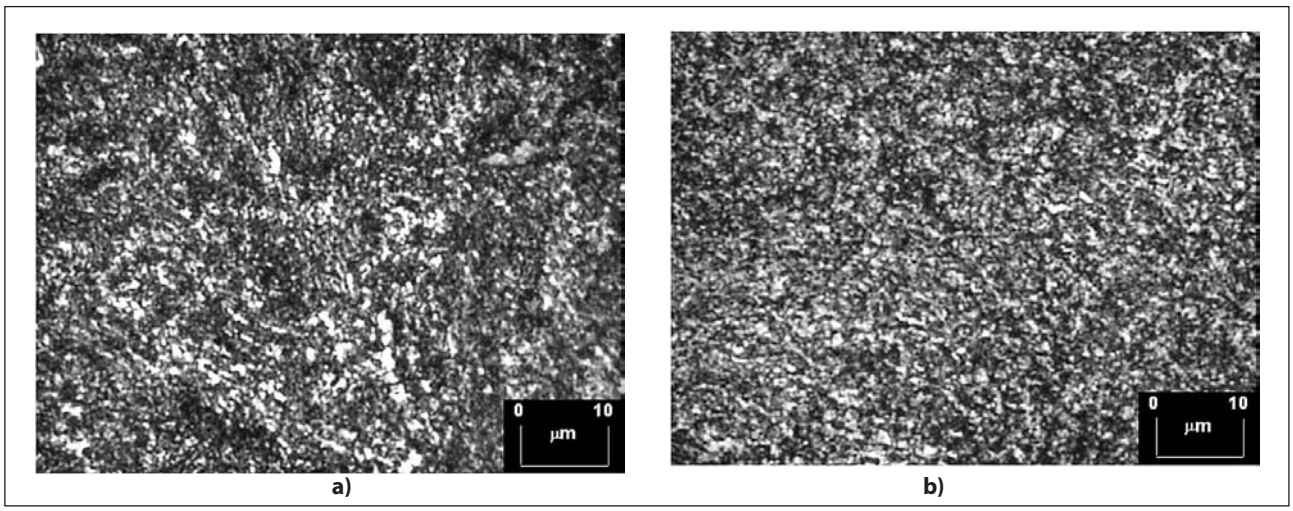

Figure 6 Microstructure for bar no. 2 - hardened in polymer cooling agent, a) surface, b) ½ R, (magn. 1 000 x)

CONCLUSIONS

The nonuniform layout of the strength proprieties in the material exposed to the heat treatment is a significant problem from the point of view further technological processes. The dispersion of the strength proprieties in the area of a given production part, as well as the conformity of these proprieties with the standard ranges and reception conditions is of great importance. All these factors have an influence in the final exploitation proprieties of the output.

The presented tests results for the selected hot rolled bars hardened and tempered with the use of water and polymer cooling agent Aqua Quench MK in the hardening process, show that the required strength properties are met independently on the used cooling agent. The bars are characterized with correct microstructure and similar dispersion of the hardness in the cross-section in the range of 32 - 33 HRC near the surface and the area of bar core 27 - 28 HRC.

The crucial problem can be the crossing of the upper limit of the strength proprieties presented in standards in case of the bars hardened in water. For the analysed case R_m was exceeded for about 21 - 39 MPa which amounts less than 5 % of the upper range. Taking into consideration the water tendency to high changeability of the cooling proprieties depending on its temperature, it can be expected that the value may increase. The hot rolled bars that were hardened and tempered, are very often a blank for the production of components working in different tribiological systems, where the selected strength, exploitation, technological proprieties determine the life and correctness of the work of the whole set [12-14].

The use of modern polymer cooling agents in the heat treatment creates the possibility to receive the given strength proprieties of the product. The possibility to control precisely the parameters of the treatment by the control of polymer condensation, the intensity of the centre movement and the temperature of the cooling agent in bath allows to control the whole process in a wider range.

The random control of a product from the selected lots is often used in the metallurgical industry.

The theme of the irregularity of the layout of the strength proprieties or with its default connected with the type of the hardening cooling agent use can be the base of different researches and analysis which should be conducted in order to optimize the heat treatment process.

Additional information

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Note: The responsible translator for English language is B. Słowińska, Katowice, Poland