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EFFECTS OF HEAT TREATMENT ON THE PROPERTIES OF LOW CARBON STEEL 19MnB4 FOR SCREWS

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In this paper is given the research conducted at the specified quality screws which had different mechanical properties after completion of the same heat treatment. Results of chemical and metallographic analysis and hardness tests indicated the deficiencies that can be corrected in the course of production and thermal processing of finished products - screws.

Key words: low carbon steel, thermal processing, microstructure, hardness

INTRODUCTION

Steels for making screws, nuts and rivets can be low carbon steels with up to 0,20 % C, carbon steels with 0,20 to 0,50 % C and low alloyed (Cr, V, Mo) steels for quenching and tempering [1, 2].

Guaranteed properties of carbon steels for screws, nuts and rivets are prescribed by standards (such as DIN 17111). Depending on the method of production these steels are divided by the level of quality in three groups with precisely defined types of steel and quality [1].

The proper selection of the type of steel for screws can be made if you know the approximate value of strength features by using the so-called strength class.

This paper investigated the characteristics of screws obtained from steel tagged 19MnB5 after heat treatment - hardening. From this steel were made screws labeled as M 16x165 in accordance with DIN or ISO 931/8.8 4014. These are hexagons screws for significant parts of machine constructions.

Steel with the mentioned tag is a fine-grain steel micro-alloyed with boron. Boron is added to unalloyed and low-alloy steels to increase hardness and hardenability [3].

Boron-containing steels are used as high-quality structural steels intended for heat treatment, hardening steels and steels for cold working such as steels for screws.

The basic effect of boron on the properties of the steel is to increase hardenability, which is evident already at a very low concentration, of the degree of 0,0010 % B. Even a relatively small amount of boron gives the same effect of hardenability enhancement as other more expensive elements which must be added in much bigger quantities [4].

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According to research, there is no difference in the hardness on the surface between the boron-containing and the boron-free steel. The hardness of the surface of hardened steel is not determined by boron, but by the martensitic structural state influenced by the carbon content. The effect of boron on the increase of hardness is essential just below the surface [3].

The operative mechanism which is decisive for the enhancement of hardenability by boron derives from a delay in the transformation to the bainite, ferrite and pearlite structures, which are softer than martensite, taking place over cooling from the austenitisation temperature after annealing or from the hot working [3].

EXPERIMENTAL WORK

This paper presents testing of the three screws made according to DIN 931 Class 8.8 (Figure1) from steel tagged 19MnB4. Screws, after quenching in oil with a temperature of 900 °C had partly unsatisfactory results of tensile strength, ie two screws did not satisfy prescribed values (screws labeled 1 and 2) and screw number 3 had satisfactory strength properties.

In order to solve the problem, apart from control of parameters in Heating Furnaces we approached the detailed analysis such as examination of the chemical composition, metallographic examination, testing the hardness and layer decarburisation.

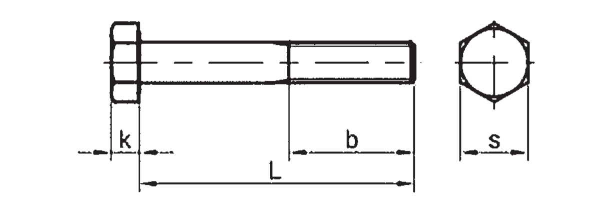


Figure 1 Appearance of hexagons screws [5]

Table 1 **The chemical compositon / wt. %**

Steel		C	Si	Mn	P max	S max	Al min	B
Sample screws	1	0,24	0,08	0,99	0,010	0,011	0,030	< 0,0001
	2	0,22	0,08	0,99	0,010	0,012	0,027	< 0,0001
	3	0,20	0,08	0,99	0,010	0,013	0,032	< 0,0001
Steel 19MnB4 (according to EN 10269)		0,17-0,24 ± 0,01	0,40 ± 0,03	0,80-1,15 ± 0,04	0,030 + 0,005	0,035 + 0,005	0,020 ± 0,05	0,0008-0,005 ± 0,0005

Table 2 **Results of hardness testing**

Mark of screw	Hardness, average values			
	The body of the screw		Head of the screw	
	Cross	Body	Surface	Area
Screw 1	200/HV10	229/HV10	35/HRC	35/HRC
Screw 2	25/HRC	29/HRC	36/HRC	36/HRC
Screw 3	30/HRC	36/HRC	37/HRC	37/HRC

Table 3 **Test results of inclusions**

Sample	ASTM E 45, method A, the worst field								
	Sulfides (A)		Aluminates (B)		Silicates (C)		Oxides (D)		Globular oxides (DS) d >13 μm
	T	D	T	D	T	D	T	D	-
1	1,5	-	-	-	-	-	2,5	1,0	-
2	1,0	-	1,0	-	-	-	2,5	1,0	-
3	1,0	-	-	-	-	-	2,5	1,0	-

T – thin; D – heavy; DS – single globular type

Chemical analysis

Results of the chemical composition of screw materials are given in Table 1. We studied the three screws, two which did not satisfy after the tensile test and the one which had the required value of tensile strength (code 3).

In Table 1 is given the chemical analysis of steel 19MnB4 prescribed by standard EN10269 for comparison [6].

The chemical analysis of all three screw samples indicates that all elements except boron are within the prescribed limits. Chemical analysis also indicates that microalloying with boron has not been achieved, and its influence could not come to the fore. Also, increased aluminum content can affect the appearance of inclusions (alumina) and also the grain size, hardenability and thus properties of the steel [7].

Hardness testing

Hardness testing was conducted on the surface of the body of the screw, on the cross-section, and on the head of the screw. Results are given in Table 2.

Testing was performed on universal hardness tester at the Institute of Metallurgy „Kemal Kapetanović“, University of Zenica.

From the Table 2 it can be seen that the results of the hardness after heating at 900 °C and then quenching in the hot oil, at the temperature of 70 °C, are not uniformed.

All three screws have uniformed hardness along the rim and on the surface of the screw heads. Hardness section and on the surface of the screw is considerably smaller for the screw 1 and 2 in relation to the screw 3 which had a satisfactory values of tensile strength.

Metallographic examination

After the hardness tests, were carried out microstructural examination and testing of the presence of non-metallic inclusions and layers of decarburisation. Test results of microstructure are given in Figure 2 for all three samples.

In the first sample microstructure is: ferrite, finelamellar pearlite, bainite, martensite,

In the second sample microstructure is: ferrite, finelamellar pearlite, bainite, martensite,

In the third sample microstructure is: bainite, martensite. Based on the testing results of the microstructure was found that the obtained microstructure corresponds to the results of the hardness.

By testing of non-metallic inclusions it was found presence of globular oxides in all screw samples while in the second sample was noted and a series of thin aluminate inclusions Table 3.

On screw samples - the body of the screw and the part of the screw with thread was noted partial decarburisation. Testing was performed according to ASTM E 1077-01 (R 2005) and by measuring microhardness according to standards EN ISO 898-1:2010.

The test results of samples of screws show partial decarburisation at the body of screws of

0,15 mm which was confirmed by testing of microhardness Figure 3.

Microhardness was tested on a Zwick apparatus for measuring the microhardness at the Institute of Metallurgy of the University of Zenica.

ANALYSIS OF RESULTS

According to the results of tests of screws it can be concluded that the screws tagged as M 16x165 DIN 931/8.8 do not have uniformed quality, ie they do not have uniformed hardness values nor the microstructure. Conducted tensile tests were eliminatory from the aspect if the screws satisfied in terms of tensile strength, which has also been uneven.

Testing of the chemical composition of steel screws tagged 19MnB4 confirmed the absence of microalloying with boron, with which this steel could not be treat-

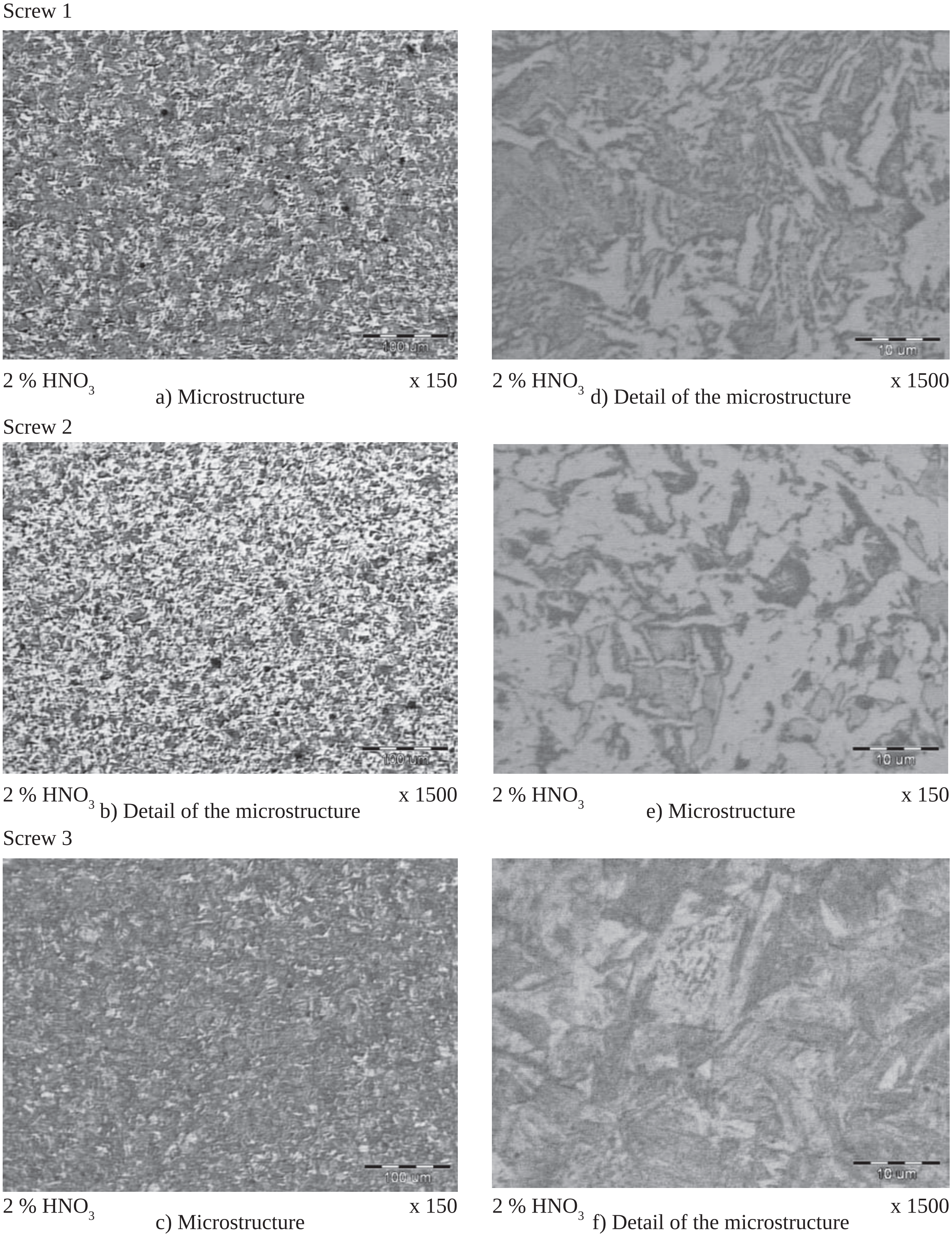
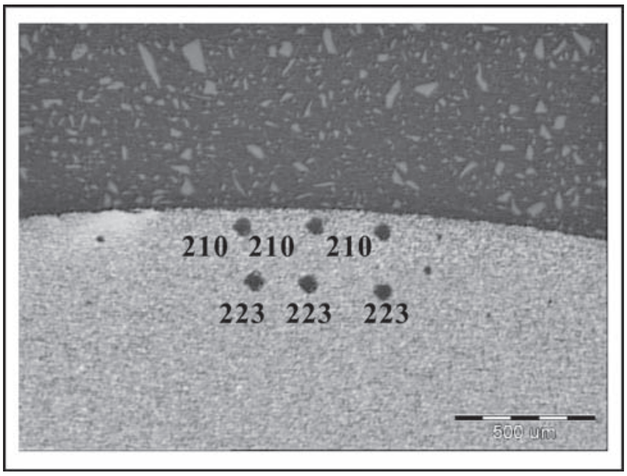


Figure 2 The microstructure of the screw 1 (a, b), the screw 2 (c, d) and the screw 3 (e, f)



2 % HNO_3 x 36

Figure 3 Sample screws 1, hardness values HV0,3 – screw body

ed as indicated. Lack of boron at this dimension of screws and heat treatment which was carried out at the production process could not provide the stability of the quality characteristics that were required.

Hardness tests revealed that only screw 3 labeled as good had a hardness value which was required by standard, while the other two screws had lower hardness values on the screw body noting that the cross-sectional hardness was greater than the hardness of the surface of the screw. This can be interpreted and by decarburisation of the surface.

Metallographic testings showed that the microstructure of the screw 3 was martensitic + beinitic and it was possible with thermal annealing treatment with cooling in oil to obtain mechanical properties.

Structure of screws 1 and 2 is ferrite, pearlite, martensite and beinitic, ie with components that will not give the required characteristics but which indicate that thermal treatment is not carried out completely [8].

The presence of non-metallic inclusions, particulary type of globular oxide contributes to poorer results by tensile testing [9].

CONCLUSIONS

- Steel from which are made screws according to DIN 931/8.8 and according to the chemical composition does not belong to the group of carbon steel alloyed with boron.
- This steel according to the percentage of carbon, during the heat treatment of quenching in oil provides martensitic- bainitic structure but must take into account the temperature at which is performed tempering and cooling rate.
- Lack of boron would affect the microstructure and consequently the maximum hardness and hardness beneath the surface.
- Increased aluminum content influences the occurrence of inclusions and the grain size, hardenability and thus the properties of the steel.
- The presence of non-metallic inclusions particular type oxide also affects the achievement of good mechanical properties, and from that aspect during production should take into account the strength of steel, which is intended to create responsible fasteners - screws.
- Controlled warm up in the oven and furnace atmosphere can affect the layer of decarburisation steel and feature enhancement.

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