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Analysis of the microstructure of 37MnMo6-3 hypoeutectoid steel

E. Rożniata*, R. Dziurka
Faculty of Metals Engineering and Industrial Computer Science,
AGH University of Science and Technology, Al. A. Mickiewicza 30, 30-059 Kraków, Poland
* Corresponding e-mail address: edyta.rozniata@agh.edu.pl

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ABSTRACT

Purpose: Present work corresponds to the research on the analysis of the microstructure of 37MnMo6-3 hypoeutectoid steel. Own research concerns the analysis of the influence of austenitizing temperature on the hardness of the 37MnMo6-3 hypoeutectoid test steel, and on the grain size of former austenite. The paper presents metallographic research, measurements of the average diameter of austenite grain, as well as hardness measurements.

Design/methodology/approach: The austenitising temperature was defined in a standard way i.e. 30-50°C higher than Ac_3 temperature for model alloy. A technique of full annealing was proposed for the model alloy. Metallographic examinations were performed on a Carl Zeiss light microscope Axiovert 200 MAT. Hardness measurements was performed with a Vickers apparatus of HPO 250 type, which imposes a force equal to 30 kG.

Findings: Material for investigations was 37MnMo6-3 steel delivered in as-cast condition after casting in the Faculty of Foundry Engineering of AGH University of Science and Technology in Cracow then reforged in INTECH-MET S.C. in Gliwice.

Research limitations/implications: The new Mn-Mo iron based model alloy.

Practical implications: The paper contains a description of one from a group of iron based model alloys with 0.35-0.40% carbon content. According to PN-EN 10027 standard this steel should have a symbol 38MnNi6-4.

Originality/value: The new Mn-Mo iron based model alloy.

Keywords: Iron based alloy; Analysis of microstructure; Heat treatment; Hypoeutectoid steel

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MATERIALS

1. Introduction

Good mechanical properties of steels are achieved by their chemical composition and the microstructure obtained by appropriately designed heat treatment [1-6]. Therefore, these steels should have a suitably complex chemical composition, carbon content from 0.35% to 0.40% and the specific kinetics of phase transformation of supercooled austenite [7-14]. These alloys represent large groups of alloy steels designated for quenching and tempering, which are subjected to high requirements regarding Re/Rm ratio as well as ductility and toughness.

The analysis of microgradients of chemical compositions seems to be important for these alloys. This mutual interaction of various elements on the effects of the others, may be the basis for among others assessment of the impact magnitude of each of them on e.g. hardenability of steel in the conditions of the presence of even one or several other elements in the above mentioned alloys with iron matrix. Until now, the impact of each element was considered separately, only sometimes, pointing to a group of alloys, in which this interaction was evaluated.

Own research concerns the analysis of the influence of austenitizing temperature on the hardness of the 37MnMo6-3 hypoeutectoid test steel, and on the grain size of former austenite. The paper presents metallographic research, measurements of the average diameter of austenite grain, as well as hardness measurements. The tests are aimed at a preliminary analysis of the effect of two elements such as manganese and molybdenum on the microstructure of the tested alloy.

2. Experimental procedure

Metallographic examinations were performed on a Carl Zeiss light microscope Axiovert 200 MAT. Specimens were etched with 3% nital (3% HNO_3 in C_2H_5OH) in order to reveal individual structural components of the 37MnMo6-3 test steel. Specimens then were etched with an aqueous solution of picric acid (picric acid + H_2O (8 g/200 ml) + 3 drops of HCl + surfactant) to demonstrate the places with distinct grain boundaries of the former austenite. Hardness measurements was performed with a Vickers apparatus of HPO 250 type, which imposes a force equal to 30 kG (HV30).

3. Material for investigations

Material for investigations was 37MnMo6-3 steel delivered in as-cast condition after casting in the Faculty of Foundry Engineering of AGH University of Science and Technology in Cracow then reforged in INTECH-MET S.C. in Gliwice. According to PN-EN 10027 standard this steel should have a symbol 38MnNi6-4. Chemical compositions of this steel is given in Table 1.

Table 1.
The chemical composition (wt. %) of the investigated alloy

C	Mn	Mo	Si	P	S	Cu	Al
0.38	1.57	0.27	0.058	<0.0010	0.0012	0.037	0.017

The microstructure of tested Mn-Mo alloy with iron matrix after reforging is shown in Fig. 1. As can be seen, the microstructure of the investigated steel after forging consists of ferrite from pearlite and bainite. The hardness of the investigated steel after forging is 258HV30.

Subsequently, full annealing was performed in order to homogenize the microstructure of the test 37MnMo6-3 steel and to reduce hardness for more comfortable processing during mechanical tests. Steel was heated to the test temperature of 850°C, hold 2 hours, and then cooled at a rate of 30°C/min to the temperature of 500°C and cooled at the rate of 3°C/min. to room temperature. The microstructure of 37MnMo6-3 steel after such annealing is shown in Fig. 2.

The microstructure of 37MnMo6-3 steel after full annealing is ferrite-bainite structure with a small portion of pearlite, where the hardness is 199HV30. One observes also ferrite in strips (compare with Fig. 2a). After such annealing a quenching series was performed, which allowed to determine the optimal austenitizing temperature, as well as the analysis of austenite grain size measurements.

a)

b)

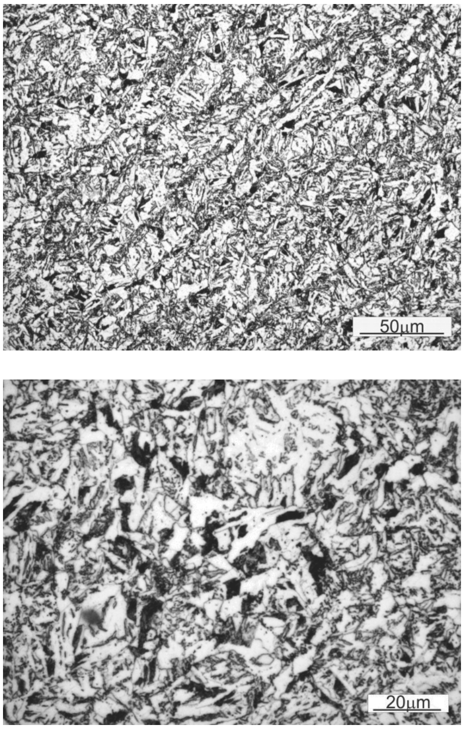


Fig. 1. Microstructure of 37MnMo6-3 steel after reforging. Hardness 258 HV30. Etched with 2% nital

4. Research results and discussion

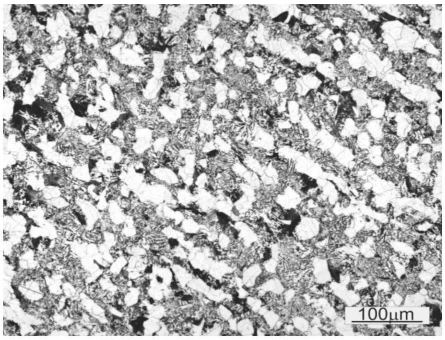
Samples of test 37MnMo6-3 steel with dimensions of 20x30x40 mm were austenitized for 20 minutes at the temperatures from the range 760-1000°C (elevating temperature every 20°C up to T_A=900°C, and then every 50°C up to T_A=1000°C), and after that cooled in water.

Fig. 3 presents the influence of austenitizing temperature T_A of the samples of test hypoeutectoid 37MnMo6-3 steel on their hardness after cooling in water.

As can be seen, (compare with Fig. 3), along with the increase of austenitizing temperature T_A the hardness of the samples rises up to the temperature T_A=830°C. The increase of hardness is most probably associated with the rising portion of martensite, which has partially transformed from austenite. Whereas starting from temperature T_A=860°C the hardness of samples begins to decrease, what is associated with slow coarsening of former austenite grains. The decrease in hardness may be most probably associated with the increase of portion of retained austenite.

Metallographic examinations from individual austenitizing temperatures are given in Fig. 4.

a)



b)

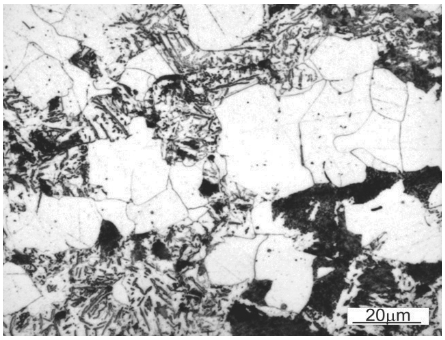


Fig. 2. Microstructure of 38MnMo6-3 steel after full annealing. Hardness 199 HV30. Etched with 2% nital

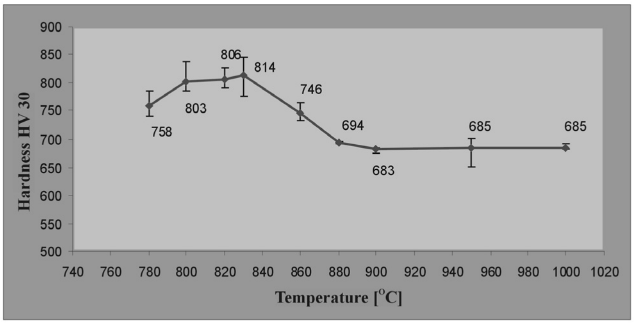


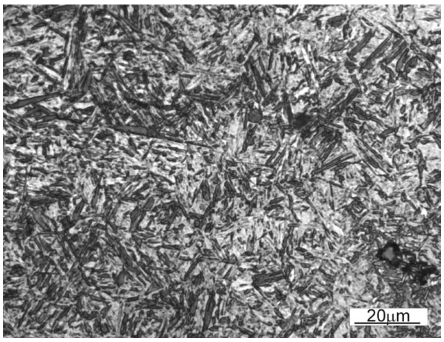
Fig. 3. Effect of austenitizing temperature on hardness of samples of test 37MnMo6-3 steel with iron matrix cooled in water

As can be seen, starting from T_A=780ºC there is martensite with increasing portion present in the microstructure of quenched samples.

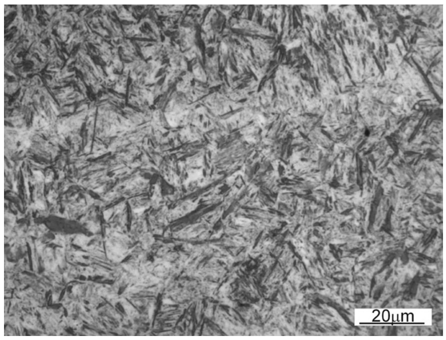
The above described results of metallographic investigation and hardness measurements were confirmed by the measurements of average diameter of the former austenite grains for the subsequent austenitizing temperatures.

For this purpose, metallographic specimens from the samples of the following austenitizing temperatures were etched with aqueous solution of picric acid. This way, former austenite grain boundaries were revealed in the microstructure of the steel, as shown in Fig. 5.

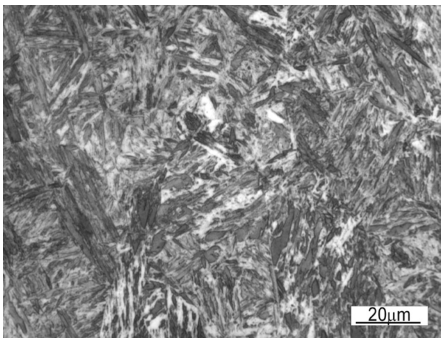
a) TA = 780°C



b) TA = 820°C



c) TA = 880°C



d) T_A = 1000°C

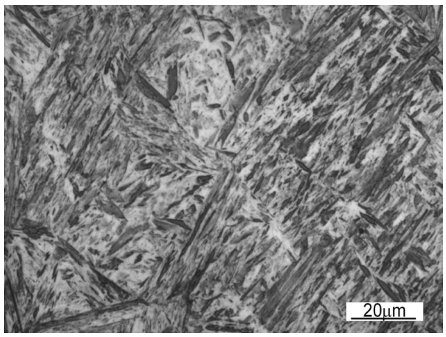
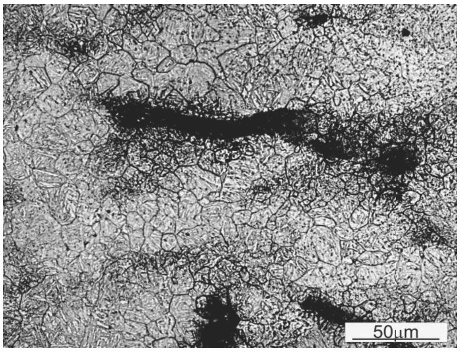
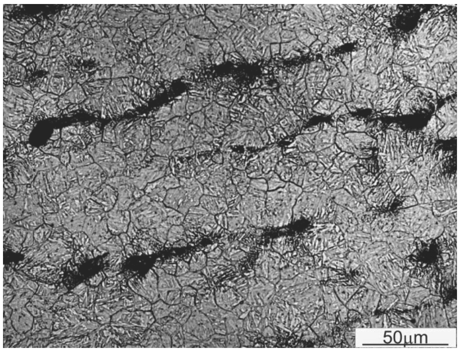


Fig. 4. Microstructure photographs of samples of test 37MnMo6-3 steel used for conducting the quenching series for the following austenitizing temperatures: a) 780°C; b) 820°C; c) 880°C; d) 1000°C. Etched with 2% vol. HNO_3

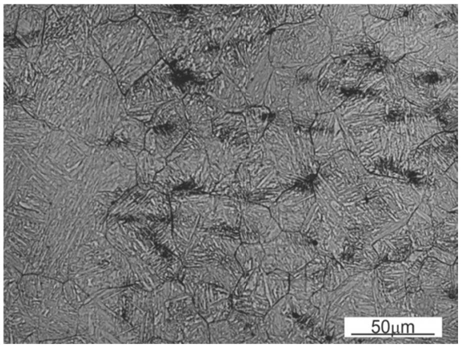
a) T_A = 780°C



b) T_A = 820°C



c) TA = 880°C



d) T_A = 1000°C

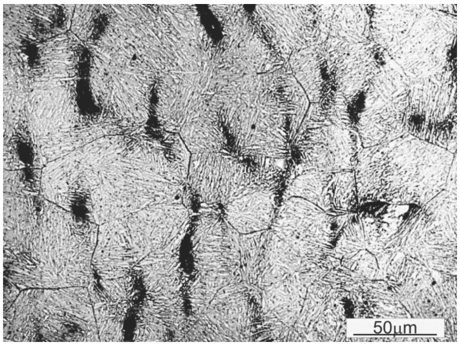


Fig. 5. Microstructure photographs of samples of 37MnMo6-3 steel from the quenching series. Etched with aqueous solution of picric acid

Figure 6 presents the influence of austenitizing temperature T_A on average diameter of former austenite grains, while Table 2 presents the measurements of austenite grain size of test 37MnMo6-3 steel in form of a table.

As can be seen (compare with Fig. 5) with increasing austenitizing temperature the former austenite grain size increases.

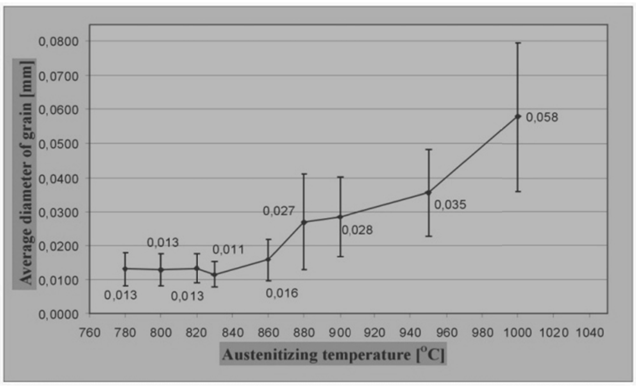


Fig. 6. Effect of austenitizing temperature T_A on average diameter of former austenite grain in 37MnMo6-3 steel

However, according to the scale of standards adopted by the ASTM one can identify austenitizing temperature ranges for which the grain size number G is constant. Namely, in the temperature range of 780-860ºC average grain diameter is 0.013 mm, which corresponds to the number of the grain size G=10, while in the temperature range of 860-1000ºC one can observe a large increase in grain size, which corresponds to changing numbers of grain size according to ASTM.

Table 2.
Austenite grain size in hypoeutectoid 37MnMo6-3 steel for particular austenitizing temperatures

Austenitizing temperature [ºC]	Average diameter of grain [mm]	Standard deviation [mm]	Number of austenite grain size G acc. to ASTM
780	0.0131	0.005	10
800	0.0130	0.005	10
820	0.0134	0.004	10
830	0.0115	0.004	9
860	0.0158	0.006	9
880	0.0269	0.014	8
900	0.0285	0.012	8
950	0.0354	0.013	7
1000	0.0578	0.022	6

The above measurements of the average austenite grain size confirmed the influence of austenitizing temperature T_A on the hardness of the samples of test 37MnMo6-3 steel cooled in water. The temperature of 830ºC seems to be the most optimal austenitizing temperature, because in accordane with the quenching series hardness of the samples of test steel begins to decrease, what is the result of sudden coarsening of austenite grains.

5. Summary and conclusions

Within the frames of research performed in this work the evaluation of the influence of austenitizing temperature on the hardness of the 37MnMo6-3 hypoeutectoid test steel, and of the grain size of former austenite was done. The tests carried out and all the results allowed to state that applying of the austenitizing temperature T_A=830ºC in order to generate CCT diagram for test 37MnMo6-3 steel seems to be the most suitable. Namely, it is the T_A=830ºC when the hardness of samples from test steel begins to decrease and the grain of former austenite coarsens.

On the basis of tests performed, it was found that the rapid growth of austenite grains occurs above the austenitizing temperature of 900°C. This type of grain growth is called abnormal growth and it occurs most often in constructional steels and low-alloy steels. Tested 37MnMo6-3 steel belongs to a group constructional steels, fine-grained, low-alloy and heat-treatable. According to the standard PN-84/H-04507-00 [15] within the range of the austenitizing temperatures grain size of former austenite according to ASTM scale corresponds to the standard no. 9.

However, such growth of former austenite grains above austenitizing temperature 900ºC, which is characteristic for medium- and high-carbon as well as highly alloyed steels, is called normal or continuous growth.

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