OPTIMIZATION OF THE AUTOMATED-STEEL HEAT TREATMENT

Lukáš VOLESKÝ, Pavel KEJZLAR, Zuzana ANDRŠOVÁ

Technical university of Liberec, Department of Material Science, Faculty of Mechanical Engineering, Studenská 2, 461 17 Liberec 1,
lukas.volesky@tul.cz

Abstract

This paper is dedicated to the parameter optimization of automated-steel heat treatment to achieve optimal mechanical properties. A quenching was performed at two different temperatures and the quenched samples were tempered subsequently at five different temperatures in range of 250 - 450°C. Two different tempering times were also applied. The three-point flexural test was used to determine a maximum bending stress, Young's modulus and a maximum strain. The matrix of mechanical properties were constructed on the basis of measured data and the optimal heat treatment parameters were determined.

Key words:

Automated-steel, Heat treatment, Metalography, Mechanical properties

1. INTRODUCTION

The automated-steel (chemical composition see in Tab.1.) is a structural material designed for manufacturing of special holders, which are used for cutting of jewellery ZrO_2-stones. Its flexural rigidity is a crucial point for a flawlesness of produced jewel-stones. The manufacturer of the jewel-stones had a problem with a stone-holder bending caused by insufficient strenght. The aim of our work was to increase rigidity and the bending strenght while sufficient toughness is preserved.

Table 1 Chemical composition of the automated steel

Component	C	Si	Mn	P	S	Pb
Content [%]	0.63	0.26	1.05	0.026	0.22	0.25

2. THE FIRST STAGE OF THE HEAT TREATMENT OPTIMIZATION

To achieve a matrix of mechanical properties depending on parametres of the heat treatment, a cycle of heat treatment was realized on the first 60 pieces of semi-finished product. This was a turned draw wire. The material of the wire was softly annealed in the inicial state, the structure was composed by a ferritic matrix with nodular pearlite and with dispersion of MnS (see Fig. 1.).

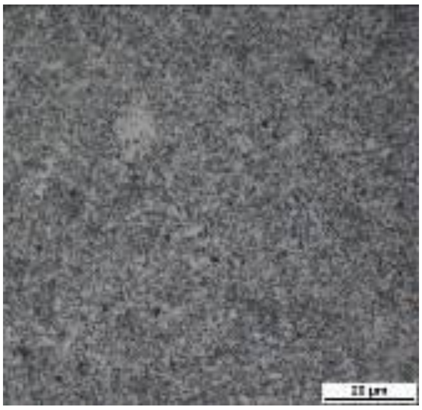

Fig. 1 The structure of automated-steel in initial state, LOM, magnitude of 1000x

The heating of the samples was realized in electric resistance furnace at the temperature of 830°C and 850 °C. Then the samples were quenched into the water with the temperature about 20 °C. Tempering followed, with the cooling period in still air with room temperature. Tempering temperatures were 250, 300, 350, 400 and 450°C with dwell time of 15 and 30 minutes. The scheme of the heat treatment is obvious from Fig 2.

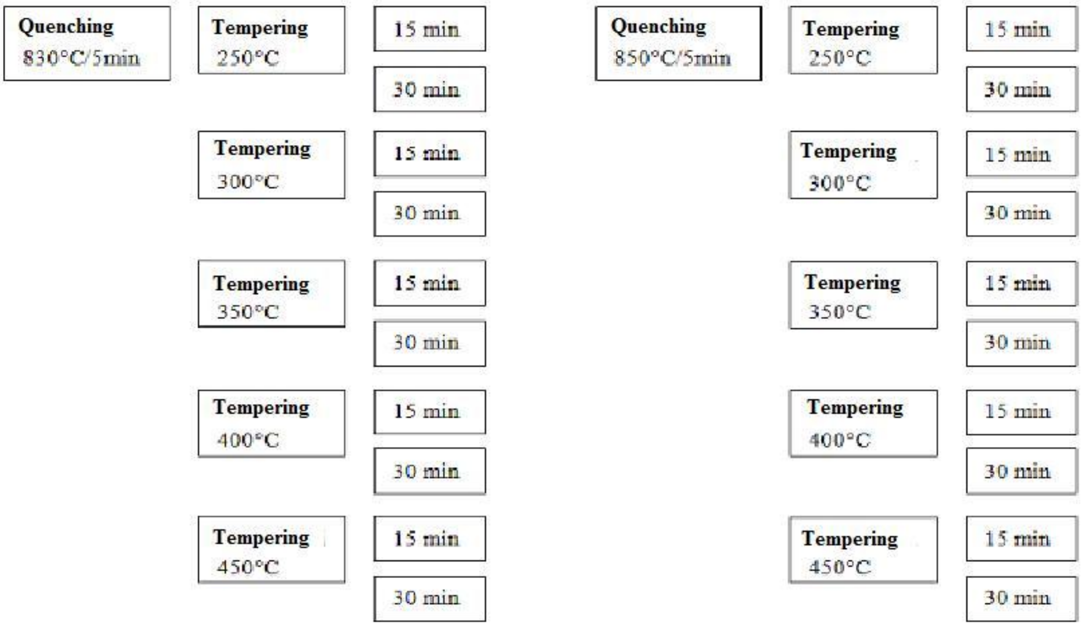

Fig. 2 The schematics of the heat treatment

The bending strenght and toughness were measured by three-point method with use of Instron 4202, where strain rate was 2 mm/min, and supports distance 30 mm. The evaluation of results was realized by a Bluehill software. The measuring included maximum bending to fracture (Fig. 3, 4), maximum bending stress (Fig. 5, 6) and the Young´s modulus of elasticity (Fig. 7, 8).

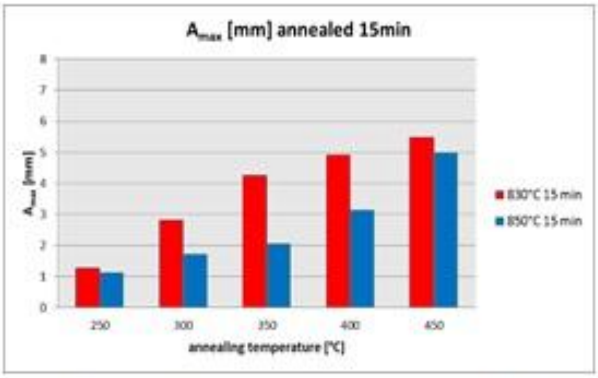

Fig. 3 Measured values of maximum bending to fracture of parts tempered for 15 minutes.

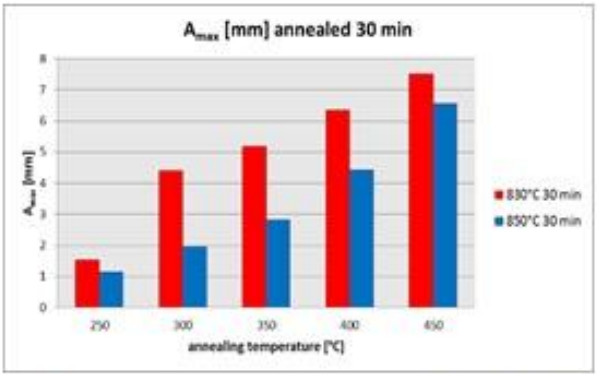

Fig. 4 measured values of maximum bending to fracture of parts tempered for 30 minutes.

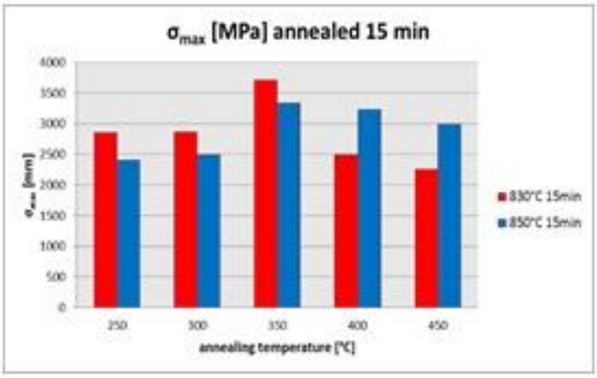

Fig. 5 measured values of maximum bending stress of parts tempered for 15 minutes.

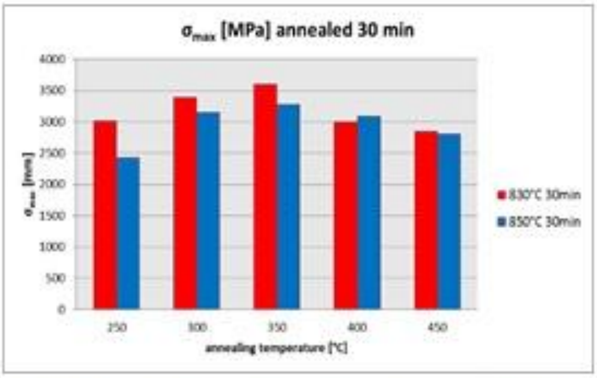

Fig. 6 measured values of maximum bending stress of parts tempered for 30 minutes.

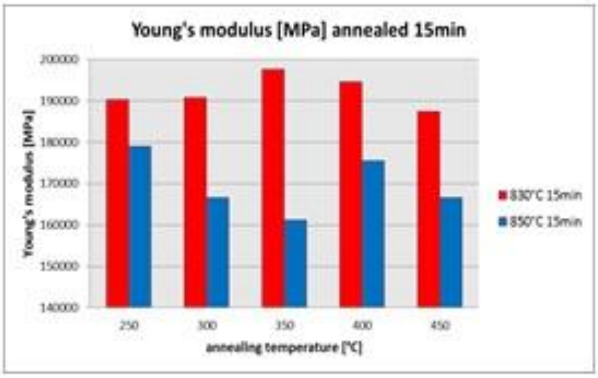

Fig. 7 Measured values of Young´s modulus of parts tempered for 15 minutes.

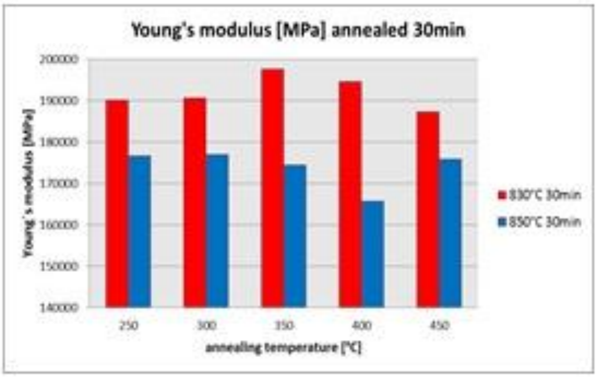

Fig. 8 Measured values of Young´s modulus of parts tempered for 30 minutes.

There are structures, acquired with light optical microscope (LOM), in Fig. 9. These structures correspond to quenching (830°C/5minutes) and tempering (250, 300, 350, 400, 450°C/15 minutes). It´s possible to observe progressive coarsening of ferritic grain and carbides. There are also visible some sulfide particles, which are shaped in the direction of wire drawing. At last the Vickers HV2 hardness was measured. It decreases with increasing temperature of tempering (Fig. 10).

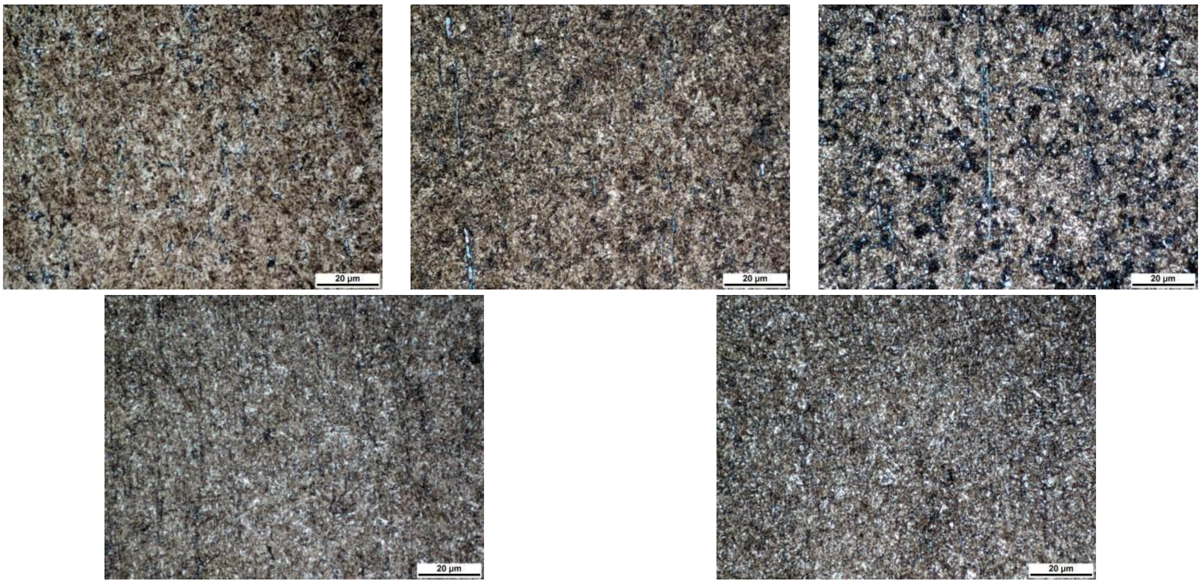

Fig. 9 LOM photos of quenched (830°C) and tempered structures , magnitude of 1000x.
a) 250°C, b) 300°C, c) 350°C, d) 400°C, e) 450°C

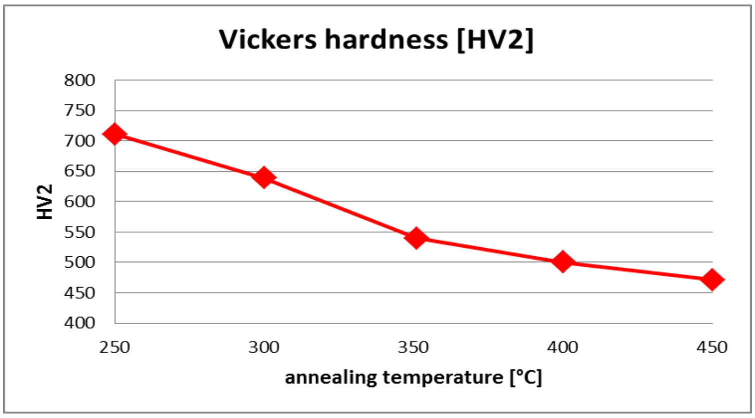

Fig. 10 The influence of the tempering temperature on HV2.

3. THE SECOND STAGE OF THE HEAT TREATMENT OPTIMIZATION

At the second stage we have been dealing only with optimizationof mechanical properties of the automated-steel depending on the dwell time of austenitization (quenching) and tempering. Temperatures were 830°C and 350°C. Dwell times of austenitization before quenching were 5 and 7 minutes, of tempering it was 10, 15 and 20 minutes (see Fig 11).

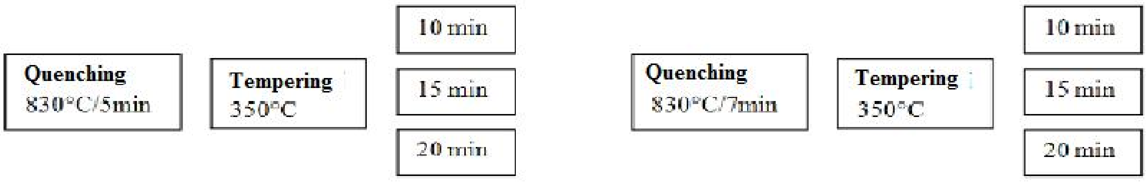

Fig. 11 The schematics of dwell times of the heat treatment at temperatures of 830°C (quenching) and 350 °C (tempering).

Values of maximum bending, maximum bending stress and Young´s modulus of elasticity were measured again (Tab.2).

Table 2 Values of the maximum bending after 830°C quenching and 350°C tempering.

	A max	σmax	Young´s m.
	[mm]	[MPa]	[MPa]
5 min. quenching + 10 min. tempering	3,7	3526	204411
5 min. quenching + 15 min. tempering	4,1	3763	206449
5 min. quenching + 20 min. tempering	3,5	3768	205980
7 min. quenching + 10 min. tempering	2,8	3757	196868
7 min. quenching + 15 min. tempering	3,4	3753	199878
7 min. quenching + 20 min. tempering	3,8	3524	202980

4. DISCUSSION

The toughness, represented by values of the maximum bending (see Fig. 3,4) increases with the temperature of the tempering. By comparision with respect to quenching temperatures is obvious, that samples quenched from 830°C are more tough.

The maximum bending stress (see Fig. 5,6) culminates in case of 830°C quenching and 350°C/15 min tempering. The value of the maximum bending stress increases with the tempering temperature until 350°C. In case of exceeding of this temperature the value of the maximum bending stress decreases because of spheroidizing a coagulation of the carbidic phase (Fig. 9). Higher values of the maximum bending stress were possible by quenching from 850°C.

The maximum values of the Young´s modulus of elasticity is material able to achieve with tempering on 350°C (see Fig. 7,8). Exceeding of the quenching temperature has a negative influence on the Young´s modulus.

From Tab. 2 is obvious, that differences of maximum bending stress values are unimportant in view of austenitization time of 5, resp. 7 minutes and tempering dwell time of 10, 15 and 20 minutes. Longer remain on the quenching temperature lead to the gentle decrease of the Young´s modulus of elasticity. It was probably caused by a coarsening of the austenitic grain.

5. CONCLUSION

By the heat treatment of the automated-steel have been achieved a considerable increase of values of flexural mechanical properties, while sufficient toughness of the material was preserved. The steel in its initial state had the maximum bending stress of 1750 MPa and the Young´s modulus of 130 GPa. By the optimization of heat treatment parametres we were able to achieve the maximum bending stress of 3775 MPa and Young´s modulus of 200 Gpa with preservation of sufficient toughness (maximum bending 4 mm).

These values of maximum bending stress and Young´s modulus is possible to acquire by quenching from the temperature of 830°C with austenitization for 5 minutes, following by the tempering at 350°C for 15-20 minutes.

Compare with initial and heat-treated state of the automated-steel we can say that the ideal heat treatment was found for this case, because increase of the maximum bending stress is 115% and of the Young´s modulus almost 50%.

ACKNOWLEDGEMENT

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