PROCEDURE FOR SELECTING THE LOW ALLOY-TEMPERED STEEL FOR MANUFACTURING THE RESPONSIBLE HIGHLY LOADED PARTS

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1. Introduction

At the very beginning of the material selection, it is necessary to perform an analysis of all the influential parameters that could lead to that selection to be optimal. The poor material selection can be the cause of various failures and damages, which could bring about both financial losses and injuries [1]. During the selection of material for manufacturing this highly loaded and extremely responsible part, authors of this paper were guided by their own experience, as well as that of other researchers. That kind of experience can also be achieved during the material selecting for reparation of the damaged machine systems by welding or surfacing/hard facing. In paper [2] authors have shown how a material can be successfully selected and thus the undesired consequences, due to presence of non-metallic inclusions in material, can be avoided. In research reported in [3], it was shown how a reparation of the damaged pulley of a bucket wheel boom hoist system can be successfully executed when the adequate material for hard facing was selected.

Material that is to be selected in this work ought to satisfy all the criteria related to good wear resistance [4-6], increased operating temperature and wear [7]. In material testing, authors were guided by procedures applied by other researchers as well [8], in order to obtain as relevant results as possible. This paper is, to a certain extent, a report on material investigation and estimate whether it could be successfully used for the given purpose.

2. Proposed material

For the machine part, analyzed in this paper, the characteristic loads are the following: impact-compression, cyclicly repetitive and high temperature. Taking into account that the part is a highly responsible one, the material selection was immediately reduced to alloyed steels. Considering the purpose and the function of the part, based on experience and recommendations from other authors, the selection was narrowed down to low-alloy tempered steel 25CrMo4 [9]. The prescribed chemical composition and mechanical properties of this material, as per manufacturer's declaration, are shown in Tab. 1.

Based on these chemical and mechanical properties, as well as based on performed analysis of the fatigue strength and toughness [4-6] and wear resistance [10], authors have assumed that this material can fulfill the requirements set for this construction.

***Tab. 1** Prescribed chemical composition and mechanical properties of steel 25CrMo4*

Content of elements, %				
C	***Si***	***Mn***	***Cr***	***Mo***
0.22-0.29	*max 0.40*	*0.60-0.90*	*1.05*	*0.25*
Mechanical properties Ø = 40-100 mm				
R_m, MPa	***$R_{p0,2}$, MPa***	***A, %***	***Z, %***	***KCV, J***
800-950	*min. 600*	*min. 15*	*min. 55*	*min. 50*

3. Experimental testing

After the material was selected, the testing on adequate samples were performed. The following properties were tested: chemical composition, mechanical properties, hardness and microstructure. The first two categories were certified by the manufacturer, but they were tested anyway, for the authors had to be certain that declared properties were correct, since any deviation could lead to part's improper functioning or damages and injuries of the user. After all the properties were tested and verified, the tube was produced from the selected material and tested in the real operation conditions.

3.1 Chemical composition

The first test was checking of the material's chemical composition. It was done by the optical emission spectrometry, according to the corresponding standard [11]. Obtained results are shown in Tab. 2. Results have shown slight deviations from the manufacturer's declaration (Tab. 1), which could be tolerated.

***Tab. 2** Analyzed chemical composition of steel 25CrMo4*

Content of elements, %											
C	*Si*	*Mn*	*Cr*	*Mo*	*Ni*	*Cu*	*Al*	*V*	*Ti*	*P*	*S*
0.273	*0.387*	*0.526*	*3.387*	*0.578*	*0.108*	*0.184*	*0.006*	*0.011*	*0.002*	*0.020*	*0.017*

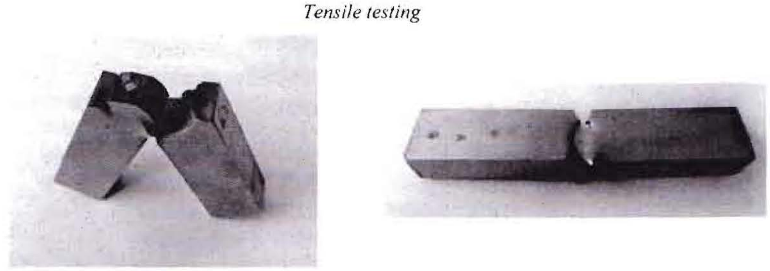
3.2 Tensile testing

After the chemical composition checking, the tensile test was performed on selected material samples. The test was performed in the accredited laboratory on the universal testing machine WPM ZD 40, on the standard cylindrical sample (Fig. 1), according to the adequate standard [10]. Obtained results are shown in Tab. 3.

***Tab. 3** Results of tensile properties test of 25CrMo4 steel*

Material	*Yield strength $R_{p0.2}$ MPa*	*Tensile strength R_m MPa*	*Elongation A mm*	*Contraction %*	*Impact energy J*	*Hardness HV 10*
25CrMo4	*784*	*925*	*40*	*68*	*143*	*275*
	775	*923*	*40*	*68*	*142*	*274*

Tensile testing



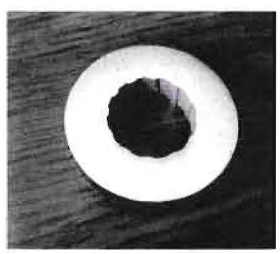
Impact toughness testing

***Fig. 1** Broken samples after testing*

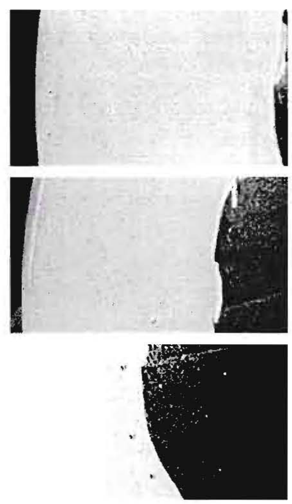
Analysis of the obtained results confirmed that the data declared by the steel manufacturer were acceptable and that the material can be used for the planned part manufacturing. In situations when the quick verification of the material properties is needed, one can also use the numerical simulations, which turned out to be quite reliable for checking the materials strength [12].

3.3 Hardness measurement and microstructure examination

The material hardness measurement and testing of microstructure was done on cylindrical ring samples, shown in Fig. 2. Tests were done at the inside edge of the tube, in the middle and at outside edge of the tube (ring). The samples' hardness was within range 273 to 275 HV (Tab. 3), while the obtained microstructure appearances are shown in Fig. 3.



Hardness measurement sample HV 10



At the outside edge

In the middle of the sample

At the inside edge

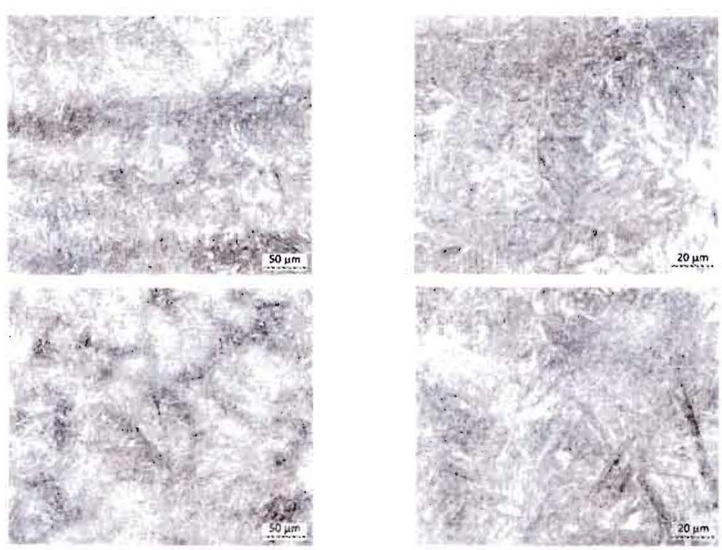


Fig. 2 *Microstructure of steel 25CrMo4: tempering microstructure – bainite + tempered martensite*

3.4 Estimate of microstructure based on the CCT diagram

Obtained microstructure can be also estimated based on the corresponding CCT diagram (Fig. 3). The red-off microstructure – bainite and tempered martensite – corresponds to quenching in water and high tempering, what constitutes the heat treatment prescribed by the steel manufacturer, as well. It is very important that there was no pure martensite in the final structure, since it could act as a stress concentrator in exploitation, due to the dynamic loading.

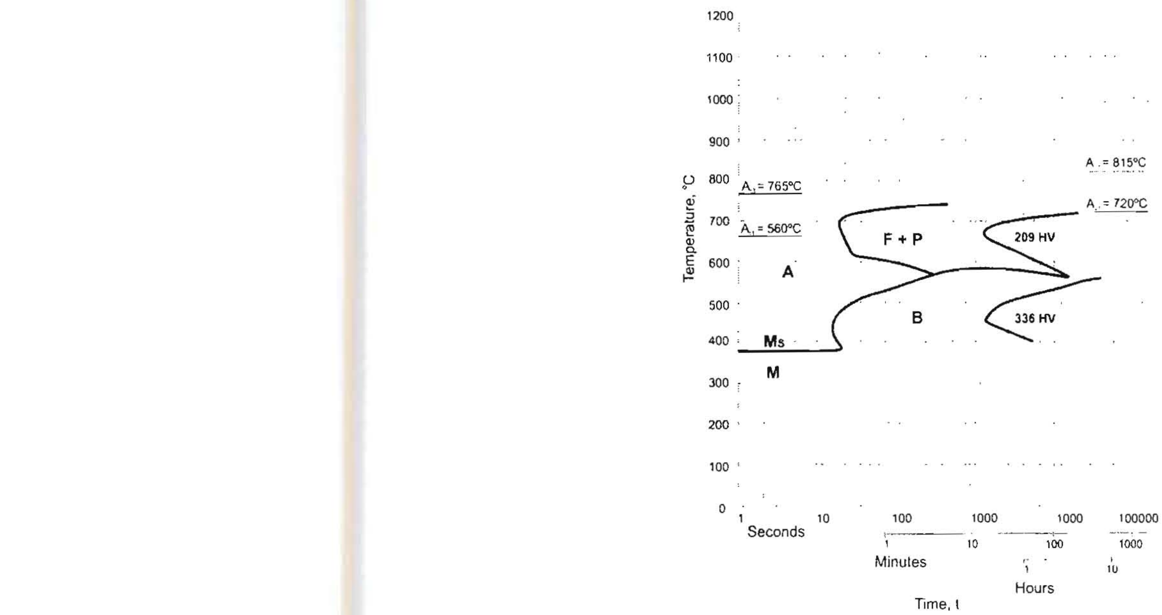


Fig. 3 CCT diagram for 25CrMo4 steel

4. Conclusion

The procedure for selecting and testing of the material for manufacturing the responsible structural part is presented in this paper. The selection was performed primarily based on authors' own experiences, as well as on recommendations from other researchers.

Since the part in question is a constituent of a very responsible structure, all the properties of the material were tested. It was confirmed that the material is adequate for the assumed application. It has fulfilled all the exploitation requirements of the structure and the tests on the real, manufactured part were also performed. The tube, made of the selected steel by forging, has passed all the tests and trials.

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