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Evaluation of retained austenite stability in heat treated cold work tool steel

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Abstract: In the paper interdependence between retained austenite volume fraction and external tensile stresses as well as temperature and tempering time have been observed. On the basis of the obtained research a parameter characterising mechanical stability of retained austenite has been introduced. Low mechanical stability of retained austenite has been observed in the structure of the researched 70MnCrMoV9-2-4-2 steel which was not tempered after hardening.

Keywords: Tool steel, Retained austenite, Stabilization; Mechanical stability

1. INTRODUCTION

From amongst all kinds of stabilization, i.e. thermal, mechanical and chemical, which have been presented in papers [1-3] in recent years mechanical stabilization of retained austenite has become increasingly meaningful. Low mechanical stability of retained austenite has been more and more often used for TRIP steel in which mechanically unstable austenite under the influence of plastic deformation changes into martensite [4-6].

The phenomenon of austenite mechanical stabilization has also practical significance upon heat treatment in the majority of tool steels. Such steels usually have low M_S temperature therefore after heat treatment in room temperature there usually remains a big amount of not transformed retained austenite which, depending on its morphology, stability and volume fraction, may have a considerable influence upon such steels' properties [7-10].

As there has been lack of information on the possibility to evaluate mechanical stability of retained austenite in such steels, the aim of this paper is to evaluate the influence of tensile stresses on the volume fraction of retained austenite in heat treated tool steel for cold work as well as to introduce a parameter which would measure the stability of retained austenite in steels of this type.

2. MATERIAL AND ITS HEAT TREATMENT

Steel designed in the frames of research [11] at the AGH University of Science and Technology has been chosen for the research. Chemical composition of the steel has been presented in Table 1. On its basis, according to the rules of labelling in standard PN-EN 10027-1, the steel has been labelled as 70MnCrMoV9-2-4-2.

Table 1.
Chemical composition of 70MnCrMoV9-2-4-2 steel (mass %)

C	Mn	Si	Cr	P	S	Mo	Ni	V
0,70	2,15	0,30	0,54	0,015	0,005	0,44	0,13	0,16

Samples of the researched steel measuring 5x10x85 mm were austenitized at 820°C, hardened in oil and then tempered at 70, 120, 170 i 220°C for 2 hrs. Tempering temperatures for the research had been chosen so as not to exceed registered on the diagram of kinetics of phase transformations upon heating from a hardened condition (CHT-Continuous Heating Transformation diagram) [12], the lowest temperature of the beginning of retained austenite thermal destabilization which in the researched steel was c.a. 225°C. The second set of samples was tempered after hardening at 150°C for 1 and 100 hrs.

3. METHODS

Samples of the researched steel after heat treatment underwent a bend test. The limit of bending strength Rg was set on the INSTRON testing machine using five samples for each tempering temperature. On the basis of the so Rg gradually one sample after another from each tempering temperature was bend with the load approaching 25, 50, 75 and 95% Rg. After each bend by means of X-ray quantitative phase analysis, the volume fraction of retained austenite was evaluated on the earlier polished surfaces in the mid-distance between support points, from the side of tensile stresses. Samples tempered at 150°C for 1 and 100 hrs were bend using loads close to 25, 50 75 and 95% of Rg value previously established for hardened and not tempered samples.

4. RESULTS AND DISCUSSION

Mechanical stability of retained austenite can be defined as its resistance to the phase transformation under the influence of stretching stresses. Assuming that external stresses application is the only cause of changes in the volume fraction of retained austenite in the structure of 70MnCrMoV9-2-4-2 steel samples which were tempered at temperatures not exceeding the initial temperature of its thermal destabilization, then the parameter which establishes defined mechanical stability could be (**q**) quotient of retained austenite fraction remaining in the structure of the researched steel following the application of stresses close to the bending strength limit (e.g.95% of this value) (**$RA_{95\%}$**) and its initial fraction (**RA**). Such a parameter could thus be established already on the basis of two measurements of retained austenite volume fraction (before and after stresses are applied). Also such a parameter allows for an easy and detailed evaluation of retained austenite mechanical stability of the researched steel depending on tempering temperature as shown in fig.1.

The presented interdependence shows that retained austenite remaining in the structure of hardened and not tempered steel 70MnCrMoV9-2-4-2 is characterised by very low mechanical stability in the result of which it is very sensitive to external tensile stresses and there is a risk it could easily transform into fresh and brittle martensite. However, already not very high tempering temperatures (70÷220°C) clearly increase retained austenite stability in the researched steel. It is worth noting that after tempering at 120÷170°C, retained austenite in the researched steel becomes practically insensitive to tensile stresses. This observation confirms data from papers [13-14] according to which at such temperatures the strongest retained austenite stabilization takes place as a result of blocking dislocation movement which is vital to martensite transformation by carbon atoms'clusters (Cotrell's atmosphere). Applying such temperatures while tempering tools made of this steel will thus guarantee complete stabilization of the remaining in its structure retained austenite with no risk of its transformation into fresh martensite even if the tools were loaded with very high stresses – close to bending strength limit.

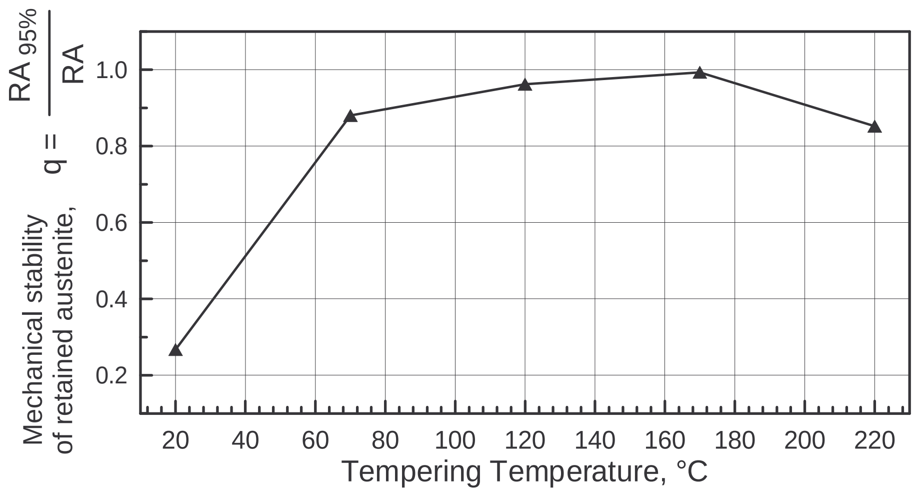

Figure1. The influence of temperature of tempering for two hours upon mechanical stability of retained austenite in 70MnCrMoV9-2-4-2 steel, hardened from 820°C

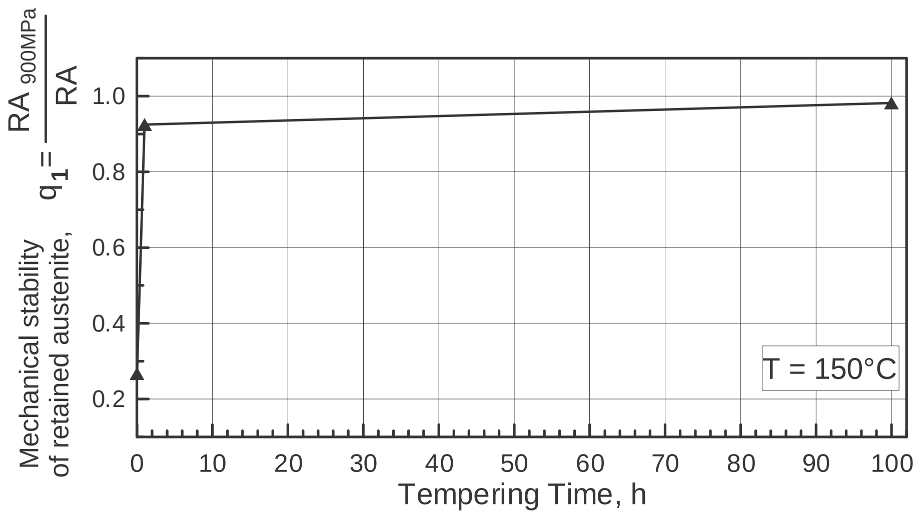

Figure 2. The influence of tempering time at 150°C on mechanical stability of retained austenite in 70MnCrMoV9-2-4-2 steel

Fig.2 presents interdependence between tempering time at 150°C and mechanical stability of retained austenite in the researched steel, which in this case is measured by the quotient (**q_1**) of retained austenite fraction that remains after applying stresses close 900MPa (**RA_{900MPa}**) and its initial fraction (**RA**). Both diagrams, for comparison, have been filled with the results of the research of retained austenite fraction changes under the influence of external stresses in the sample which after hardening was not tempered (assuming that its tempering time at 150°C is 0 hrs). Temperature 150°C was chosen for the research as it is nearly in the middle of the established on the basis of fig.1 range of temperatures for tempering, at which mechanical stability of retained austenite was the highest

As shown, tempering time is also a factor which increases mechanical stability of retained austenite in the researched steel's structure. Already after one hour of holding at 150°C retained austenite becomes stable despite external stresses application close to 900 MPa. Extending this time to 100hrs makes this phase practically insensitive to stretching stresses.

5. CONCLUSIONS

1. Retained autenite, which remains in the structure of the researched steel directly after hardening, is very sensitive to tensile stresses and with their increase this phase's share significantly decreases.
2. Tempering (soaking) of hardened samples of the researched steel at temperatures from the range 70÷220°C causes strong stabilization of retained austenite.
3. Strongest stabilization of retained austenite in steel 70MnCrMoV9-2-4-2 takes place as a result of tempering at temperatures ranging 120÷170°C.
4. In the structure of the researched steel retained austenite becomes a stable phase already after 1hr of tempering (at 150°C). Extending this period to 100hrs makes it completely insensitive to tensile stresses.
5. Stability parameter **q** alfor easy and quick evaluation of the stretching stresses influence on the retained austenite volume fraction in steels for tools.

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