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STRUCTURAL TRANSFORMATIONS DURING TEMPERING IN THE STEELS WITH HIGH CONTENT OF MO AND CO

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Abstract. *The structural transformations occurring at tempering for some high-speed steels are a subject of research for which have been dedicated numerous studies. More complex compositions of the high-speed steels were direct consequence of the complexity of structural transformations which occur during heat treatment. On the other hand, current tendency in energy requires maximum efficiency and rational use of heating sources used in industry. Thus, only a precise knowledge of the kinetics of transformations occurring at tempering can be a basis for optimizing this treatment. Although cobalt is used for a long time as an alloying element, though relatively recently it was considered important to the properties of rapid steel. These circumstances, combined with the lack of quantitative information on the kinetics transformation at tempering operation treatment for some steel has led to this paper. The thickness of the studied samples is 5 mm and was taken from the annealed steel bars. These samples were subjected to hardening and tempering treatment in salts bath. Heating for hardening was performed in two steps, at 5500C and 8300C. Austenitizing was done at 12000C, during 120 seconds. The cooling was done up to 5300C in salts bath, with a keeping of 15 seconds, and then air cooling was done. On these samples were carried out, HRC Rockwell hardness measurements, and X-ray diffraction analysis.*

Keywords*:* *high-speed steels, heat treatment, tempering operation, hardness measurements*

1. INTRODUCTION

Alloying elements such as cobalt, molybdenum, wolfram, chrome and others have considerable influence on the properties of high-speed steels. These circumstances, combined with the lack of quantitative information on the kinetics transformation at tempering treatment for some steels has led to this paper. High-speed steels of tools (STAS 7382-80) are rich alloy steels (up to 25%) with W, Cr, Mo, V, Co, with a 0.7- 1 %. carbon content. High-speed steels are steels that unlike carbon steel and alloy steels of tools possess the most appropriate assembly for cutting properties (wear resistance and heat stability).

These steels are intended for manufacturing cutting tools who process at high speeds (40-50 m/min) hard materials (HB 280), lathe tools, milling cutters, drills, threading tools, etc. The most high-speed steels are steels with W (Rp3) with Co (Rp1, Rp2) and with Mo (Rp5, Rp10). Mechanical properties of hardened and tempered alloy steel, differ greatly from the mechanical properties of a carbon steel of the same carbon content, hardened and tempered at the same temperature. Alloy steel will present strength and toughness superior to carbon steel. Tempering temperature influences the mechanical properties of alloy steels, according to the literature [1-8] can be illustrated by diagrams of variation a mechanical properties with tempering temperature

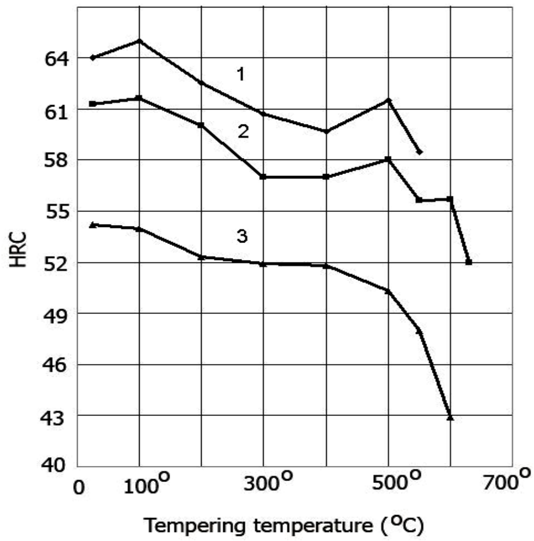


Figure 1. Tempering temperature influence on the hardness of high-speed steel, tempered at different temperatures [8]

Variation of hardness of high-speed steel in tempered state depends on temperature.

Hardness variation and the proportion of residual austenite on the tempering at 5600 C are shown in the images below (figure 1 and figure 2):

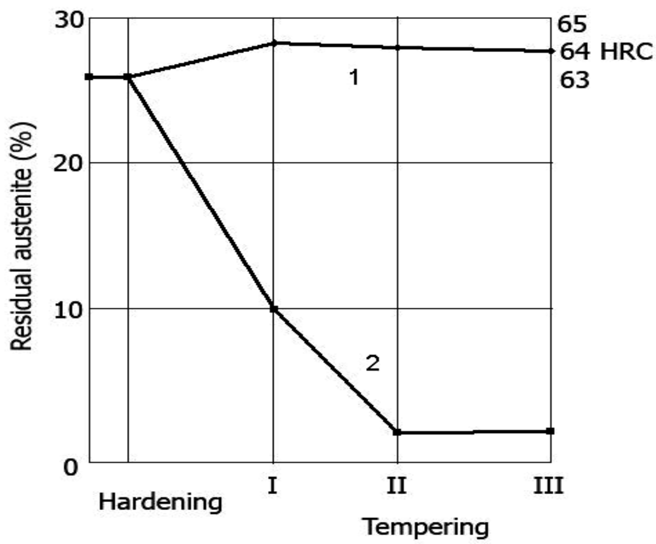


Figure 2. Variation of hardness and the amount of residual austenite on the tempering at 560^0 C [8]

2. EXPERIMENTAL TECHNIQUE

Table 1. Chemical composition of sample

Elements	C	Mn	Si	S	P	Cr	Ni	Cu	Mo	Co	W	V
Concentration(%)	1.03	0.27	0.09	0.09	0.26	3.78	0.16	0.17	9.56	8.63	2.03	1.23

For this study we used the annealed steel bars at Φ = 30, from which were cut samples, in the form of a disc. By mechanics machining all samples were brought to the 5 mm same thicknesses. Samples thus prepared were hardened and tempered in salts bath. Heating for hardening was done in 2 stages at 550^{0}C and 830^{0}C. Austenitization was executed at 1200^{0}C for 150 seconds. Cooling has been done up to 530^{0}C in salts bath, for 15 seconds, and then, in the air. The conditions of tempering have been preset in order to obtain the information necessary for drawing kinetic curves.

For these samples thus treated were made -HRC Rockwell hardness measurements, and also the X-ray diffraction measurements. After each treatment stage, by machining, the surface layer was removed having about 0.2-0.3 mm thickness. After this stage was carried out chemical corrosion to remove damaged layer because mechanical processing. After this processing were carried all measurements. For hardness measurements were carried out a minimum 6 hardness tests at a device type PH-C-01/02, with a maximum load of 150kgf. The X-ray diffraction analyzes was carried out on a Phillips PW 1130/90 diffractometer equipped with a vertical goniometer PW 1050/70 type.

Registration of diffracted radiation was done with a proportional counter and for the monochromatic radiation has been used curved crystal graphite mounted in diffracted beam. Depending on the aimed purpose has been used radiation of copper, cobalt and iron. To determine the lattice constant for martensite is best to use the maximum (211).
This maximum occurs in iron radiation at 2θ = 110.50^0 angle and does not overlap with other peaks obtained for other structural constituents present in the sample.

3. EXPERIMENTAL RESULTS

Preliminary determinations have been preliminary tempering treatments at a temperature of 100-3000 C for 1h, for thermal stabilization of austenite. Based on preliminary determinations, according to the tempering temperature, in the conditions recommended by current standards, was obtained hardness variation with tempering temperature for 3 tempering operation of 60 minutes each. The result is shown in Figure3:

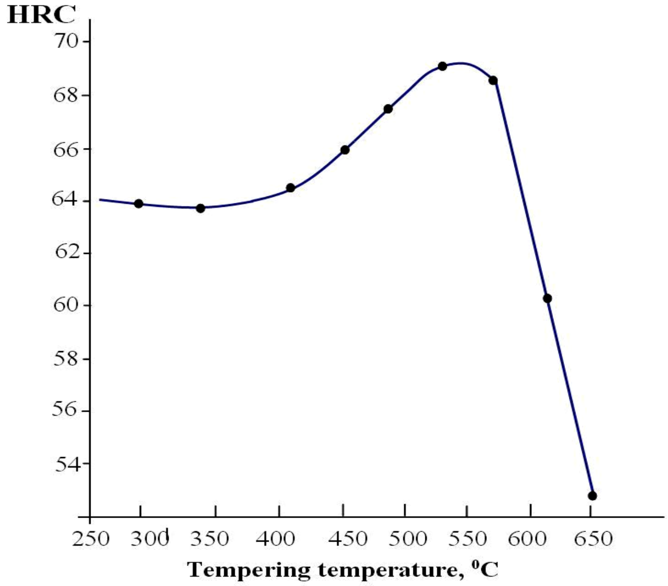


Figure 3. Hardness variation with tempering temperature

From this curve resulted that the temperature for obtain a maximum hardness is situated in the range 540^{0}C -560^{0}C and therefore she was chosen as tempering temperature the temperature of 550^{0}C. In the hardening state steel structure consisted of: martensite, residual austenite and M_6C, MC and $M_{23}C_6$ carbides. The largest share of carbides in the tempered state had a M_6C. The other types of carbides were found in much smaller amount but they gave diffraction peaks clear enough to be identified without doubt. During tempering treatment of steel, in the initial stage, initial austenite is transformed to martensite. The amount of residual austenite decreases after at least 2 tempering treatments attaining minimum values (< 15%) with beneficial effects on physical and mechanical characteristics of steels. In figure 4 is shown kinetics curve for transformation of residual austenite.

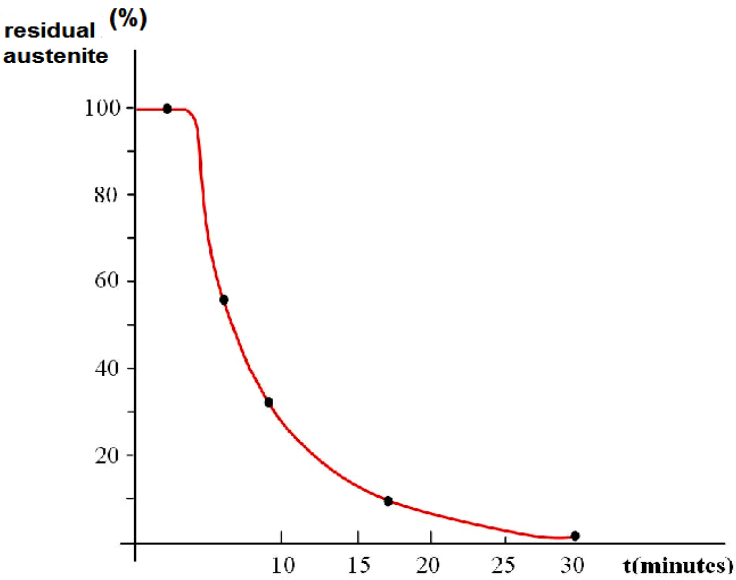
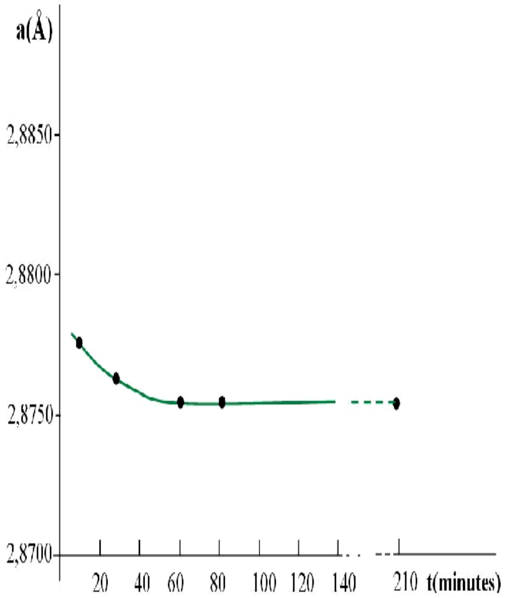


Figure 4. Kinetics curve for transformation of residual austenite

From figure 4 we see that after isothermal maintaining approx. 4 minutes the transformation starts.Just two minutes after the start the transformation residual austenite amount reaches half of the initial (in figure 4 represented by ordinate axis the amount of austenite in relative units, considering initial amount that corresponds at division 100). With further increasing the duration of maintenance, transforming speed begins to decrease. It will be seen that after a 30 minute maintaining at 550^{0}C, the amount of residual austenite reaches the limit of detection obtainable by X-ray diffraction (1.5%), a value below which no practical influence material properties. During of the tempering operation the martensite lattice parameter varies with time as shown in figure 5.



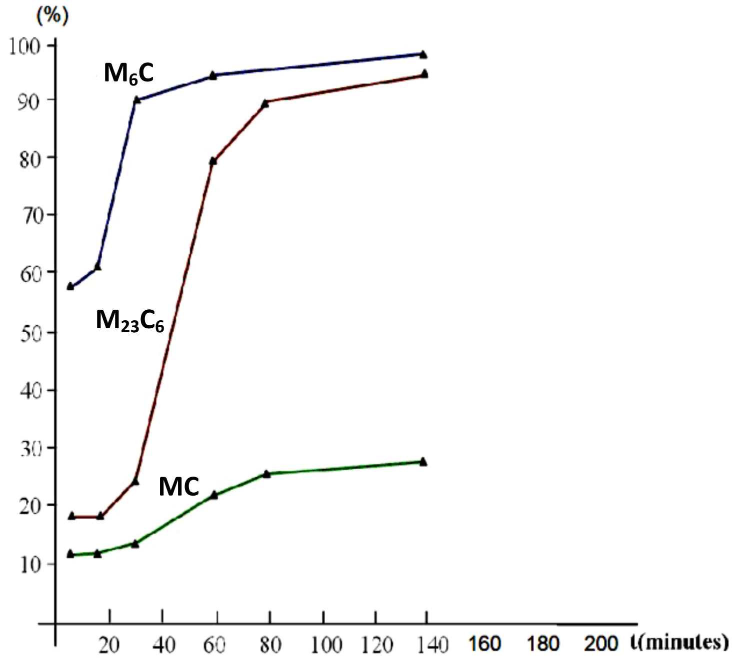


Figure 5. The martensite lattice parameter variation according to the time of tempering

Figure 6. The curves depicting the kinetics of precipitated carbides

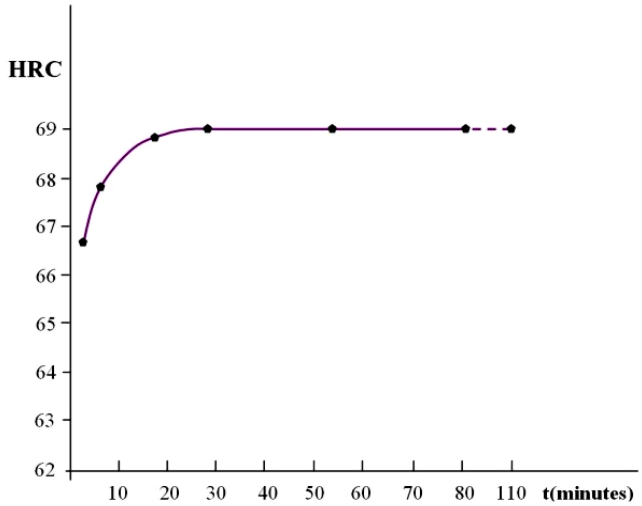


Figure 7. The maximum hardness of investigated steel

Figure 6 shows, in relative units, the curves depicting the kinetics of precipitated carbides, the maximum value being reached precipitates after a period of 80 minutes. In consensus with the other transformations has been observed as well as compounds such as the carbides, reach the maximum amount after about 80 minutes of isothermal maintaining.

4. DISCUSSION

For high-speed steels, the tempering must lead, first of all, to a high value of secondary hardness and also this treatment must eliminate the annealing tensions in order to improve the resistance of tools. High-speed steels after quenching have a significant amount of residual austenite (20% -30%). Therefore is need to execute tempering treatment for increasing resistance at plastic strain for tools and it is necessary as to obtain a total transformation of residual austenite [9]. For this purpose we recommend multiple tempering operations.

For the studied steel these requirements are made for shorter heat treatment durations in comparison with the recommended standards for high-speed steels [10÷16]. Thus, as shown in figure 7, the maximum hardness is obtained at 550°C after a maintaining interval of 30 minutes (figure 7). Analysis figure 3-7 allow us to conclude that the tempering operation is completed after a total duration of 80 minutes when the martensite lattice parameter attain a constant value (see figure 5) and the amount of precipitated carbides attain a the maximum value. Further increasing the duration of treatment, leaves practically unmodified the constant lattice. There are, however, other changes in the diffraction image,that changes the shape and width of the lines, both the matrix and the carbides. But because these changes are closely related the fine structure and the existing defects in phases, this problem will be the subject of another paper.

Determined measurements, i.e. hardness, lattice constant and precipitated carbides behave additive compared to isothermal maintaining time. Therefore, the final tempering treatment may be achieved by three tempering with of shorter duration. Of course, depending on the use of steel should have different properties so cannot establish a definitive treatment without knowing the properties that result from tempering operation.

The experimental results presented in this paper are intended to create a database relating to optimizing the applications of tempering treatments on high-rapid steels. This fact is to reduce the number of tempering treatments applied to steels and correlation of these with the amount of martensite at the expense of the amount of residual austenite, and implicitly to increase hardness and resistance to plastic strain at tools. Thus, the total final time of heat treatment is low and has positive effects on reducing production costs. Hot hardness test was conducted on a number of three samples subjected to three tempering of 30 minutes each at a temperature of 550 ^{0}C. After being held for four hours at 640^{0}C hot hardness for the three samples was respectively 60.5 HRC, 61 HRC and 60.8 HRC. All these values is higher than the permissible limits of the standards for high-speed steel, value is 58 HRC.

5. CONCLUSIONS

The analysis of data presented in the paper result as follows:

a) The tempering operation of the studied steel processes practically ends after approx. 80 minutes to isothermal maintaining at 550^{0}C.

b) The hardness, lattice constant, the amount of precipitated carbides are determinations that behaves as well as the additive size in relation to isothermal maintaining time at 550^{0}C, which shows that the same results can be obtained by repeated tempering, but shorter.

c) Variation a lattice constant with to isothermal maintenance time highlights the diffusive nature of the transformation occurring into martensite during tempering operation.

d) The process of tempering achieved by multiple tempering operations is much shortened compared to the recommended standards. From the data of this papers may be recommended to make a tempering operation in three consecutive tempering to 550^{0}C with duration of 25-30 minutes each.

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