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INFLUENCE OF THE HEAT TREATMENTS ON THE WEAR-RESISTANT STEELS PROPERTIES

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Abstract: *The paper presents how the final heat treatments quenching (hardening) followed by tempering influence the properties of the wear-resistant steels. The quenching temperature and maintaining time at quenching temperature have influence on the studied steels hardness. The study shows that maintaining time has an optimum interval for which the maximum hardness is reached. Also the quenching temperature influences the hardness; higher values are obtained when the quenching temperature attend the maximum allowed. The resilience and wear, other essential tools properties, were studied to find the optimal heat treatment parameters to provide the highest values of mechanical characteristics.*

Key words: *wear-resistant steels, heat treatments, mechanical properties.*

1. Introduction

The tool steels for cold processing are dedicated to the tools manufacturing used in cutting or plastic deformation processes. The operation diversity of mechanical or plastic machining currently under taken and the specific features of the materials being processed, lead to the creation of many types of steels for tools [1]. The large number of these materials makes it difficult to establish criteria for their classification, one of these groups represents the wear-resistant alloy steels (short name: alloy steels) usually used for the cold manufacturing. These steels are alloyed with Mn, Cr, W and V, the presence of those chemical elements influence favourably the technological and utilization properties. Because the alloy elements move the eutectoid point to smaller values, the result is that correlation of carbon content with the total content of the alloy elements constitutes the main problems. The alloy element influence is highlighted by:

- quenching capacity growing;
- wear-resistance extension due to the alloy carbide presence;
- high mechanical shocks resistance;
- increased stability of the tool mechanical characteristics at the working temperature.

These steels constitute a special class from carbon tool steels, which are the hypereutectoid steels with the high hardness. The wear-resistant alloy steels (tool alloy steels) are still weak and medium alloyed hypereutectoid steels, at which the wear-resistance grows due to the presence of the alloy carbides in structure more hard, than cementite. The wear resistance is superior to that obtained for the carbon tool steels.

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Chemical composition of the wear-resistance steels Table 1

Steel type	Chemical composition [%]						
	C	Mn	Si	Cr	Ni	V	W
90VCr10	0.8-1	0.2-0.6	0.15-0.4	0.8-1.5	-	0.2	-
105MnCrW11	1-1.1	0.8-1.1	0.1-0.4	0.9-1.1	0-0.35	-	1.1-1.3

2. Theoretical Considerations

Within the framework of research were studied two steels: 90VCr10 and 105MnCrW11. The tools obtained of these steels are: broaches, mills, top borers, threading die, bores, dies for cold working or drawing die. The chemical composition of the studied steels is presented in the Table 1 [3].

The alloying elements present in steel have well defined roles, influencing certain characteristics. Summarizing, the elements role is described further on. Manganese (Mn) is an element of the gamma area, lowering the steels austenitizing temperature and reducing the quenching temperature. The silicon (Si) is an element of the alpha area that raises the austenitizing temperature, more precisely the quenching temperature. Also the silicon raises the wear resistance. The chromium (Cr) is also an element of the alpha area, forming carbides, which enhance the wear resistance and high temperature stability. The nickel (Ni) is an element of the gamma area with important influence on quenching capacity and tenacity to the low temperature. It is used as alloying element in the steels resistant to the thermal shocks. The vanadium (V) forms the hardest carbides in the tool steels. The vanadium improves the wear resistance when the working is made at hot or cold. It also increases the hardness and characteristics stability at hot and reduces the tenacity. The tungsten (W) has a stronger tendency than chromium of forming hard carbides, favouring the increasing of the wear resistance. Also, increases the hot characteristics stability and the secondary quenching of the tool steels. In the Figure 1 is presented the tempering temperature influence on the 90VCr10 steel hardness [3], depending of the alloying elements concentration.

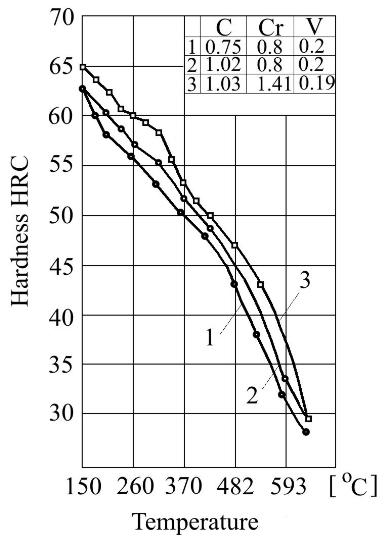

Fig. 1. *Dependence between hardness and tempering temperature* [3]

From theoretical point of view, the austenite formation speed depends of distance between the pearlite lamellas or of the cementite spheroidal size and also of the grain (particle) size obtains at the steel elaboration. When the separation interface between phases is large, the austenite formation speed is larger. Simultaneously with the austenite formation is developed the carbon diffusion process in it (austenite). This process is kept until the austenite will achieve the saturation concentration, which depends of temperature. The speed of pearlite transformation in austenite can be established by direct observations on microstructure, or by indirect methods, by measuring the physical and mechanical properties.

One of the most sensitive methods is to measure the resistivity that increases with the carbon concentration increasing, in austenite [5]. The structure and properties of the quenched products depend on the austenite grain size formed, martensite content [8] and on the chemical composition of the solid solution (γFe+αFe). This is influenced by the degree of carbide dissolution after heating, which is different from an alloy to another and depends on the original structure. The composition of the solid solution, its alloying degree and the structure after quenching will depend both on the quenching temperature and on the maintaining time at this temperature. Measuring the electrical resistance and hardness will highlight the changes in the alloying degree of the solid solution.

The demonstration of alloying degree transformation of the solid solution by the electrical resistance modification is based on the property that resistance is changed with the alloying degree. This alloying degree is influenced by the initial structure. When there is a non-homogeneous structure with small and large carbides, the formation and saturation of austenite has place in stages. The process is more intense at the beginning because there are little carbides and after it slow down, that will restart, because the large carbides enter in transformation. The solid solution concentration, alloying degree and structure after quenching will depend both of the quenching temperature and the maintaining time at this temperature. In this moment it is made numerous trials to increase the wear resistance of the tools. The solutions consist in coatings deposited by laser cladding [6] or by the DLC coating, which determine the excellent anti-sticking properties and sufficiently good wear resistance [7]. Other methods are the application of heat treatment of multi-element [4] or the thermomechanical treatment [2].

3. Experimental Results

The final heat treatment (quenching followed by tempering) determines the tools properties. The quenching temperature, cooling speed and maintaining time will have influence on the wear-resistance steels.

The paper shows the influence of the quenching temperature and maintaining time on the studied steels characteristics. The quenching temperature range is 760-820 ^{o}C for 90VCr10 and 780-830^{o}C for 105MnCrW11 [3]. The quenching applied on the steels was at the next temperatures: 780 ^{o}C, 790 ^{o}C, 800 ^{o}C, 810 ^{o}C, 820 ^{o}C and 830 ^{o}C. For all heat treatments the quenching medium was the oil. The sample dimensions ϕ 25.4 x 100 mm.

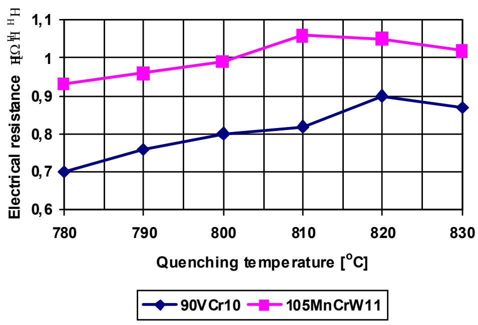

Fig. 2. *Electrical resistance variation for the quenched samples at 820 ^{o}C and tempered at 150 ^{o}C*

The alloying variation degree of the solid solution was highlighted by the electrical resistance measuring. The electrical resistance modification depends of the alloying degree size. A solid solution with greater resistance means that it has a higher alloying degree. The Figure 2 shows the austenite alloying intensity by the studying the electrical resistance at the samples quenched at 820 ^{o}C. The maintaining times were different and tempering time was 2 hours at 150 ^{o}C. It is found that increasing the maintaining time, can raise sensibly the solid solution concentration and therefore may increase the studied steel quenching capacity. The solid solution saturation and the carbides dissolution process can be revealed through the hardness (see Figure 3 - tempering 2 hours at 150 ^{o}C).

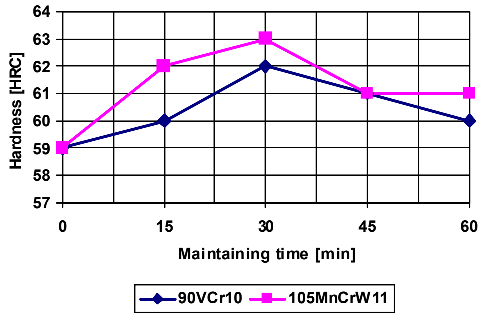

Fig. 3. *Dependence between the hardness and maintaining time at 820 ^{o}C*

It is noted that for the studied steels the lines shape is similar. After complete heating the hardness is minimum but in the next minutes to increase slightly and than decrease again.

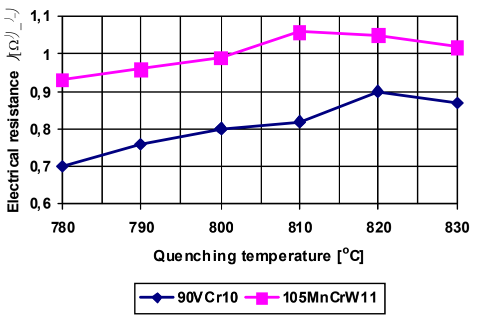

Fig. 4. *Influence of the quenching temperature on electric resistance*

The quenching temperature influence on the saturation degree of the solid solution is presented in Figure 4 (maintaining time 30 minutes). The tempering was 2 hours at 150 ^{o}C. The Figure 4 shows that proportional with the quenching temperature increasing, the electrical resistance grows, after which the limitation appears. Also, the hardness value depends of the dissolved carbides quantity in the maintaining time.

The Figure 5 presents the evolution between the hardness and tempering temperature for the samples which have been quenched at 820 ^{o}C. The quenching maintaining time was 30 minutes and the quenching medium was the oil. For each tempering temperature the maintaining time was 2 hours.

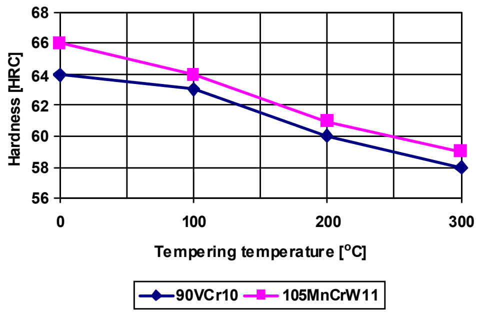

Fig. 5. *Tempering temperature influence on hardness (samples quenched at 820 ^{o}C)*

The Figure 5 shows that the hardness decreases when the tempering temperature increases, this behaviour being explained by the existence of the lamellar pearlite in the initial structure. This strongly influences the alloying degree of the solid solution and martensite respectively. The residual austenite evolution, measured by magnetic method was studied. For these tests, the quenching maintaining time was 30 minutes and the quenching medium was the oil. For each tempering temperature the maintaining time was 2 hours.

The Figure 6 shows that percentage of the residual austenite decreases when the tempering temperature increases.

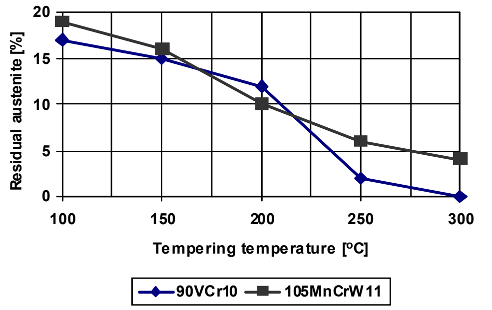

Fig. 6. *Dependence between tempering temperature and the residual austenite proportion (samples quenched at 820 °C)*

Another studied property that is important for all tools types was the resilience. The influence study of the different heat treatment processes on the resilience was performed on the standardized samples with "U" notch and 10 x 10 mm section. The quenching temperature influence on the resilience (impact energy 30 kgm) is shows in Figure 7.

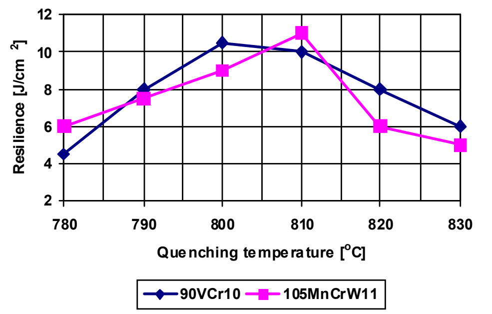

Fig. 7. *Quenching temperature influence on the specific impact energy*

The quenching maintaining time was 30 minutes and the quenching medium was the oil. The tempering temperature was 200 °C and the maintaining time was 2 hours. The Figure 7 shows that concomitant with the quenching temperature increasing, the resilience increases, because grows the residual austenite quantity. When a certain temperature is exceeded, the resilience begins to decrease.

The steels utilised for cold processing and especially for cutting tools are subjected to the action of the manufacturing forces. The action of these forces causes the cutting edges wear fallowed by their resharpening. For the wear study were used plate samples, having the 44 x 21 x 8 mm dimensions. The testing is made without lubrication, for one hour, the pressing force was 50 N and rotation speed 10,000 rpm. The specimens used in the tests were quenched at different temperatures. The determination of wear was made on the basis of the mass loss recorded by the tested specimens. The figure 8 shows the wear test results (quenching maintaining time was 30 minutes).

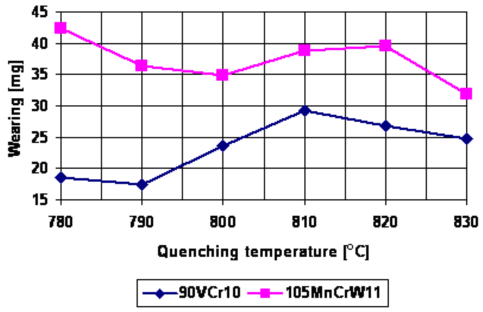

Fig. 8. *Quenching temperature influence on the wear (tempering 2 hours at 200 °C)*

The Figure 8 shows that good results of point of view of wearing are obtained when the quenching temperature is of 810 °C for the 90VCr10 steel and of 780 °C for the 105MnCrW11 steel. The form of the wearing lines is not well defined.

The wear variation with the tempering temperature for the quenched samples at 820 °C (maintaining time 30 minutes) is shown in the Figure 9. The tempering maintaining time for each temperature was 2 hours. The figure shows that as the tempering temperature increases, the wear decreases, that is, the wearing resistance increases.

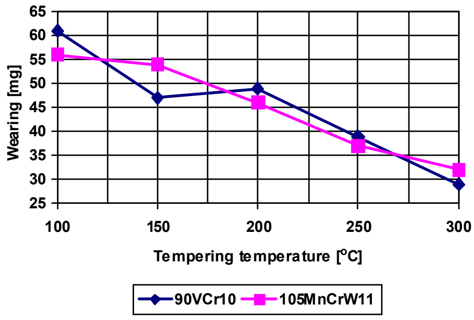

Fig. 9. *Tempering temperature influence on the wear (quenched to 820 °C)*

4. Conclusions

The paper presents the influence of the final heat treatment (quenching followed by tempering) on the studied steels properties (90VCr10 and 105 MnCrW11). The study shows that the maintaining time at a quenching particular temperature influences the studied steels hardness. The solid solution (γFe+αFe) quantity, established on the basis of the electrical resistance, also depends of the quenching temperature, when this is higher the electrical resistance will increase. The studied steels hardness depends of maintaining temperature high hardness is obtained for the lower maintaining temperature. A reduced wear is obtained for the high quenching and tempering temperatures. Depending on the tool type and destination their heat treatment can be particularized for the obtaining of mechanical and technological properties that to maximize the tools durability.

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