THE PROPERTIES OF HIGH-SPEED STEEL P6M5, DEPENDING ON THE COMBINED CHEMICAL HEAT TREATMENT

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Abstract – The article provided results of chemical and thermal treatment of high-speed steel R6M5. Carbonitriding of the high-speed steel performed at 1200-1230 °C and tempering at 600-620 °C. The microhardness of the metal surface layer reached 11000 MP at 0.1-0.15mm depth of the surface. Studies were conducted on the effect of quenching and tempering temperatures on the parameters of the steel structure (physical width of the x-ray line, dislocation density, lattice parameters, and hardness of steel R6M5).

Keywords: Quenching, tempering, Low-temperature carbonitriding, Residual austenite.

1. Introduction

Heating for quenching for steel R6M5 was carried out in salt baths NaCl and BCl_2. Heating temperature for quenching 1200-1230 °C. After heating, the oil was quenched. The process of carbonization with the release was carried out in a special container. A solid medium was used as a carburizing: 60-80% carbon black and 30-40% carbamide $Co(NH_2)_2$. The container with the samples and the saturating medium was placed in a preheated to different temperatures (550-620 °C) furnace and the saturation time was calculated from the moment the temperature was established after loading the container. Consisting fine structure was determined by x-ray on a DRON-3 unit. To measure the hardness used Rockwell hardness tester TK-2, to measure the microhardness device IMT-3.

In previous works [1-5], it was found that when steels are heated above the phase transformation point, there are extreme temperatures, during cooling from which a structure with a maximum defectiveness of the crystal structure is created. It was found that extreme heating temperatures for tool steels are 1100-1200 ^{0}C. This is due to the dissolution of the impurity refractory phases [2-7], as well as the beginning of the dissolution of special carbides. When these carbides dissolve, areas of non-uniformity of doping arise, which, when cooled, creates additional dislocations between the micro volumes. The heating temperature of high-speed steel P6M5 reaches 1230 °C. At this temperature, there is no complete dissolution of the carbides in the solid solution.

At low heating temperatures of 950–1000 °C, carbide M23C6 is dissolved, and at 1200 °C, basic carbide M6C dissolves. First of all, carbides M6C, containing more chromium, but less tungsten, dissolve; at higher temperatures, carbide M6C with a large amount of tungsten is dissolved. However, even at a high heating temperature, most of the M6C carbides with a high concentration of tungsten remain insoluble [8-12].

2. Methodology

Thus, the possibility of the existence of an extreme temperature of heating for quenching in high-speed steels remains minimal, since any increase in temperature above 1230 °C leads to the additional dissolution of some more carbides and homogenization requires more time. It should also be noted that R6M5 steel refers to precipitation hardening steels, then the maximum increase in hardness up to HRC 65 falls on the tempering temperature of 550-560 °C, with 2-3 times of tempering. This circumstance is because it is at this temperature that the transformation of residual austenite into martensite takes place and it is at this temperature that the fine carbides of alloying elements release to increase the heat resistance of steel.

3. Results and Discussion

Studies were conducted on the effect of quenching and tempering temperatures on the parameters of the steel structure (physical width of the x-ray line, dislocation density, lattice parameters, and hardness of steel R6M5). Research results are presented in Figure 1-3.

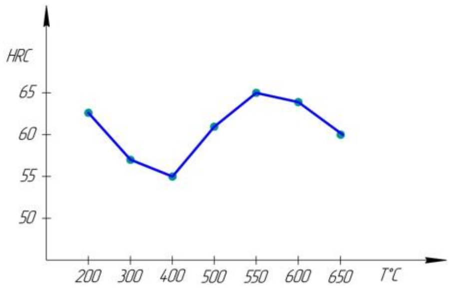

Figure 1: Tempering temperature effect on the hardness of P6M5. Case after quenching at 1200 ^{0}C

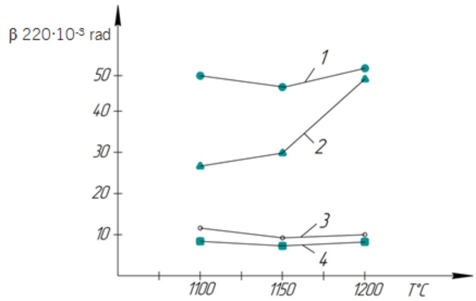

Figure 2: Tempering and quenching temperature affect the wideness of the physical line(β) of P6M5. Tempering: 1 – 560 ^{0}C, 2 – 620 ^{0}C, 3 – 700 ^{0}C, and 4 – 730 ^{0}C

Analyzing the above data on the effect of quenching temperature on the structure parameter we can conclude. As for steel R6M5, the extreme quenching temperature is standard quenching from 1200-1230 ^{0}C. When, after quenching, the maximum dislocation density is formed.

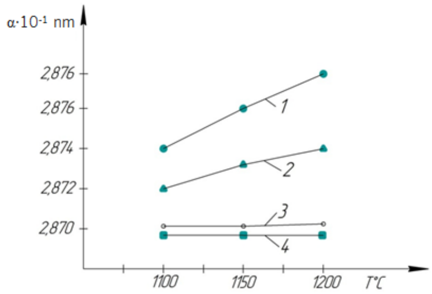

Figure 3: Tempering and quenching temperature effect on the parameters of crystals of P6M5. Tempering: 1 – 560 ^{0}C, 2 – 620 ^{0}C, 3 – 700 ^{0}C, and 4 – 730 ^{0}C

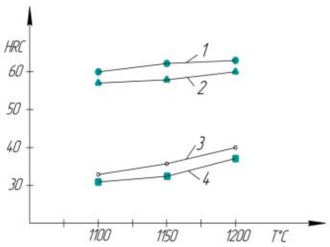

Figure 4: Tempering and quenching temperature effect on the hardness of P6M5. Tempering: 1 – 560 ^{0}C, 2 – 620 ^{0}C, 3 – 700 ^{0}C, and 4 – 730 ^{0}C

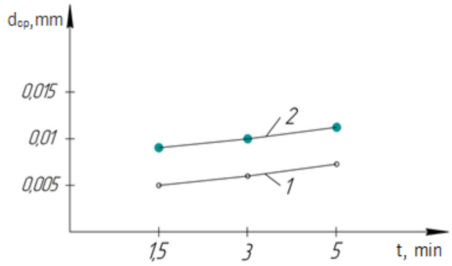

Figure 5: Effect of quenching time on the austenite grain size of P6M5 at 1200 ^{0}C. Tempering: 1 – 560 ^{0}C, 2 – 620 ^{0}C

In addition, the alloying of the solid solution is maximum, and the softening during tempering is the smallest. It is known [3] that at a sufficiently high heating temperature for quenching high-speed steels, the heating time for quenching has a strong influence on the size of the austenitic grain. To determine the effect of holding time for hardening of steel R6M5 on the size of the austenitic grain, studies were separately conducted (Fig. 4.) on the influence of the size of austenitic grain on the holding time for quenching.

The growth of austenitic grains can be avoided by reducing the time the steel is kept when heated to quenching temperatures. The introduction of accelerated and short-term heating changes the size of an austenitic grain to 12 points (dav ≈ 0.0055mm)

In general, the structure of hardened high-speed steel consists of martensite, residual austenite, and undissolved carbide alloying elements. Subsequent tempering of steel leads to a decrease in residual austenite and to the release of finely dispersed carbides of alloying elements, which provide the steel with the necessary level of heat resistance. As a result of heat treatment of steel R6M5, a complex structure is formed, the basis of which is tempered martensite interspersed with finely dispersed carbides, residual austenite, and the inclusion of special carbides not dissolved when heated for quenching.

To determine the effect of tempering temperature on the hardness of steel R6M5, hardened samples were prepared from standard temperatures of 1200-1230 °C and subjected to tempering from various temperatures. Studies have shown that the highest hardness value is achieved with tempering at 540-560 °C, and with further increasing the tempering temperature up to 620 °C there is no critical reduction in steel hardness. This circumstance makes it possible to carry out a single final vacation at a temperature of 600-620 °C.

It is known [4] that the intensive release of vanadium carbides occurs at a tempering temperature of 560 °C, and the release of tungsten carbides which is the main alloying element at temperatures above 600 °C. In addition, an increase in the carbonitriding temperature from 540 to 600 °C to 620 °C makes it possible to intensify the carbonation process. A slight decrease in hardness at tempering of 600 °C to 620 °C should be compensated for by an increase in surface hardness due to the combination of tempering with the process of carbonitriding.

To study the possibility of carrying out the combined technology with carbonitriding, samples of quenched R6M5 steel with temperatures of 1200-1230 °C were prepared [13]. The final tempering of carbonitriding combined with the process was carried out in the temperature range of 550-620 °C with a saturation time from 1 to 4 hours. The composition of the saturating medium was selected based on the results of the saturation of die steels (60% carbon black + 40% urea) [5]. Containers were prepared where samples of steel were placed with the appropriate backfill. The lids of the containers were coated with refractory clay. The finished containers were placed in an electric furnace heated to a predetermined temperature. Investigated the depth of saturation depending on temperature and exposure time (Fig. 5).

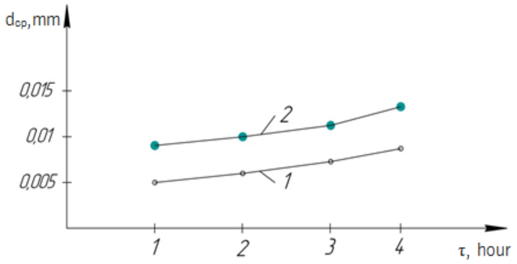

Figure 6. Effect of quenching time on the depth of the diffusion layer of P6M5. Tempering: 1 – 560 ^{0}C 2 – 620 ^{0}C

It can be noted that the most intensively carbonitriding process takes place at a saturation temperature of 620 °C. Moreover, a saturation depth of 0.1 mm is achieved at this temperature for one hour. A further saturation process at this temperature leads to a saturation depth of 0.15 only after 4 hours. During tempering at high-speed steel, two mutually competing processes occur:

1. The process of transformation of residual austenite to martensite with the simultaneous release of finely dispersed carbides of alloying elements.
2. Beginning of the tempering process of martensite obtained after quenching. The first process gives an increase in hardness and heat resistance of steel, the second partial decrease in hardness of martensite is obtained in the quenching process. When the hardened steel is heated to temperatures of 550-600 °C and a certain exposure at this temperature, special carbides are released. Because of this, the martensitic point increases, which leads to the transformation of residual austenite to martensite, respectively, to an increase in the hardness of the steel. Usually, after the first tempering, the residual austenite decreases from 25 to 10% in Fig. 6.

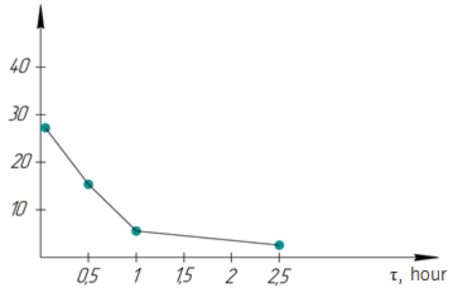

Figure 6: Effect of tempering at 560 °C on the amount of austenite of P6M5 quenched at 1200 – 1300 °C

Changes in the microhardness of the carbonitrided layer of steel R6M5 showed that the surface carbonitrided steel layer reaches the microhardness values of HV 11000 MPa figures 7-8.

The obtained dependences fig. 7.8 show that saturation temperatures practically give one microhardness value. With an increase in the exposure time, the microhardness value increases slightly. The drop in microhardness with an increase in the depth of saturation is insignificant.

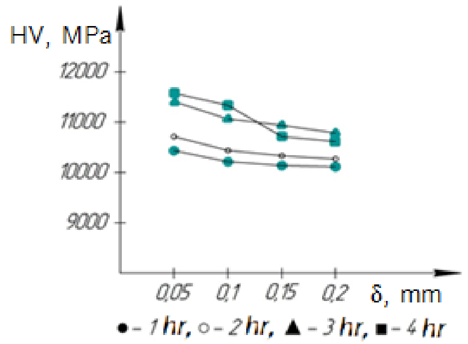

Figure 7: Effect of microhardness of cyanided at 550 °C

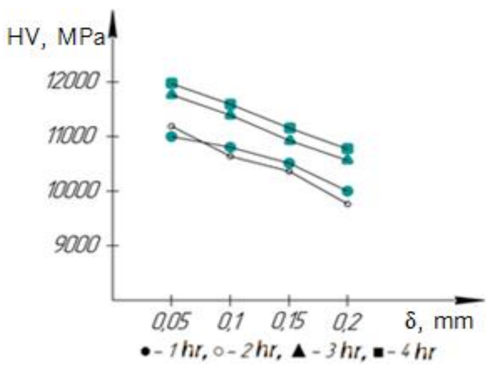

Figure 8: Effect of microhardness of cyanided at 620 °C

Thus, it can be noted that the increase in the exposure time at low-temperature carbonation steel R6M5 does not give a noticeable increase in the microhardness of steel R6M5.

4. Conclusions

Analyzing the above results of research on the combined chemical heat treatment of high-speed steel R6M5, we can come to the following conclusions:

- the optimum tempering temperature of steel P6M5 is the heating temperature of 1200-1230 °C;
- the grain size of austenite in steel R6M5 depends on the exposure time at a shutter speed of 5 minutes;
- the grain grows to 10 points at a shutter speed of 1.5 minutes it reaches 12 points;
- tempering temperature can vary from 560 to 620 °C depending on the wished hardness.

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