The influence of temperature and time parameters of thermal treatment on structural change and properties of carbon chromium molybdenum steel has been studied. It has been shown that there are considerable areas with grainy morphology of cementite after high temperature tempering in the structure of steel. It assures reduction of steel microhardness by 25%, and there are no substantial structural changes after medium temperature tempering.

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MORPHOLOGY MODIFICATION OF CARBON CHROME MOLYBDENUM STEEL STRUCTURE INFLUENCED BY HEAT TREATMENT

Hot rolled section from structural alloy steel normally has rather high hardness values and it can result in considerable decrease of tool durability and reduction of maximum allowed deformations when producing parts. That’s why prior to machining such rolled section is exposed to preliminary heat treatment. Required hardness of rolled section from alloy structural steel can be ensured by high-temperature tempering at subcritical temperature 650–700 ºC with long isothermic exposure or spheroidizing annealing with heating in inter-critical area (Ac_1-Ac_3) with subsequent exposure at temperature lower than Ac_1. The last type of processing suits only the steel with carbon content more than 0,5%, since totally spheroidized structure leads to big steel softening and it worsens its cutting. Rolled section from alloy steel, containing carbon up to 0,5%, normally is exposed to high-temperature tempering, however the overall time of such processing can be up to 50 hours, since heating and cooling of rolled section have to be performed slowly. After such a processing the steel structure must contain sheet-like particles and spheroidized carbidic particles.

In order to reduce the thermal treatment time the research was done on the influence of temperature and time parameters of tempering on the structure and properties of hot rolled section from structural alloy steel. Basic material for researches was samples of carbon chrome molybdenum steel of the following chemical composition: 0,39% C; 1,06% Cr; 0,25% Mo; 0,26% Si; 0,75% Mn; ≤0,013% P; ≤0,023% S. Small samples were thermally treated. They were heated with temperature intervals 500–700ºC and exposure from 1 to 6 hours. Cooling after tempering was done in the air and in the furnace.

The microstructure of samples was studied after thermal treatment.

Original microstructure (Fig.1, *а*) of hot rolled steel consisted of bainite, pearlite (5–10%) and ferrite (up to 15%). Structural changes in the steel structure after medium-temperature tempering, compared with original condition, were insignificant (Fig. 1, *б*, *в*). The morphology of cementite in pearlite at max. exposure of 6 hours will be modified only by 10%.

However in the structure of pearlite area after high-temperature tempering it is noticeable that there is a modification of cementite morphology as a result of structural changes: coagulation and spheroidization, thermodynamical impetus of which is reduction of free energy (Fig. 1, *г*–*е*).

Spheroidization of sheet-like pearlite includes dividing of carbidic plates into parts of irregular shape and, as a matter of fact, spheroidization and subsequent coagulation of carbidic particles. Since structural changes progress when tempering depends on diffusion rate of carbons and atoms of iron, then as long as temperature increases, the changes increase and it is noticeable in the steel microstructure after medium and high temperature tempering within 3 hours.

Fig. 2 shows the results of changes of microhardness of samples of carbon chromium molybdenum steel after performed thermal treatments. It is noticeable that after medium temperature tempering with various isothermic exposures the reduction of micro-

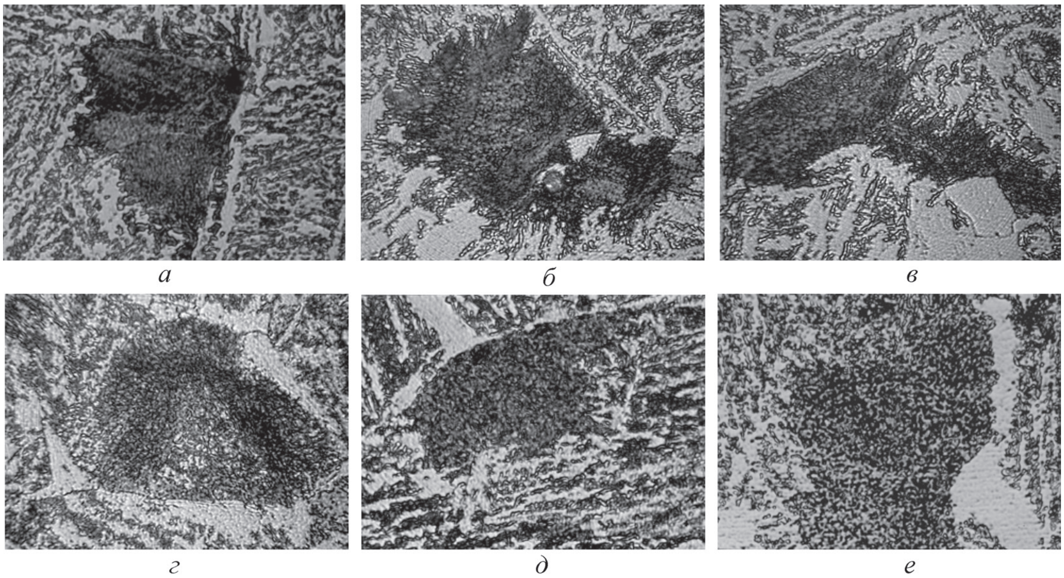

Fig.1. Microstructure of chrome molybdenum steel: *а* – initial condition and after mideum (*б*, *в*) and high (*г*–*е*) tempering with exposure of 1 hour (*г*), 3 hours (*б*, *д*) and 6 hours (*в*, *е*) with subsequent air cooling (*а*, *б*, *г*, *д*) or in the furnace (*в*, *е*) (×800)

hardness relative to original condition was not observed, even after 6 hours of exposure. At that, steel microhardness, tempered at higher temperatures, starts going down at short exposures and it reduces by 32% at exposure of 6 hours.

Simultaneously with decrease of microhardness at high temperature tempering the rate of spheriodization of carbides in pearlite starts going up from 10% at exposure of 1 hour up to 60% at exposure of 6 hours (Fig. 3). After medium temperature tempering the max. carbide spheriodization amounts 10%.

It is known [1], that at tempering temperature of about 500 °C alloy carbide forming elements can improve steel hardness due to formation of fine-grained carbidic particles. No-carbide-forming elements (for instance silicone), being in solid solution, in ferrite, harden it, and it also improves hardness. Hardness decreases due to strong insularity (coagulation) of carbides, which speeds up at the temperatures close to point Ac_1. That's why to go through spheroidization and coagulation of carbides it is required to perform high temperature tempering.

When microhardness of steel changes – the steel that was tempered at temperatures lower than 600ºC – it has been noticed that the values of pearlite area microhardness exceed the values of bainite areas microhardness by 150–330 N/mm^2. Based on this, one can suppose that structural changes start in a more thermodynamically unstable bainite at reduced temperature. It proves [1] that for bainite structure as a result of annealing at temperature about 400ºC hardness drops, because dispersed carbides in bainite coagulate easier, than in a pearlite area. That is why aiming to save energy resources (reduction of tempering temperature when producing rolled sections from carbon chromium molybdenum steel) it is desirable to provide for bainite structure after hot rolling.

The researches have been carried out [2] on the influence of cooling rate on structure formation in carbon chromium molybdenum steel with preparation of revised continuous cooling transformation diagram (Fig. 4).

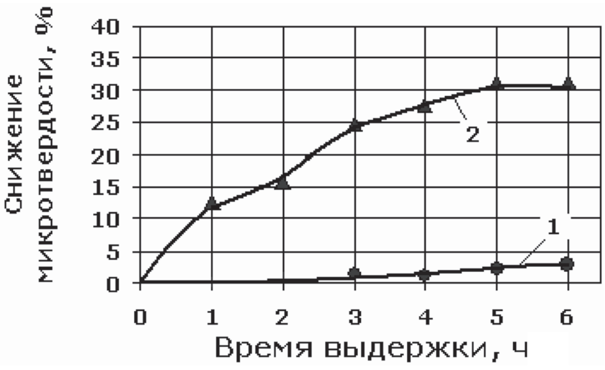

Fig. 2. Influence of exposure duration at medium (*1*) and high (*2*) tempering on microhardness of studied steel

Fig. 3. A share of spheroidized pearlite in steel after medium (*1*) and high (*2*) tempering

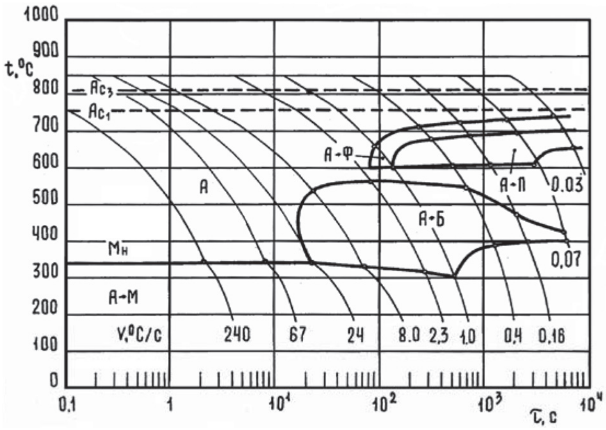

Fig. 4. Continuous cooling transformation diagram of quality carbon steel, containing 0,39% C; 1,08% Cr and 0,25% Mo

According to the given continuous cooling transformation diagram, one can obtain mainly bainite structure in chromium molybdenum steel when cooling rolled section with velocity interval 1–1,7 ºC/sec. With these cooling speeds pearlite does not form, however insignificant share of martensite formation is possible. The martensite which will break up into ferrite and carbides at subsequent thermal treatment.

Based on obtained results, it should be noted that medium tempering within 6 hours yields worse results, than high temperature tempering within 1 hour. Good results of steel softening have been reached already at exposure of 3 hours, besides steel microhardness compared with hot rolled condition reduces by 25%, and it corresponds to formation of 30% spheroidized pearlite. Further increase of isothermic exposure does not result in essential reduction of microhardness. Thus, exposure time at high temperature tempering of rolled section from alloy steel can be reduced by 40% assuring necessary properties. Such type of treatment is planned to be tried out in slow cooling pits in mill 850 at the Republican unitary enterprise ‘Byelorussian steel works’.

For further reduction of thermal treatment and energy sources saving by means of tempering temperature reduction assuring necessary properties, the structure should be mainly bainite in rolling prior to thermal treatment. With this end in view cooling of rolled section after rolling is necessary to be done with velocity interval of 1,0–1,7ºC/sec.

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