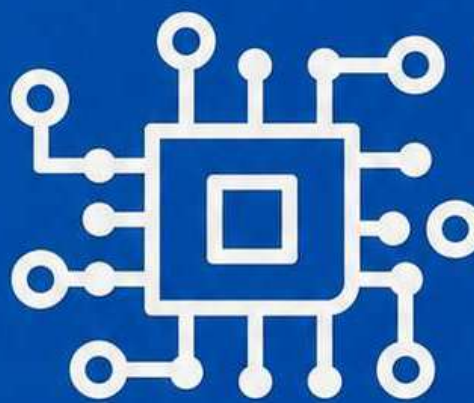




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PARAMETERS FOR THERMAL CYCLIC TREATMENT OF HIGH ALLOY STEELS

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Annotation. High-alloyed steels are widely used in the manufacture of parts operating under deformation conditions and under impact stress. Parts made from these steels are of great importance for heat treatment, which improves physical and mechanical properties. Thermal cycling treatment (TCT) is based on repeated heating and cooling without keeping the steel at constant heating temperatures, which requires the development of separate modes for each steel grade. This paper presents the parameters for thermal cycling of high-alloyed steels.

Keywords: high alloy steel, tempering, issue, thermocyclic processing, hardness, pearlite, austenite.

YUQORI QOTISHLI PO'LATLARNI TERMAL SIKLIK ISHLASH PARAMETRLARI

Ergashev Dilshodbek Mamasidiqovich

Texnika fanlari doktori

Andijon davlat texnika instituti ilmiy xodimi

Annotatsiya. Yuqori qotishmali po'latlar deformatsiya sharoitida va zarba kuchlanishi ostida ishlaydigan qismlarni ishlab chiqarishda keng qo'llaniladi. Ushbu po'latlardan tayyorlangan qismlar issiqlik bilan ishlov berish uchun katta ahamiyatga ega, bu esa fizik va mexanik xususiyatlarni yaxshilaydi. Termik siklli ishlov berish (TCT) po'latni doimiy isitish haroratida saqlamasdan takroriy isitish va sovutishga asoslangan bo'lib, bu har bir po'lat navi uchun alohida rejimlarni ishlab chiqishni talab qiladi. Ushbu maqolada yuqori qotishmali po'latlarning termik sikl parametrlari keltirilgan.

Kalit so'zlar: yuqori qotishmali po'lat, chiniqtirish, muammo, termosiklik ishlov berish, qattiqlik, perlit, ostenit.

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Introduction. Thermal cycling (TC) is based on the idea of repeatedly heating and cooling steel without maintaining it at a constant temperature. In this case, the values of the upper and lower temperatures and the heating and cooling rates can be constant or vary from cycle to cycle [1]. The repeated exposure to thermal effects is based on the occurrence and accumulation of structural-phase changes in the object, which manifest themselves in a relatively limited primary thermal cycle. Unlike conventional thermal cycling, each subsequent thermal cycle is formed in a new structural-phase state. In turn, in TC, it is necessary not only to activate the structural-phase changes that occur traditionally, but also to cause a reaction that is not possible with a single thermal treatment at all or is limited. This ultimately leads to a significant increase in the properties of steels after the last cycle of TC or during the final heat treatment, and to the acquisition of various characteristics that are often unattainable with traditional heat treatment [2].

At present, a large number of different TC regimes have been developed for steels [3]. All TC methods are divided into low-, medium-, and high-temperature types [4]. In the low-temperature TC method, heating is carried out at a temperature not exceeding the corresponding temperature before the onset of $\alpha \rightarrow \gamma$ transformations, in which case phase transformations do not occur. Medium-temperature TC involves heating in the region of two-phase states (A_{c1} and A_{c3}). In high-temperature TC, heating is carried out in the region of complete phase recrystallization (A_{c3} and A_{cm}). It should also be noted that in addition to the above-mentioned classes of TC, combined modes including sequential heating in the field of different temperatures are also used [5,6,11].

The fundamental characteristics of the implementation of various schemes of TC and its efficiency parameters have been analyzed in detail in the literature [7].

Steel grade X12M is a high-chromium steel with high wear resistance. The chemical composition of this steel provides high resistance to abrasion. By structure, these steels are characterized by the presence of excess carbides [8].

Research materials. The chemical composition of the studied steels is given in Table 1.

Table 1

Chemical composition of the studied steel

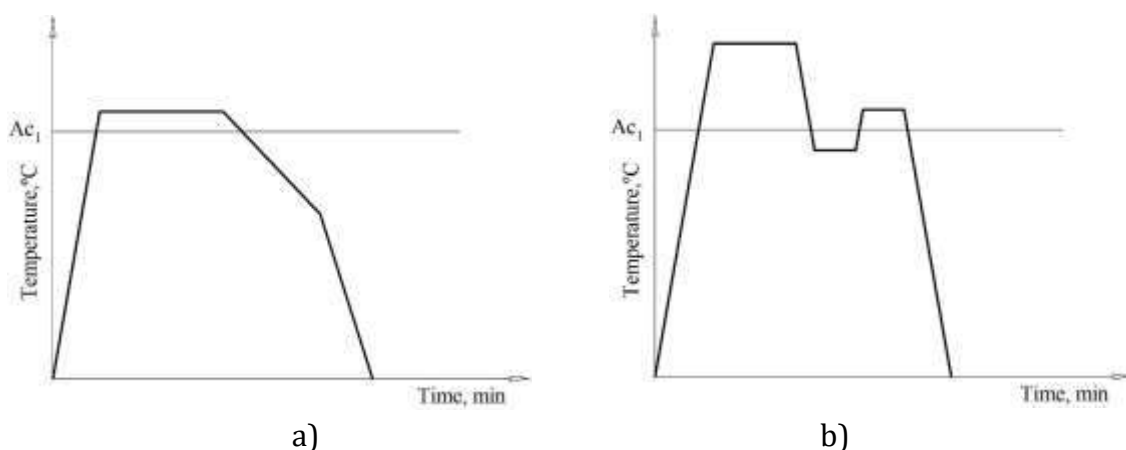
Steel grade	The amount of chemical elements included in steel, %							
	C	Si	Mn	Cr	W	Mo	S	P
X12M	1,45-1,65	0,15-0,35	0,15-0,40	11,0-12,5	-	0,4-0,6	0,03	0,03

When studying the thermal cycle treatment regimes, the temperatures generally accepted for the corresponding grades of steels for which the heating regimes are intended were used.

The annealing temperature was in the range of 200 to 500 °C depending on the required hardness. The heating of steel samples was carried out in salt baths containing NaCl and BaCl₂. The holding time for a 1 mm section of the sample was 0.5-3 minutes.

As a controlled parameter, the hardness was determined on the HRC scale, and an aqueous solution of hydrochloric acid was used as an etching agent to determine the presence of cracks.

Heat treatment was carried out based on the data of structural studies obtained using optimal regimes. This heat treatment consists of the following: first, the initial cycle treatment, which replaces the standard softening modes, was performed, then the heating mode was set to heat up to a temperature of 1150° C, then the tool was put into a furnace with a temperature lower than A_{s1} , and kept at a temperature lower than this temperature by 200° C, and then heated again to a temperature higher than A_{s1} , and then the cooling process was carried out in air. This situation is illustrated in Figure 1.



a) softening to obtain granular perlite; b) combined thermocycling

Fig. 1. Schemes of preliminary heat treatment of X12M steel

The final heat treatment process consists of forging and cooling at a standard heating temperature. In the last release, heating was carried out at a temperature of 540 - 650⁰ C in the cyclic pulse mode. During the release period, the heating time was chosen based on the need to heat the device until the desired time, and that time was from 10 to 15 minutes. Recommended final heat treatment schemes are shown in Fig. 2.

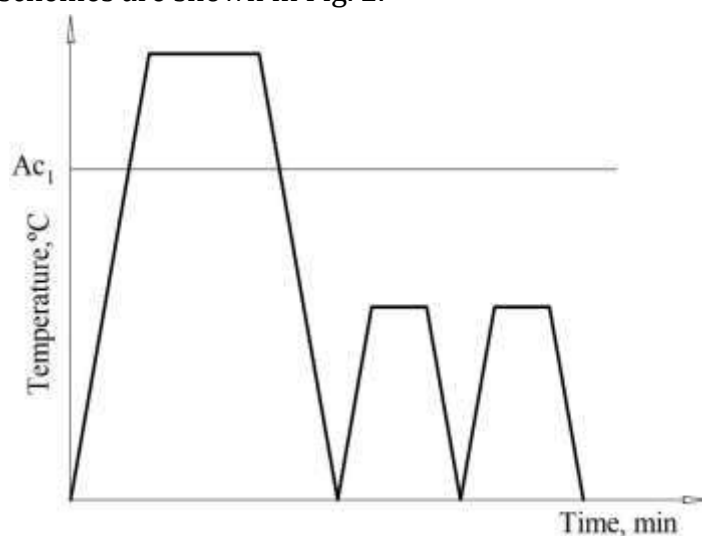


Fig. 2. The final thermal treatment scheme

Metallographic analysis. Metallographic analyses were performed to assess the microstructure parameters of the steel. These parameters include grain size, martensite structure, retained austenite content, and carbide distribution.

The preparation and etching of micrographs were performed using widely known methods [9]. The austenite grain size was determined according to GOST 5639-65.

Microscopic studies were performed using an Oxion Inversio OX.2653-PLMi microscope at magnifications from 100 to 1000 times.

X-ray structural analysis. X-ray structural analysis is a direct method for studying the phase composition, structure, state of soft crystal structure, and measurements of crystal lattice parameters. The study of soft crystal structure was carried out by physical broadening of the X-ray line, interference of the α phase with the (220), (110), (211) and broadening of the (200) line of the γ phase.

The amount of retained austenite after heat treatment of steel is determined by the ratios of the integral intensity lines of the α phase (211) and γ (200) [10].

Mechanical testing. The hardness of the heat-treated samples was determined using a THR-45/150DX hardness tester.

Results. Tempering of steel grade X12M is carried out by cooling at a temperature of 830-850° C to a temperature of 720-740° C at a rate of 40° C/h and holding for 3-4 hours, then cooling in air at a rate of 50° C/h to a temperature of 550° C [9].

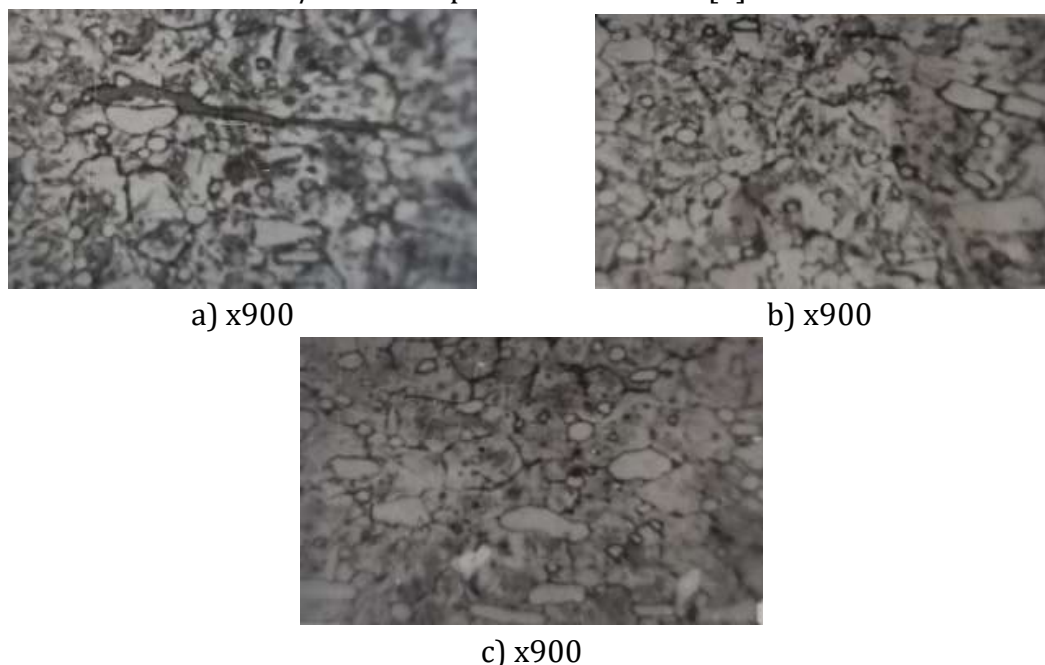


Fig. 3. Microstructures of X12M steel tempered at different temperatures

a – heating at a temperature of 1030° C;

b - heating at a temperature of 1240° C;

c- is cyclic heating, the first heating temperature is 1240° C, the second heating temperature is 1030° C, the discharge temperature is 540° C

The quenching of steel grade X12M is carried out at a heating temperature of 950-980° C to obtain a hardness of 63-65 HRC, and the tempering is carried out at a heating temperature of 180-200° C to obtain a hardness of 60-62 HRC and at a heating temperature of 320-350° C to obtain a hardness of 57-58 HRC.

In order to determine the optimal modes of the initial cyclic heat treatment, the first heating for the quenching of steel grade X12M is carried out at temperatures of 1030° C, 1100° C, 1150° C, 1250° C and 1300° C, and the second heating is carried out at a standard heating temperature for the above steel. In this case, an attempt was made to achieve the goal of eliminating the non-uniformity of carbides to the maximum extent. Then pulse discharges were carried out at temperatures of 540, 600 and 650° C, and some of the samples were taken without discharge.

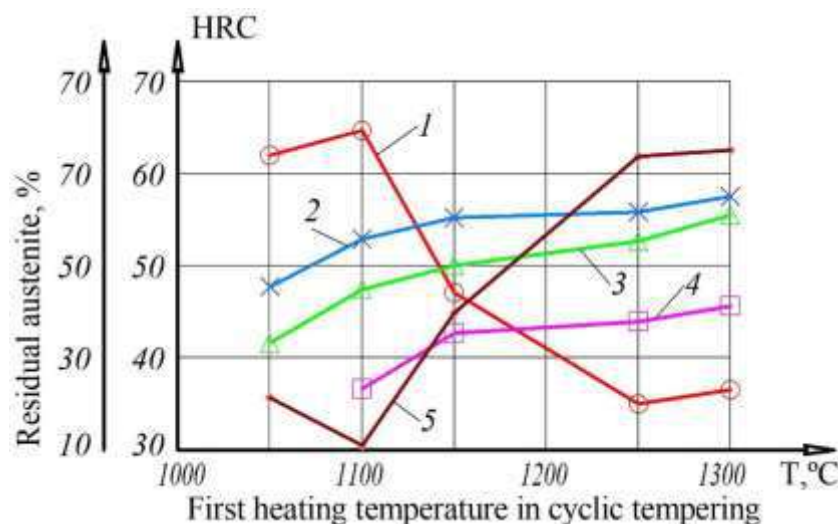


Fig. 4. Variation of hardness and amount of residual austenite in % of X12M steel depending on the mode of initial cycle heat treatment. The heating temperature for the second heating is 1030° C

- 1 - without discharge;
- 2 - pulse discharge at a temperature of 540° C;
- 3 - pulse discharge at a temperature of 600° C;
- 4 - pulse discharge at a temperature of 650° C;
- 5 - the percentage of residual austenite.

As can be seen from Figure 4, as a result of increasing the annealing temperature, the hardness increases up to 1400° C, then the hardness value decreases rapidly with increasing temperature. This is explained by the increased dissolution of alloying elements in austenite, which leads to the formation of a large amount of retained austenite after annealing. The subsequent pulsed annealing at a temperature of 540° C leads to an increase in hardness (secondary hardness), but the hardness value is less than the primary hardness value after annealing.

Microanalysis showed that after annealing of steel at a temperature of 1050 - 1100° C, a large amount of secondary carbides and a non-uniform presence of primary carbides in the structure remain. The basic structure consists of very small amounts of martensite and retained austenite.

When heating the annealing temperature to a temperature above 1150° C, intensive dissolution of secondary carbides, growth of austenite grains and a rapid increase in the amount of retained austenite occur (Fig. 4). After annealing at a temperature of 540° C, a decrease in the amount of retained austenite is observed in the structure, but at the same time, areas with a troostite structure are also observed (Fig. 3). Annealing at a temperature of 600° C ensures a relatively complete decomposition of the solid solution with the formation of a troostite structure.

Annealing at a temperature of 1300° C leads to the preservation of a certain part of the martensite structure after annealing at a temperature of 600° C. This indicates that the solid solution is strongly alloyed at very high temperatures.

If the initial cycle grinding is carried out in order to transfer the alloying elements to the maximum solid solution, and the additional phases serve to obtain the maximum dislocation

density, then the main subsequent heat treatment is carried out in order to grind the austenite grain while maintaining a high dislocation density.

Discussion. The results of the study of the initial cyclic heat treatment of steel grade X12M showed that the highest hardness values with the lowest amount of retained austenite are obtained in the following heat treatment regimes: the first heating temperature for annealing is 1150°C and the second heating temperature for annealing is 1030°C with cyclic annealing at a temperature of 600°C . These heat treatment regimes were adopted as the basis for steel grade X12M.

The final heat treatment of this steel was carried out by annealing at a standard temperature of 1030°C and annealing at a temperature of 200°C . Samples made of steel grade X12M, which were subjected to X-ray diffraction studies (Fig. 5).

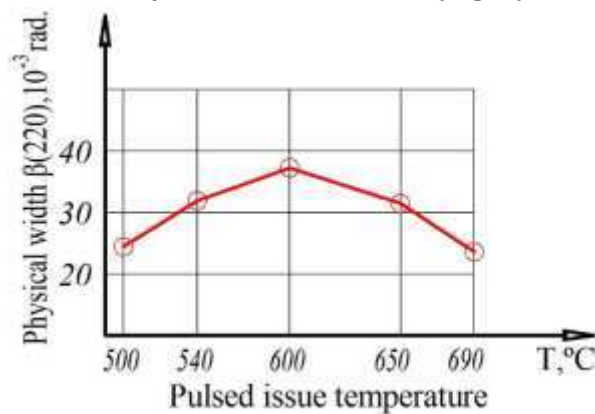


Fig. 5. Dependence of the X-ray line width (220) of the b phase in the X12M steel after the final heat treatment on the pulse discharge temperature

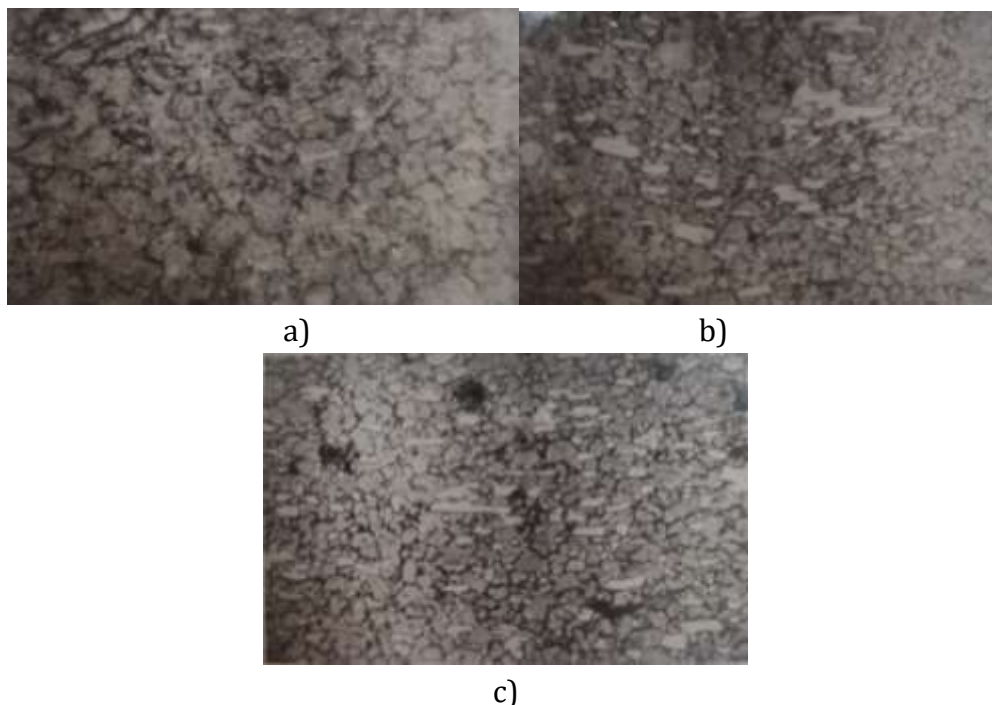


Fig. 6. Microstructure of X12M steel after final heat treatment as a function of pulse discharge temperature

- a – pulse discharge at a temperature of 540°C ;
- b – pulse discharge at a temperature of 600°C ;
- c – impulse discharge at a temperature of 650°C .

The research results show that the crystal structure of X12M steel is subjected to thermocycling at a temperature of 600° C to the maximum degree of defects. As an alternative option, thermocycling processes consisting of pulse discharge at temperatures of 540° C and 650° C were obtained. The final heat treatment was also carried out in standard modes. The above modes have been shown to be achieved by pulsed discharge.

Microstructural studies have shown that if a second annealing at 1030° C is followed by tempering at 180–200° C, the following microstructure can be observed: Pulse tempering at 540° C produces an alloyed solid solution with a large amount of retained austenite. The most favorable is pulse tempering at 600° C, which does not lead to austenite grain growth and forms a moderately fine-grained martensite structure and a small amount of retained austenite (Fig. 6).

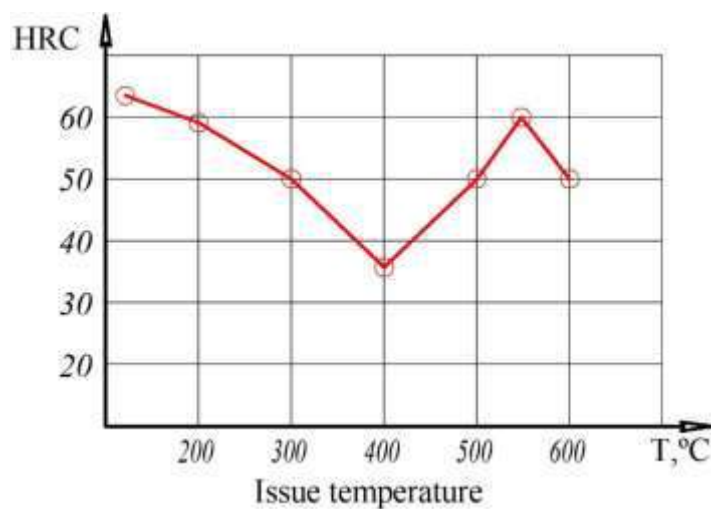


Fig. 7. Changes in the hardness of X12M steel after thermocycling depending on the final release temperature

The study of the change in hardness depending on the annealing temperature after a full cycle of thermocycling showed that with an increase in the annealing temperature, the secondary hardening effect of steel grade X12M increases, and the maximum increase in this hardness occurs at a temperature of 550° C, which is 50° C higher than the standard thermal treatment temperature. Thus, it can be noted that thermocycling treatment, combined with pulse annealing, can increase the heat resistance of steel by 50° C (Fig. 7).

Conclusions.

1. The use of thermocycling technology for tool steels allows for an additional increase in tool performance due to multiple thermal effects.
2. The use of double annealing in combination with intermediate annealing allows for an increase in the wear resistance of steel due to the formation of a high degree of crystal structure defects.
3. It was found that for steel grade X12M, thermocycling and double pulse annealing eliminate carbide heterogeneity resulting from standard thermal treatment.
4. For steel grade X12M, a full cycle of thermocycling treatment leads to the formation of a structure with the maximum degree of crystal structure defects in the following heat treatment modes: the first heating at a temperature of 1150° C, the second heating at a temperature of 1030° C with oil quenching and pulse tempering at a temperature of 600° C, and tempering at a temperature of 1030 ° C and tempering at a temperature of 200° C.

5. The recommended full cycle of thermocycling treatment for steel grade X12M increases the heat resistance of the steel by 50° C.

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