RESOURCE-SAVING MANUFACTURING TECHNOLOGIES AND THERMAL HARDENING OF MACHINE PARTS AND TOOL

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Abstract – *A* large range of high-value imported machine-building products is manufactured and operated in Uzbekistan. To reduce costs, it is of interest to use unconventional technologies for the manufacture and hardening of machine parts and tools using energy and material-saving technologies from components produced in the Republic of Uzbekistan. These components include powder materials and polymeric materials produced in Uzbekistan. When using these materials, powder metallurgy and heat treatment methods are applied.
As a result of using these methods, four technological problems were formulated and solved:
- development of cast metal layered compositions of tool material-structural steel for various types of tools by casting according to gasified models;
- development of unconventional methods of thermal hardening of tools made of high-alloy steels to sharply increase their durability and, on this basis, to save alloy steels;
- selection of the type of water-soluble polymers produced in the Republic of Uzbekistan for the manufacture of quenching media that replace quenching oils and allow (due to their higher cooling rates) to replace alloyed steels with carbon ones;
- development of the composition and technologies for the production of porous cermet products for antifriction purposes from powders obtained from the waste of metallurgical production of the republic.

Keywords: Crystallization, Metalworking Tools, Hardening, Tempering, Thermocycler Treatment.

1. Introduction

Currently, a large number of machines and tools made from high-quality and very often high-alloy steels are manufactured and operated in the republic. Many of these products are manufactured in the republic, and some are imported in finished form (rolling equipment, spare parts for agricultural machinery, molds, various types of cutting tools, etc.). All these products are quite expensive due to the scarcity of the materials themselves, and also because of the high complexity of manufacturing or restoration. All of the above products are thermally processed for high strength and wear resistance.

Therefore, it seems appropriate to take an integrated approach to this problem, including increasing the resource of the finished product through the use of non-traditional technologies of thermal hardening of machine parts and tools, restoration and manufacturing of products using energy and material-saving technologies, as well as the use of new cooling in the process of thermal hardening media from components produced in the Republic of Uzbekistan.

The current development trend of this scientific direction is the continuous improvement of hardening technologies, production of products, restoration to reduce the consumption of energy, materials, improve the environmental situation. A significant part of these tasks has already been solved, others are in the process of being solved. In particular, according to the first task, the technology for producing cast metal layered compositions for cutting tools (cutters, dies) was fully developed.

The developed technology is based on a well-known scheme - an insert made of tool material with a bearing base of cast structural steel [1-5]. However, in the practice of tool production, the casting method for gasified models was used for this purpose. The simplicity of the technology, the convenience, and reliability of the placement of inserts - work items, the possibility of obtaining high-precision castings, and the use of a reducing atmosphere in the form of an atmosphere create undeniable advantages for this method compared to other known casting methods [1-5].

One of the main objectives of this work was to develop the composition and technology for producing the sintered powder composition of the

Mo-TiC system. In addition to the main components of Mo and TiC, the composition was introduced to improve the technological and operational characteristics of Ni, Fe, W, and LaB_6 [2].

A comparative evaluation of the alloy was carried out according to two characteristics of bending strength (σ_{ben}) and Rockwell hardness (HRA). As you know, these characteristics correlate well with characteristics such as hot hardness and heat resistance, which determine the operability and durability of a die tool for hot forming. Therefore, when developing the alloy, $\sigma_{ben,}$ and HRA were taken as evaluation criteria in determining the optimal composition.

The second and third tasks are inextricably linked, since cooling during the thermal hardening of steel is the main factor affecting the subsequent phase state and properties of the steel. As non-traditional methods of thermal hardening, the method of thermal cycling was chosen.

The thermal cyclic processing (TCP) scheme is based on repeated heating and cooling of steels without holding at a constant heating temperature [6]. The values of the heating and cooling temperatures, as well as the rates of these processes, are constant or vary from cycle to cycle. Repeated exposure to heating and cooling leads to the accumulation of phase changes in the structure of steel. Compared with standard heat treatment in the heat treatment plant, it is possible to achieve enhanced steel properties.

There are a large number of different modes of TCP [8,9]. According to [8], all methods are divided into three types: low, medium, and high-temperature methods. The low-temperature method of TCP is carried out at temperatures up to the start of $\alpha \rightarrow \gamma$ transformation. The medium temperature is carried out in the temperature range between the points Ac and Ac_3.

High-temperature conduct above the point Ac_3 or Ast. It is also possible to carry out combined TCP modes with the transition to different temperature ranges. The medium and high-temperature TCP for tool steels is mainly used for the annealing process with the aim of enlargement and spheroidization of carbides [9].

From the point of view of improving the mechanical and technological properties, the most optimal modes of the TCP are the modes of the combined TCP.

Combined TCP includes quenching from elevated or standard heating temperatures, intermediate tempering, and subsequent standard heat treatment, consisting of quenching from generally accepted temperatures and final tempering [9].

It should be noted that the issues of the application of TTZ to tool steels are not sufficiently studied. In particular, the use of medium temperature TCW for spheroidizing, annealing gave positive results.

However, the influence of the annealing regimes of TCP on subsequent phase transformations during heat treatment was practically not studied. Tool steels work under conditions of high loads on the working edges of the tool, and the application of various modes of the TCP is not tested enough due to the difficulty of applying high heating temperatures for hardening, which can lead to cracks in the hardening process, as well as to the decarburization phenomenon.

Therefore, the issues of the possibility of effective application of the regimes of TCT for carbon and alloyed tool steels are still relevant.

In most cases, mineral oils are used as a cooling medium for hardening tool steels. The use of mineral oils has well-known disadvantages: it is a high cost, a high degree of flammability, the formation of oil fog during quenching.

In recent years, work has been done on the search for oil substitutes used as quenching media. Many quenching media are solutions of various substances in water, the most widely used are water-soluble polymers. All quenching media based on water-soluble polymers produced in the CIS countries can be classified as follows [9].

On a basis:

– polyacrylamides (polyacrylamide and ZSP-1);
– incomplete iron salt;
– polyacrylic acids (PC-2);
– solution water and alkaline methacrylic copolymers (UZSP-1);
– sodium salt carboxyl methylcellulose (NaCMC);
– copolymers of chlorine with methyl methacrylate and methacrylic acid ("Nairit").

From all considered structures, solution based on a copolymer of methacrylic acid with acrylonitrile in a ratio of mono measured links (90-10)-(50-50) on the weight and concentration of copolymer of 0.1-10.0% (UZSP-1) is considered as universal. Extremely limited information is available about an opportunity to use as a component of the hardening environment, the copolymer of acrylic acid, and the acrylamide produced under the "Uniflock" trademark. At the same time, the need to develop programs for a standardized complex for certification of quenching oil substitutes is emphasized [9].

The fourth task is related to powder metallurgy methods.

The method of powder metallurgy makes it possible to manufacture products of specified sizes with high accuracy, which completely or partially eliminates the need for mechanical processing. Sometimes only individual operations for finishing the dimensions after installation in the assembly (boring, alignment, etc.). The dimensions of the sintered part are usually within the tolerances specified in the drawing and are easily adjusted to a higher calibration class.

Using the methods of powder metallurgy, it is possible, in some cases, to get rid of the complex machining required by traditional technology [10, 11].

Thus, the use of sintered products allows you to achieve the following advantages [11]:

- saving metal by obtaining the exact dimensions of the parts, reducing losses during machining, and reducing production waste and product mass by 20-30% due to pores.
- the complete elimination or significant reduction of the metal processing equipment fleet;
- saving expensive non-ferrous metals (bearing alloys) as a result of replacing them with less scarce iron-based alloys;
- easy automation and high culture of the processes of manufacturing parts by powder metallurgy, which improves the working conditions of workers. In the end, it is possible to significantly reduce the complexity of production and increase labor productivity;
- the use of waste products from the metallurgical and other industries to obtain the initial powders (iron, copper, nickel, etc.).

The last advantage in this work was fully used since it solved the issues of replacing imported powders of the Russian plant with local, iron powders obtained by the formation of mill scale of the Bekabad Metallurgical Plant. Also, pyrite is used as an additive material — waste from the production of the Almalyk Mining and Metallurgical Combine (AGMK).

2. Methods and Materials

Modern theoretical and experimental methods for studying metal layered compositions (macro and micro, as well as X-ray diffraction, analyzes, and others) were selected in the work. The strength and physic mechanical characteristics of metal layered compositions and products are determined according to the requirements of state standards.

To study the modes of thermo-cycler processing of TCP, heating modes were used, starting from commonly accepted temperatures for these grades of steel to temperatures of 1100 ^{0}C -1150 ^{0}C, then steel samples were transferred to a furnace with a temperature below Ac_1 by 20 ^{0}C, holding at this temperature and heating again to standard quenching temperatures followed by cooling in the air (Fig. 1) [9].

The final heat treatment for these steels consisted of quenching from standard heating temperatures for each steel grade and cooling in the water-polymer medium of the Uniflock preparation. The final tempering was carried out cyclically in a pulsed mode when heating У12 steels to temperatures of 300-500 ^{0}C, steel 9ХС (0,09 % C, 0,95-1,25 % Cr, 1,2-1,6 Si) 450 ^{0}C, the heating time during tempering was selected based on the necessary time for heating the tool and ranged from 10 to 15 minutes.

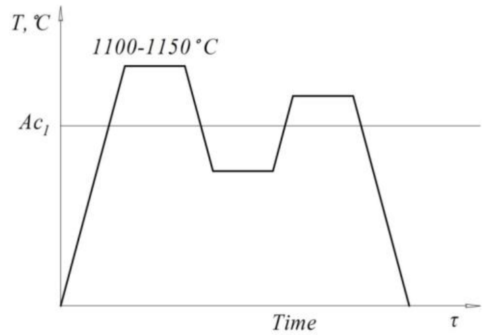

Figure1. Scheme of preliminary TCP

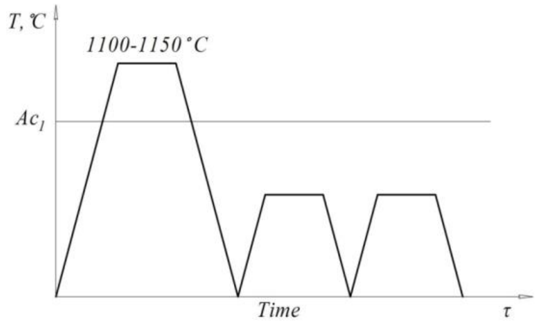

Figure 2. The scheme of final heat treatment of tempering from the standard temperature of a double discrete issue

Subsequent cooling was also carried out in a water-polymer medium based on the «Uniflock» preparation (Fig. 2) [9].

Steel was heated in salt baths of NaCl and $BaCl_2$. During quenching, steel samples were quenched in water-soluble polymers NaCMC and Uniflock. The cooling ability of polymer solutions was determined.

To determine the state of the fine crystalline structure of steel, an X-ray diffraction analysis was performed. The physical width of the x-ray interference lines of the α phase was determined. The surveys were carried out on a DRON-2.0 installation in the radiation of an iron anode at a tube voltage of V = 30-35 kV, anode current J = 9 Ma.

The objects of research were products obtained by pressing and sintering powders from local raw materials.

Iron powders were obtained by reducing the iron oxide of the Bekabad Metallurgical Plant. The reduction was carried out in an environment of dried hydrogen at a temperature of 1100-1150 ^{0}C. Pyrite, which is a waste of mining and metallurgical production, was used as a sulfur-containing additive. The obtained iron powders corresponded to the grades reduced iron powder 5, 450. 24 and reduced iron powder 5. I60,28 according to GOST 9849-86 - “Iron powder. Technical conditions” Introduced 01.05.1990.

To compose the mixture used graphite and pyrite. Graphite was taken elemental or pencil according to GOST 4404-78 "Graphite for the production of pencil rods. Technical conditions." Pyrite was used after grinding to a fraction of 0.45-0.16 mm.

The powders were mixed and the mixture was prepared in cone mixers with the addition of gasoline and zinc stearate. The graphite content was constant -2%. The pyrite content was: 0.5; 1.0; 1.5; 2.5; 3.0; 3.5; 4.0%. After preparation of the charge, the samples necessary for testing were prepared (pressed) by the required sizes and configuration for samples for tensile, compression, and impact strength [11].

Tests were carried out according to GOST 25698-83 - "Powder products. Hardness determination methods"; GOST18227 - Powder materials. Tensile test methods; GOST 9495-75- "Powder materials. Methods for determining impact toughness". To determine the antifriction characteristics, special samples were prepared in the form of bushings with an outer and inner diameter of 30 and 20 mm. Samples in the form of bushings were subjected to radial compression tests according to GOST 26529-85 - "Powder materials. Test Method for Radial Compression" [11].

Compressed samples were sintered. For this, the compacts were packed in stainless steel containers and then covered with an asbestos sheet. Cast iron shavings about 40 mm thick were poured onto the asbestos sheet, the container was covered with a lid, and the details were coated with refractory clay. Sintering was carried out at a temperature of 1100 °C for 2 hours. After sintering, the containers were cooled in the air.

The resulting samples were tested for hardness, strength following the above standards.

Density and porosity were determined following GOST 18398-73 - "Powder metallurgy. Methods for determining density and strength." The oil content in the impregnated powder products was determined by the gravimetric method according to GOST 24903-81.

3. Research Results

During the research work on the preparation of layered compositions, a formulation of the sintered powder composition of the Mo-TiC system was developed: comprising 45-47% TiC; 1.5-25% Fe; 1.5-2% Ni; 0.5-1% W; 0.1-0.2% LaB_6; Mo is the rest [2, 5].

The mechanism is determined and the features of the formation of the connection between the MSC elements are established, according to which, upon contact of the structural steel melt with the surface of the insert - the working cutting element, crystallization occurs with the formation of a hard crust followed by melting of the intermediate layer material and the interaction of the formed melt with solid surfaces bounding it: on the one hand, tool material, on the other - steel. As a result, a transition zone of the composition is formed, having a complex structure and phase composition, including the interaction products between the melt elements and the main components of the composition. An analysis of the mechanism and features of the formation of compounds of all the obtained types of MSCs allows us to predict the process and select technological conditions for creating MSCs with desired properties.

For the manufacture of metal layered compositions, it is necessary to perform the following basic technological methods: preparation of polystyrene foam for the manufacture of a foam model; manufacturing foam model tools; work item preparation; preparation, and receipt of the casting; getting tool.

Obtaining a metal layered composition such as foundry structural steel - working insert is possible if the physical-mechanical characteristics of the materials are comparable. Compositions of this type are a connection between tool and foundry structural steels. The main advantages of this class of joints are the reduction in the consumption of alloyed tool steels due to their partial replacement with more affordable structural steels and the reduction in the complexity of manufacturing stamped and multi-blade cutting tools with complex profiles.

An analysis of the ratio of the geometric parameters of the working elements and the tool bodies made it possible to establish that for this class of tools, the thickness of the insert in the zone of contact with the melt should be 2-5 mm.

As mentioned earlier, for the manufacture of a complex multi-blade tool, heat-resistant, high-speed steels — cast structural steel — were used. The specificity of operation of this class of tool is also due to the high requirements for the tool body working under dynamic and cyclic loads (steel 40XL (0,35-0,45% C, 0,8-1,1% Cr), 40XGL (0,35-0,45% c, 0,8-1,1% Cr, 0,8-1,1% Mn), 40XGFL (0,35-0,45% C, 0,8-1,1% Cr, 0,8-1,1% Mn, 0,8-1% V)). The following were selected as heat-resistant tool steels: R6M5 (0,80-0,88% C, 5,5-6,5% W, 3,0-5,5% Mo), 10R6M5-MP, R6M5K5, and others [1,2, 4,5].

The option with an intermediate layer is practically the only one for compositions, the components of which differ significantly in physical characteristics. These compositions include hard alloys - steel, molybdenum alloys - steel. For stamping tools (dies for hot pressing of metals) and drilling tools (drill bits, bits, and cutters), carbide inserts designed for soldered tools were used. To create compositions as the material of the intermediate layer, we used alloys of the Cu – Ni – Mn and Cu – Ni systems with a thickness of 0.2–0.6 mm, sprayed by the plasma method.

When solving the second and third problems, we used the method of thermo-cyclic processing (TCP). Preliminary TCP was conducted according to the scheme in fig. 1 steel of the U12 (1,1-1,29% C, 0,17-0,33% Si) and 9XC (0,09 % C, 0,95-1,25 % Cr, 1,2-1,6 Si) brands heated up to the extreme heating temperature of 1100-1150 ^{0}C. The existence of extreme temperatures of heating explains the fact that after cooling, it is formed the structure with a maximum deficiency of the crystal building which affects wear resistance of steel [6]. X-ray diffraction researches of preliminary TCP of steel U12 (1,1-1,29% C, 0,17-0,33% Si) and 9XC (0,09 % C, 0,95-1,25 % Cr, 1,2-1,6 Si) showed that the maximum deficiency of the crystal building forms at these steels at the application of the high-temperature modes of heating (Fig 3) [9].

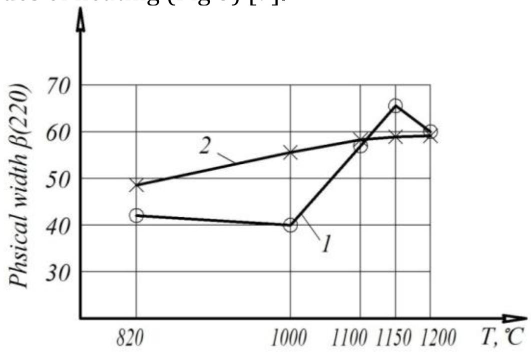

Figure 3. Dependence of Physical Width of the x-ray line (220) of steels U12 and 9XC depending on preheating temperature and temperature of final heating, cooling on air 1st steel U12, 2nd steel 9XC

For the reduction of a fabrication cycle and reduction of hardening tension in steels, final heat treatment was conducted according to the scheme (Fig.2). Tempering was conducted from the standard heating temperature of 820 ^{0}C for steel U12, 840 ^{0}C for steel 9XC, cooling in waters to the polymeric environment based on the medicine "Uniflock". Tempering of steel was spent in a double discrete mode at different temperatures, with cooling in waters to the polymeric environment. X-ray diffraction researches showed that at the application of preliminary TCP with high-temperature heating the structure with a high level of crystal deficiency in steel forms. A final heat treatment according to the scheme (Fig.2), there is an effect of inheritance of deficiency of the crystal structure at different temperatures of discrete issue. (Fig. 4,5) [9].

The definition of optimum hardening lubricant based on water-soluble polymers was conducted by the research of refrigerating capolyacrylamideity of these polymers in different concentrations.

Preliminary experiments were made by the removal of curves of cooling with the special thermometer made of steel 12X18N10T (0,12% C, 18% Cr, 10% Ni, 1,0-1,5% Ti). The thermometer heated up in the furnace without the protective atmosphere to a temperature of 870±5 ^{0}C and was maintained within 5 min. Then in less than 2 sec., moved in the cooling medium. The volume of liquid was 2 l, and temperatures of liquid changed from 20^{0}C to 40 ^{0}C. Temperature changes in the course of cooling registered on a self-balancing potentiometer of KCP-4.

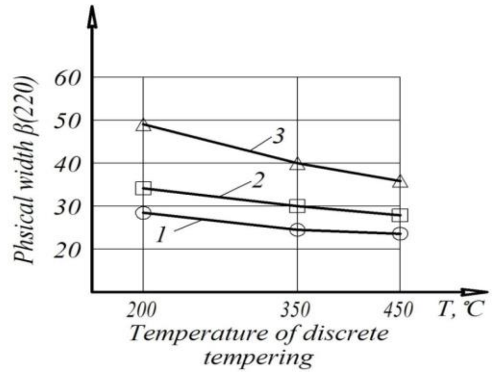

Figure 4. Dependence of the physical width of the x-ray line (220) of steel У12 depending on the temperature of the final discrete issue

Tempering of temperature at 820 ^{0}C.

1st Preliminary TCP from the heating temperature at 820 ^{0}C.

2nd Preliminary TCP from the heating temperature at 1000 ^{0}C.

3rd Preliminary TCP from the heating temperature at 1150 ^{0}C.

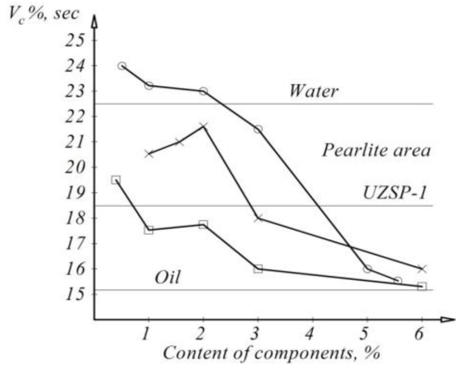

Figure 6. Influence of maintenance of polymeric components in hardening liquid on cooling speeds, an interval 870-275 ^{0}C. O- NaCMC X-Uniflok, O- NaCMC of 2% marked acrylate

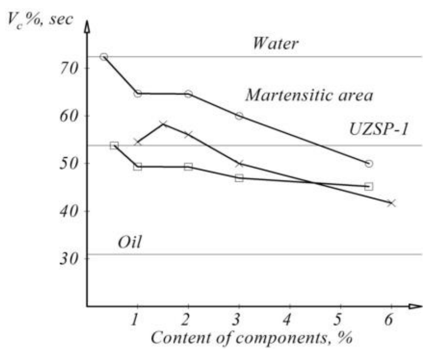

Figure 7. Influence of maintenance of polymeric components in hardening liquid on cooling speeds, an interval 275-55 ^{0}C. O- NaCMC X-Uniflock, O- NaCMCs-2% methyl acrylate

Cooling curves determined the average speed of cooling around perlite transformation, in the range of temperatures 870-275 ^{0}C, and in the range of temperatures of martensitic transformation for carbonaceous and low-alloy steels 275-55 ^{0}C (fig. 6.7).

Experiences showed that NaCMC solutions are the least natural as cooling speed strongly depended on the change of concentration of the solution. The use of “Uniflock” solutions is in this respect more favorable. The required speeds of cooling corresponding to 0.7% to UZSP-1 solution are reached at the maintenance of a component in solution about 3% [11].

In solving the fourth problem of obtaining an antifriction material, iron powders obtained by reducing the iron oxide of the Bekabad Metallurgical Plant were used as starting materials. The reduction was carried out by heating the scale in a hydrogen atmosphere. The reduction powder underwent additional grinding, after which sieving was carried out on sieves to obtain the desired particle size distribution. The technical composition of the prepared powders corresponded to GOST 9849-86.

The prepared powders were mixed and the pyrite produced by AGMK with a particle size of 0.1–0.071 mm was added as a sulfur-containing component [11].

A mixture was prepared from the starting materials by mixing powders of iron, graphite of the elementary grade GE-3, and pyrite. The composition of the resulting alloys was chosen corresponding to the grade of the JGr2 (2% graphite, the remaining iron) alloy. The products were pressed on a K0628 press machine with a productivity of 15 samples per minute. Sintering was carried out in stainless steel containers with filling parts with cast-iron shavings at a temperature of 1100 0C for 2 hours [11].

The obtained products and samples were subjected to mechanical tests, metallographic studies, as well as other types of tests by TU23.1.324-83, applicable to products from iron-based powder materials of grades J intended for the manufacture of anti-friction structural purposes. The test results are shown in Fig. 8.

The density of the obtained products was somewhat overestimated, and the oil absorption was somewhat underestimated. Hardness is somewhat higher.

The introduction of pyrite from 0.5 to 1.5% into the charge leads to a certain decrease in density and an increase in oil absorption [9, 11]. This is accompanied by a certain decrease in hardness and strength, however, with a pyrite content of up to 1%, all properties meet the requirements of ТУ 23.1.324-83.

For tribological tests, bushings were made. The resulting bushings had dimensions: outer diameter 32 mm, inner diameter 20 mm, height 10 mm. The bushings were turned over the outer diameter to a diameter of $30^{+0,05}$ mm [11].

Tribotechnical tests were carried out on an MI-1M machine with sliding friction without additional lubrication.

The sleeve was mounted on a lower rotating spindle of a testing machine. The counter body was axle boxes made of steel 45 and heat-treated for hardness HRC 52 - 54. The number of revolutions of the lower spindle of the machine is 500 rpm, which gives a sliding speed with an outer diameter of the sleeve 30 mm - 0.78 m / s (47.1 m / min). The normal axle load was 50 KGF (or 490 N). Since the axle box had a friction area of 2 см^2, the specific pressure was 245 N / sm2. [11].

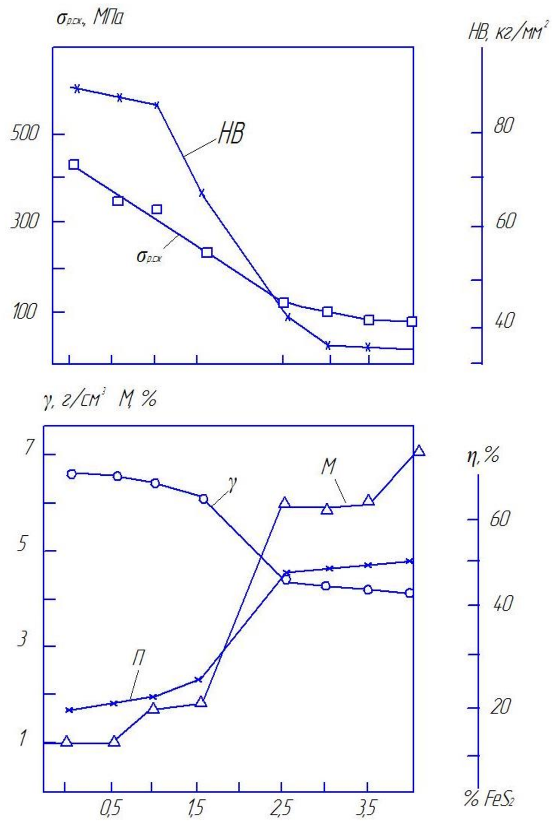

Figure 8. Dependence of HB hardness, radial compression strength $\sigma_{r.c.s.}$, density γ, porosity P, oil absorption M of a porous antifriction alloy based on iron on the content in pyrite charge

The friction coefficient was determined by the moment of friction recorded by the friction machine. The test time was 10,000 rpm of the lower sample.

The amount of wear was determined by the linear method of measuring the diameter of the sample with a micrometer in two mutually perpendicular directions both before and after the test [11].

Table 1. The friction coefficient to the amount of wear of porous cermet bushings during sliding friction tests, depending on the composition of the charge in the preparation of alloys

№	Type of charge	Wear, mm	Coefficient of friction
1	Iron	0.28	0.16-0.23
	powder	0.07	0.36-0.23
	+ 2% graphite	0.03	0.13
	No pyrite	0.15	0.13
2	Iron	0.02	0.06
	powder	0.09	0.13
	+ 2% graphite	0.01	0.13
	+0.5 % pyrite	0.01	0.13
3	Iron	0.015	0.05
	+2% graphite	0.02	0.05
	+1 % pyrite	0.01	0.13
4	Iron	0.015	0.13
	Powder	0.02	0.05
	+2% graphite	0.02	0.05
	+1.5% pyrite	0.01	0.13
5	Iron	0.23	0.1-0.16
	Powder	0.12	0.16
	+2% graphite	0.07	0.13
	+2.5% pyrite	0.04	0.13

The friction coefficient was determined by the moment of friction recorded by the friction machine. The test time was 10,000 rpm of the lower sample.

The amount of wear was determined by the linear method of measuring the diameter of the sample with a micrometer in two mutually perpendicular directions both before and after the test [11].

As can be seen from the presented results, during sliding friction of porous metal-ceramic bushings over steel hardened axle boxes, the wear of the bushings and the friction coefficient are not stable: if the alloy does not contain pyrite or its content is about 0.5% [11]. When the alloy contains 1 - 1.5% pyrite, the amount of wear and friction coefficient takes the minimum values. This fact can be fully attributed to the anti-seize properties of sulfides in alloys with a pyrite additive. Under our conditions, tests in sliding friction without supplying additional lubricant to an alloy without a pyrite additive, the relatively stable operation of the bushings is violated quite quickly. This is due to the exhaustion of the possibility of working in the mode of self-lubrication when the lubricant released from the pores ends. If sulfides are present in the alloy structure, the resistance to scoring increases significantly, and the operating time without scoring increases significantly.

The test results are shown in Table 1.

When the alloy contains 2.5% pyrite, its substantial softening occurs. In this case, the amount of wear increases significantly due to the softening of the alloy.

Based on the data obtained, an alloy with an additive of 1% pyrite was selected and the technical specifications for the antifriction porous iron-based alloy with an additive in the pyrite mixture. For this alloy, a technology was developed to obtain products from cermet alloys in large-scale production.

4. Discussions

According to the first task, when developing the technology for producing layered compositions, it can be noted that the study of the mechanism and features of the formation of compounds of all types made it possible to predict the process and choose technological conditions for creating such compositions.

Analysis of the results of macro-and microstructural studies of the compositions showed that continuity violation in the transition zone was not detected. Microprobe studies of compositions are characterized by high depths of mutual penetration of Cr, Ni, W elements up to 300 μm and deeper. The distribution of microhardness over the cross-section of the compositions showed that the carbide subzone has the highest hardness (1100-1400 HV), then the hardness curve monotonically decreases in the eutectic and hypereutectic sub-bands and reaches a minimum in the crust and carburization regions, 250 ... 350 HV.

Considering and summarizing the results of studies of all types of compositions, one can imagine the mechanism and features of the formation of compounds between the elements of the compositions with the participation of the intermediate layer.

In the process of research, the mechanism was determined and the features of the formation of the connection between the elements of the metal layered compositions were established, according to which, upon contact of the structural steel melt with the surface of the insert - the working, cutting element, crystallization occurs with the formation of a hard crust with subsequent melting of the material of the intermediate layer and the interaction of the formed melt with its limits hard surfaces: on the one hand, tool material, on the other - steel. As a result, a transition zone of the composition is formed, having a complex structure and phase composition, including the interaction products between the melt elements and the main components of the composition. Based on the studies (studying the microstructure, microhardness, distribution of elements in the transition zone, X-ray phase analysis), technologies have been developed for obtaining some metal layered compositions for metalworking and tillage tools. An analysis of the mechanism and features of the formation of compounds of all the obtained types of metal layered compositions allows us to predict the process and choose technological conditions for creating metal layered compositions with desired properties.

According to the second and third tasks, it can be noted that for the main operations of heat treatment of tool steels (including final hardening and tempering), positive results were obtained when implementing some double heat treatment schemes, which can be attributed to combined schemes of heat treatment plants.

Variants of such processing are implemented for carbon steels U8A (0,8% C, 0,17-0,33% Si), U10A (0,96-1,3% C, 0,17-0,33% Si). For tool materials working under conditions of significant loads (low-, medium- and high-alloyed high-carbon steels), multiple hardening schemes, and even more so TCP and its "classical" interpretation (how many cycles) are practically not tested. This is due, in our opinion, to two main reasons. Firstly, with the existing difficulties of using multiple and, especially, cyclic machining for tool steels of the above classes (we are talking about, again, operations like hardening). This is due to the need to use high heating temperatures for quenching by the inevitable formation of a defective surface layer during TTZ with the possible subsequent appearance of cracks within this zone, as well as with the tendency of many of these steels and a naphthalene fracture.

Accordingly, the issues of expediency and the possible field of effective use of multiple heat treatments for high-carbon low-, medium- and high-alloy tool steels remain open to date. In the present work, these issues are systematically studied with the high-carbon low-alloy steel 9XC in the comparative aspect for some other tool steels of grades U10, U12.

As for the coolant, it is necessary to cancel that water and oil are widely used in industry, however, they have some disadvantages and often cannot satisfy the needs of modern production. Water is the cheapest and most affordable quenching medium and provides high physical and mechanical properties of the metal. At the same time, defective parts are mainly observed after quenching in water, as this results in cracks and warpage. Oil, unlike water, has a lower cooling ability in the range of martensitic transformation, which provides a sharp decrease in rejects for quenching defects. However, in the pearlite interval, the cooling rate is in many cases insufficient to obtain the required physical and mechanical properties. Given all this, the class of water-soluble polymers is of great interest, since it is possible to obtain a quenching medium that combines the positive properties of oil and water. The results of a study of the effect of the content of polymer components in the quenching fluid in two temperature ranges show the possibility of their use as quenching fluid (Fig. 6.7).

According to the fourth technological task, it can be noted that iron powder is obtained by reducing the scale of the Bekabad Metallurgical Plant. Scale recovery is carried out in electric furnaces in the atmosphere of dried hydrogen at a temperature of 1000-1100 ° C in boats made of heat-resistant steel.

After recovery, the resulting material (pitch) is ground in ball mills and the powder is sieved through sieves. According to the granulometric composition, the obtained iron powder corresponds to GOST 9849-86, but not completely, because some brands lack a fine fraction.

The chemical composition of locally produced iron powders is also slightly different from the data of GOST 9849-86. This is because the iron scale obtained from the Bekabad Metallurgical Plant may include related elements that are not present in the scale of large iron powder plants.

In particular, in the scale of the Bekabad Metallurgical Plant, elements present in the rolled steel may be present. Non-metallic impurities are completely removed by magnetic separation, but the elements that make up the solid solution with iron remain. In particular, when processing the technology for producing porous antifriction alloys, iron powders with a high silicon content were used (0.97% versus 25%, stipulated by GOST 9849-86). In some batches of iron powders, the sulfide content reached 0.25%.

5. Conclusions

Based on the studies, the following conclusions can be drawn:

1. The possibility of obtaining metal layered compositions of the Mo-TiC system has been established. This composition allows the manufacture of cutting and stamping tools by casting on gasified models.
2. The technology of thermocycling processing (TCP) has been developed during which structures are formed with a maximum of crystal structure defectiveness.
3. As a quenching liquid, instead of oil, it is possible to use the water-soluble preparation "Uniflock" produced in Uzbekistan.
4. Sintered antifriction cermet alloys obtained from local raw materials, both in terms of mechanical and antifriction properties, meet the requirements of technical conditions.
5. The optimal composition of the charge in the production of ceramic-metal alloys of antifriction purpose is: 97% iron powder, 2% elemental or pencil graphite, and 1% pyrite.

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