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DEVELOPMENT OF THEORETICAL AND TECHNOLOGICAL BASIS OF PRODUCTION AND HEAT TREATMENT OF METAL LAYERED COMPOSITIONS

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Abstract. In this work, a mechanism for joining metal layered compositions has been developed, an analytical technique has been improved that describes the emergence of the force of internal stresses during crystallization of metals, an optimal composition of metal layered compositions with high impact strength has been developed, a mechanism for the formation of metal layered compositions has been identified, taking into account the quasi-polycrystallinity of the liquid melt and the diffusion mechanism, modes of heat treatment of metal layered compositions are developed, functional dependences of metal-layered and non-metallic compositions on the thickness of the intermediate layer in the composition are shown.
Keywords: Heat treatment, metal layered compositions, production, quality of tools, performance properties, energy- and material-saving, improvement, development, production, processing, strength, casting, alloy, microstructure, microhardness.
抽象的。 **在**这项工作中，开发了连接金属层状组合物的机制，改进了描述金属结晶过程中内应力出现的分析技术，开发了具有高冲击强度的金属层状组合物的最佳组合 ， **已**经确定了形成金属层状组合物的机制，考虑到液态熔体的准多晶性和扩散机制，开发了金属层状组合物的热处理模式，金属层状和非层状组合物的功能依赖性 **金属成分**对中间层厚度的影响如图所示。
关键词：热处理，金属层状成分，生产，工具质量，性能特性，节能节材，改进，开发，生产，加工，强度，铸造，合金，显微组织，显微硬度。

INTRODUCTION

Research and development work on the creation of metallic layered compositions is carried out

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in more than thirty countries around the world. A tenfold increase in the processing speed on metalworking machines (3500-50,000 rpm), an increase in the effect of internal stresses during the machining of parts and, in general, the improvement of production leads to an increase in the quality requirements of tools - equipment and parts. This, in turn, requires high performance properties from the material of the parts. According to statistics, every year 5-6 billion US dollars are spent in the world for the development of high-quality materials, including for Europe and the CIS countries this figure is 1 - 2 billion US dollars, and in other developed countries 4-5 billion are spent. US dollars. Currently, in the context of intensified production in the production of high-quality products, the development of metallic and non-metallic compositions with high mechanical properties is one of the important production tasks.

During the years of independence of our republic, special attention has been paid to the production of high-quality and competitive machine-building products on the world market. The development of the machine-building industry, its products, which must meet modern requirements to increase the reliability, safety and service life of manufactured machines and mechanisms, apparatus and equipment and their materials - all this has led to the achievement of significant results.

Currently, it is important to increase the economic efficiency of economic sectors to create a new composition of produced materials; effective and economic improvement of technologies for producing products by casting is important for improving the indicators of the national economy. In this aspect, purposeful research work, including research in the following areas, is one of the important tasks: creation of composite materials using special metal layered compositions that ensure product quality; development of technologies for obtaining metal layered compositions; improvement of the theoretical and technological foundations of heat treatment, contributing to the increase in the strength of metal layered compositions; creation and production of energy- and material-saving new metal layered compositions based on the latest advances in science and technology, implying saving scarce tool materials and increasing productivity. The above research areas, as well as the results of scientific research carried out in these areas, serve to substantiate the relevance of the topic of this dissertation.

MATERIALS AND METHODS

REVIEW AND ANALYSIS OF FOREIGN SCIENTIFIC RESEARCH

Scientific research aimed at improving production and heat treatment technology is carried out in many leading research centers and higher educational institutions of the world, including: in “U. S. Smelting Refining and Mining Co "(USA), Toyo Ko ue Hiroshima" (Japan), Reikin Piston of Tokyo (Japan) and Subota Jron and Mashinaru (Japan), Institute of Casting Problems of the Academy of Sciences of Ukraine, Institute of Electric Welding named after EO Paton of the Academy of Sciences of Ukraine together with PA "Azovmash", at the Scientific Research Institute of Hard Alloys (Russia) and at the Tashkent State Technical University (Uzbekistan).

As a result of research carried out in the world to study methods for obtaining metal layered compositions and the use of improved production and heat treatment technology, a number of scientific results have been obtained, including: a technology has been developed for obtaining parts and tools with hard coatings and a high service life (US Smelting Refining and Mining Co, USA, Toyo Ko ue Hiroshima and Reikin Piston of Tokyo, Japan); developed a centrifugal casting method with the use of two-layer rolling rolls for hot and cold strip mills (Subota Jron and Mashinaru, Japan); the technology of pouring metal layered composites has been developed (Institute of Casting Problems, Academy of Sciences of Ukraine); a technology for producing multilayer die castings has been developed (EO Paton Electric Welding Institute of the Academy of Sciences of Ukraine jointly with PO "Azovmash", Ukraine); the compositions of eutectic alloys operating at high temperatures have been developed (Scientific research tel Institute of Hard Alloys, Russia); a technology for obtaining a hard-alloy coating of products from light composites has been developed (Tashkent State Technical University, Uzbekistan).

In the world, research is being carried out on the development of the composition and technology and the improvement of the heat treatment of metal layered compositions in a number of priority areas, including: on the development of a new technology for the production of metal layered compositions; on the creation of theoretical and technological foundations for heat treatment of metals; identification of mechanisms of formation of multicomponent metal systems; development of scientific foundations for obtaining composite materials with specified technological and operational properties.

Scientific research works of scientists from leading countries of the world, such as Kane M. M., Stibel M. K., Kotrin Y. I., Keen W. L. are devoted to obtaining parts with high strength, based on the development of metal layered compositions. They developed two-layer milling rolls by centrifugal casting, but in this method, melting of the first layer is observed under the influence of the second portion of the metal. Goma C. A. and Beiss P. P. have developed, with long service life, a technology for producing hard-coated parts and tools, as well as a technology for the use of metal laminated rolls by centrifugal casting. They determined the mechanism of metal melting - the first layer of castings when receiving bimetallic blanks. Scientists from the Countries of Independent States have created materials for metal layered compositions and the development of a pouring technology for creating a material for metal layered composites (A.A. Nagaytsev, Yu.V. Shevakin, V.N. Piguzova, I.I. Novikov, and others). Chekurov V.V., Galyautdinov M.N., Bekmurzaev N.Kh. and Nurmuradov S.D. developed a technology for producing cast bimetallic compositions and a technology for a new alloy composition for creating wear-resistant coatings of compositions. They have developed technologies for increasing the strength of the metal coating of the new composite material by heat treatment.

Despite the great achievements of numerous scientific results in the field of creating and using metal layered compositions, there are many unsolved problems. In particular, the theoretical and technological foundations for the production and heat treatment of metal layered compositions have not yet been created. This can be observed in the formation of metal layered compositions taking into account the quasi-polycrystalline liquid melt and the diffusion mechanism in the "quasi-polycrystalline melt - solid insert" system.

Analysis of scientific, technical and patent literature shows that the most relevant and promising method for the use of metal layered compositions is the casting method according to gasified models. The application of this method with the use of metal layered compositions will allow to develop the scientific foundations of the production and heat treatment of metal layered compositions and is one of the problems solved in this dissertation work.

At present, various methods have been developed and applied to increase the durability and wear resistance of machine parts at the stage of obtaining castings or their subsequent processing. To obtain a layer of considerable depth and with the required properties, it is advisable to use the method of surface alloying of castings.

The study and analysis of the technology of surface hardening of metal compositions showed that bimetallic and surface-alloyed castings have indisputable advantages over other methods of increasing the wear resistance of castings in terms of the final results. In addition, both methods are technologically simpler and more cost effective. That is why the development of a technology for obtaining multilayer layered compositions by casting in order to increase the wear resistance of the mating surfaces of parts and tools is a very promising direction and is the basis of this work.

Analyzed, from a critical point of view, the state of production of samples that meet the requirements of a targeted high-performance composition and products (parts and tools). It is shown that the lack of scientific foundations for the formation of metal layered compositions and products based on them becomes a barrier to the development of production technology.

For high-temperature pressing of refractory metals, a prefabricated matrix is promising, combining the advantages of an insert made of eutectic alloys of the Mo- (W) -Ti-C system for the zone of the gauge point and the steel lead-in section of a given geometry.

The disadvantages of the alloy include the technology of melting and casting, which is characterized by high labor intensity, complexity and energy consumption, and the process of machining requires the use of a special tool with cutting elements made of superhard materials, which together significantly reduces the efficiency of using this alloy. Therefore, a new sintered Mo-TiC alloy should be developed that eliminates the disadvantages of a molybdenum-based eutectic alloy.

The analysis of studies on the heat treatment of metal layered compositions showed that the existing technological modes used do not take into account the peculiarities of the combination of dissimilar materials, which reduces the efficiency of the results of heat treatment, does not allow to fully reveal the potential capabilities of metal layered compositions. This makes it necessary to determine the main regularities of changes in the structure and properties of metal layered compositions of high-speed steel, hard alloys, sintered molybdenum alloy of the system Mo - TiC - cast structural steel, depending on the thermophysical properties and geometric parameters of the main elements that make up the composition.

The theoretical prerequisites for the need to study the scientific foundations of creating MSCs based on molybdenum alloys, as well as technologies for obtaining targeted products with specified operational properties, determine the relevance of the following tasks:

- study of the formation mechanism of MSCs taking into account the quasi-polycrystalline liquid melt and the diffusion mechanism in the system "quasi-polycrystalline melt - solid insert";
- development of mathematical models of thermophysical processes and the formation of joints and stresses in MSC;
- development of scientific and methodological principles for the formation of special purpose products with specified performance characteristics;
- development of a new technology for the production of tools for various purposes by the method of casting according to gasified models using the specific heat treatment of MSC, as well as surface boriding and borotitanium.

2.SELECTION OF OBJECTS AND RESEARCH METHODS FOR THE FORMATION OF THE STRUCTURE OF METAL LAYERED COMPOSITIONS

Analysis of the existing and prospective assessment of the possibilities of using the proposed technology made it possible to select as objects:

a) for metalworking tools (machine-building direction), the most representative and widely used solid and composite metal-cutting, metalworking and stamping tools: round dies of the M18x2 and M42 type; three-sided disc cutters; perforated dies; matrices for various purposes;

b) for tillage tools (agricultural direction): working bodies for soil cultivation, in which an important indicator is wear resistance and ensuring self-sharpening and the most worn out running gear of excavators;

c) for rock cutting tools (oil-gas and hydro-reclamation directions): drill bits; chisels; cones.

The main goals of creating metal layered compositions are to reduce the consumption of scarce alloy steels, labor costs, and create a high level of compressive stresses in the working element of metal layered compositions both during manufacture and during heat treatment.

Taking into account the chosen method of obtaining metal layered compositions - casting according to gasified models, as well as the fact that casting metal alloys should serve as the carrier base of metal layered compositions, metal materials were taken as the instrumental component.

It is the above group of materials that plays a major role in tool production. It includes tool steels and carbides. The paper gives the chemical composition of the used tool steels, hard alloys, molybdenum, as well as their alloys.

3.THERMOPHYSICAL FEATURES OF CREATION OF METAL LAYERED COMPOSITIONS

Despite the constant developing instrumental technique, up to the present time, the questions concerning: the relationship of the structure and properties of liquid metals and alloys; interaction of liquid metal with solids. Liquid metal is a combination of two structural components: ordered regions (clusters) and disordered zones, which is the essence of the quasi-polycrystalline model of a liquid.

From the standpoint of the quasicrystalline model of a liquid, it can be argued that the crustal zone is formed mainly by clusters, the rest (rapid freezing of liquid metal) solidified due to clusters of the disordered zone.

When the liquid metal interacts with the surface of the insert, on which a coating can be additionally applied or a bandage is fixed, the elements of the coating or bandage pass into liquid steel and are distributed unevenly in it. The crustal zone, due to the lower solubility of elements in it, will be depleted in dissolved elements, most of them are localized in the disordered zone. Investigation of the diffusion mechanism in the MSC transition zone in the presence of liquid steel makes it possible to a certain extent to assess the interdiffusion between the components of the composition. Diffusion is a direct physical process at the interface between the insert and liquid steel.

To calculate the self-diffusion coefficient, it is assumed that the radius of a diffusing atom in a liquid metal is equal to the Goldschmidt metal radius, and that the radius of the first coordination sphere differs little from the doubled metal radius, then

$$D = 0{,}15\frac{kT}{h}\left(\delta z_1\right)^2 , \quad (1)$$

Where D - diffusion coefficient,

k - Boltzmann constant,

h - Planck's constant,

r - radius of the first coordination sphere,

$\delta z_1 = \sqrt{\frac{\overline{\Delta z_1^2}}{z_1}}$ - relative root-mean-square fluctuation of the first coordination number.

The same penetration depths mean the closeness of the velocities of the diffusing elements in the process of their dissolution. Flows of dissolved elements appear in liquid steel, which means a high degree of their interaction with each other and the influence of the melt, i.e. possible formation of new phases. Thus, the necessary conditions for the occurrence of reactive diffusion are realized.

The depth of diffusion of elements into liquid iron was estimated by the formula

$$L = 2\sqrt{D\tau} , \quad (2)$$

Where D - diffusion coefficient, τ - interaction time.

Analysis of the structure of the diffusion mechanism and its decisive role in the mechanism of contact formation in the transition zones suggests that only by varying the concentrations of the introduced elements, the temperature and duration of the process, it is possible to achieve a given phase composition in the transition zone and exclude the appearance of undesirable (brittle) intermetallic phases.

The finished instrument is a combination of different materials, therefore the requirements are not related to a particular material, but to their combination in compositions.

The created stresses, with a certain amount of interaction and sign, play an important role in the creation of MSCs and determine the reliability and performance of the composition as a whole.

When creating metal layered compositions of various options with the formation of a reliable connection between the components of the composition, it is necessary to study the temperature distribution of the liquid melt during cooling, which makes it possible to predict the geometry of future metal layered compositions before its production.

For the formation of a reliable connection in MSC, it is necessary to know the mechanism and kinetics of the processes occurring during the interaction of the melt with an insert - a working element made of instrumental material.

In the most general terms, the crystallization of ingots and castings is reduced to several successive stages: the formation of a zone of small equiaxed "frozen" crystals in the peripheral mold contacting with the walls - a crust, the formation of a zone of columnar crystals and a zone of equiaxed crystals.

The transfer of these general ideas to the heterogeneous melt considered by the candidate for the dissertation - the insert allows you to make some corrections and clarifications. First, when the melt interacts with a cold solid (the contact surface of the insert), a large thermal supercooling is achieved. In this case, a thermal shock is created in the contact layer of the liquid, which acts only at the beginning of crystallization, as a result of which a crust zone is formed - a zone of small misoriented crystals.

Secondly, thermal shock completely determines the structure of the cortical zone, the distribution of impurities dissolved in it.

In the case considered above, it is the crustal zone that determines the conditions for the formation of the transition zone between the components of the metallic layered compositions, providing the required level of operational properties of the metallic layered compositions.

To determine the most probable scheme for the development of the process of forming a bimetallic compound, it is necessary to solve the following tasks:

- the distribution of temperature in the volume of the workpiece at any time moment for a given chemical composition of the components that make up the system, their thermophysical properties, geometric dimensions and specified initial temperature distributions in the workpiece;
- determination of temperature at any given point (or several) of the workpiece at any time points at:
- a given chemical composition of the components that make up the system; - their thermophysical properties, geometric dimensions for a given
initial temperature distribution in the workpiece;
- determination of the rate of cooling (or heating) of the workpiece material at a given point (or at several specified points) at any

moments in time for a given chemical composition of the components that make up the system, their thermophysical properties, geometric dimensions for a given initial temperature distribution in the workpiece;

- determination of the physical state of the material (the value of the thermophysical characteristics of the material, its structural and aggregate state) of the workpiece at any time at a given point (at several given points) for a given chemical composition of the components that make up the system, their thermophysical properties, geometric dimensions for a given initial distribution temperatures in the workpiece.

The tasks listed above belong to the class "Atypical problems of unsteady heat conduction", because it is currently not possible to obtain an analytical solution to these problems. Therefore, to solve them, it seems promising to use the method "Numerical mathematical modeling of physical processes" occurring in the workpiece during its cooling.

The most complete mathematical model of the heat transfer process in a workpiece, consisting of several dissimilar materials with different thermophysical properties, takes into account the presence of uneven space-time fields in the sought quantities - temperatures of the workpiece material, which is in both solid and liquid (molten) state, heat fluxes , radiation intensities, convective flows, etc. Such a model is a system of partial differential equations, integral and integro-differential equations. The implementation of such a model is difficult due to its complex structure and the large number of elements included in it.

A universal method for the approximate solution of differential equations and systems of these equations, applicable for a very wide class of equations of mathematical physics, is the finite difference method (or the method of grids). Moreover, restrictions were introduced when considering the nonstationary one-dimensional heat conduction problem. In solving the problem, the candidate used an implicit finite difference balance.

It should be noted that the newly obtained residue can also exceed the level of energy required to complete the process of phase transformation of a neighboring element. This rule is used until the remainder of the heat becomes zero. Thus, the developed algorithm for calculating temperature distributions in metal layered compositions makes it possible to predict, without conducting experimental studies, the possibility of forming a reliable joint and thereby creating a composition as a whole.

A phenomenology of the process of interaction between a melt and a solid insert is proposed, on the basis of which a method is proposed for creating metal layered compositions by casting according to gasified models.

One of the main tasks of this work was the development of the composition and technology for obtaining a sintered powder composition of the Mo-TiC system. In addition to the main components Mo and TiC, Ni, Fe, W, and LaB_6 were introduced into the composition in order to improve the technological and operational characteristics. Comparative assessment of the alloy was carried out according to two characteristics of bending strength (σy) and Rockwell hardness

(HRA). As is known, these characteristics correlate well with such characteristics as hot hardness and heat resistance, which determine the performance and durability of a stamping tool for hot forming. Therefore, when developing the alloy, σfrom and HRA were taken as evaluation criteria in determining the optimal composition. The optimization of the composition was carried out using the method of mathematical planning of experiments.

As a result, the optimal composition of the powder composition was obtained, which includes: 45-47% TiC; 1.5-2.5% Fe; 1.5-2% Ni; 0.5-1% W; 0.1-0.2% LaB6; Mo is the rest.

An important role in achieving a high level of properties is played by the preparation technology of the composition and the modes of its sintering. The technological process for the manufacture of samples or products by the powder metallurgy method was carried out according to the usual technological schemes for the production of hard alloys.

As a result of research, it was found that the sintered composition of the Mo-TiC system has the following physical and mechanical properties:

linear expansion coefficient, grad^{-1} - 6,61·10^{-6};

density, g/cm^3 - 6,4 – 6,6;

hardness, HRA - 88 - 90;

flexural strength, MPa - 800-1000.

Phase X-ray diffraction analysis has shown that the composition of the alloy corresponding to the optimal one includes the following phases: TiC, Mo_2C, Mo (Ti).

Analysis of the position of the interference maxima and their shape indicate a significant degree of doping of the main phases and the presence of microdistortions of the crystal lattice in them.

The study of the structure of the above alloy showed that the basis is made up of equiaxed grains with insignificant differences in size, the average grain diameter fluctuates within 10-20 microns, which corresponds to 9-10 points (GOST -5639-65).

At the base, finely dispersed inclusions of the second phase are distributed. The distribution is uniform throughout the body of the grain, with occasional sparse clusters along the boundaries. Along the grain boundaries, sometimes precipitations of an excess phase are encountered, indicating the formation of a liquid phase during sintering.

The hot hardness of the sintered composition of the Mo-TiC system was determined on a special high-temperature hardness device - UVT in the temperature range 20-16000C.

The development and implementation of metal layered compositions for various purposes is described. When obtaining the recommended castings, it is necessary to design and manufacture tooling that differs from the known technology.

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

Obtaining a metal layered composition of the type cast structural steel - working insert is possible if the physical and mechanical

characteristics of the materials are comparable. Compositions of this type represent the bond between tool and foundry structural steels. The main advantage of this class of joints is a reduction in the consumption of alloyed tool steels due to their partial replacement with more affordable structural steels, and a decrease in the labor intensity of manufacturing a die and multi-edge cutting tool of a complex profile.
The composition "non-heat-resistant tool steel - casting structural steel" is selected for the manufacture of round dies - dies (Fig. 1).

a) b)

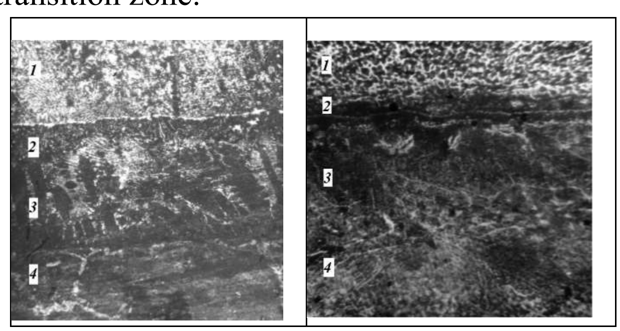
FIGURE 1. Metallic layered compositions "steel 9KhS - cast structural steel 40KhL" - cast round dies.

Analysis of the ratio of the geometric parameters of the working elements and 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.
Microstructural studies on the use of metal layered compositions with a solid working element made of non-heat-resistant tool steel have been carried out. In the process of studying the metal layered composition, steel 9KhS - steel 40KhL were tested for the production of round dies M18x2 and M42. In the compositions, various fluxes (Na2B2O7 and others) were used as an intermediate layer.
As mentioned earlier, for the manufacture of a complex multi-edged tool, compositions of heat-resistant, high-speed steels were used - cast structural steel. The specificity of operation of this class of tools is due, among other things, to high requirements for the body of the tool operating under dynamic and cyclic loads (steel 40HL, 40HGL, 40HGFIL).
The following heat-resistant tool steels were selected: R6M5, 10R6M5-MP, R6M5K5 and others.
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 punching tools (dies for hot pressing of metals) and drilling tools (drill bits, bits and cutters), carbide inserts intended for brazed tools were used. To create the compositions, as the material of the intermediate layer, alloys of the Cu-Ni-Mn, Cu-Ni system with a thickness of 0.2 - 0.6 mm, sprayed by the plasma method, were used.
As indicated above, casting structural steel was used for the tool body, and as its main working part, molybdenum and its alloys (MCH, VM and Mo-TiC), as well as hard alloys of the VK and TK group.
The mechanism of formation, composition, structure, physical and mechanical properties of metal layered compositions of the type "non-heat-resistant steel - structural steel", "heat-resistant steel - structural steel", "hard alloy - structural steel" and "molybdenum and its alloys - structural steel" were studied comprehensively (fig. 2).

The study of metal layered compositions of the "Tool material - structural steel" type confirmed the receipt of solid joints.

The proposed version of the manufacturing technology for MSCs with a low-melting working element was intended mainly for the manufacture of various types of soil-cultivating tools. In this case, powdered hard alloys on a binder are applied in the form of a paste or are placed in the form of pre-made inserts in a specially prepared cavity. The melt temperature at the time of pouring is 1650-17000C. The use of boron-containing compounds for the manufacture of various composite materials with a high level of mechanical, thermal, electrical and other properties is becoming widespread, primarily through the use of boron-containing compounds themselves. It should be noted that boron carbide has a complex of particularly valuable physical and mechanical properties. Alloys of the Fe-Cr-C system were used as "inserts"; namely PG-S27 and PG-S27-TN-20, and 65GL cast structural steel as a load-bearing base. In this case, the "insert" coating is completely melted with preservation of the crust.

The thickness of the coating in the compositions PG-S27 - steel 65GL, PG-S27-TN-20 - steel 65GL ranged from 2.8 to 3.2 mm. No discontinuity was found in the transition zone.



a)	b)

FIGURE. 2. Microstructure of the transition zone of metal layered compositions: "sintered alloy Mo-TiC - PR-N58F - cast structural steel 40KhNML" (a), metal layered composition "sintered alloy Mo-Ti C - Ni - cast structural steel 40KhNML" (b). X150

1- migration zone; 2- the zonebased on transition layer material; 3- crust;

4- carburizing zone.

The results of considering the mechanism and features of the formation of all types of compounds made it possible to predict the course of the process and select the technological conditions for creating such compositions.

The results of macro- and microstructural studies of the compositions showed that no discontinuity was found in the transition zone. Indicators of microprobe studies of compositions are characterized by high depths of mutual penetration of elements Cr, Ni, W up to 300 microns 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 hypoeutectic subzones and reaches a minimum in the crust and carburization areas, 250. 350 HV.

Taking into account and summarizing the results of the studies of all types of compositions, it is possible to imagine the mechanism and features of the formation of a connection between the elements of the compositions with the participation of an intermediate layer.

The mechanism has been determined and the features of the formation of a connection between the elements of metal layered compositions have been determined, according to which, upon contact of a structural steel melt with the surface of an insert - a working, cutting element, crystallization occurs with the formation of a hard crust, followed by melting of the material of the intermediate layer and the interaction of the resulting melt with the bounding solid surfaces: tool material on one side and steel on the other. As a result, a transition zone of the composition is formed, which has a complex structure and phase composition, including the products of interaction between the elements of the melt and the main components of the composition.

Based on the studies carried out (study of microstructure, microhardness, distribution of elements in the transition zone, X-ray phase analysis), technologies have been developed for obtaining a number of metal layered compositions for metal-working and soil-working tools. Analysis of the mechanism and features of the formation of compounds of all types of metal layered compositions obtained makes it possible to predict the course of the process and select technological conditions for creating metal layered compositions with desired properties.

In the manufacture of industrial products, the technological process is developed in such a way as to create compressive residual stresses in the surface layers of the product in areas subject to high loading during operation in order to increase their wear resistance, strength and other characteristics.

However, the most important is the development of optimal modes of heat treatment of metal layered compositions, which make it possible to create a high level of residual compressive stresses in the working element of the tool.

When performing thermal hardening in metal systems, in addition to structural transformations, volumetric changes occur associated with various parameters of the crystal lattices of the structural components involved in the transformations. Volumetric changes cause the appearance of internal stresses.

Comparison of the results of resistance tests of serial monolithic and bimetallic dies (Tables 1 and 2) makes it possible to note the fact that M42 bimetallic dies have higher resistance, and M18x2 dies are lower than those of serial analogs. This is explained, apparently, by the stressed state of the working elements (Table 2): for M42 dies, the working element is in a state of all-round compression, and for M18x2 dies, tensile stresses are recorded in the transverse direction and along the height of the inserts (Tables 1 and 2).

The influence of the scale factor on the durability of metal layered compositions and the stress state of the working elements is due to a change in the ratio between the magnitude of the thermal, structural and total stresses of the working element.

TABLE 1. Test results for durability of dies made of various materials

T yp e of die	V ie w	M od e t he	tenacity, S mm		N ote
			s t e	12 X18	

	Dies	n.*	el 45	H10T	
M42	whole.	standard	4520	2340	S - arithmetic mean of durability at n = 20
	MSC	step.	5016	2855	
M27x2,0	whole.	standard	4400	2460	
	MSC	step.	4874	2899	
M18x2	whole.	standard	5300	2760	
	MSC	step.	5720	3166	

* Standard heat treatment-hardened 860 ° C in oil, 180 ° C.

Step quenching-heating 8600C, cooling in an environment with a temperature of 220-240-300 ° C, then into oil, tempering 180°C.

TABLE 2. Changes in the stresses of a working element made of 9KhS steel in dies made of metal layered compositions with a load-bearing base made of 40KhL steel, depending on the heat treatment modes

Type of die	View Dies	Mode then.*	Voltage in the work. element, MPa		
			along	across	in height
M42	MSC	standard	-584	-406	-284
	MSC	standard	-622	-435	-312
M27x2,0	MSC	standard	-475	-322	-260
	MSC	standard	-541	-376	-302
M18x2	MSC	standard	-309	+478	+215
	MSC	standard	-415	-241	-134

* Standard heat treatment-quenching 860 ° C in oil, refractory.180°C

It is known that the occurrence of thermal stresses is associated with a difference in the cooling rate in different sections of the casting, and structural stresses - with phase transformations.

Table Tables 1 and 2 show the results of tests for resistance with standard and step heat treatment of solid and metal layered round dies. As a result, changes occur in the stressed state of the working element of the metal layered compositions (see Table 2). In the M42 and M27x2.0 dies, the compressive stresses increased by an average of 10-15% in all three directions, and in the M18x2 dies, all-round compression was achieved.

A technology has also been developed for heat treatment of a composition of the type hard alloy - steel, molybdenum and its alloys - steel.

A heat treatment technology has been developed for metal layered compositions 35KhNML - VPr-2 - VK15 steel for heat treatment of a hard-alloy die matrix.

It is known that the magnitude and sign of stresses in the working elements of the matrix largely determine its resistance. In this regard, tensometric studies of internal residual stresses arising in the Mo-TiC insert, depending on the production method, as well as before and after heat treatment, were carried out. In the dissertation, the results of determining the values of internal residual stresses in the working element of the Mo-TiC insert are given in the dissertation. Standard hardening heat treatment, adopted for steel 40ХНМЛ, increases the stress level by 2 times. The creation of internal residual compressive stresses on the working surface of the matrix is the result of the effect, on the one hand, of the difference in the coefficient of thermal expansion of the Mo-TiC alloy and steel, on the other hand, of the process of phase recrystallization, which takes place with the formation of martensite in the steel component of the composition.

The test results showed that with an increase in the casting modulus, the static strength of the joint increases by 20-30%. For specimens that have undergone hardening heat treatment, an increase in the ultimate shear and tear strength of the joint is observed by an average of 8-15%. The determination of the static strength between the components of this group of compositions was carried out on special samples with cylindrical and flat inserts. The test showed that in this case the performance of the compositions increased by 15 - 20%.

The indicators of the statistical strength of the joint in compositions with complete melting of the insert, the PG-S27-steel 65GL alloy and the PG-US25-65GL steel alloy are given in table. 3.

TABLE 3. The static strength of the joint in MSC with full by melting the insert

Composition	Strength, MPa		Note
	on a cut τ_{cp}	to break away $\sigma_{в}$	

Alloy PG-S27 - 65GL	160-240	250-320	Carbide Thickness - 4,0-5,0mm.
Alloy PG-US25-65GL	140-200	230-260	

The test results showed that the value of the critical crack opening for all bimetallic specimens, both in the cast and in the heat-treated state, is 10-20% higher.

As shown by the test results, the resistance of matrices during pressing of molybdenum of the MCh grade made from cast compositions is 10 - 15% higher than when using standard matrices obtained by pressing.

CONCLUSION

Based on the research carried out on the doctoral dissertation on the topic "Development of the theoretical and technological basis for the production and heat treatment of metal layered compositions", the following conclusions are presented:

1. The mechanism of interaction of liquid metal with the surface of the insert in metal layered compositions is revealed. These mechanisms will be useful in the future when creating metal layered compositions.

2. Revealing the diffusion mechanism in metal layered compositions makes it possible to assess the interdiffusion between the components of the composition.

3. The conditions for the formation of a transition zone between the components of metal layered compositions have been developed. These are important in the formation of metal layered compositions.

4. A mathematical model of thermophysical processes of creation of metal layered compositions has been developed. The developed algorithm for calculating the temperature distribution when obtaining metal layered compositions made it possible to create compositions with specified properties without preliminary experiments.

5. The optimal composition of a powder alloy based on

Mo-TiC and physical, mechanical and technological properties of powder alloy based on Mo-TiC, which surpass the well-known casting eutectic alloy of the Mo-TiC system in all respects.

6. The technological foundations for the preparation of working elements from instrumental materials, necessary and sufficient for the formation of a reliable and efficient composition, have been developed. These technological bases play an important role in the preparation of metal layered compositions.

7. Original technologies have been developed for obtaining a number of metal layered compositions for metalworking, tillage and drilling tools.

8. Analysis of the mechanism and features of the formation of compounds of all types of metal layered compositions allows predicting the course of the process and choosing technological conditions for creating metal layered compositions.

9. The mode of heat treatment for metal layered compositions has been developed. These modes will be useful in the future when creating metal layered compositions with high mechanical and technological properties.

10. In terms of performance, reliability and durability, the developed metal layered

compositions are not inferior to serial analogs. This makes it possible to use metal layered compositions for the manufacture of tools and parts.

11. The applied and economic components of the technology for the production of metal layered compositions of special purpose tools have been determined. These factors are necessary in the manufacture of metal layered compositions.

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