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Manufacturing of Forming Tools with the Combination of Strength and Plasticity by Using Powders of Fused Metals Working in Extreme Conditions

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ABSTRACT: The article discusses the results of a study on the manufacture of shaping tools with a combination of strength and ductility using powders of refractory metals working under extreme conditions. The results of a study on the creation of a new alloy of the Mo-TiC-Ni-W-Fe system, produced by powder metallurgy with enhanced performance characteristics, are given, and the development, which is the introduction of new materials obtained by high-tech methods, is of particular importance. materials in a highly dispersed state. It is shown that one of the main tasks of the work was the development of a new composition of a sintered powder alloy of the Mo-TiC-Ni-W-Fe system. In order to improve the technological and operational characteristics of the experimental roller of the introductory box of the rolling mill stand, metal-ceramic material was created for the manufacture of rollers based on it, which increases their wear resistance when operating under extreme conditions, by reducing their density, increasing hardness and bending strength.

KEYWORDS: refractory metal, metal powder, molybdenum powder, mixture, mixture, powder metallurgy, sintering, alloy, hard alloy, metal-ceramic material, shaping tool, roller, strength, hardness, ductility.

I. INTRODUCTION

In the world, industries are facing the task of obtaining carbide tools with special mechanical, technological and physical properties based on powders of refractory metals. In solving a set of problems to improve the performance, reliability and durability of tools, improve the quality of products, it is important to create new materials or improve the physical and mechanical properties of existing ones. This study relates to the field of metallurgy, in particular, to the production of alloys based on refractory metals used for the manufacture of molding tools for high-temperature pressing.

Known alloy based on molybdenum, containing, mass. %: B-0.01-0.03; Ti-0.4-0.5; Ni-3-4; Co-3-4; Fe-0.1-0.3; Mo-rest, which is used to improve the weldability of alloys and can not be used to obtain molding products of high-temperature pressing. There is an alloy based on molybdenum containing titanium carbide and technological additives with tungsten. The composition of the alloy includes, mass. %: Mo-85%, TiC-10.5%, W-1.0%, Zr-0.6%. The disadvantages of the above alloy is the instability of the technological properties of the alloy and the high cost, due to the introduction of a large amount of expensive molybdenum [2,3].

The closest analogue to the technical essence is a metal-ceramic material based on molybdenum, containing titanium carbide and tungsten, and, in addition, nickel, iron and lanthanum hexaboride, in the following ratio of components, mass%: titanium carbide-45-48%, nickel 1.5 -2.5%, tungsten 1.0-1.5%, iron 4.0-5.0%, lanthanum hexaboride-0.15-0.25%, molybdenum-the rest [5,6]. The disadvantage of this cermet material is the presence of rare and expensive lanthanum hexaboride in the composition, as well as its rather high density and low degree of hardness and bending strength of the shaping tools, which reduces the wear resistance and reliability of the tool operating under extreme conditions.

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II. OBJECT AND METHODS OF RESEARCH

The object of the research is powders of refractory metals and compact products based on them, rollers of the opening box of cage № 23 and № 25 of the mill - 300 СПЦ-2 at ACUzmetkombinat, the technological process of producing alloys with operational and important characteristics, the new alloy of the Mo-TiC system -Ni-W-Fe, manufactured by powder metallurgy. The creation of a cermets material for the manufacture of shaping tools, namely the rollers of the introductory box of the mill stand on its basis, which increases their wear resistance when working in extreme conditions, by reducing their density, increasing the hardness and bending strength.

The task is solved by the fact that in the new metal-ceramic material based on molybdenum, containing titanium carbide, tungsten, nickel and iron, the sintered powder alloy of the Mo-TiC-Ni-W-Fe system contains components in the following ratio, wt. %: titanium carbide 39-42%, nickel 11-12%, tungsten 3-4%, iron 3-4%, molybdenum - the rest. Determination of the technological and operational characteristics of the alloy and blanks were carried out by methods of analysis using the existing standard measuring instrument fleet in enterprises.

III. SCIENTIFIC RESULTS OBTAINED AND THEIR ANALYSIS

The essence is that the metal-ceramic material based on molybdenum contains titanium carbide 39-42%, nickel 11-12%, tungsten 3-4%, iron 3-4%, molybdenum the rest. A significant difference and novelty are the modified quantitative ratios of the components, allowing to obtain a new quality of products from the proposed composition of the cermet material, with improved properties. In the proposed composition, unlike the analogue, the amount of titanium carbide was reduced and the amount of binding metals was increased. It was experimentally found that reducing the amount of titanium carbide to 39-42%, while obtaining a cermet material, reduces the sintering temperature of the alloy and the energy costs of the sintering operation, while nickel, titanium and iron, being alloying elements, in the proposed ratio contribute to the preservation of deformability and homogeneity of the structure of the material with a uniform distribution of elements, enhancing also their synergistic interaction with titanium carbide, which is a modifier, which rivodit to improvement of structure. This makes it possible to obtain higher-quality hard alloys from the cermet material according to technological parameters with a density of 5.5-6.1 g / sm3, a hardness of 82-84 HRC and a bending strength of 1080-1150 MPa, exceeding the above-mentioned technological indicators due to the composition of the cermet material, indicators of analogue 1.2-1.3 times, which indicates the achievement of the technical problem posed in the invention, and the presence of a causal link between the invention and the technical problem posed.

The metals that are in the composition of the proposed cermet material based on refractory molybdenum, the new sintered powder alloy of the Mo-TiC-Ni-W-Fe system, during high-temperature sintering, manifest themselves as follows:

Nickel introduced into the composition in the range of 11-12% activates hot sintering and, with the chosen process temperature and a given amount of the component, the surface of the particles is covered with tungsten with nickel and due to the significant solubility of tungsten in nickel, contributing to the increase of plasticity, therefore, the compressibility of the cermet material and the compaction of hard alloys, which leads to improved operational performance Leu, such as durability and reliability of products derived therefrom.

Increasing the content of tungsten in the composition up to 3-4%, contributes to the hardening of the molybdenum base and obtaining a higher hardness compared to the analogue of the alloy. In addition, as a result of processing titanium carbide with iron at a concentration of 3-4%, oxides are reduced on the surface of titanium carbide particles and molybdenum is completely absorbed by titanium and, as a result, material is hardened and plasticity increases, because molybdenum lends itself well to pressure treatment.

The content of titanium carbide, which is a modifier, in an amount of 39-42% in a metal-ceramic composition, when interacting with the rest of the above doping components in an increased amount, allows for optimal physical and chemical interaction of the components at a lower sintering temperature, which ensures the achievement of higher technological parameters in density and hardness and plasticity of the cermet material, due to which the material lends itself well to subsequent processing TKE.

Here is a description of the elements that make up the metal-ceramic material:

- Titanium carbide (TiC) has a fine-grained structure, high stability, refractoriness, low plasticity. Used in metallurgy to modify alloys. Increases wear resistance.

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- Nickel (Ni) metal of silver-white color, malleable, ductile. Resistant to air and water. It is used in the form of powder in the manufacture of solid and superhard materials as a binder. - Tungsten (W) has a color from gray to black, heavy, refractory metal. Chemically active, used in the metallurgical and chemical industries.Is a reducing agent.
- Molybdenum (Mo) is a refractory metal, light gray in color, characterized by high ductility, malleability and low coefficient of expansion at high temperature, T_{melt} = 26250C. It is used in metallurgy in heat-resistant alloys and a reducing agent.
- Iron (Fe) is a shiny, silver-white metal, T_{melt}= 15390C. It is plastic, easily forged, amenable to rolling, drawing. The ability to dissolve carbon and other elements serves as the basis for a variety of alloys that can withstand high and low temperatures, high pressures, etc.

The invention is implemented as follows.

According to a known method, the preparation of a mixture of powders for the production of a cermet material is carried out by separate grinding in different small-sized ball mills of one part of the mixture, which includes a portion of specified amounts of nickel, tungsten, iron and molybdenum and the second part of the mixture, which is titanium carbide.

Next, the compositions are combined, and the final mixing also continues in the mill for another 6-8 hours. After that, the mixture is dried in a distiller at a temperature of 100-1200C for 8-12 hours and mixed with a plasticizer of an 8% rubber solution in gasoline, then dried again for 20-30 minutes at the same temperature. The finished mixture is pressed in molds under a pressure of 100 kgf / mm2 on a П4626 press unit.

After pressing, the products are dried in a steam cabinet for 18-24 at a temperature of 100-1200C hours, then they are subjected to preliminary high-temperature sintering (1000-11000C), in an atmosphere of hydrogen with a holding time of 1 hour. The final sintering mode is selected depending on the purpose of the product. At the end of the process, measurements of indicators of density, hardness, bending strength on standard samples are carried out according to the methods established by the State Standard of the Republic of Uzbekistan for hard alloys, on the following devices:
- density (unit weight), ρ, g / sm3 - by the method of hydrostatic weighing apparatus 33 №. 67761.
- hardness, HRC - on the Vickers-ZIP device model TK-2M, GOST, 13407-67 №. 1793;
- bending strength, σ out - on a tensile testing machine YMM -5.

Example 1.The preparation of a cermet material, a new sintered powder alloy of the Mo-TiC-Ni-W-Fe system in the form of a powder mixture, for the manufacture of the roller of the opening box of stand No. 25, was carried out in small-sized ball mills with the ratio of the volumes of the mixture to the volume of hard alloy balls BK6, with a diameter of 30 mm, equal to 1: 4.

To achieve the above, the weights of the components included in the composition were divided into two groups: the first group included a weighed portion from Ni- 11% (1100 g), W-3% (300 g), Fe-3% (300 g), Mo- 41% (4100 g), and the second - TiC- 42% (4200 g).

A portion of powder from nickel, tungsten, iron and molybdenum in the amount of 5800 g was loaded into a ball mill, in which they conducted preliminary mixing in an environment of ethyl alcohol at a flow rate of 1.2 liters of ethyl alcohol per 1 kg of powder, for 11 hours. A portion of titanium carbide weighing 4200 g was loaded into another mill and also made mixing in an environment of ethyl alcohol. Next, the compositions were combined in one mill and held a joint mixing for another 7 hours.

The resulting mixture was dried in a distiller at a temperature of 110 ° C for 10 hours, then kneaded with a plasticizer - in an 8% solution of rubber in gasoline and again dried in a dryer at a temperature of 110 ° C for 30 minutes. The finished mixture was pressed in the prescribed forms, on a П4626 press unit, under a pressure of 100 kgf / mm^2.

After pressing, the product was dried in a steam cabinet at a temperature of 110 ° C for 20 hours with an exposure of 1 hour, then moldings were subjected to preliminary sintering in an atmosphere of hydrogen at a temperature of 1100 ° C, with an exposure of 1 hour.

Next, the final operation of high-temperature sintering was carried out, which was carried out in the medium – vacuum mode of 10–3 mm Hg. Art. within 2.5 hours, at the same time, the sintering temperature was 1400 ° C at a shutter speed of 1 hour. The mode of final sintering of products is selected depending on the purpose of the manufactured product. After completion of the sintering process, in order to determine the technological parameters of the obtained solid-sintered material, standard samples were taken - beads, subjected to sintering, 5x5x34 mm, on which measurements were made according to the methods established by the State Standard of the Republic of Uzbekistan for solid sintered alloys.

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Example 2.According to the technology of example 1 for comparing the physicomechanical indicators of the invention with the analogue, from the cermet material analogue, composition, wt.%: TiC- 45-48; Ni-1.5-2.5; W-1.0-1.5; Fe 4.0-5.0; LaB_6 - 0,15-0,25 Mo-rest, and at a sintering temperature of 14500C an experiment was carried out using the analog technology with obtaining a hard alloy, from which a sample was also made for testing. A sample of the analogue obtained the following results of measurements of technological parameters: density of 6.5 g / sm3, hardness of 80 HRC, bending strength of 800 MPa (Table 1).

In addition to the products given in the examples, according to a similar technology, other samples were made and tested from a metal-ceramic material, a new sintered powder alloy of the Mo-TiC-Ni-W-Fe system: shaping tool, Form 8- GOST9457-75, form 07, 67- GOST25426-86, forms 110114-110 408- GOST190 65-80, forms 02, 114-100608- GOST19048-8. The results of measurements of technological indicators of these products were within the results of the samples of example 1. The results of the experiments are shown in Table 1.

Table 1.Physico-mechanical properties of samples from a cermet material, a new sintered powder alloy of the Mo-TiC-Ni-W-Fe system, depending on its composition, sintering temperature 1400 ^{o}C

№	Components of alloy, mass. %						Properties		
	TiC	Mo	Ni	W	Fe	LaB_6	Density, ρ ,g/sm^3	Hardness, HRC	Strength, $\sigma_{f.s}$, MPa
Analog									
	46	47,0	1,5	1,0	4,5	0,2	6,5	80	800
Asuggestedcermetmaterial									
1	39	44	11	3	3	-	5, 6	82,0	970
2	41	41	10	4	4	-	5,5	82,5	980
3	40	42	11	3	4	-	5,5	83,5	1000
4	40	41	11	4	4	-	5,5	83,8	1030
5	42	41	11	3	3	-	5,5	84,0	1045
6	42	39	12	4	3	-	5,5	84,0	1050
7	45	38	11	3	3	-	5,6	82,0	980
8	45	35	12	4	4	-	5,6	82,0	970

As can be seen from table 1, the best indicators of the level of hardness, density and bending strength, made samples of parts, the authors obtained using components of a cermet material, a new sintered powder alloy of the system Mo-TiC-Ni-W-Fe in the amount, wt. %: TiC-39-42, Ni-11-12, W-3-4, Fe-3-4, Mo-39-42. The optimal composition of the composition includes: TiC-42%; Ni-12.0%; W-4.0%; Fe-3.0%, Mo-39.0%. When changing the number of components of the cermet material in the direction of decreasing or increasing from the specified amounts, there was no improvement in the physicomechanical parameters. The test results showed that the hardness limit of the test samples was 82-84, HRC; density - 5.5-6.5 (specific weight), g / sm3 and flexural strength $\sigma_{f.s}$-1000-1050 MPa.

As follows from table 1, indicators of density, hardness and bending strength exceed the performance of the analogue by 1.2-1.3 times, which confirms the achievement of the technical task. All the above-mentioned samples from the proposed new sintered powder alloy of the Mo-TiC-Ni-W-Fe system were manufactured as part of economic agreements with AC “УзКТЖМ” and passed pilot tests for density, hardness, bending strength, and at the experimental industrial base of the AC "УзКТЖМ", LLC "TURON ABRAZIVE" and in the conditions of the joint venture "SPZ-BEARINGS", in the period 2015-2016.

As a result of experimental-industrial tests of samples of molding products from the proposed cermet material, it was found that due to the increase in ductility, characterized by increased bending strength and hardness, the wear resistance of tools increased, compared with the analogue by 1.5 times, and due to a decrease in density, decreased the proportion of products, which contributed to a decrease in weight of 1.2 times the mechanisms and improved working conditions, compared with the analog. In addition, by reducing the sintering temperature by 1000 ° C, the energy costs of the sintering process have decreased [8.9].

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IV. CONCLUSION

1. A new alloy of the system Mo-TiC-Ni-W-Fe, produced by powder metallurgy with enhanced performance characteristics, is of particular importance, and the relevance of the development, which is to introduce new materials obtained by high-tech methods, is of particular importance.
2. Replaced in the technological process of processing of large powders on the finely dispersed, allowing to reduce the sintering temperature of the work pieces and making it possible to obtain a more homogeneous and fine-grained structure of the sintered products.
3. The composition and properties of the new sintered alloy of the Mo-TiC-Ni-W-Fe system produced by powder metallurgy were studied and established.
4. The best option for obtaining high-quality powders of refractory metals is to obtain their recovery of hydrogen.
5. Analysis of the data obtained shows that alloys with a ratio of 60:40 carbide and fine fractions have the most favorable combination of plasticity and wear resistance.

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