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SINTERED MATERIAL BASED ON TITANIUM CARBIDE TO INCREASE THE SERVICE LIFE OF SLIDE GATES

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A new cermet material based on titanium carbide with a complex binder consisting of nichrome and nickel, additionally hardened with chromium carbide and a solid solution of chromium in titanium carbide, has been obtained. The influence of the technological parameters of the SHS-extrusion method (the delay time before the application of pressure, the pressing pressure, the speed of the press plunger movement) on the length of the extruded rod is studied, the optimal parameters are found. The microstructure and phase composition of the obtained material was investigated, the physical and mechanical characteristics were measured, and a comparison with analogues was given. It is shown that the microstructure, phase composition, and crystal lattice parameters of the phases do not change depending on the diameter of the extruded rod.

Keywords: SHS extrusion, cermet material, slide gate, titanium carbide.

INTRODUCTION

In modern technology of continuous casting of steel, slide gates are used with the gates made out of plates of refractory and wear-resistant materials [1, 2]. The problem with the operation of such gates lies in their short service life, and their failure is accompanied by losses of the cast steel and stoppage of the technological line for plate replacement. During operation, the plates experience extreme thermal and mechanical stress. The material from which the vane plates are made must be resistant to corrosion by molten steel and slag, sufficiently resistant to abrasion under the action of a metal flow, resistant to thermal cracking and oxidation by free oxygen in the metal or air, which may penetrate the surface of the plates.

To date, production of new composite materials with unique physical and mechanical properties plays a significant role in the development of the machine-building industry [3 – 6]. Traditional hard alloys based on tungsten carbide such as VK6, VK8 and others are widely known [7, 8]. These alloys have high physical and mechanical characteristics and are widely used in industry. The cheaper alloys are tungsten-free and are not inferior to tungsten alloys in their physical and mechanical properties [9].

At this time, a wide range of technological methods are known for obtaining composite materials, such as hot pressing, injection molding, rolling, etc. SHS extrusion is one of the most promising methods [10]. The advantages of this method are due to the fact that the synthesis of the material and the molding of products proceed in tens of seconds, in contrast to traditional powder metallurgy (molding lasts several hours) and in one technological stage, while there is no need for auxiliary technological operations and external heating.

The purpose of this work is to obtain new materials based on titanium carbide with a complex nichrome binder (PKh20N80) by SHS extrusion, to study the effect of technological parameters (delay time before the application of pressure, pressing pressure, speed of movement of the press plunger) on the length of the extruded rod, and to investigate the physical and mechanical properties of the obtained materials.

OBJECTS AND METHODS OF RESEARCH

For SHS-extrusion, initial blanks were prepared from premixed powders of titanium, soot, and nichrome. The initial composition of the charge was as follows, wt%: Ti 56, C

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14, $Cr_{1.12}Ni_{2.88}$ 30. The billet had the following characteristics: diameter 28 mm, height 40 mm, weight 78 g. The temperature and combustion rate of materials based on TiC with different contents of the metal binder (nichrome) were investigated. Based on the results, the optimal composition and relative density (0.62%) were determined at which the maximum combustion temperature is reached.

Long rods up to 300 in length and 3 and 5 mm in diameter were obtained by SHS extrusion [10]. Matrices with a lead angle of 120° and heights of 15 mm (for 3 mm diameter) and 20 mm (for 5 mm diameter) were used.

X-ray phase analysis was performed on an ARL X'TRA x-ray diffractometer. The structure of the obtained rod was analyzed using a Carl Zeiss Ultrapluss ultra-high-resolution field emission scanning electron microscope. The hardness was measured on a TH500-01 hardness tester at a load of 60 N on the *HRA* scale. Ultimate strength at bending was measured on an Instron 1195 according to GOST 20419–75.

RESULTS AND DISCUSSION

One of the important technological parameters of the SHS extrusion method, which significantly affects the ability of a composite material to plastic deformation and, as a consequence, to extrusion, is the delay time t_d, which is counted from the moment of initiation of a chemical reaction until the moment of application of pressure. Based on the experimental dependence of the length of the extruded rod on t_d (Fig. 1*a*), the optimal intervals were established at which the length of the extruded rod is maximum (see Fig. 1*a*, dashed lines). These dependencies are extreme. At small values of t_d, the synthesized material does not have time to consolidate and is squeezed out in chunks, and at large t_d, the material cools down, loses its plastic properties and extrusion stops.

The dependence of the length of the extruded rod on the speed of the press plunger is also extreme (Fig. 1*b*). At low speeds, the material cools down and loses its plastic properties to a greater extent than at high speeds. It should be noted that there is a limiting value for the speed of the press plunger, above which the length of the extruded rod drops sharply. This is more noticeable when extruding rods with a smaller diameter (3 mm) since the cooling rate after extrusion is higher for them than for rods with a larger diameter (5 mm).

Unlike the previous ones, the dependence of the length of the extruded rod on the pressing pressure has a threshold value (Fig. 1*c*). At pressures up to 50 MPa, the dependence is linear: with an increase in the pressing pressure, the length of the extruded rod increases. When the pressing pressure is increased above 50 MPa, it no longer affects the length of the rod. The synthesized material has plastic properties in a certain temperature range; therefore, a relatively low pressure (less than 50 MPa) is sufficient for its deformation.

It was found that, depending on the diameter of the rod obtained, the phase composition and the parameters of the crystal lattices do not change (Table 1, Fig. 2). The material consists of 4 phases: TiC, $Cr_{0.2}Ti_{0.8}C$, $Cr_{1.12}Ni_{2.88}$, Ni. When x-ray diffraction patterns were taken at small angles, the strengthening phase Cr_3C_2 was additionally revealed in a small amount (3 wt.%).

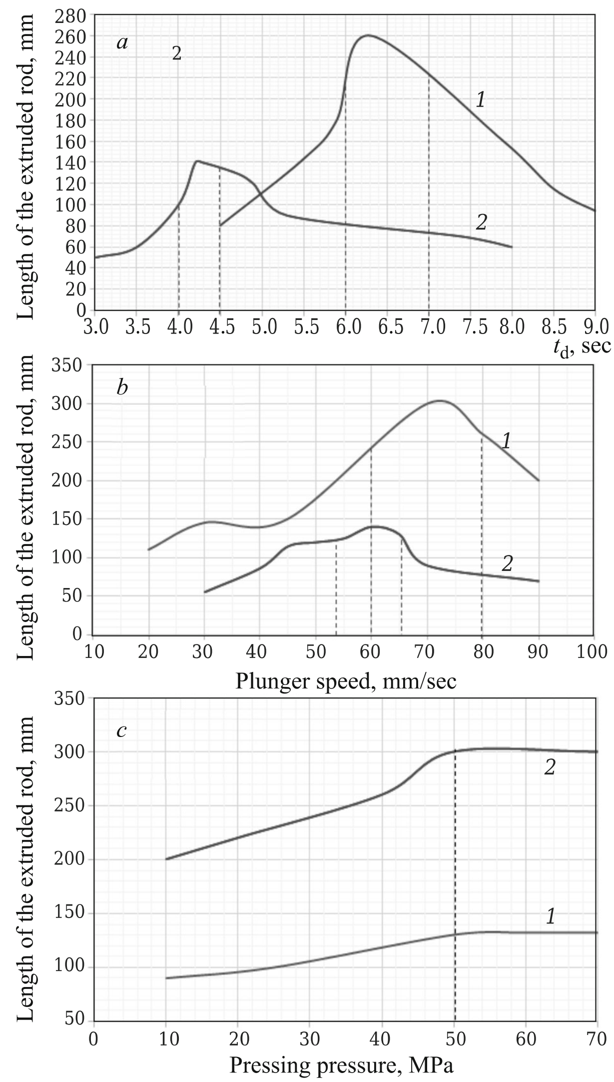

Fig. 1. Dependence of the length of the extruded rod with a diameter of 3 (*1*) and 5 mm (*2*) on t_d (*a*), plunger speed (*b*) and pressing pressure (*c*).

TABLE 1. Crystal Lattice Parameters

Phase	Lattice type	Dimensions, Å
TiC	Cubic	$a = 4.3178$
$Cr_{0.2}Ti_{0.8}C$	Cubic	$a = 4.299$
$Cr_{1.12}Ni_{2.88}$	Cubic	$a = 3.54$
Ni	Cubic	$a = 3.5238$
Cr_3C_2	Rhombic	$a = 5.532$, $b = 2.829$, $c = 11.471$

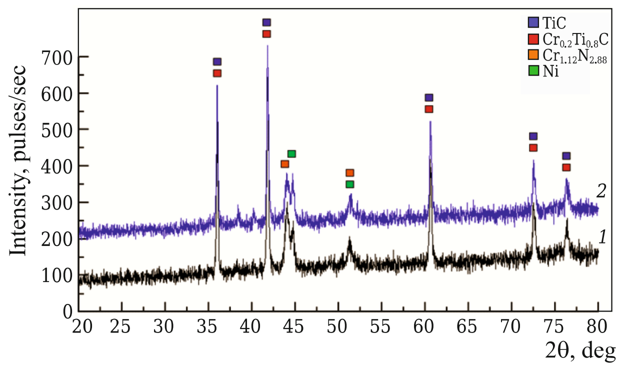

Fig. 2. Results of XRD analysis of the obtained rods with a diameter of 3 (*1*) and 5 mm (*2*).

The microstructure of the obtained materials (Fig. 3) is presented in the form of rounded TiC grains (see Fig. 3, dark areas) located in the matrix ($Cr_{1.12}Ni_{2.88}$) and nickel. The average TiC grain size for rods with a diameter of 3 and 5 mm was 3.8 μm. This similarity in grain size is due to the fact that during the formation of the microstructure, there was a uniform heat removal from zone *Z1* (hottest) to zone *Z3* (coldest). In some places in the bulk of the material, regions with a hardening phase of chromium carbide are observed (see Fig. 3, dark gray areas). The presence of a complex matrix in the material makes it possible to increase the heat resistance, plasticity, and shape stability [11]. A similar composite material is widely used in the operation of parts and assemblies in corrosive environments [12–14].

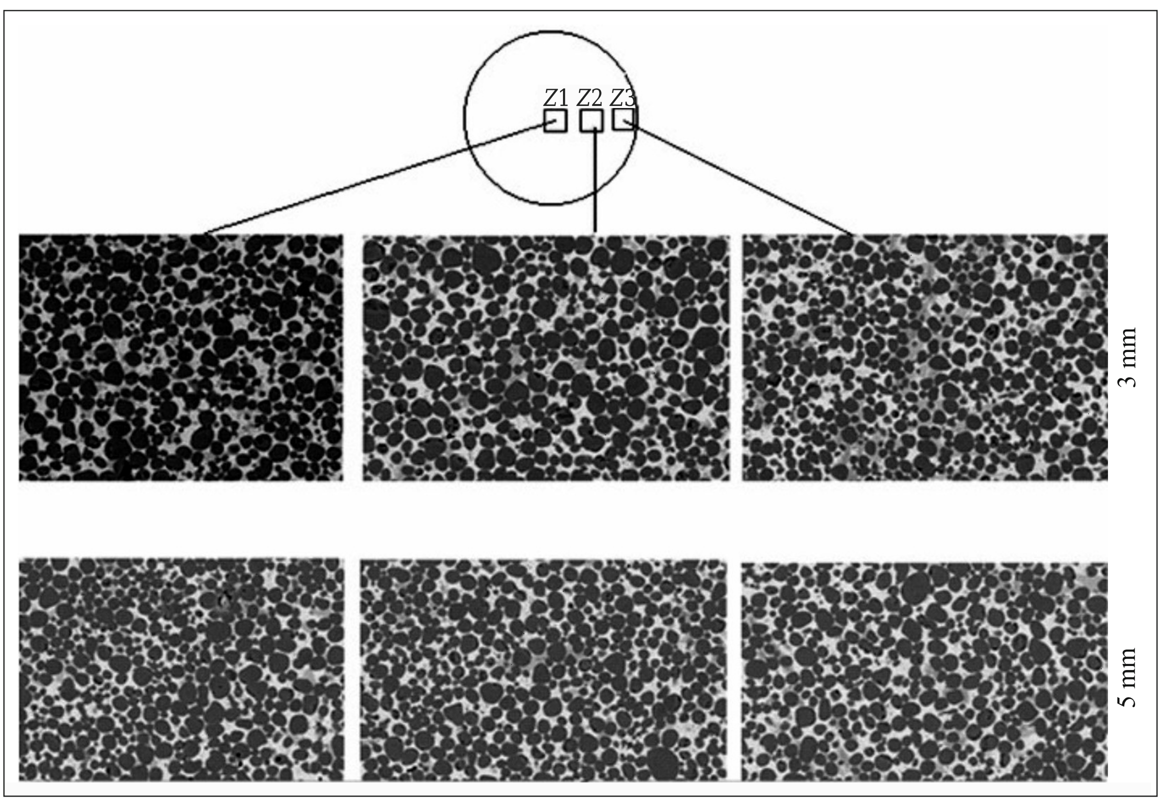

Fig. 3. Microstructure of the obtained rods.

TABLE 2. Physical and Mechanical Characteristics of the Obtained Materials in Comparison with Analogues

Name	Chemical composition, wt.%	Flexural strength, MPa	Hardness *HRA*	Density, kg/m^3
STIM-2/30NKh[M]	$68TiC–20Cr_{1.12}Ni_{2.88}–9Ni–3Cr_3C_2$	1080 – 1800	85.5	5.6 – 5.8
TN20	74TiCN–6.5Mo–19.5Ni	1050	90	5.5 – 6.0
VK3	97WC–3Co	1176	89.5	15.0 – 15.3
VK6	94WC–6Co	1519	88.5	14.6 – 15.0
VK8	92WC–8Co	1670	87.5	14.6
T30K4	30TiC–66Co–4WC	980	92	9.5 – 9.8
T15K6	15Ti–79Co–6WC	1176	90	11.1 – 11.6

The measured values of the physical and mechanical properties of the obtained materials are at the level of values for tungsten and tungsten-free hard alloys (Table 2). The ultimate bending strength of the obtained materials depends on their porosity and ranges from 1080 (porosity 1.5%) to 1800 MPa (porosity less than 0.5%). Considering that the porosity and, as a consequence, the physical and mechanical properties are regulated by the technological parameters of the SHS-extrusion method, by changing them it is possible to obtain a material with a given structure and a set of properties.

The obtained cermet material is suitable for use as electrode material for applying protective coatings to the surface of the slide gate by electric spark alloying and electric arc surfacing. The increased physical and mechanical characteristics of the electrode material will make it possible to multiply the wear resistance of the processed parts during their operation at elevated temperatures and the effects of aggressive media.

CONCLUSION

A new cermet material based on titanium and chromium carbides with a complex binder consisting of nichrome and nickel was obtained by SHS extrusion. The optimal technological parameters of SHS-extrusion (delay time before the application of pressure, pressing pressure, speed of movement of the press plunger) have been established to obtain rods of maximum length. It was found that with a change in the diameter of the extruded rod, the microstructure, phase composition, and crystal lattice parameters of the phases in the material do not change.

The obtained material is promising for use as electrode material for applying protective coatings to the surface of slide gates by electric spark alloying and electric arc surfacing.

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