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FORMING COATINGS FROM SELF-FLUXING POWDER BASED ON STEELS OF AUSTENITE CLASS CADDING CERAMICS

To obtain wear-resistant coatings with high heat resistance and resistance to aggressive media, with high hardness and adhesive strength at elevated temperatures, resistance to shock loads, low residual stresses and uniformity of structure, it is necessary to introduce chromium and tungsten carbides with cladding the protective materials of the starting carbides susceptible to high oxidation during thermal spraying to maintain chemical composition. As a result, wear-resistant coatings are formed which are effective during molecular-mechanical and abrasive wear under adverse friction conditions (boundary lubrication or lack of lubricant, increased temperature effects) due to the effect of reducing surface friction of coatings, which allows reducing the wear rate by microcontact setting, the process which is most common in tribological conjugations
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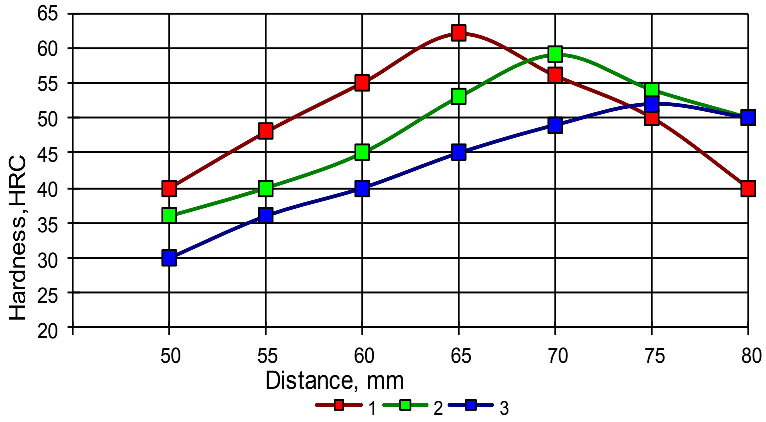
Introduction. Tungsten carbide with a hexagonal crystal lattice has a very narrow region of homogeneity, the crystal lattice is unstable when carbon atoms are removed from it, which occurs during thermal spraying, it is highly oxidizable due to the formation of a fusible volatile oxide film on the surface. also, that with increasing arc power and sputtering distance, the oxidation of carbon in the sprayed particles substantially increases. Some reduction in carbon loss was achieved with the use of protective devices on the plasmatron. The reduction in carbon loss during sputtering in an open atmosphere was mainly ensured by applying nickel plating to the particles. At the same time, the introduction of ductile metal into the coating was achieved [1-6]. The application of nickel plating to tungsten carbide particles by chemical and electrochemical methods with a thickness of up to 5 μm did not provide effective protection of the carbide from carbon oxidation. Experiments have shown the creep of a shell from a particle during its heating and transfer. The optimum thickness is 15-20 mm. The microhardness of the phases is in a wide range: from (3-4) × 103 MPa to (40-50) × 103 MPa. Moreover, the hardness is HV 1000-1450 MPa, porosity 3-7% (vol.). The maximum hardness of the coating is achieved at 30-40% (but the mass) of nickel in clad carbide. In this case, the maximum values of productivity and instrumentation are achieved. [7-9].

Chromium carbide with a rhombic crystal lattice has a wide area of homogeneity; during oxidation, a protective film is formed on the surface from strong oxides that impede oxidation in depth. It is distinguished by the highest heat resistance, resistance to aggressive environments, high hardness at elevated temperatures. The oxidation process of a chromium carbide particle stops when a Cr_2O_3 oxide is created on its surface of sufficient thickness and continuity. As practice has shown, carbon losses during thermal spraying of chromium carbide are small and amount to 0.1-0.3% (by weight). During the thermal spraying of chromium carbides, a plastic component – bond – is also introduced into the coating composition. The most fully investigated the introduction of ligaments due to cladding of powder particles of Nickel. Mass fraction of nickel in the coating is 25-30%. A decrease in carbon oxidation due to the shielding effect of the cladding shell was experimentally confirmed. An active interaction of molten carbide with nickel is observed. It is known that nickel is practically insoluble in Cr_3C_2. In the process of sputtering, Cr_3C_2 turns into Cr_7C_3. The latter is saturated with nickel, forming double carbide $(CrNi)_7C_3$. [3-6]. And so on the basis of the foregoing, we can conclude the addition of tungsten carbide, a self-fluxing powder based on austenitic steels and nickel aluminum to chromium carbide, which has high heat resistance, resistance to aggressive media, high hardness at elevated temperatures, and carbide protection from oxidation during deposition, by creating a nickel protective film, it will significantly improve the properties of the resulting wear-resistant coating.

Formation of a coating from a mixture of clad tungsten and chromium carbides, a self-fluxing powder based on austenitic steel and nickel-aluminum. Coatings from a mixture of clad tungsten and chromium carbides, self-fluxing powder based on austenitic steel and nickel-aluminum were applied using a UPU-3D plasma system. The characteristics of the initial powders are given in table 1. The parameters of the plasma spraying are current 400 A, the spraying distance is 100 mm, the plasma flow rate of nitrogen gas is 55 l / min, the fraction is 50-100 microns, powder consumption 4.5 kg / h, thickness 350 microns. Reflowing was carried out in the same installation under the following conditions: current-450 A, reflow distance - 65-80 mm, plasma-forming nitrogen gas flow for - 65 l / min, travel speed 108 mm / min, number of passes-3. [10-12]. The percentage of powders in the mixture was selected on the basis of experiments (table 2). The influence of the deposition distance on the operational characteristics of plasma wear-resistant coatings obtained at optimal spraying and surfacing conditions is shown in Fig. 1 (a-c). Porosity studies were performed on an Epiguant automated structural analyzer. The hardness of the coatings was measured by the Rockwell method on a TK2M instrument on a "C" scale in accordance with the requirements of GOST 20017-74. Tests for friction and wear were carried out on a special stand according to the scheme: blocks coated with nitrided steel (St45). Tribotechnical tests were carried out in the absence of a lubricant at a load in the friction pair of 5 MPa for 10 hours, simulating the operating conditions of the wearing parts of internal combustion engines. Test conditions (gas 1% SO_2-76% O_2-N_2; Na_2SO_4-3.6% salt PbSo4-5mg cm -2, T = 850C°) corresponded to the most unfavorable operating parameters of engines of autotractor equipment in dry friction conditions. The data of the friction and wear parameters of the coatings from the powders obtained by the prototype and the claimed invention are given in table 3. Analyzing the test results shown in table 3, we select the following percentage in the powder mixture - tungsten carbide powder plated with nickel (15 wt.%), Chromium carbide powder plated with nickel (20 wt.%), Self-fluxing powder based on austenitic steels class ПР – Х18Н9; ПР – Х18Н10; ПР – Х18Н15 (35 wt.%), Nickel-aluminum powder (30 wt.%). At this percentage, the characteristics of the obtained wear-resistant coatings correspond or exceed the analogue.

Table 1. Hardness, density and particle size distribution of powders

Powder grade	Hardness, HRC	Bulk density, g / cm^3	Granulometric composition, microns
Tungsten carbide	60-65	15,77	10-50
Chromium carbide	52-59	6,70	10-50
ПР–Х18Н15	32–38	3,48	45-100
Nickel-aluminum	26–30	2,79	10-50



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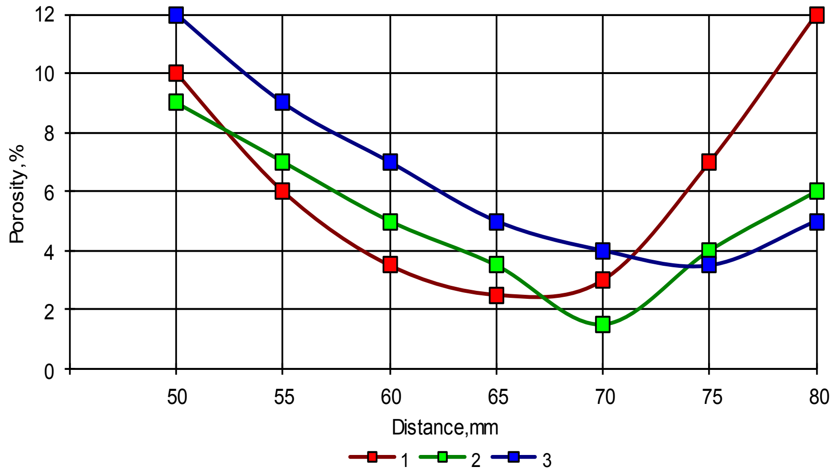

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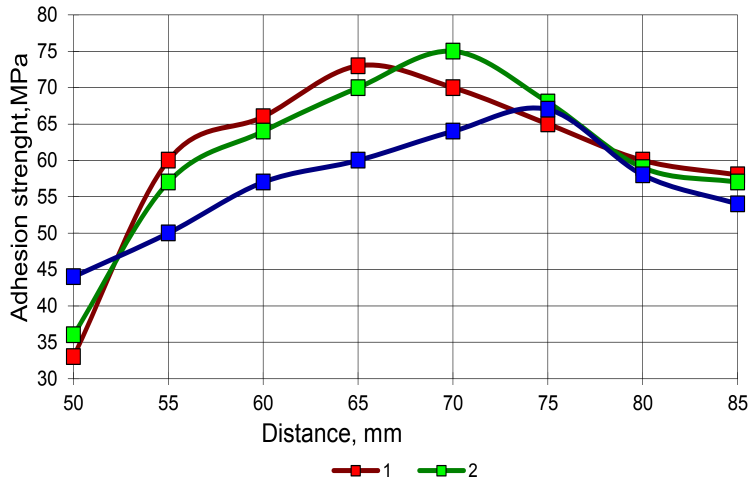

c

Figure 1 - Dependence of hardness (HRC) (a), porosity (%) (b) and adhesion strength (MPa) (c) on deposition distance L, mm for powders ПР – X18H15 - (WC-Ni) - (Cr_2C_3-Ni) - NiAl (1-30 ПР – X18H15 - 15 WC-30NiAl -25Cr_2C_3; 2-35 ПР– X18H15 - 15 WC-30NiAl-20Cr_2C_3; 3 -45 ПР – X18H15 - 15 WC-30NiAl-10Cr_2C_3; fraction 40 .. .63 µm, I = 450 A, RN = 65 l / min, travel speed 108 mm / min, number of passes-3)

Table 2. Results of a study to optimize nickel cladding

Powder composition	The thickness of the shells of Ni on the powder particles, microns (τ-cladding time in hours)					
	τ = 3	τ = 5	τ = 7	τ = 8	τ = 10	τ = 12
35 ПР–Х18Н15 - 15 WC-30NiAl-20Cr_2C_3	1,7	2,5	3,5	4,3	5,3	6,4
Note - The table provides averaged data on the thickness of nickel shells.						

Table 3. Test results of powder compositions for thermal spraying

The composition of the mixture, mass% %	Hardness HRC	Porosity, %	Adhesion, MPa	Dry friction according to St 45 (gas test conditions 1% SO_2-76% O_2-N_2; Na_2SO_4-3.6% salt $PbSo_4$-5 mg cm^{-2}, T = 850C°)	
				Wear couting, μ m	Load badass, kg
40 ПР–Х18Н15 - 30 WC-30NiAl(прототип)	53-58	2,5	64-66	6,9	8,6
45 ПР–Х18Н15 – 15(WC-Ni)-30NiAl -10(Cr_2C_3 -Ni)	50-52	3,0	67-72	6,4	10,0
40 ПР–Х18Н15 – 15(WC-Ni)-30NiAl -15(Cr_2C_3 -Ni)	54-59	2,0	69-74	5,0	10,2
35 ПР–Х18Н15 – 15(WC-Ni)-30NiAl -20(Cr_2C_3 -Ni)	56-60	2,5	69-76	4,9	10,7
30 ПР–Х18Н15 – 15(WC-Ni)-30NiAl -25(Cr_2C_3 -Ni)	57-62	3,5	63-67	5,9	9,5

The deposition of a thin-film shell of metal on WC and Cr_2C_3 powder particles was a chemical nickel plating. When performing the main operation, a solution of the following composition was used: nickel chloride - 28 g / l; sodium hypo-phosphite - 30 g / l; sodium citrate - 10 g / l; acetic acid - 10 ml / l. The temperature of the solution was maintained in the range 363–368 K, and the pH was 9.0–9.5. To obtain a uniform coating of particles, the solution with the powder in the bath was forcedly mixed. The duration of the nickel plating process (τ) was optimized for the formation of Ni shells 15–17 μm thick on particles. The results of the study on optimizing the duration of the process are presented in table 2. As can be seen from table 2, the optimal nickel duration is 10-12 hours. During this time, a thin-film shell of Ni with a thickness of ~ 15-17 μm is formed on the particles, which is necessary and sufficient according to the accepted criterion for optimizing the cladding of powders for plasma spraying of coatings. The mass content of Ni - P in the form of a cladding shell is about 32 - 39%.

Conclusions. As can be seen from the conducted studies, coatings obtained from powders 45 ПР – Х18Н15–15 (WC-Ni) -30NiAl-10 (Cr_2C_3-Ni) made according to the proposed method [14] have 1.4 times higher wear resistance with dry friction on steel than the coating obtained from the powder, ПР – Х18Н15 - WC-, made according to the analogue [13], the porosity is 1.25 times lower, the adhesion strength is 1.2 times higher. Thus, the proposed method allows to increase the wear resistance of coatings in adverse friction conditions (boundary lubrication or lack of lubricant, increased temperature effects) and improve the technological characteristics of the coating.

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