



INVESTIGATION OF WEAR RESISTANCE OF COMPOSITE ALLOYS UNDER THE CONDITIONS OF GAS-ABRASIVE WEAR AT ELEVATED TEMPERATURES

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Given are the results of laboratory investigations of wear resistance of composite alloys, based on fused tungsten carbides WC + W₂C (relite), under conditions of gas-abrasive wear. Given is the technical characteristic of laboratory stand OB-876Ts for tests of deposited metal for gas-abrasive wear. The scheme of tests was developed, maximum corresponding to real conditions of service of parts during the effect of abrasive flow within the temperature range of 25–450 °C. It was established that wear of composite alloys bears a selective, cyclic character and does not essentially depend on properties and hardness of matrix at small attack angles. The application of tungsten carbide with spherical granules increases wear resistance of composite alloy, and the increase in temperature up to 400 °C considerably decreases it due to oxidation of carbide component of alloys. At room temperature the wear resistance of composite alloy 2.7 times exceeds the wear resistance of nickel carbide chromium alloy. 9 Ref., 3 Tables, 3 Figures.

Keywords: *gas-abrasive wear, composite alloys, fused tungsten carbide, spherical granules, matrix, microhardness, plasma-powder surfacing, relative wear resistance, test stand*

The present work is the continuation of the earlier investigations, performed at the E.O. Paton Electric Welding Institute, on gas-abrasive wear of different types of hardfacing alloys [1–4], among which the composite alloys on the base of fused tungsten carbides WC + W₂C (relite) are of a peculiar interest. These alloys are featured by a unique wear resistance and widely applied for deposition of drilling tool and a number of critical parts in metallurgy and machine building. In work [2] the investigations of wear resistance of such alloys under the conditions of gas-abrasive wear were conducted in machine OB-876 [5] at the temperature of 400 °C on cylindrical specimens of 60 mm diameter with different compositions of matrix alloys, reinforced with fused tungsten carbides by granulation from 0.18 to 2 mm. The specimens were manufactured using laboratory method in induction furnace by pouring the granules of crushed tungsten carbide through the layer of flux with the next cutting out of the most reinforced areas by the anode-mechanical method. The composite alloys produced on the specimens in such a way are considerably different from real ones deposited using the arc or gas method. Therefore, there was an interest to investigate the wear resistance of com-

posite alloys produced using industrial conventional methods of hardfacing, among which the most characteristic method for producing of such alloys is the method of plasma-powder surfacing, which found over the recent years the wide development in the world practice. This method restricts the heat effect of the arc on the granules of carbides during their supply to weld pool that considerably decreases their dissolution in the matrix alloy. The concentration of reinforcing phase in the deposited layer can reach 50 %.

For the tests the specimens were prepared deposited using plasma-powder method by composite alloys in one layer. As the reinforcing phase the powders of fused tungsten carbides WC + W₂C (relite) with traditional crushed and also spherical granules were used. The spherical granules, produced according to the technology of thermal centrifugal spraying of ingots of fused tungsten carbides [6, 7] developed at the E.O. Paton Electric Welding Institute, are featured by high microhardness, homogeneous structure and as to the physical and chemical properties they are superior to the similar domestic and foreign materials produced according to other technologies [8, 9].

The granulation of powder of crushed and spherical tungsten carbides was within the limits of 50–250 μm. The averaged chemical composition and microhardness of both types of carbides are given in Table 1.



Table 1. Chemical composition and hardness of tungsten carbides with spherical and crushed particles (tungsten – base)

Type of granules of tungsten carbide	Chemical composition, wt.%				Microhardness HV100
	C _{total}	C _w	Fe	Impurities	
Spherical	3.98	0.05	0.10	0.95	2600–3100
Crushed	3.89	0.15	0.14	1.45	1900–2200

Table 2. Chemical composition and hardness of alloy of matrices (nickel – base)

Type of powder of matrix alloy	Chemical composition, wt.%					Hardness HRC
	C	Cr	Si	B	Cu	
PG-SP2	0.53	13.82	2.43	2.25	–	58.63
PG-ND42SR	0.15	–	1.05	1	42.5	38.46

For the matrix alloy the powders on nickel base PG-SR2 and nickel-copper base PR-ND42SR were used, the averaged chemical composition of which is given in Table 2.

After deposition the thickness of composite layer on the specimens was 5.0–5.5 mm. Here it should be noted that due to a great mass the reinforcing granules of tungsten carbide, as a rule, are located in the lower part of weld pool. Therefore, to obtain the optimal concentration of reinforcing phase on the surface of deposited layer, the specimens were subjected to grinding aflush for the depth of 1.0–1.5 mm. Finally the thickness of deposited layer amounted to about 4 mm, and concentration of carbide inclusions to the tested surfaces of specimens varied in the limits of 45–50 %.

As the reference, the specimens were accepted deposited by nickel carbide chromium alloy using flux-cored strip PL AN-111 in three layers with the thickness of deposition of 12 mm after grinding. The type of deposited metal is 500Kh40N40S2GRTs. The chemical composition of reference specimens is as follows, wt. %: 5.1 C; 34 Cr; 36 Ni; 2.1 Si; 1.2 Mn; 0.3 B; 0.3 Zr, the hardness of specimens was HRC 52–55.

Table 3. Types of specimens for tests on gas abrasive wear

Marking of specimens	Composition of matrix	Hardness of matrix HRC	Type of reinforcing phase	Hardness of reinforcing phase HV100
KN-1	Ni–Cr–Si–B	58–63	50 % crushed 50 % spherical	1800–2200 2800–2930
KN-2	Ni–Cr–Si–B	58–64	100 % spherical	2650–2880
KN-3	Ni–Cr–Si–B	54–59	Same	2730–3000
KM-4	Ni–Cu–Si–B	38–46	»	2750–3050
KM-5	Ni–Cu–Si–B	39–49	»	2800–2980
Reference specimen	C–Cr–Ni–Si–Mn	55–62	–	–



Figure 1. General view of stand OB-876Ts

In all the cases the deposition was performed on the plates of steel of St3 grade 20 mm thick.

In Table 3 the types of specimens of deposited composite alloys for gas-abrasive wear tests at 25 and 400 °C are given. Each type of alloy for obtaining the maximum reliable data is represented by three specimens.

The tests on wear resistance of composite alloys, deposited using plasma-powder method, were carried out under the conditions of modeling the gas-abrasive wear on modified stand OB-876Ts. The stand allows performing wear of specimens using air-abrasive flow according to the certain scheme.

The acceleration of abrasive parts is performed by centrifugal accelerator in the form of a discrotor, in the centre of which the abrasive in the form of quartz sand of 0.05–0.50 mm granulation is gravity fed to the receiving hole.

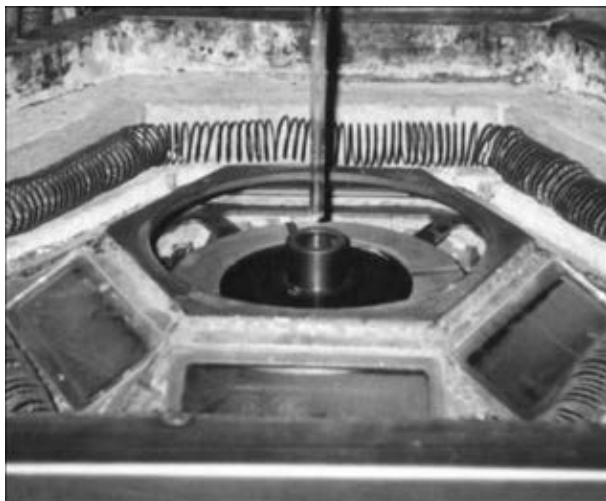


Figure 2. Cassette with specimens in heating chamber

The particles of sand are accelerated along four inner channels up to 200 m/s. Having achieved the outer diameter of rotor, the abrasive flow overcomes the air gap of 25 mm length and by the impacts of abrasive particles is wearing out the working surfaces of simultaneously six specimens of 170 × 70 × 19 mm. Here the angle of attack of abrasive with respect to the surface of specimens amounts to 15°. The cassette with specimens is located in the chamber, the temperature in which can be controlled in the limits of 25–450 °C. The general view of stand OB-876Ts and cassette with specimens are shown in Figures 1 and 2, and its main technical characteristics are represented below.

Technical characteristics of stand OB-876Ts

Rotor diameter, mm	220
Number of rotations of rotor, rpm	6000
Angle of attack of abrasive flow, deg	5–70
Temperature of heating of specimens, °C	up to 400
Duration of heating of specimens up to 400 °C, h	3.5
Consumption of abrasive, cm ³ /s	0.5–0.3
Capacity of electric motor of rotor drive, kW	0.75
Number of test specimens, pcs	6

The wear of specimens was evaluated according to the decrease in volume in cm³, which was determined by the method of hydrostatic weighing. Also the intensity of wear in cm³ during consumption of each 100 kg of abrasive and relative wear resistance as to the reference, deposited by nickel carbide chromium alloy, were determined. The averaged data of investigations of three specimens of each type of composite alloy are given in Figure 3.

As it was expected, the general regularity of wear of composite alloys in gas-abrasive wear is its selectivity and cycling, i.e. change of wear resistance with time. Initially the matrix is worn out intensively, stripping the carbides, which protect matrix and sufficiently delay the wear of

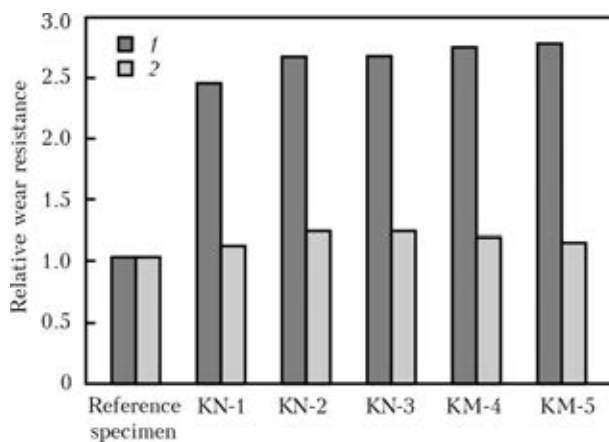


Figure 3. Relative wear resistance of specimens of composite alloys at 25 (1) and 400 (2) °C

alloy due to the shadow effect. After wear of matrix and washing out of carbides the cycle is repeated. The obtained results correlate well with the data of investigations described in [2].

At the angle of attack of abrasive of 15° the composition of matrix and its hardness practically does not influence the wear resistance of the composite alloy.

Under the conditions of room temperature the highest wear resistance belongs to composite alloys KN-2, KN-3 composed of spherical granules of tungsten carbide and matrices of the Ni–Cr–Si–B type. Their wear resistance approximately 2.7 times exceeds the wear resistance of reference specimen of nickel carbide chromium alloy. Alloy KN-1 with the similar matrix, but containing the mixture of spherical and crushed granules of tungsten carbides, possesses wear resistance of approximately lower by 10–12 %, that corresponds to the lower strength characteristics of crushed particles as compared to the spherical ones.

At 400 °C the wear resistance of composite alloys decreased considerably, though the tendency of increased resistance of compositions with spherical granules of carbides, as compared to the mixture, preserved. The increase in wear at elevated temperatures is, first of all, connected with oxidizing processes of the carbide component of alloys. The wear of tungsten carbides occurs not only due to the effect of abrasive flow, but also due to their oxidation. This factor should be considered during hardening of parts using composite alloys based on tungsten carbides operating at high temperatures in the oxidizing environment. In the restoration or inert environments the temperature almost does not influence the wear resistance of composite alloys. At the practice this is observed during operation of charging equipment of blast furnaces after hardfacing by composite alloys based on relite, which are operated in the restoration gas environment.



This equipment is labor-intensive in manufacture, however its resistance several times exceeds the equipment after hardfacing by carbide-chromium alloys.

Conclusions

1. The wear of composite alloys on the basis of fused tungsten carbides under the conditions of effect of gas abrasive flow bears selective, cyclic nature and negligibly depends on properties and hardness of matrix at the angle of attack of 15°.

2. Even partial use of spherical granules of tungsten carbide as the reinforcing phase instead of crushed increases the wear resistance of composite alloy by 10–12 %.

3. Wear resistance of composite alloys under the conditions of gas-abrasive wear at the room temperature approximately 2.7 times exceeds the wear resistance of nickel carbide chromium alloy, and at the temperature of 400 °C it decreases considerably due to oxidation of carbide component of the alloy.

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