

GRADIENT COMPOSITE COATINGS FOR WORKING SURFACES OF BRAKING DEVICES

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ABSTRACT

In this paper a study to develop a composite wear-resistant coatings for application to the working surface of linings of brake devices, which is based on a rule of a positive gradient of mechanical properties was carried out. These devices and so coatings work in conditions of rapid rise of temperature. Thermal properties of matrix and inclusions should not differ a lot. Otherwise this will cause internal cracking and deterioration of coating. With this purpose we did the analyses of thermal properties of matrix and carbide particles of coating and concluded that a material with balanced composition based on thermal properties will have the best wear resistance. It was created and tested eutectic composites based on alloy steel 12X18H9T based on thermal characteristics of all components. Wear tests indicated the best wear resistance of coating with composition: steel 12X18H9T (matrix) – 75%; fillers TiB₂ – 10%, VC – 15%.

Keywords: coating, eutectic, plasma, composite, friction, surface.

INTRODUCTION

Friction materials used in dynamic friction devices, which include brake pads, special support slipping, clutches, variators. These devices are designed to break up (clutch) and stop (brakes, sliding slip resistance) transport machines and drives for process equipment (different friction clutches and regulators) and the transmission and to change the direction of motion.

To achieve high and stable friction coefficient the intermediate layer should have specific heterogeneous structure and properties would provide a large coefficient of internal friction at high temperatures and prevent damage to the friction surface of the material.

However, there are theoretical and experimental study of the effect of temperature and temperature gradients on the friction and wear of

friction pairs for various purposes [3, 6, 8]. In addition to direct effects of temperature on the wear, friction factor, theoretically and experimentally, it was found that the coefficient of friction increases with increasing temperature gradient and a decrease in overall temperature in friction. Also other authors have researched in similar field [1, 2, 11, 14].

In this regard, there is scientific and applied interest in creating composite friction materials and coatings that would allow strong thermal control. Eutectic composite alloy as the matrix use a 12X18H9T austenitic steel. As the reinforcing phase are the most heat-resistant and wear-resistant carbides and borides were used.

The objects of the study were composites based on alloys steel 12X18H9T, which include borides of titanium and chromium (HTN), borides of titanium and vanadium carbide (VTN).

The chemical and phase composition of the alloys are given in Table 1, thermal properties in the Table 2 [4].

STRUCTURE AND PROPERTIES OF PLASMA COATINGS

For coating powders of eutectic alloy of two systems: VTN and HTN [2] were used. In sputtered eutectic coatings ‘white’ areas were observed, white layers, partially melted or unmelted powder and a small amount of pores (Fig. 1).



Fig. 1. Microstructure of plasma coating VTN; x500

EXPERIMENTAL PROCEDURE

Tests on the friction and wear were performed on a friction machine M22-M, which allows in the process the experiment to automatically record basic characteristics of friction and wear (linear wear of friction pair) without notables model of it. As counter body the rollers of diameter 40mm, made of cast iron MF-15-32 were used. At a distance of 0.5 mm from the surface of friction of the sample introduced chromyl-koppel thermocouple, which allows to control temperature change in the friction zone and to fox the stabilization of friction and wear. Test specimens with coatings was carried out in terms of friction without lubrication by the scheme ‘shaft-plane’ and the load was $P = 20; 40; 60; 150$ N, sliding speed $V = 0.1-2.0$ m/s. Friction distance $L = 1$ km [11].

The chemical composition and structure of the components of the surface layer formed as a result of tribological interactions were determined by X-ray analysis with the use of REMMA-106N microscope-microanalyzer [5].

RESULTS AND DISCUSSION

The cross-section micrographs of tested friction samples shows that the friction surface coating VTN have areas with eutectic structure (Fig. 2a). They determine the amount of wear and wear rate dependence on the specific load. Lots of white layers placed between the eutectic areas, due to the low ductility and lack of cohesion spall out from the surface.

Battered solid white layer, getting in the zone of friction, act as an abrasive (Fig. 2b) with this enhancing wear. Brittle fracture at the surface friction explicit plasma coating HTN. Specific loads of 8 MPa bursting of the coating are typical phenomena. Tribological properties of plasma sputtered UC depend on load and temperature determined by the degree of non-equilibrium condition, porosity and adhesive-cohesive strength. Normal plasma friction coating operation is observed in a narrow range of loads and temperatures. If the load $P > 5$ MPa, there is an intensi-

Table 1. Chemical and phase composition of eutectic alloys

Alloy	Chemical composition, %							Phase composition		Hardness, HB	Melting point, K
	Cr	Ni	Ti	V	B	C	Fe	Matrix	Hardening elements		
BTH	15.4	0.7	3.2	8.1	1.4	1.9	62.3	12X18H9T	TiB ₂ + VC	470	1460
XTH	20.5	8.6	2.5	—	2.6	—	65.8		(Ti, Cr)B ₂	370	1490

Table 2. Thermal properties of the alloy components

Material	Thermal Conductivity λ , W (m·deg)	Heat capacity C, kJ (kg·deg)
12X18H9T	15.9	0.505
VC	25.0	0.531
TiB ₂	21.0	0.636
CvB ₂	22.0	0.695

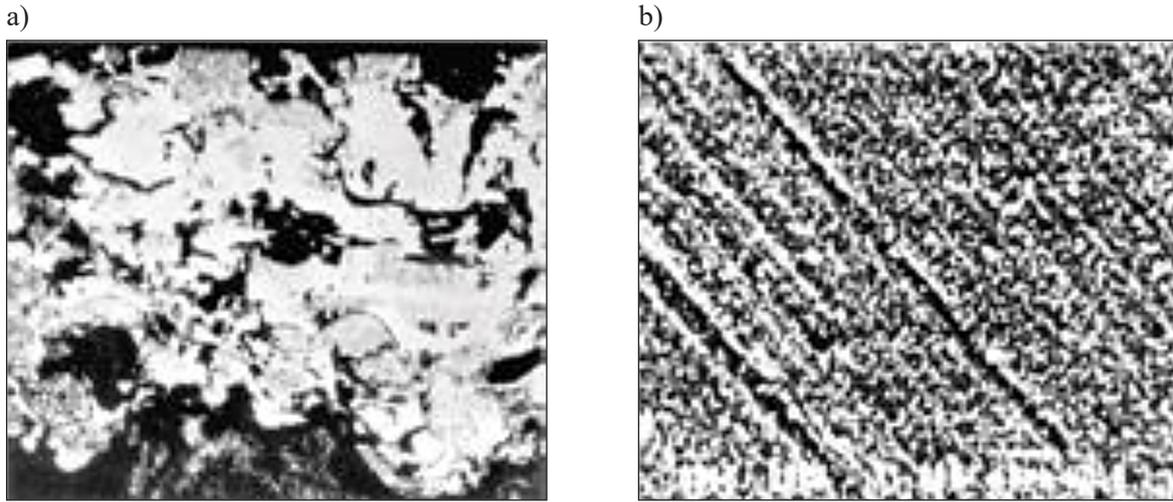


Fig. 2. Microstructures plasma coating (a), x200 and the friction surface (b), x500 of eutectic powder VTN

fication of wear due to brittle fracture, accompanied by chipping of elements that have abrasive properties. By elevated temperatures ($T > 600\text{ }^{\circ}\text{C}$) low durability is predetermined by decrease in hardness of the coating due to the collapse of supersaturated solid solutions and coating wears through withdrawal from the zone of friction due to loose of porous oxide films, that rapidly form on the surface of friction.

In the diffractograms of the friction surface of HTN coating reflexes of oxides Fe_3O_4 , Fe_2O_3 , Cr_2O_3 , TiO_2 , B_2O_3 were detected. In the coating of HTN compared with VTN coating formed larger number of oxides B_2O_3 and Cr_2O_3 . Perhaps this factor, and high heat resistance is explained by the higher wear resistance of coating HTN at elevated temperatures than at lower ones. Thus, plasma coating can not realize their potential high tribotechnical properties. There is only a

limited range of external factors in which coating workable, fair running in and form secondary structures.

Structure, mechanical properties and tribotechnical gradient of plasma coatings obtained by laser melting. Laser treatment due to its specificity (rapid heating and subsequent accelerated cooling) gives fine-dispersed structures supersaturated solid solutions and, therefore, high wear resistance of coating. Because of practical interest it is the consideration of the structural features and properties of plasma coating after processing them using laser melting.

In this mode of exposure was chosen such that the depth of penetration equal to the thickness of the applied coating or exceed it. Figure 3 presents the microstructure of plasma coating on steel 40X, melted by the laser beam. Coating has a columnar structure – dendritic structure. Compared

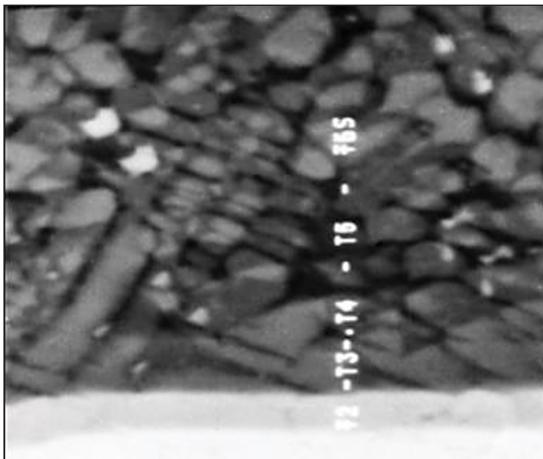


Fig. 3. Microstructure fused plasma coating VTN, x500

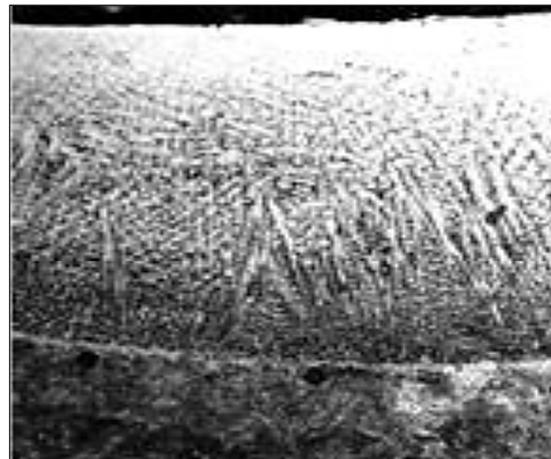


Fig. 4. Microstructure gradient plasma coating system VTN, x500

with the initial microstructure it can be noted that the metal as a result of the concentrated radiation energy was in the liquid state. Under the influence of a large temperature gradient and the resulting high speed crystallization, the growth of dendrites principal axes held parallel to the heat sink. Note that near the surface area heat sink is less pronounced, and is parallel to the displacement of the laser beam on the surface. Thus, the orientation of dendrites in the melting zone is determined by the direction of heat.

Melting of the coating are almost 100% dense (porosity of 0.5–1.0%), adhesion strength is increased to 400–450 MPa. The process of formation of gradient coatings obtained a patent [8]. The micrograph if the coating is shown in Figure 4. Tribological tests found increasing resistance of melted surfaces to wear compared to the original without processing more than in 2 times. Thus, if the reduced wear of sprayed coating VTN at 293 K is 51.1 mg/cm²·km, and of melted – 27.9 mg/cm²·km. The task was to provide a method of drawing plasma coating with high wear resistance and working in by forming its gradient structure: a thin surface layer of dispersed structure with low shear resistance and depth of the columnar structure oriented normal to the friction surface. To draw such a coating an alloy VTN of the system 12X18H9T-TiB₂-VC was chosen, because it is more durable than the alloy HTN. Previously the optimal structure of hardening phases (TiB₂, VC) on the wear resistance coatings, based on their thermal properties was investigated.

It should be noted that the decrease in wear and friction coefficient in the temperature range 300–500 °C with increasing content of vanadium carbide probably due to its ability to oxidation. Unlike the diboride of titanium, vanadium carbide under these temperature begins to oxidize. The resulting oxide film containing FeO, TiO₂, V₂O₃, B₂O₃ serves as a solid lubricant and protect the surface from wear.

Therefore, for further research, given optimal tribotechnical properties of the coating (I, f, Θ), we selected an alloy with eutectic composition with 10 vol.% TiB₂ and 15 vol.% VC.

Research has established that such properties as wear, the maximum surface temperature and the coefficient of friction depends on the ratio of the content of TiB₂ inclusions and VC (Fig. 5). This is probably not only due to their different physico-mechanical properties, but also thermophysical.

In Figure 6 the microstructure of their friction surfaces are given. By sliding speed of 0.2–0.8 m/s (surface temperature 300 °C) the formed secondary structure has smooth surface (Fig. 6a). With increasing sliding speed to 1.2 m/s (temperature 400 °C) and up to 1.6 m/s (temperature 550 °C) processes of friction and wear are determined by the formation of oxide films (as in Fig. 6b and 6c). In the sliding speed range 1.8–2 m/s (temperature 800–850 °C) occurs contact friction. Wear scars on the samples – are flows and solidified eutectic crystals (Fig. 6d). Thus there is a sharp decrease in the coefficient of friction to values characteristic to boundary friction (0.05–0.10).

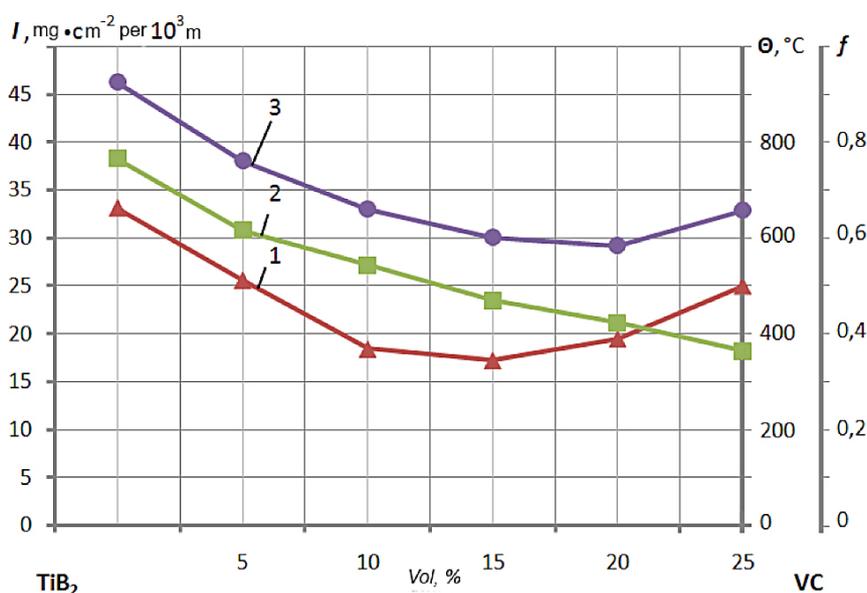


Fig. 5. Dependence tribotechnical properties melted coating VTN plasma volume content of TiB₂ and VC at P = 2 MPa, V = 0.5 m/s, 1 – f; 2 – Θ; 3 – I

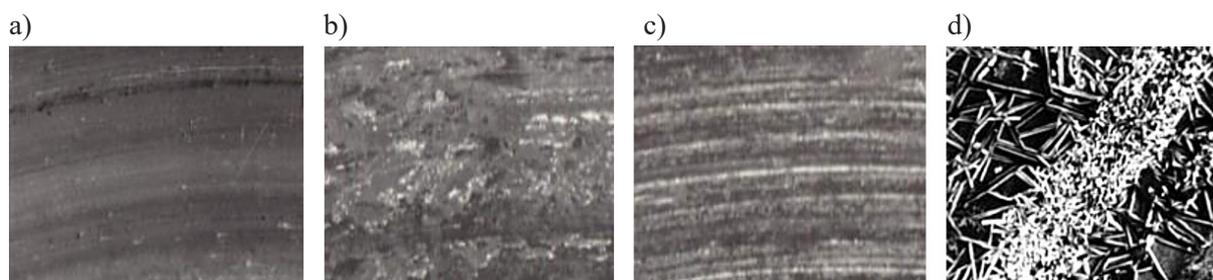


Fig. 6. Microstructure surface friction gradient coating, $P = 2$ MPa, a - $V = 0.4$ m/s, $t = 250$ °C; b - $V = 1.2$ m/s, $t = 400$ °C; c - $V = 1.6$ m/s, $t = 560$ °C; d - $V = 2$ m/s, $t = 850$ °C.

CONCLUSIONS

1. It was proved and experimentally confirmed the composition of the eutectic composite alloy gradient coating based on thermo physical properties of the binder and fillers (thermal conductivity, heat capacity): steel binder 12X18H9T – 75%; fillers TiB_2 – 10%, VC – 15%.
2. Double fusion of plasma coatings have improved wear resistance due to its gradient structure, where the surface layer has elastic - plastic fine-grained structure contributes to running in, and is located below the layer with columnar structure efficiently damps external normal and shear loading. This increases the contact strength of the coating and reduces the friction and temperature gradient.
3. Designed coating for braking devices can be attributed to friction materials for medium friction conditions (short-term temperature up to 400 °C, long – up to 250 °C, pressures up to 1.5 MPa).

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