STRUCTURE AND MECHANICAL PROPERTIES OF "THICK"
TUNGSTEN PLASMA COATINGS

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In the work described below the authors continued their investigation [1-3] into the formation and properties of tungsten plasma coatings on OT4 titanium alloy and BrKh0.8 chromium bronze† substrates. The work was undertaken with the aim of studying the dependence of the structure and mechanical properties of thick (of the order of 2 mm) tungsten plasma coatings on the main controllable parameters of the technological process and on the properties of the substrate materials and also of examining the reactions of such coatings with the substrates.

One characteristic feature of thick plasma coatings is that they are formed in a number of spraying passes, involving repeated heating and loading of the substrate by the jet and particles of the material being sprayed. The strength with which a coating adheres to its substrate depends to a large extent on the degree of chemical affinity the two materials in contact have for each other, which may manifest itself, in particular, in the formation of solid solutions. The substrate metals chosen for investigation (titanium and bronze) differ radically in the character of their reaction with tungsten. The differences between such substrate materials can be quite accurately assessed on the basis of examinations of shear fractures, macro- and microanalyses of structures, mechanical tests, and electron probe microanalyses.

Coatings were plasma-sprayed under the following constant process conditions: rate of flow of plasma-forming gas (argon) 37-40 liters/min, rate of consumption of material being sprayed (tungsten wire of 1-mm diameter) 1.0 kg/h, and rate of specimen rotation 36.0 rpm. The variable process parameters determining the heat content of the material being sprayed were the spraying range and the arc current. The preparation of specimens for the testing of coatings in shear by Krechmar's technique [4] is described in detail in [3]. Fractographic and microstructural examinations were made with MBS-2 and MIM-8 optical microscopes and an EM-7 electron microscope. The key parameters evaluated in the microstructural investigation of tungsten plasma coatings were their porosity and the thickness of their "lamellas."

The distribution of chemical elements at the interaction boundaries between coatings and substrates was studied with the aid of a Cameca MS-46 electron probe microanalyzer. Two microanalysis parameters—an accelerating voltage of 20 kV and an electron probe diameter of ~ 3 μ—were maintained constant. As controls pure chemical elements were used. Characteristic portions of substrate—coating contact boundary zones were studied by the scanning technique.

Character of Rupture of Specimens in Shear Tests. Experimental investigations demonstrated that the character of rupture of thick tungsten coatings in shear tests varied depending on the nature of the substrate metal. The following observations were made.

1. On a titanium substrate the fracture passed between lamellas of the tungsten coating and on a bronze substrate along the coating—substrate interface. The breaking off of the tungsten ring was preceded

*Deceased.
† OT4 is Ti with 2.0-3.5 Al and 1.0-2.0% Mn and BrKh0.8 is Cu with 0.8% Cr — Translator.


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by some plastic strain [3], as a result of which a bright band appeared on the substrate. Plastic deformation ended with the coating breaking off in a brittle manner (Fig. 1).

2. Tungsten rings sheared off titanium substrates as a rule broke up into several fragments, but no disintegration of the rings occurred when they were stripped from bronze substrates (Fig. 1).

3. Microsections of tungsten coating rings sheared off OT4 alloy substrates were found to exhibit microcracks in a 0.04- to 0.08-mm-wide zone adjacent to the substrate (Fig. 2a). No microcracks were detected in rings stripped from bronze substrates. The microcracks were distinctly oriented along lamella boundaries in the coating and originated mainly from areas of increased porosity. In Fig. 2b is shown a good-quality fragment of a coating.

In the case of a titanium alloy substrate the strength of a coating is determined by the strength of the bonds between the tungsten lamellas, and in the case of a bronze substrate by the strength of the coating–substrate bond.

Shear Strength Tests. In Fig. 3a are shown typical curves of shear strength vs spraying range for specimens with titanium substrates coated at various currents. It will be seen that OT4 alloy substrates are characterized by curves with maxima. With increase in spraying range from 75 to 175 mm, other things being equal, the shear strength $\tau_s$ at first slightly grows and then sharply falls. With bronze substrates variation in spraying range has no significant effect upon strength characteristics (Fig. 3b).