EFFECT OF PREPARATION METHOD OF A SURFACE FOR DEPOSITION ON
THE COHESIVE STRENGTH OF A GAS-THERMAL COATING

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The cohesive strength of a coating with a base is studied for different methods of base preparation. A method is suggested which avoids the initiation of stress concentrations which have a deleterious effect on cohesive strength when the coating is loaded. The advantages of this method over others is demonstrated.

For wear-resistant coatings intended to restore components of heavily loaded friction assemblies there are increased requirements for cohesive strength with the base due to the action during operation of high contact or shear forces. A marked increase in cohesive strength may be achieved by using different methods for preparing the surface for deposition [1, 2].

The cohesive strength of a coating with a base is provided by forces of mechanical engagement and physicochemical interaction [3]. Prior preparation of a surface for deposition promotes acceleration of physicochemical interaction of the deposited material with the base as a result of activating the surface for deposition due to removing an oxide film and creating work hardening. However, for many coatings the main contribution to cohesive strength with a base is mechanical engagement [4]. This is confirmed in Fig. 1 by the results of our experimental studies for the cohesive strength in shear of a PG-19M-01 coating 2 mm thick with brass L-63. With shear tests for coatings deposited in ground specimens there is no mechanical engagement and the whole of the cohesive strength is provided by physicochemical bonds (curve 1 in Fig. 1). With deposition on a surface formed by fine turning the contribution to the cohesive strength of both mechanisms of bond formation is the same (curve 2). With use of abrasive-flow treatment the role of mechanical engagement increases sharply in view of an increase in microroughness, and it almost determines the cohesive strength of a coating with a base (curve 3).

With considerable loads it is necessary that the bond strength of the coating with the base approaches in value the cohesive strength. The increase in cohesive strength in this case compared with the cohesive strength obtained with abrasive-flow preparation of the surface for deposition is achieved by using machining methods; cutting a ragged thread, knurling, and turning a trapezoidal thread.

These treatment methods create a surface in the form of grooves whose side faces slope in the direction of external load application. As a result of this a component force develops directed along the normal to the base—coating interface which leads to occurrence of stress concentration and cohesive failure of the coating with formation of cracks and separation over a cylindrical specimen. Failure may occur over the thickness with much lower loads than if they were accomplished along the interface of the coating and the base. Therefore, in order to improve the cohesive strength of the coating with the base in shear tests it is necessary to prepare the surface for deposition so that forces directed perpendicular to the interface do not arise. For this it is necessary to prepare grooves of rectangular shape to prevent this unfavorable redistribution of forces.

The maximum strength of a coating bond with a base in cutting rectangular grooves will be with a groove width and distance between them which satisfy the equal strength condition in shear tests for materials of the article and coating:

\[ a \tau_a = b \tau_c, \]  \hspace{1cm} (1)

where \( a \) is the distance between grooves; \( b \) is groove width; \( \tau_c \) is cohesive strength limit in shear for the coating; \( \tau_a \) is strength limit in shear for the material of the restored article.
Fig. 1. Dependence of cohesive strength in shear for a PG-19M-01 coating with brass on the width of deposited layer with preparation of the surface for deposition by grinding (1), fine turning (2), and abrasive-flow treatment (3).

Fig. 2. Loading scheme for a coating with cohesive strength testing in shear.

With a groove width less than follows from the equal strength condition the coating will shear (along line 1 in Fig. 2). If the groove width is less than we have from condition (1) the base material will fail (along line 3 in Fig. 2).

With preparation of 'dovetail' type grooves the failure load will be less than with the use of rectangular grooves since in the first case with stable uniform conditions the area over which cohesive failure of the coating occurs (line 1 in Fig. 2) is less, and there is less area at the base of projections separating grooves.

Presented in Fig. 3a is the dependence of cohesive strength in shear for a PG-19M-01 coating with brass L-63 on groove width. It follows from the ratio of the strength limits in shear for the coating and base materials that the cohesive strength should be at a maximum with b/a \approx 10. Prior measurements of the strength limit in shear gave a value for the coating material \( \tau_c = 49 \pm 6 \text{ MPa} \), and for the substrate material it was an order of magnitude higher, i.e., \( \tau_a = 450 \text{ MPa} \). It can be seen from Fig. 3 that with this ratio of b/a the cohesive strength is at a maximum.

In order to estimate the effect of rectangular groove depth on the strength of the bond for the coating and base we separate two planes parallel to the direction of load application and distant from each other by a unit distance, a section of coating and base, and we consider one groove filled with coating. The coating element filling the groove may be considered as a cantilever beam of unit width loaded over one of its surfaces by a distributed load \( \sigma_n \) (Fig. 2). The maximum stresses which arise in the coating element are determined by the well-known material strength equation

\[
\sigma_{\text{max}} = \frac{M_{\text{max}}}{W},
\]

where \( M_{\text{max}} \) is maximum moment; \( W \) is moment of beam cross-section resistance. In our case

\[
M_{\text{max}} = \frac{\sigma_n \cdot 1 \cdot h^3}{2}, \quad W = \frac{1 \cdot b^2}{6},
\]

where h is groove depth. After substituting \( M_{\text{max}} \) and W in expression (2) we obtain

\[
\sigma_{\text{max}} = \sigma_n \frac{3h^2}{b^2}.
\]

The maximum stresses that arise in the coating element under the action of load \( \sigma_n \) will be at its base (along line 1 in Fig. 2), and from the direction of the load tensile stresses operate, and from the opposite direction there is compression. Considering that the cohesive strength of the coating is less in tension than in compression we calculate the maximum stresses that arise under the action of the failure load:

\[
\sigma_s^c = \frac{\sigma_n 3h^2}{b^2}.
\]