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ANALYSIS OF THE INFLUENCE OF THE PLASMA TORCH VELOCITY ON THE THERMAL STATE OF THE COATING–SUBLAYER–BASE SYSTEM

Summary. *This paper presents the results of mathematical modeling of numerical studies on the effect of plasma torch velocity on the thermal state of a multilayer coating-sublayer-base system. Studying the thermal processes occurring during thermal spraying plays a key role in the development of new multi-resistant coatings.*

Key words: *layered heterogeneous systems, thermal spraying, "multilayer coating-sublayer-base", mathematical modeling, high-temperature zone, heat transfer.*

Introduction. Thermal spray coatings for various functional purposes are currently finding wider application. Their enhanced thermal, electrical, wear-resistant, and corrosion-resistant properties, as well as the challenges of improving existing thermal spraying technologies and developing new ones, are crucial in wartime. Studying the thermal processes occurring during thermal spraying plays a key role in the development of new coatings. Composite clad powders containing solid lubricants are currently becoming increasingly popular for the production of antifriction coatings using various thermal spraying methods.

Composites with graphite as the primary core are widely used in spraying. Coatings made from composite powders of this composition are used in friction units operating without lubrication and under boundary friction conditions. These coatings are used as bearing surfaces in plain bearings, in gas turbine engines, in abradable starter coatings, in vane compressors, in ring pump seals, and in specialized military equipment. Therefore, the development and improvement of coating technology necessitates additional research into the thermal phenomena observed in all these situations. Of significant interest are the results of mathematical modeling of heat transfer processes during the formation of coatings from clad composite powders containing graphite. This paper presents representative results of mathematical modeling of numerical studies investigating one of the important factors influencing the thermal state of a system—the plasma torch velocity.

A three-dimensional, non-stationary heat conduction problem for a multilayer system is considered. Two different research formulations are considered. In the first formulation, the spraying rate is constant, and the coating thickness Δ_{3c} is inversely proportional to the plasma torch velocity V. The originality of the first formulation lies in taking into account the variable coating thickness with a change in the velocity V, and this largely corresponds to the real spraying situation. In the second formulation, the sprayed layer thickness is constant, while the spraying rate is variable, and it is directly proportional to the plasma torch velocity. It should be noted that the second formulation is close to the traditional one, in which the effect of velocity V is studied under conditions of constant geometric characteristics of the object under study.

Typical results of the performed numerical studies corresponding to the following values of the initial parameters x_1=2.56; δ_1=0.34 base thickness; sublayer thickness Δ_2= 0.0085; thickness of a single coating layer Δ_3= 0.00425; number $Bi_{x1} = Bi_{y1} = Bi_{z0} = Bi_{z1}$ = $5.96 \cdot 10^{-3}$; $\theta^* = \theta/\theta^*_{max}$ – maximum temperature of an individual steel base; parameter $K_V = \theta_{Pe=Pei}/\theta_{Pe=233.25}$, where Pe =77.25; 116.625; 155.55).

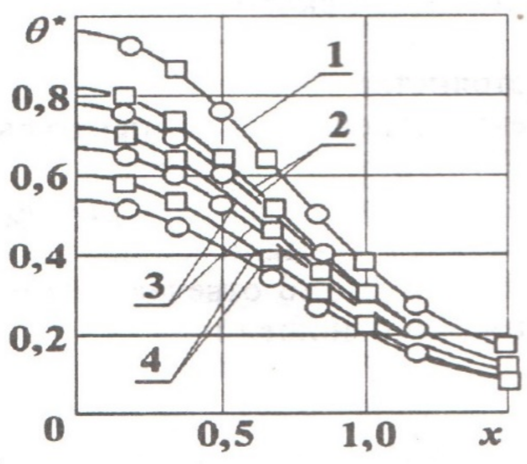

Fig. 1. Dependence $\theta^* = f(x)$ – for $y = 0$, $z = -0.513$ in the layered heterogeneous system "five-layer coating-sublayer-base": 1 - Pe = 77.75; 2 - Pe = 116.625; 3 - Pe = 155.5; 4 - Pe = 233.25; —□— - constant spraying productivity; —o— - constancy of coating thickness Δ_{3c} =0.0255

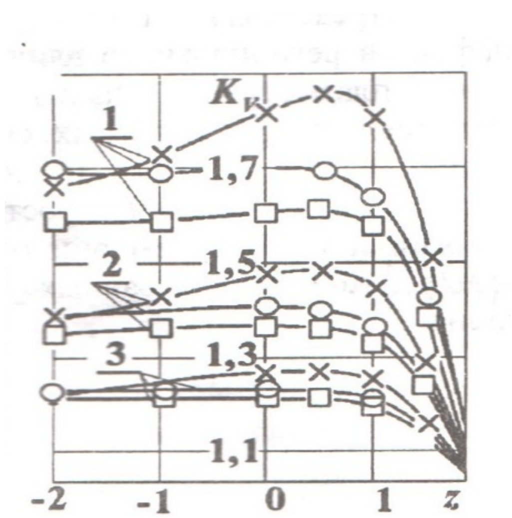

Fig. 2. Change in the K_V simplex along the *z* axis: 1 - *Pe* = 77.75; 2 - *Pe* =116.625; 3 - *Pe* =155.5; —□— - the "five-layer coating - sublayer - base" system with constant spraying productivity; —x— - the "five-layer coating - sublayer - base" system with constant coating thickness Δ_{3c} =0.0255; —o— - separate steel base

The data obtained show that quantitatively, the impact of velocity for the compared situations differs significantly. However, qualitatively, the impact of velocity is similar.

In the two cases under consideration, an increase in the plasma torch velocity, characterized by the *Pe* number, leads to a decrease in the temperature levels of the entire system as a whole. A narrowing of the isotherms along the *x*- and *y*-coordinate axes, which are perpendicular to the movement of the energy source, and a shortening in the direction of the *z*-axis are also observed. The quantitative differences in the compared data differ more significantly with a higher *Pe* number. Thus, on the heat sink surface, these differences do not exceed 0.038 at *Pe* = 116.625, and at *Pe* = 233.25, the differences reach 0.0625 (Fig. 1). A feature of the data corresponding to the first formulation is the compensating effect of the thinning of the coating layer, which occurs with an increase in the plasma torch velocity. It is shown that, with a constant coating thickness, an increase in velocity leads to a decrease in the temperature of the entire system as a whole. However, with a decrease in coating thickness and an increase in velocity, the effects are opposite. Therefore, in the first version of the formulation, with a change in velocity, the temperature value changes less.

For comparison, Figure 2 shows data for a single, uncoated steel base and under otherwise identical conditions. The results indicate that the effect of plasma torch velocity on the coating-sublayer-base system is significantly different quantitatively than on a single steel base. These differences become greater at higher coating thicknesses and increase further with decreasing plasma torch velocity V. In the second study (with constant coating thickness), the temperature change due to velocity changes, characterized by the Pe number, appears more significant. The least significant effect is observed with constant spraying performance, which is typical for the first study. For a single steel base, the data corresponding to it occupy an intermediate value compared to the other cases.

Conclusion. Analysis of the obtained data shows that in all three cases under consideration, the dependence of the manifestation of the effects of the regional influence of the heating source on the velocity of the plasma torch is of interest, and the effects of the complete regional influence of the heating source, the effects of the regional influence of the features of the spatial distribution of the energy source, etc. are observed. It can be concluded that the higher the velocity of the plasma torch, all other things being equal, the more pronounced the effects of the regional influence of the heating sources.

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