Structure of Plasma-Sprayed Molybdenum Coatings

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One of the principal advantages of the plasma-spraying technique is that, by varying the main technological parameters of the process, it is possible to alter within wide limits the structure and properties of coatings [1, 2]. Particularly effective in this respect is the influence of geometric and electrical parameters, namely, spray range and current intensity, which largely govern the temperature and velocity of the plasma jet and, in the last analysis, influence the formation process of the plasma coating.

In the majority of published investigations [3, 4] into the kinetics of the plasma-spraying process, studies were made of the distribution of the temperatures and velocities of particles being sprayed in the plasma jet. However, no results have been published of metallographic investigations of plasma coatings, particularly those that might establish the relation between the deposit structure and the temperature and velocity of the plasma jet.

In the present work, a study was made of the fine crystalline structure, microhardness, and degree of oxidation of plasma molybdenum coatings produced by spraying at various geometric and electrical process parameters.

Molybdenum powder with a particle size of 15 μ was plasma-sprayed in a UPU-3M unit at a voltage of 30 V, a plasma-forming gas (argon) flow rate of 25 liters/min, current intensities of 400, 500, and 600 A, and spray ranges of 50, 100, 150, and 300 mm. SChM-1 gray cast iron was used as the substrate material.

Specimens were studied by x-ray diffraction in a URS-501 ionization x-ray apparatus in iron radiation with automatic recording of intensity-distribution curves. A reference standard was provided by a specimen prepared from molybdenum powder by pressing, sintering at 1250°C in a hydrogen atmosphere, and subsequent slow furnace-cooling.

Microdistortions and crystal block sizes were determined by studying the breadths of the (110) and (310) interference lines, using the technique proposed by Lysak [5, 6]. The true line breadth β was calculated with the formula:

$$β = \frac{1}{2} (B - b + \sqrt{B(B - b)})$$

because in our case the curves of intensity distribution over the breadth of the interference lines for the specimens under investigation were described by the function

$$\frac{1}{(1 + αx^2)^2}$$

where B and b are, respectively, the line breadths of the test and reference specimens, x is the line breadth coordinate, and α is a coefficient depending on the form of the approximating function.

The effects of spray range on crystal lattice distortions and block size are illustrated in Fig. 1. It will be seen that, as the range is changed from 50 to 300 mm, the magnitude of the distortions decreases, while the block size increases.
There are two possible reasons for the appearance of crystal lattice distortions in the sprayed layer: Firstly, the particles are accelerated during spraying to a high velocity (attaining, for molybdenum particles, 150 m/sec [7]), so that, at the instant of collision with the substrate, they become plastically deformed, as a result of which their crystal lattice is distorted; secondly, lattice distortions may be of a thermal origin, because the surface layers of the particles, being in a zone of high temperatures (8000-15,000°C in low-temperature plasma [7]), heat up to their melting and vaporization temperatures, after which they are drastically cooled during deposit formation.

The decrease in the magnitude of crystal lattice distortions (Fig. 1) may be attributed, in the authors’ opinion, to the fact that the particle flight velocity diminishes as the distance between the torch nozzle and the surface being sprayed is increased. The variation of the microhardness is analogous to that of the distortions: with increase in the distance from the substrate to the torch nozzle, the microhardness falls (Fig. 1).

Varying the current intensity (Fig. 2) has practically no effect on the microhardness of plasma-sprayed molybdenum coatings. It is only when a current intensity of 600 A is attained that the microhardness slightly rises, which is probably due to an increase in the magnitude of thermal stresses.

The plasma jet invariably contains atmospheric oxygen, the amount of which grows with increase in the distance from the torch nozzle orifice. However, x-ray diffraction investigations of sprayed coatings revealed the presence of molybdenum oxides, Mo₃O₆ and MoO₃, only at the two extreme – the least (50 mm) and the greatest (300 mm) – spray ranges. This peculiarity of the oxidation behavior is linked with the specific nature of the plasma-spraying process. In the case of spraying from a distance of 50 mm, the oxygen content of the jet is relatively low, but the part is heated up by the plasma jet to a temperature which is sufficient to cause oxidation of the metal being sprayed. In spraying from a distance of 300 mm, air is drawn into the plasma jet and the heated metal particles come into contact with atmospheric oxygen.

CONCLUSIONS

1. The structure of molybdenum coatings deposited by the plasma-spraying technique is characterized by the presence of crystal lattice distortions. Their magnitude is governed by the distance from the surface being coated to the torch nozzle, diminishing as the latter is increased. The effect of current intensity on the magnitude of these distortions is negligible.

2. During plasma spraying, the oxides Mo₃O₆ and MoO₃ are formed. Their formation is caused, at a spray range of 50 mm, by substrate over-heating and, at a spray range of 300 mm, by air being drawn into the plasma jet.

LITERATURE CITED