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FORMATION OF ANTIFRICTION AND WEAR-PROOF COATINGS BY HETEROGENEOUS ARC PLASMA

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Abstract. Formation of coatings of the various functionality on electrode-detail while injecting of metal particles in plasma flow of short argon arc is considered. The possibility of formation both antifriction and wear-proof dense coatings, which have a metallurgical bond with a base, is shown.

1. INTRODUCTION

Application of plasma technologies to produce coatings allows obtaining high quality working surfaces and considerable lowering of consumption of non-ferrous metals and steel alloys. For the cohesion and adhesion parameters of coatings to be improved it is necessary to rise temperature in a zone of contact of sprayed particles with a workpiece surface. The level of particle heating depends on plasma parameters in a plasma device where sprayed powder is injected. Increasing of particles' temperature as contrasted to traditional technologies may be reached at their heating in near-electrode regions of arc discharge where plasma temperature can exceed 20 000 K (see for example Hsu et al. 1983 and Zolotovsky et al. 2002). According to Smyaglikov et al. (2003) the heat flux density from arc plasma to a metal particle amounts to $4.3 \cdot 10^8$ W/m^2. The opportunity of deposition of dense homogeneous coatings with application of a short argon arc was shown by Shimanovich et al. (2002, 2003). Measurements of size and velocity distribution functions of the particles for various distances from a cathode has shown that bronze particle in plasma flow moves with acceleration of $2.8 \cdot 10^3$ m/s^2 and loses up to 50% of its mass du to vaporization. High cohesion and adhesion parameters of the coatings are due to metallurgical junction between deposited particles as well as between coating and substrate (when transition layer between them is a metal alloy).

2. EXPERIMENT

The coatings were formed at an experimental setup comprising a plasmatron with an arc ignition system, power supply, powder feeder, control unit, and manipulator providing reciprocal motion of the plasma generator and rotation of a workpiece–electrode. The electric arc was struck between workpiece and rod tungsten electrode blown with argon. The arc voltage was U = 20–30 V. The powder feeding was fulfilled in a form of annular flow into a high-temperature region of the arc at the outlet of plasma nozzle near the tungsten electrode. The sprayed particles with average diameter of 90 μm were injected into a laminar plasma stream of a short argon arc at atmospheric pressure at an initial particles velocity of ~ 0.6 m/s so optimal conditions for their heating were ensured.

The following types of powder were used:

- Powders of phosphorus (90% Cu + 9% Sn + 1% P) or zinc (85% Cu + 5% Sn + 5% Zn + 5% Pb) bronze to make antifriction coatings;
- Powders of iron-base (89.6% Fe + 1.2% C + 3.7% Cr+ 2.2% Si+ 3.3% B) or nickel-base (75.7% Ni + 16.5% Cr + 0.8% C+ 3.7% Si+ 3.3% B) alloys or their mixtures to make wear-proof coatings.

The investigations have shown that the following regimes are the most optimal for the coating deposition:

- A distance from the nozzle orifice to workpiece surface is 8÷12 mm;
- Plasma-forming gas rate (argon) is 3÷5 l/min;
- Carrier gas rate (argon) is 5÷15 l/min;
- Linear speed of workpiece surface movement is 4÷12 mm/s.

The coatings should be applied at the arc current of 100–200 A in case of direct polarity of arc (when workpiece is an anode) or at current of 80–140 A in case of reverse polarity of arc (when workpiece is a cathode). The powder consumption is 1.5–3 kg/h and powder utilization factor can exceed 0.95. The required coatings 0.5–5 mm in thickness are formed on a workpiece surface as a result of one passage of plasmatron with 2–4 mm overlapping of deposited beads.

3. ANTIFRICTION COATINGS

Plasma technologies were widely adopted for details of tribomechanical systems demanding special technical requirements for homogeneity of the coatings and its adhesive strength with a base.

As an example the sliding bearing with a bronze coating on an internal surface is shown in Fig. 1, *a*. The structure of coating (obtained at constant current of reverse polarity arc of 110 A, and speed of workpiece surface movement of 4 mm/s) is represented in Fig. 1, *b*. It is clear from the figure that coating has a structure typical of cast metal. Defects such as cracks and blebs are absent. According to analysis of images fulfilled with the help of scanning electron microscope, the porosity of coating does not exceed 0.5% if all pores with size of more than 1 μm will be taken into account. At the same time the pore size varies in a range of 3–10 μm. A zone of thermal influence of arc plasma on a substrate is about 100 μm. The adhesive strength of coating to a detail surface exceeds tensile strength of the coating material (> 150 MPa). The transition layer "substrate – coating" is a cast bronze with inclusions of iron grains about 10 μm in size.

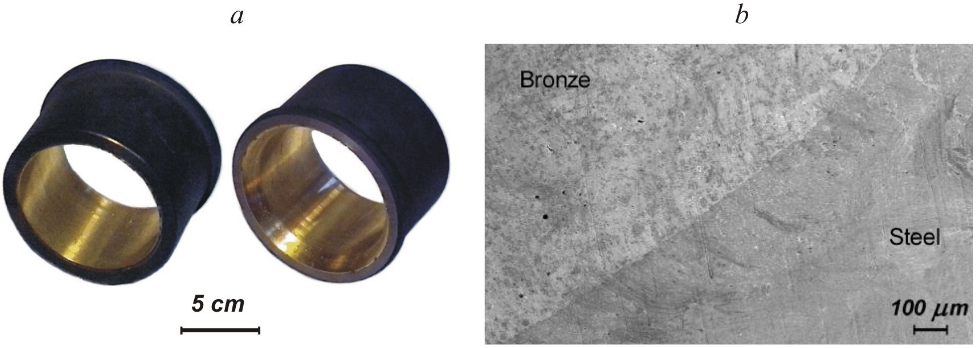

Figure 1: The sliding bearing with a bronze coating on an internal surface (*a*) and SEM image of metallographic section of the coating (*b*).

Kinetic friction coefficients of bronze coatings obtained for reverse polarity of arc at current of 110 A and speed of workpiece surface movement of 4 mm/s and for direct polarity of arc at current of 200 A and speed of workpiece surface movement of 10 mm/s vary over the ranges of 0.05÷0.2 and 0.1÷0.25 respectively. Thus, the obtained bronze coatings are referred to a group of friction materials.

4. WEAR-PROOF COATINGS

Formation of wear-proof metallurgical coatings is actual problem especially for machine components and mechanisms working in the conditions of abrasive wear and high impact loads. As an example the view of harvester knife with wear-proof coatings on cutting edges is given in Fig. 2, *a*.

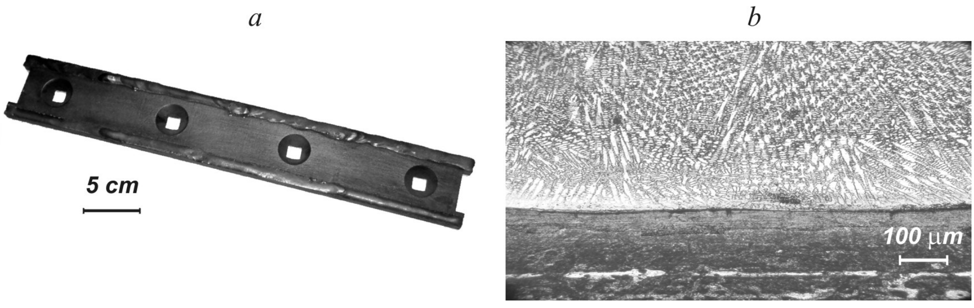

Figure 2: The harvester knife with wear-proof coating on cutting edges (*a*) and SEM image of metallographic section of the coating (*b*).

The structure of coating is shown in Fig. 1, *b*. The obtained wear-proof coatings are characterized by high adhesive resistance and have surface microhardness of 58 to 65 HRC, while hardness of steel base is 20–29 HRC. Intermixing of base metal with coating material does not take place. The thermal influence zone is thinner than 100 μm.

5. CONCLUSION

The carried out studies of structure and properties of the obtained coatings reveal a high efficiency of process of powdery material spraying in a plasma flow of a short argon arc for application of high-quality coatings on details of machines and mechanisms. The proposed technology can be used to produce both antifriction and wear-proof coatings with unique features and metallurgical junction with a base (see. Smyaglikov et al. (2005).

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