UDC 621.375.826

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FUNCTIONAL PLASMA-DEPOSITED COATINGS

The paper focuses on the problem of low adhesion of plasma sprayed coatings to the substrate. The subsequent laser treatment modes and their influence on the interface were studied. Proposed method of laser-aided thermocycling increases the adhesion 4-5 times comparing to as-deposited coating. Obtained complex of properties also allows to significantly improve wear resistance of coatings.

Key words: *plasma deposition, coating, laser treatment, thermal cycling, mass transfer, adhesion, wear resistance.*

Introduction. At contemporary manufacturing processes of machine elements the technologies of depositing of functional coatings are widely used. This allows to increase the service life of parts, and to cut manufacturing and service expenses. Among the most convenient and most common are coatings deposited by plasma spraying of powder materials [1; 2]. The data collected about this method are enough to predict and control their properties.

A well known disadvantage of these coatings – is their poor adhesion, which is about 20-30 kg/mm^2 and very seldom is stronger. They also can not be used at cyclic loading because of the risk of spallation. Their porosity makes them impossible to use in aggressive media (gases, oils), high temperatures,

A well known fact that the mechanical properties of plasma sprayed coatings properties can be advanced by laser treatment. Both in liquid and solid phases the alloying elements under laser radiation are redistributed. The rate of redistribution is extremely high, what cannot be achieved by conventional heating [3-5]. This phenomenon, if realized on coating, may improve the coating adhesion. To investigation of mode of laser radiation, which will provide such redistribution – is the aim of current paper.

Aim of investigation. This paper is focused on general relations of mass transfer in the interface plasma coating-substrate under the laser radiation what will provide better adhesion and higher wear resistance.

Experimental facilities and materials. Material for plasma coating – are alloys VTN (TiB2-VC+0,12C-18Cr-10Ni-Ti steel) and CrTN(TiB2-CrB2+0.12 C-18Cr-10Ni-Ti).

The surface laser treatment was done by CO_2 Laser. Radiation power – P = 1000 W, ray diameter – d = 2,5–10 mm. The speed of ray motion – =0,5 m/min. Pitch of treatment – S = 1,5–5 mm. This allows to heat or remelt the coating to the required depth. The specimens were analyzed for structural arrangement, hardness distribution. The distribution of chemical elements was studied by microanalyze «CameBaxSX50». The adhesion was determined by pull-off adhesion test.

After spray deposition coatings were treated by laser thermal cycling (oscillating heating-self cooling).

For wear testing a ring-on-ring method was used. Disks slide one over the other with speed up to 15m/sec. Allowable temperature range: from room – up to 1000 ˚C.

Experimental results and discussion. The microstructure of remelted coating. exhibits dendrite appearance. Under high solidification rate the dendrites are directed to the side of heat removal. At the top surface the solidification rate was extremely high, as the there are no dendrites. The structure is fine-dispersed. It was obtained by double remelting of plasma coating with higher speed of ray motion (more then 1m/min). The hardness of this surface layer is 11000–12000 MPa. Their hardness is lowered comparing to initial plasma coating with no subsequent treatment. (fig. 1). Hardness gradually decreases from top to the interface in remelted coating, and transition is more raped for untreated coating.

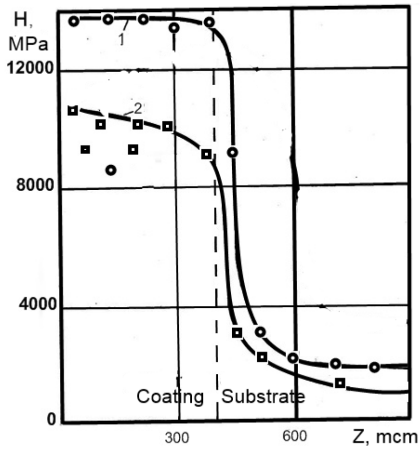

Fig. 1. Hardness gradient of plasma-sprayed coatings from top to depth: as-deposited (*1*), remelted (*2*). Substrate – steel 0,12C-18Cr-10Ni-Ti

Microhardness of substrate material is unchanged and is about 2700 MPa. The coating after remelting becomes almost fully solid with porosity only about 0,5-1,0 %, the adhesion rises up to 400-450 MPa.

A great attention was paid to the distribution of alloying elements in the interface zone. Metallographic analyses of remelted coating on 0,12C-18Cr-10Ni-Ti-steel substrate indicates the absence of cracks and spallation, and a distinct boundary «substrate-coating» A «grey zone» (upper layer of substrate) was found. Its thickness is about 1,5-2 μm, and its chemical composition differs from those of coating and substrate – the content of Vanadium, Chromium and Manganese is increased. We may state, that matrix and substrate materials diffuse into each other. Iron from substrate interacts with Vanadium and Chromium and diffuses into coating. It is necessary to point on high Titanium content of titanium in coating material (fig. 2).

These data show that rapid heating by laser causes in the coating-substrate interface a mass transfer and formation of transition zone. This provides much higher adhesion and positive slope of hardness.

To determine positive influence of laser treatment (without remelting) special investigation was carried out. The V-Ti-Ni (VTN) and Cr-Ti-Ni (CrTN) were plasma sprayed to the surface of 0,12C-18Cr-10Ni-Ti austenitic steel. They were laser treated in thermocycling mode (laser rapid heating + self cooling). The temperature range was 1000↔600 ºC, what encloses the polymorphic transformation.

The three-times cycling causes noticeable decrease of hardness and brittleness. The grey transition zone increases.

After 4 times treatment hardness of eutectic zone decreases from 9750 MPa to 8740 MPa. White metstable layers on the top of the coating also became softer: decrease from 13400 down to 9100 MPa.

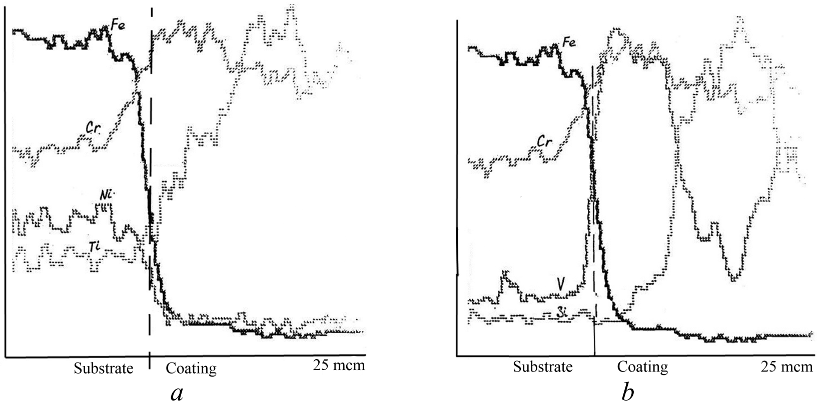

Fig. 2. Distribution of chemical elements in the interface of remelted plasma-sprayed coating and VTN 0,12C-18Cr-10Ni-Ti steel substrate (*a, b*)

Increasing of treatment up to 5 times, excessive brittleness is removed completely. The separation of insoluble particles from solid solution is observed.

After 6 thermocycles the hardness of upper and internal layers of coating are almost identical. It is lower then hardness of as-deposited coating, but is higher then of remelted coating. Further increase of thermocycles do not give any positive results. It is seen from tab. The 4-times cycling has positive influence on material's properties and adhesion.

Table

Properties of the coatings

Condition of the coating	Microhardness, MPa	Porosity, %	Adhesion, MPa
Plasma coating	12400	10-12	16-20
Laser melting	8200	0,5-1,0	400-450
Laser thermo-cycled plasma coating (4 cycles)	10050	7-9	90-110

Wear test (fig. 3) indicate decrease of wearing for 4-times remelted coating and lower friction factor. The friction process is also more stable comparing to as-deposited coating. Friction factor decreases in almost three times, what may be explained by the loss of mechanical strength due to friction-induced heat and cold metal flow under load. But in this case the wear intensity also would be very high. In contrast, it is slightly changed while 7-times increase of load. This is explained by formation of wear resistant protective layer on the surface of wear track.

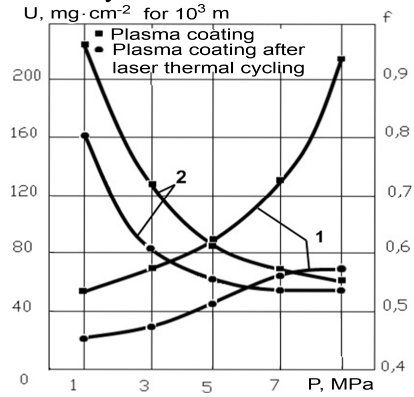

Fig. 3. Wear test results chart for VTN-coating: *1* – wearing, *2* – friction factor

Decrease of brittleness and increase of plasticity promotes the formation of stable friction-induced surface structures, and thus increases wear resistance. Also these structures cover the entire surface, in contrast to the wear surface of as-deposited pasma-sprayed coatings, which have only partially formed friction induced structure (island-type).

Conclusions. If the coating is laser-melted, the liquid phase interaction with substrate results in intensive mass transfer and formation of very strong interface. The adhesion is raised to 400-450 MPa and porosity is below 1%.
Laser thermocycling causes valuable redistribution of alloying elements in the coating-substrate interface. The thermocycling in a range of polymorphic transformation temperatures leads to increase of adhesion in 4-5 times (up to 90-110 MPa),removes excessive hardness and brittleness. This also promotes the formation of stable full-area friction-induced surface layer, what results in low wearing and friction factor.

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Стаття надійшла до редакції 12.10.2015.

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ФУНКЦІОНАЛЬНІ ПЛАЗМОВІ ПОКРИТТЯ

Розглянуто проблему низької адгезії плазмових покриттів до основи. Досліджено вплив поверхневої лазерної обробки на міцність зчеплення покриття з субстратом. Запропоновано термоциклювання нанесених покриттів лазером для покращення адгезії у кількості 4-5 циклів, що також істотно підвищує їх зносостійкість.

Ключові слова: плазмове нанесення, покриття, лазерна обробка, термоциклювання, масоперенесення, адгезія, зносостійкість.

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