LASER SUFRACE REMELTING OF HVOF SPRAYED Co-Cr-W COATING

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Abstract

The technology of Laser Surface Re-melting (LSR) is used to modify the surface layer of bulk materials or coatings in order to improve their surface properties, usually wear resistance. In the case of thermally sprayed coating, its application leads to elimination of porosity and internal oxides on the coating splat boundaries. The increase of corrosion resistance and inner cohesion strength of the coating is expected as a result of laser post-treatment. In the paper, the Co-Cr-W HVOF sprayed coating was subjected to the series of LSR procedures with varying laser parameters to study their influence on the thickness of remelted layer. The laser power and processing speed was the main studied parameters. The optimal parameters for LSR of coating with given thickness were found. Besides the laser parameters, the influence of spraying procedure, namely the procedure of grit blasting, on the creation of cavities in the remelted coating is discussed.

Keywords: Co-Cr-W, Stellite 6, coating, HVOF, laser surface remelting

1. INTRODUCTION

The CoCrWC alloy, well known as Stellite Alloy 6, is the most widely used alloy in the Co-based group of alloys. It has an excellent resistance to many forms of wear and corrosion over a wide range in temperature. The hardness of bulk Stellite 6 ranges from 36 to 54 HRC or from 380 to 490 HV. Its microstructure composes from Co fcc dendrites surrounded by Co phases and carbides. Cr content ensures resistance to oxidation and corrosion and strength thanks to the formation of M_7C_3 and $M_{23}C_6$ carbides [1].

The superior Stellite 6 properties are widely used in surface engineering for coating of the surfaces of highly stressed components in many branches of industry. They are deposited by welding [2], laser cladding [3, 4] or thermal spraying [5,6] technologies. While welding and laser cladding offer the well adhered coatings with minor porosity, but suffers from the high thermal and residual stress, thermally sprayed coatings are more beneficial from the stress point of view, but on the other hand are less adhered to the parts surface and can include some amount of pores and oxides.

The microstructure defects, unfavorably influencing the thermally sprayed coatings corrosion resistance and cohesion strength, such as pores, oxides and intersplat boundaries, can be removed by various post-treatment processes. The flame, furnace or laser surface treatment can be applied to remelt the coating [7-9]. The successful attempt was realized to increase the hot corrosion resistance of plasma-sprayed Stellite-6 coating by remelting it using high-power laser [10].

In presented work, the Laser Surface Re-melting (LSR) process was applied onto the Stellite coating, deposited by High Velocity Oxygen Fuel (HVOF) spraying technology. The attention was paid to the process of laser parameters optimization. The aim of optimization was to find laser parameters, suitable for remelting of the coating to the coating-substrate boundary and to the half of the thickness and compare the properties of remelted coatings with the HVOF as-sprayed coating. During remelting, the problems related to the creation of cavities in the coating emerged and had to be analyzed.

2. EXPERIMENTAL

2.1 Coatings preparation

The Stellite 6 coating was sprayed by HP/HVOF TAFA JP5000 spraying equipment in VZU Plzen onto grit blasted 11 523 substrate. For spraying, FST 484.33 powder was used. Its nominal chemical composition is: 28%Cr; 5%W; 1.2%C, 1%Si; Co rest. The grit blasting was realized by Al_2O_3, F22 (with a grain size 0,8-1 mm). The optimized spraying parameters were set, based on the previous studies [11]. The dimensions of substrate (200 x 100 x 10 mm) were chosen to ensure sufficient heat dissipation during re-melting process. Two series of experiments were done – first the samples were grit blasted by commonly used Al_2O_3 abrasives, the second by Al_2O_3 dried for 8 hours at 100°C in the air furnace to reduce the moisture contained in the abrasive particles.

The HPDD 4kW laser Coherent HighLight ISL-4000L; 808 ± 10 nm wave length was used for laser re-melting. Based on previous experiences [12] the set of laser processing parameters was designed. By variation of laser power and speed of the laser spot movement, the different values of specific energy (SE) [J/mm^2] were obtained and used for remelting. As a consequence, SE varied from 13 to 43 J/mm^2. Constant spot size (12 x 1 mm) and the overlap 2 mm was used. To prevent the high thermal gradient and connected coating cracking, the substrate was pre-heated up to 350°C.

2.2 Sample Analyses

The microstructure of the as-sprayed and remelted coatings were evaluated on the cross sections (grinded and polished using automatic Leco grinding and polishing equipment) by optical microscope Nicon Epiphot 200, by digital optical 3D microscope Hirox KH7700, and SEM Quanta 200 from FEI equipped by EDAX NEW XL-30 Silicon doped by Lithium detector.

The surface hardness HR15N was measured on the as-sprayed coatings surfaces using hardness tester Rockwell HT 8003. The reported values are average from at least 5 measurements. The coating microhardness HV1 was measured on the coatings cross-sections, in varying distance from the surface, to evaluate the microhardness profile.

3 RESULTS AND DISCUSSION

The Stellite 6 HVOF sprayed coatings was remelted using laser parameters, providing 6 different levels of SE. The coatings cross sections, corresponding to each used SE, can be seen in the Fig. 1. With increasing SE, the thickness of remelted layer increased almost linearly (see the graph in the Fig. 2). Using low values of SE (13-18 J/mm^2), the cracking occurred in the area of laser tracks overlap. Increasing SE, the cracking tends to be less pronounced, but the cavities, originated on the coating/surface boundaries, started to take place (Fig.1 c-f).

On the coating/substrate boundary, the Al_2O_3 particles are embedded on some places, as a residual from the foregoing grit blasting of the substrate. In as-sprayed coatings, the embedded Al_2O_3 particles usually don't cause big difficulties. Their negative influence can be observe in relation with fatigue loading, where they can play their role as stress concentrator and can initiate the grow of fatigue crack in both directions – to the coating or to the substrate, or can cause the loss of coating-substrate adhesion and following coating spallation [13].

In the Fig. 1, the progressive changes of coating/substrate boundary influenced by the increasing SE can be observed. In the Fig. 1e) the coating/substrate boundary did not yet change its morphology – the roughness created during grit blasting is still recognizable, but significantly higher amount of cavities with various size range is located near the coating / substrate boundary. In some of them, the impurities were observed (Fig. 4).

To determine the origin of the created cavities, the deeper analyses by means of SEM combined with EDX was done. The cavity observed in the coating almost half-thickness remelted is shown in the Fig. 3. It can be said, that the cavities originated nearby the Al_2O_3 particles embedded in the coating/substrate boundary. The EXD analyses of cavity inner surface (Fig. 3b) proved the 5% content of oxygen. No other composition changes were registered. Also the cavities containing the impurities (Fig. 4) were evaluated. The impurities contained in most cases the high amount of Al and O_2 (e.g. Fig. 4b), and Fe in one case (Fig. 4a). It indicates the presence of destroyed or deformed Al_2O_3 particles from coating / substrate boundaries. The occurrence of Fe can be related to the substrate material, torn out from the surface during grit blasting.

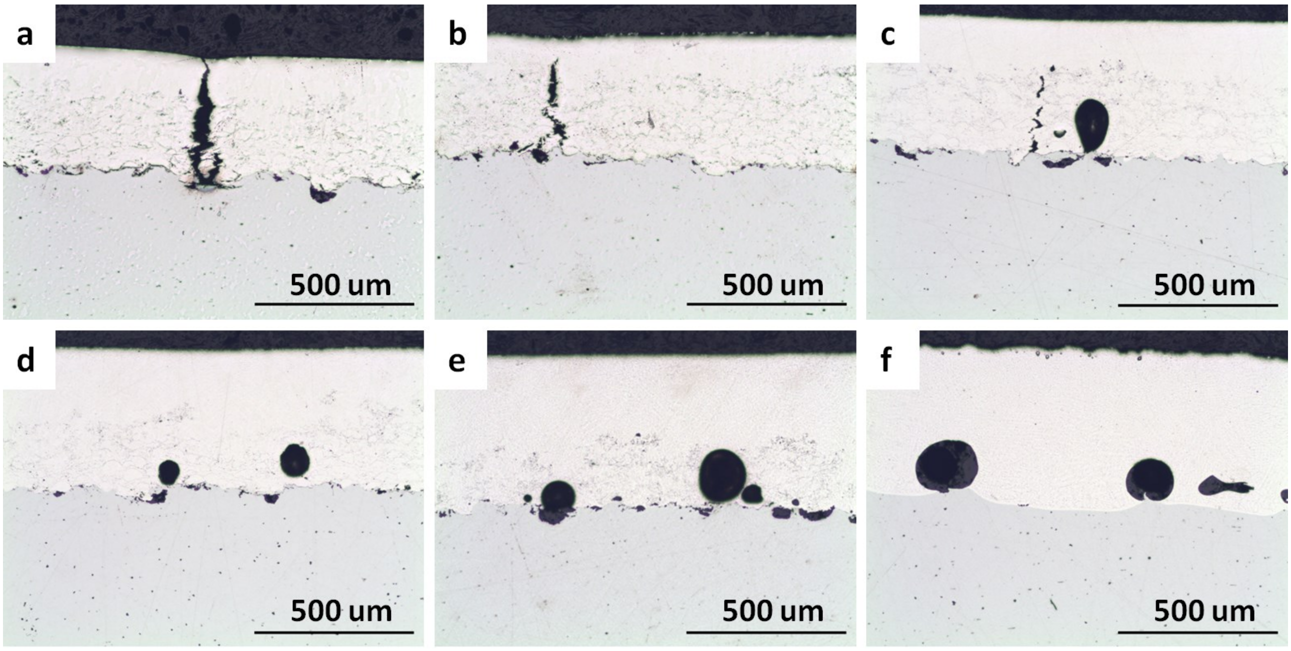

Fig. 1 The micrographs of remelted coatings cross sections in dependence on laser specific from the lowest (a) to the highest (f)

The connection of cavities occurrence with Al_2O_3 particles led to the hypothesis that the Al_2O_3 abrasives, used during spraying, were contaminated with moisture, coming from the air. The Al_2O_3 sand is stored in the job shop without any particular prevention against moisten. The possibly moisture absorbed in The Al_2O_3 particles can change its state due to the heat related to coating remelting process, increase its volume and creates pressure leading to the cavities formation.

The above mentioned hypothesis was proved by preparing another set of samples, grit blasted by Al_2O_3, which was previously dried in the hot air for 8 hours. The usage of dried Al_2O_3 has led to a significant decrease of the amount and size of the cavities, created in the coating after remelting – compare Fig. 5 vs 5b.

Nevertheless, the presence of embedded Al_2O_3 particles on the coating/substrate boundaries is unfavorable, even if the attention is paid to its moisture condition, and should be eliminated by optimization of substrate pre-treatment process.

For further analyses, the coatings remelted the half-thickness remelted coating and fully remelted coating was chosen to study the influence of LSR post treatment on the coatings mechanical properties. The microhardness measured on the as-sprayed, half-remelted and fully remelted coating was measured across the coatings thickness (Fig. 6.). The as-sprayed coating reached in average the highest hardness, but the scatter of the microhardness values is the highest due to the non-uniform microstructure, typical for TS coatings. The microhardness in the remelted part of the half-remelted coating is lower compare to as-sprayed part. The thickness of both coating is the same, the coating/substrate boundary was not influenced by LSR. The microhardness of the fully remelted coating is the lowest, but very homogenous across the coating thickness. The boundary of fully remelted coating was moved towards to the substrates. A certain amount of dilution can be observed. The average hardness trend is confirmed by measurement of superficial Rockwell hardness HR15N – 82.82HR15N for as-sprayed coating, 75.67 HR15N for half-remelted coating and 73.52 for the fully remelted coating (corresponding to 45, 31 and 27 HRC values, resp.) and its in agreement with results published previously [12].

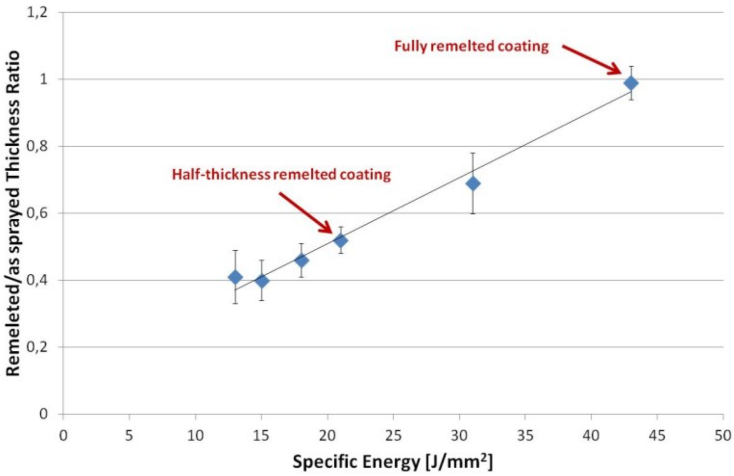

Fig. 2 The dependence of ration between remelted coatings thickness to the original coatings thickness in dependence on laser specific energy

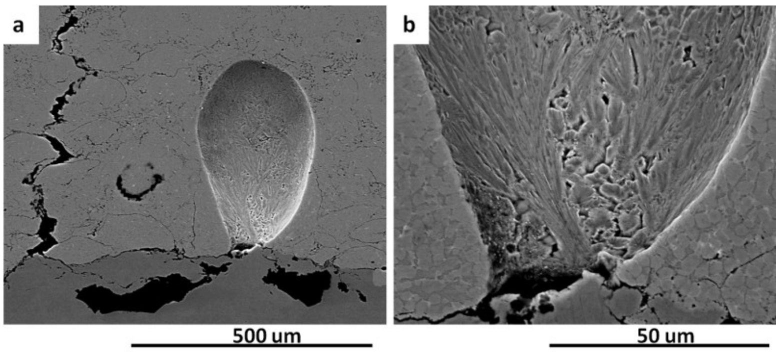

Fig. 3 SEM of cavity formed on the coating/substrate boundary

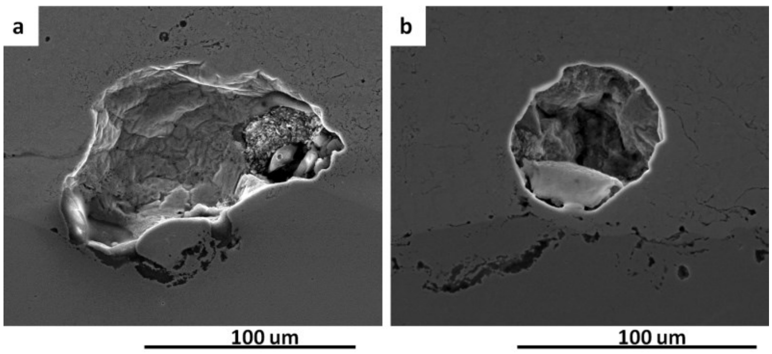

Fig. 4 SEM of cavity formed on the coating/substrate boundary with contamination

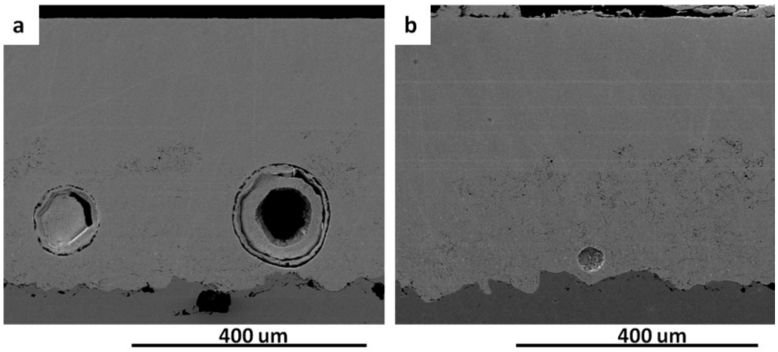

Fig. 5 SEM of cavity half-thickness remelted coating cross section a) grit blasted by usual Al_2O_3; b) grit blasted by dried Al_2O_3

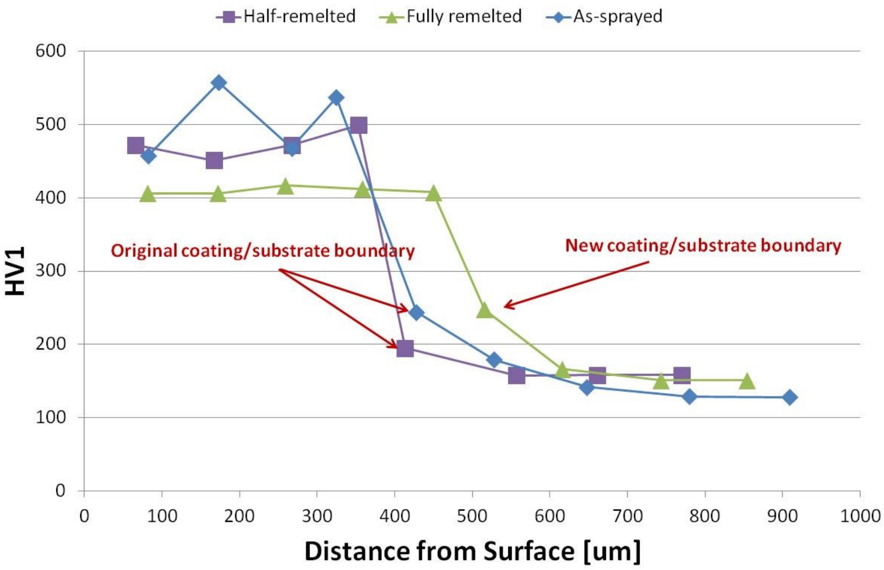

Fig. 6 The coatings Vickers microhardness HV1 measured on coatings cross section

CONCLUSION

The technology of Laser Surface Re-melting was successfully applied onto the HVOF sprayed Co-based coating. Varying laser parameters, namely laser power and velocity of laser spot movement, increasing specific energy was used to remelt the surface of Stellite 6 HVOF sprayed coating. In dependence on the used specific energy, increasing depth of coating was re-melted. The dependence between the specific energy and the remelted depth is can be considered as linear and can be used for estimation of specific energy necessary for remelting of defined coating layer thickness. To obtain the crack-free coating, higher specific energy should be used. At higher specific energies, the cavities occurred in the remelted coatings near the coating / substrate boundary. The moisture, absorbed in Al_2O_3 particles, embedded in the substrate after the grit blasting, was identified as a cause of the cavities occurrence. To avoid them, the alternative methods of substrate pre-treatment should be developed. The hardness of remelted coating is lower compare to the as-sprayed coating. The reason can be found in different state of inner stress in the coatings- compressive stress in the as-sprayed coating vs. tensile stress in the remelted coatings.

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