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Effect of laser heat-treatment on microstructure and micro-hardness of HVOF-sprayed WC-CoCr coating

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Abstract : The microstructure and micro-hardness of high velocity oxygen fuel-sprayed (HVOF) WC-CoCr coatings are comparatively studied for both before and after laser heat-treatment (LT) of the coatings. The results indicate that compared to HVOF WC-CoCro coating, the laser treatment has eliminated the pores almost entirely providing a more homogeneous and densified microstructure. And the compact interface of the coating with substrate is achieved by laser treatment. The thickness of the coating has decreased from 300 μm to 225 μm. As a result, the average porosity is five times higher in HVOF coating than in the coating by laser treatment. The laser treatment has produced a considerable increment in the hardness of the coating near surface whose average value increases from Hv0.2=1262.4 in the HVOF-sprayed coating to Hv0.2=1818.7 in the coatings treated with laser.

1. Introduction

The hard WC particles in the coatings lead to high coating hardness and high wear resistance, while the metal binder (Co, Ni, or CoCr) supplies the necessary coating toughness [1]. Even though tungsten carbide has a very high hardness of 2200 Hv, the hardness of HVOF coating of WC-CoCr based powder is lower than 1200 Hv [2]. In addition, compared to other conventional spray coating such as flame spraying and plasma spraying, although the bonding strength of the HVOF coating with substrate is greater, the application of this coating is limited because of poor interface characteristic[3].

Therefore, a heat treatment may be necessary in order to reduce further the porosity and to improve the mechanical properties of coatings. However, the mechanical and wear resistance of the coating with conventional heat treatment was not improved or slight [4]. Other methods, such as laser treatment, have also been used to densify the coatings to eliminate porosity and enhance the coating strength, chemical homogeneity and other performance [5].

In the present study, the results from an experiment study to investigate the microstructure and microhardness of HVOF-spray WC-CoCr coatings before and after laser heat-treatment are reported.

2. Experimental

WC-CoCr powder (86wt% WC, 10wt% Co and 4wt% Cr) is coated on Inconel 718 substrate by JK3000 HVOF thermal spraying equipment. The substrates are pre-cleaned in acetone for 5 minutes and then blast cleaned by 60 mesh aluminum oxides. And the HVOF spraying parameters are listed as: 38 O2 flow (FMR), 61 H2 flow(FMR), 7 Spray Distance(inch) and 25 Feed rate(g/min).

The equipment used for laser heat treatment is a 5 kW TJ-HL-T 5000 type continuous wave CO2 laser system.Laser heat treatment parameters are: 400 W laser power, 400 mm/min scanning speed, 20 W/mm2 power density and 0.8 seconds laser irradiation on a spot. The samples are heat-treated in furnace at 150 ℃ for 2 hours before and after laser heat treatment.

Microstructures and phases of the coatings are investigated by OM, SEM and XRD. The depth profile of microhardness ismeasured by Vickers hardness tester with load of 1.96 N and loading time of 10 s.

3. Results and discussion

3.1 Microstructure of HVOF and LT coatings

Fig. 1 shows back scatter SEM images from polished cross sections of HVOF WC-CoCr coating from near surface to interface with the substrate before and after LT. Though a remarkable change has not taken place in the microstructure of the HVOF WC-CoCr coatings before and after LT, the LT has eliminated the pores almost entirely providing a more homogeneous and densified microstructure. That indicates the laser treatment with 400 W power and 400 mm/min scanning velocity process to the HVOF WC-CoCr coating is a suitable power density. However, it should be noted that holes of considerable size appeared occasionally, probably due to the formation of gas pockets in the coating by LT. As seen in Fig. 2 (a), a porous strip with width of 1-3 μm appears in the HVOF WC-CoCr coating. Fig. 2 (b) shows the compact interface of the coating with substrate is achieved by LT, which is advantageous to improve the bonding strength of the coating with substrate.

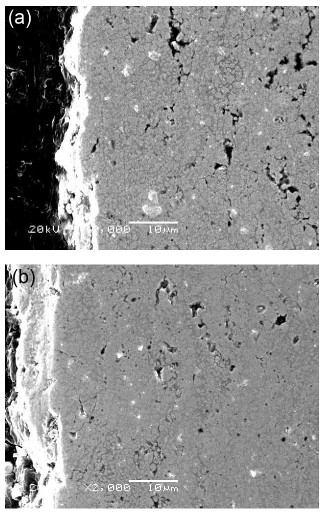

Fig. 1 Microstructure of HVOF WC-CoCr coating near surface before (a) and after (b) laser treatment

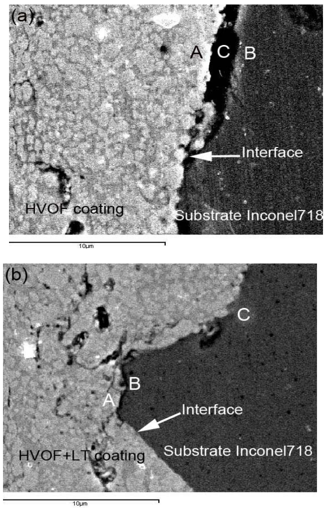

Fig. 2 Microstructure of HVOF WC-CoCr coating at interface before (a) and after (b) laser treatment

3.2 The porosity of the coatings

Fig. 3 shows the optical micrographs of the unetched cross-sections of HVOF-sprayed WC-CoCr coatings before and after LT. The average porosity of the HVOF-sprayed coatings is equal to 2.2% in volume; after laser heat treatment, the porosity can be considered practically null. The structure of the coatings was densified as LT. After laser heat treatment, the thickness of the coating has decreased from 300 μm to 225 μ m (Fig. 3). Sintering during high temperature heat treatment fills up the voids. It may also be possible that the small and thin oxide layers on the splats in the HVOF process enhanced easily splat boundary bonding and better intimacy between layers.

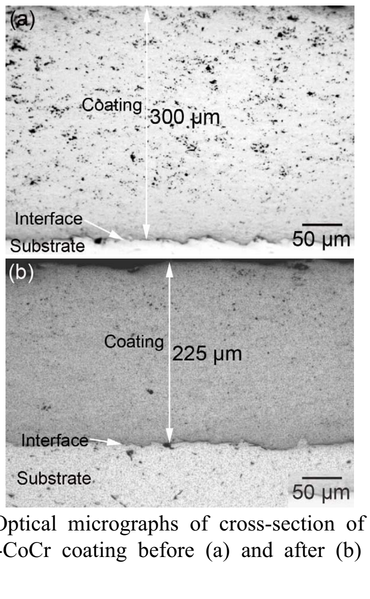

Fig. 3 Optical micrographs of cross-section of HVOF WC-CoCr coating before (a) and after (b) LT

3.3 The microhardness of the coatings

Fig. 4 shows the variation of microhardness along the depth for the various coatings before and after LT. The values of microhardness for each HVOF-sprayed coating are non-uniformly distributed along the depth due to the existence of discrete splats, pores and the WC hard phase [6]. After laser treatments, average value of microhardness of the coating increases drastically from 1161.7 Hv to 1579.8 Hv, but more non-uniformly distributed along the treatment depth due to the reduction of the remelted depth. In addition, the microhardness of the coating is increased with the decreasing the porosity of the coating cross-section. What's more, the laser treatment has produced a considerable increment in the hardness of the coating near surface whose average value increases from $Hv_{0.2}$=1262.4 in the HVOF-sprayed coating to $Hv_{0.2}$=1818.7 in the coatings treated with laser; this means an increment of 44.1%.

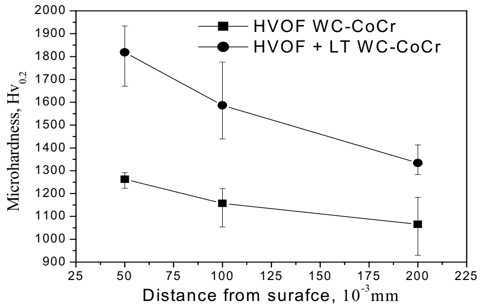

Fig. 4 microhardness of cross-section of HVOF WC-CoCr coating before (a) and after (b) LT

4. Conclusions

Compared to HVOF WC-CoCro coating, the laser treatment has eliminated the pores almost entirely providing a more homogeneous and densified microstructure. And the compact interface of the coating with substrate is achieved by laser treatment. As a result, the average porosity is five times higher in HVOF coating than in the coating by laser treatment. The laser treatment has produced a considerable increment in the hardness of the coating near surface whose average value increases from $Hv_{0.2}$=1262.4 in the HVOF-sprayed coating to $Hv_{0.2}$=1818.7 in the coatings treated with laser.

Acknowledgement

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