MICROSTRUCTURE CHANGE OF LASER SURFACE REMELTING WC-Co COATING①

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ABSTRACT Microstructure change of laser surface remelting WC-Co coating has been studied in detail by optical microscope and SEM. The results demonstrate that with increasing laser power and scan time, microstructure change order is as follows:

WC particles+Co+gasholes→WC particles+Co→WC particles+Co+dendrites→eutectic structure.

Key words WC-Co laser surface remelting microstructures

1 INTRODUCTION

WC-Co as a good wear-resistant alloy has been widely applied in industry. Especially in recent years, great attentions have been paid to the alloy being used as surface coating, thus not only keeping the excellent comprehensive mechanical properties in workpiece core part, but also improving surface wear-resistance greatly. At the same time, a large amount of tungsten and cobalt can be saved in industrial applications.

The main forming methods of WC-Co surface coating are plasma spray, laser surface remelting as well as cladding[1, 2, 3]. But the bonding strength between plasma spray WC-Co coating and substrate is lower, and there are many gases in the coating. For eliminating the faults, laser surface remelting treatment is adopted after plasma spray. In this paper, the microstructure change regulation has been studied by laser surface remelting plasma spray WC-Co method, so as to lay the theory base for optimizing microstructure and industrial application.

2 EXPERIMENTAL

Experiments were made with 2 kW CO_2 lasers. Scan speed and distance are precisely controlled by a microcomputer. Defocus plus oscillating method was adopted for getting uniform distribution of laser power density. Defocus value is 45 mm, oscillating frequency is 30 Hz. Sample is $d150\ mm \times 10\ mm$ SKD61 circle. There is a 50 μm thickness plasma spray WC-17Co(%) Co coating on its surface.

Laser processing parameters: when 4 mm/s scan speed and 5 mm scan width were chosen, the laser power were 1 200, 1 000, 900, 800, 700, 600, 500, 400, 300 W; when the scan speed was 2 mm/s, the scan width was 5 mm and the power was 700 W. A time interval was allowed for cooling of previous track and substrate before starting next track. Ar gas was used to protect surface from oxidation.

3 RESULTS

Fig. 1 is the cross-section microstructure of sample after plasma spraying 50 μm WC-Co

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Fig. 1 Cross-section microstructure of sample after plasma spray 50 μm WC-Co coating, ×400

coating. Top grey part is rasin for making sample, the part next to the top is the WC-Co coating, bottom part is SKD61 substrate. The microstructure of the coating part consists of WC particles and Co surrounding WC particles as well as many small gasholes. The bonding between WC-Co coating and SKD61 substrate is mechanical. There is an obvious interface between them.

When the 4 mm/s scan speed, 5 mm scan width and less than 600 W power were adopted, the laser remelting zone is made up of WC particles and Co surrounding WC as well as many big gasholes, as shown in Fig. 2. At this processing parameter extent, the higher the power value, the bigger the gasholes. The remelting depth is less than 50 μm.

With increasing laser power, the melting depth increases. When the depth is a little deeper than the coating thickness, the remelting zone is composed of WC particles and Co phase surrounding WC. The gasholes almost disappear. At this time, the bonding between the remelting zone and substrate is metallurgical, as shown in Fig. 3. It can be found from Fig. 3 that the WC particles uniformly distribute in the Co substrate. The WC volume fraction is about 70%, its size is less than 3 μm. The microhardness of remelting zone can reach HV 1 360 (1 N). This kind of microstructure not only has very good wear

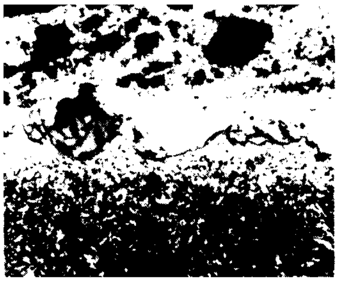

Fig. 2 Cross-section microstructure after laser surface remelting
(500 W, 5 mm, 4 mm/s)

resistance, but also has high toughness. It is a kind of ideal particle reinforced composite.

With increasing laser power further, the remelting depth also increases. WC particles take place dissolution partly and the SKD61 base melts partly too. The microstructure in the melting zone is made up of WC particles and dendrites as well as network-like structure around the dendrites, as shown in Fig. 4. The WC particles are usually located in middle or bottom parts. The higher the power, the finer and fewer the WC particles, the deeper the depth melting into substrate.

When the power is 700 W, the scan width is 5 mm, the scan speed is 2 mm/s, the microstructure in the remelting zone consists of eutectic structure, as shown in Fig. 5. The eutectic structure presents chunk cell, its size is less than 10 μm. The distance between lamellae is less than 0. 5 μm.

4 DISCUSSION

As shown above, when the power is lower and the remelting depth is less than the coating thickness, there are many gasholes in the remelting zone. The size of some gasholes is bigger than 250 μm. This greatly decreases the properties of the surface. The gashole forming mechanism is as follows.

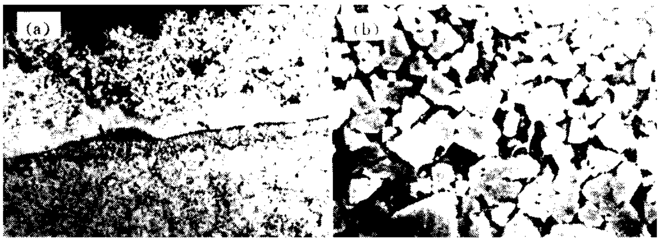

Fig. 3 Surface composite of WC particle reinforced Co base in laser surface remelting zone (700 W, 5 mm, 4 mm/s)
(a)—×400; (b)—×5 000

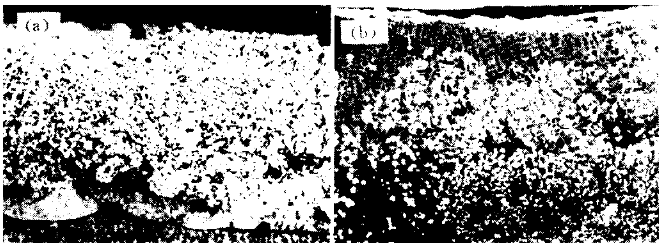

Fig. 4 Mixture structure in laser surface remelting zone (800 W, 5 mm, 4 mm/s)
(a)—×400; (b)—×1 000

Fig. 5 Eutectic structure in laser surface remelting zone (700 W, 5 mm, 2 mm/s)
(a)—×400; (b)—×10 000

There are many small gasholes in the original plasma spray WC-Co coating. When laser irradiates, the temperature of the surface coating increases suddenly and the gas of small gasholes is heated to expand rapidly. If the temperature is lower than Co melting point, the surface coating is solid and it is very difficult to deform because of its high strength in solid state. At this time, the gas of the small gasholes can not expand freely. Instead of this, the pressure in small gasholes increases. With increasing laser irradiation time, the temperature of the surface coating reaches Co melting point rapidly and Co becomes molten, the small gasholes can expand and form big gasholes. The big gasholes can not float out and remain in the remelting zone because the time that the molten state exists is short and the viscosity is big.

When the remelting depth is less than the coating thickness, the deeper the remelting, the more the gasholes collection chance, therefore the biger the gasholes.

When the laser power increases and the remelting depth is a little deeper than the coating thickness, the big gasholes almost disappear and the microstructure in the remelting zone is composed of WC particles reinforced Co base composite. Under this condition, not only there is enough time for the big gasholes to float out, but also it is ensured that WC dissolves very little. This is because that the melting points of WC and Co are rather different. They are 2 777 ℃ and 1 495 ℃ respectively, hence if the temperature in surface zone is higher than 1 495 ℃ and lower than 2 777 ℃, as well as the time that Co is in molten state is shorter, the composite of WC particle reinforced Co base alloy can be obtained, as shown in Fig. 3.

With increasing laser power further, the remelting depth increases too and the time that Co is in molten state becomes long. This results in part dissolution of WC. On the other hand, Fe, Cr elements etc melted in the substrate enter coating zone and mix with the coating, finally the alloy melt including Fe, Co, Cr, WC is formed. WC particles sink into the middle or bottom part of the remelting zone because of its higher density than the alloy melt. The alloy melt solidifies during sequent cooling processing. As a result, the microstructure as shown in Fig. 4 is produced. X-ray diffraction results indicate that they are Fe-Cr, Co_3W_3C and WC etc. The material having the microstructure is very brittle and easily cracks because the hard and brittle dendrites connect mutually and become substrate.

With increasing laser irradiation time greatly, the time that surface zone is in molten state increases outstandingly and WC particles have enough time to dissolve. WC dissolution results in the raise of W, C contents in melt. When eutectic content is reached, the eutectic structure is formed, as shown in Fig. 5. X-ray diffraction demonstrates that it is the eutectics of Fe-Cr and Co_3W_3C. To sum up, the key of plasma spray WC-Co plus laser surface remelting is to control WC dissolution.

5 CONCLUSIONS

(1) With increacing laser power and scan time, four kinds of microstructures, that is, WC particles + Co + big gasholes, WC particles + Co, dendritic Co_3W_3C + (Fe, Cr) + WC particles, Co_3W_3C + (Fe, Cr) eutectics, can be orderly obtained.

(2) Big gasholes are results of the sudden expansion of small gasholes in the plasma spray coating.

(3) Different microstructures result from the different levels of WC dissolution. Therefore the microstructure can be controlled through controlling WC dissolution.

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