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To cite this article: Wei Zhang *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **585** 012006

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Microstructure and Property of Fe-based Wear-resistant Alloy Coating Prepared by Laser Cladding on the Surface of Super High-speed Elevator Parts

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Abstract. Aiming at the problem of poor wear-resistance of wear-resistant parts used in super high-speed elevator, the experiments of laser cladding to prepare composite coating were made. Fe-Cr-Ti-V-Mo-C powder was used as cladding material. The microstructure and property of composite coating were tested by relevant equipment. The research results show that the composite coating is made up of Cr_3C_2 , TiC, VC, WC, Fe_3C , Fe-based solid solution. The carbides present as network-like and distribute in solid solution. The average hardness of composite coating is 743 HV0.2, which is 91% higher than that of matrix. Using this technology to the surface strengthening of elevator parts, the wear resistance and service life can be greatly improved.

1. Introduction

Super high-speed elevator generally refers to the elevator which runs faster than 6 m/s or is used when the height of the building exceeds 100 m. With the increasing population concentration, more and more skyscrapers are built in cities, and the corresponding demand for super high-speed elevators is growing. The manufacturing level of super high-speed elevators has become one of the symbols to measure the scientific and technological strength of elevator enterprises [1-2]. High-quality elevator machine must be based on high-performance elevator parts. Especially some key components, such as traction wheel, safety clamp, brake shoe, rope clamp and so on, belong to the core components of elevator safety system. Their quality directly determines the accuracy, safety and life of elevator [3-4]. The above parts work under the complex and tough conditions of impact, vibration, friction, high pressure and tension, bending and torsion loads. They are prone to wear, fatigue, fracture, deformation and so on. The performance requirements for manufacturing materials are higher than those of ordinary elevator wear-resistant parts. If the above parts are made of high hardness materials, the cost is high and the processing technology is difficult. Beside these, the whole high hardness material is easy to brittle fracture. Therefore, in order to prolong the service life of the above parts, surface strengthening is a feasible method.

Laser cladding technology is a surface modification technology which has developed rapidly in recent years. The process of coaxial powder feeding (as shown in Figure 1) is adopted. The high-energy laser beam radiates to the surface of the substrate and forms a liquid melting pool. Driven by the carrier gas, the cladding powder sprays along the circular conical nozzle coaxial with the laser beam and injects into the melting pool after it converges in the air. With the help of the robot arm, the laser head moves along the predetermined trajectory. After the laser is removed, the molten pool solidifies rapidly, forming a cladding layer [5-6]. Laser cladding technology has become a research



hotspot in the field of surface strengthening of key parts because of its high laser power, wide range of forming materials, controllable cladding layer performance, high degree of automation and free forming [7-10]. In view of the special working conditions of elevator parts, the composition design of Fe-Cr-Ti-V-C powder was carried out. The high temperature wear resistant coating was clad on the surface of the abrasive parts of the super high speed elevator to improve the service life of elevator parts.

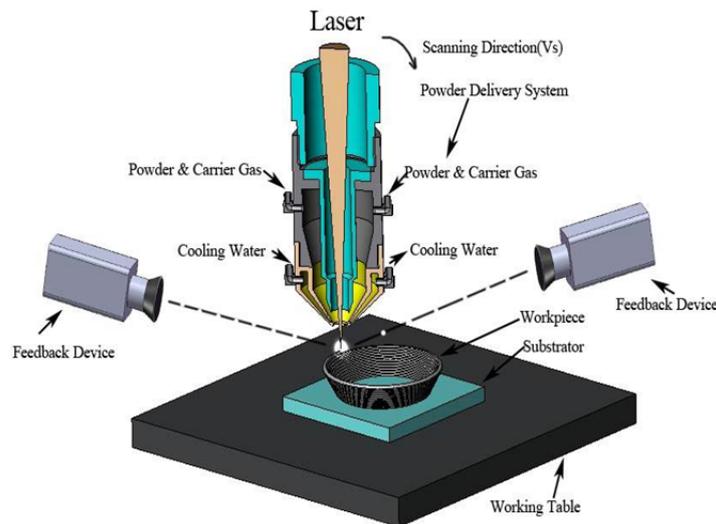


Figure 1. Schematic representation of coaxial powder feeding laser cladding

2. Material and Methods

45 steel was used as matrix material in the experiment. Fe-Cr-Ti-V-Mo-C alloy powder with the chemical composition shown by Table 1 was used as cladding powder. The alloy powder was uniformly mixed by ball mill and sprayed and granulated with an average particle size of 50 μm . LASERLINE LDF4000-1000 fiber-coupled semiconductor laser, KUKA KR 120 R2500 Pro six-axis industrial robot and control system were used for laser cladding experiments. Coaxial powder feeding single-channel cladding process was adopted. The powder feeding rate was 5-15 g/min, the carrier gas velocity was 3-10 L/min, the laser power range was 0.5-1.2 kW, the beam diameter was 3 mm, and the scanning rate was 5-8 mm/s.

After the experiment was completed, the test samples were prepared by wire-electrode cutting, embedding, wear, polishing and erosion. Corrosive agent is 4% nitric acid alcohol solution. Zeiss SUPRA 55 scanning electron microscopy (SEM) and energy dispersive spectrometer (EDS) were used to analyze the morphology and energy spectrum composition of the samples, and HXS-1000AY vickers hardness tester was used to measure the hardness distribution (load 200 g) of the cross section of the samples.

Table 1. Chemical composition of Fe-based alloy powder (wt%)

C	Cr	Ti	W	V	Mo	Fe
1.0	10	10	10	5.0	3.5	Bal.

3. Microstructure

Figure 2 was the microstructure of cross section of laser cladding layer (scanning rate 5 mm/s, laser power 1.2 KW). Figure 2(a) was the low-power morphology of the cladding layer. From the figure, we could see that the structure of the cladding layer was compact, without cracks and pore defects. Figure 2(b) and Figure 2(c) were the upper metallographic morphology of the cladding layer. It could be seen that the cladding layer mainly consisted of black and white structure, and the white structure presented a network uniform distribution in the black structure. Fixed-point energy spectrum analysis of the

above two kinds of tissues showed the results as shown in Table 2. Figure 2(d) showed the metallographic morphology of the middle and lower parts of the cladding layer. It could be seen from the figure that the cladding layer and the matrix were metallurgically combined, and there was no problem of shedding.

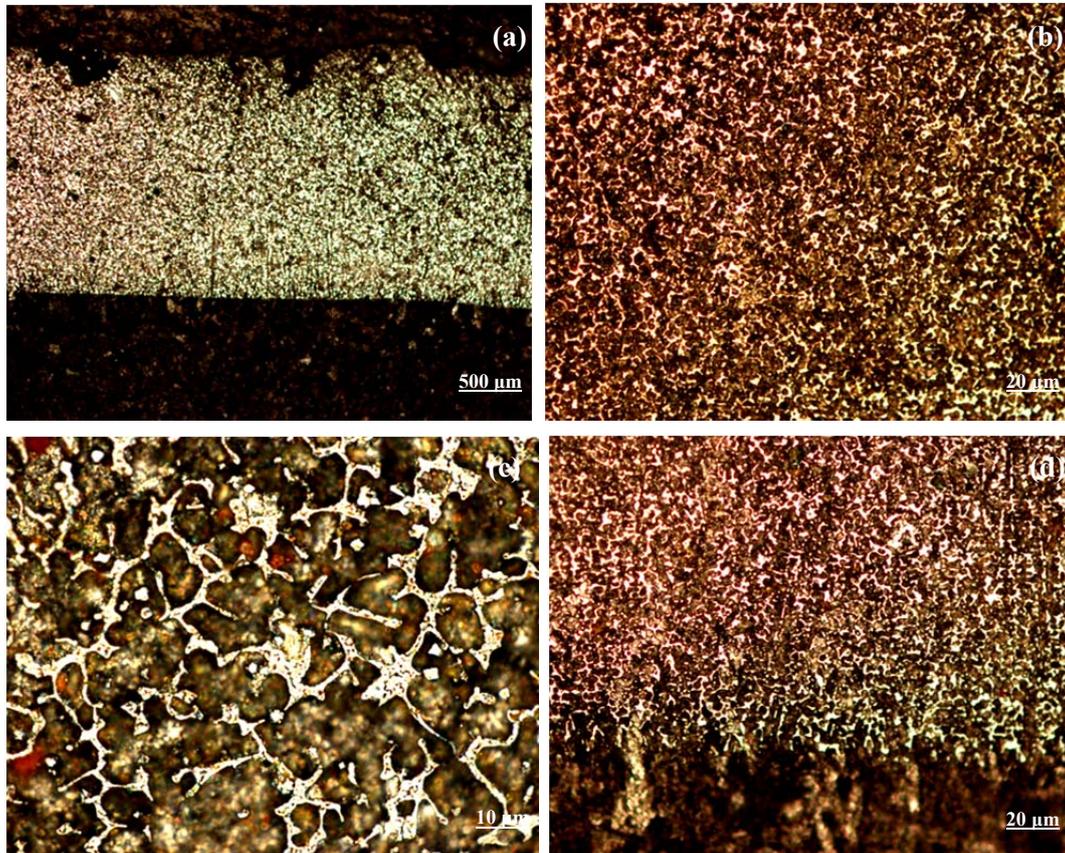


Figure 2. Microstructure of cross-section of laser cladding specimen (a) full view of cross-section (b) upper zone, low magnification (c) upper zone, high magnification (d) middle and bottom bonding zone

Table 2. EDS results of different position in cladding coating

Position	Percent	C	Cr	Ti	V	W	Mo	Fe
Network	Mass %	17.62	16.60	11.79	9.48	11.19	2.98	30.34
	Atom%	51.43	11.18	8.62	6.52	2.14	1.09	19.02
Base	Mass%	3.48	9.42	8.17	2.34	1.02	1.96	73.61
	Atom%	14.28	8.87	8.38	2.27	0.27	0.98	64.95

From Table 2, we could find that the two kinds of tissues basically contained seven elements of Fe, C, Cr, Ti, V, W and Mo, but the contents were quite different. The six elements C, Cr, Ti, V, W and Mo mainly came from the cladding powder, while the element Fe came from the cladding powder and the melting matrix. Because the structure of the cladding layer was superfine and the sampling range of point energy spectrum was large, it was difficult to avoid that the results of energy spectrum analysis contained many elements. From the content point of view, dense network structure mainly consisted of C, Fe, Cr, Ti and W. Combining with morphology analysis, it should be a framework composed of Cr_3C_2 , Fe_3C , VC, WC, TiC and other carbides. Black matrix structure mainly consisted of Fe and should be a Fe-based multielement solid solution.

Based on the above analysis, when the high energy laser beam irradiated the mixed powder, the powder melted instantaneously to form a liquid melting pool. During the progress of solidification, carbides with high melting point such as TiC, Cr_3C_2 , WC, VC and Fe_3C , nucleated and precipitated.

Because of the large temperature gradient of the cladding layer, the carbides tended to grow along the dendrite. With the decrease of temperature, Fe-based multielement solid solution was obtained between dendrites after solidification.

4. Microhardness

The hardness distribution curve of cladding specimen was shown in Figure 3. The average hardness of laser cladding layer was 743 HV0.2. The average hardness of matrix was 386 HV0.2. The hardness of cladding layer was 91% higher than that of matrix, and the hardness presented gradient transition, which was conducive to improve the wear resistance of cladding layer. The high hardness of the cladding layer was the result of the combined action of fine grain strengthening, dispersion strengthening and solution strengthening. The laser cladding layer had fine grains, more grain boundaries, larger impediments to dislocation movement and was difficult to expand plastic deformation. The darker matrix phase of the cladding layer was Fe-based multielement solid solution. The solute elements such as Cr, Ti, V, W and C could cause lattice distortion and greatly increase the grain strength. Hard carbides of elements such as Cr, Fe, V, W and Mo in the cladding layer played a role of dispersion strengthening and greatly improved the hardness of the cladding layer.

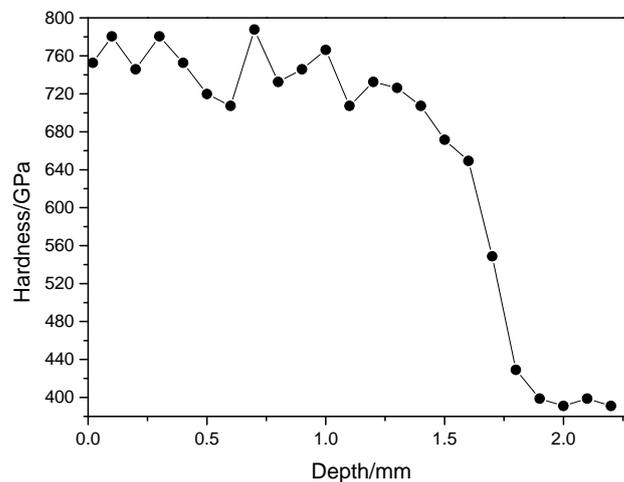


Figure 3. Hardness distribution curves of laser cladding

5. Conclusions

[1] Using Fe-Cr-Ti-V-Mo-C alloy powder as raw material and optimized laser cladding parameters, the cladding layer with dense structure, no cracks and pore defects could be obtained.

[2] By in-situ reaction, the structure of the cladding layer was TiC, Cr₃C₂, Fe₃C, WC, VC and other carbides and Fe-based multielement solid solution. The carbides were distributed uniformly on the solid solution matrix in a network form.

[3] The average hardness value was 743 HV0.2, which was 91% higher than that of the matrix. It could greatly improve the wear resistance. Its application in the strengthening field of elevator wear-resistant parts would produce great economic value.

6. Acknowledgements

The authors would like to appreciate financial support from research project of public welfare technology application in Zhejiang province (Grant No.2017C31057).

7. References

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