Microstructure and property of laser cladding Ni-based gradient wear-resistant coating

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Abstract

The alloy powder of St6, St12B and Ni60+5%w (WC) was successively fused on the surface of 20CrMnMo steel by laser cladding to fabricate the Ni-base gradient wear-resisting coating which thickness was about 2.4mm, and then microstructure analysis and property test were carried out. The results showed that the surface layer appeared the dense amorphous crystals, the transition layer appeared the large columnar crystals, and the bottom layer appeared the flat crystals and dendrites. The microhardness of wear-resistant layer reached 683HV0.1, and the wear resistance increased by 300% compared with the substrate. These results provide a reference for the preparation of Ni -based gradient wear-resistant coating by laser cladding.

Keywords

Laser cladding, Ni-based, gradient wear-resistant coatings, microstructure, property.

1. Introduction

In some industrial areas such as aerospace and equipment manufacturing, many components and parts were required to work in the scurviness conditions such as high temperature, high pressure and rough wear[1]. The heat treatment of 20CrMnMo steel with carburize, boron or nitride is fabricated the products such as manufacturing camshaft, gear, pin shaft, which is often used in the above working environment [2-4]. The laser cladding can produce excellent abrasion resistance, high temperature resistance and high - density metallurgical coating [5]. The high thickness gradient wear-resistant coating was fabricated by laser cladding is greatly concerned because of its many excellent properties. Dong jiang[6]fabricated the Co-Ni-Cu gradient coating with a hardness of up to 655HV, and the coating was well combined, and the composition, tissue and thermal physical properties were all distributed in a gradient. Pan X[7]fabricated the Ni/Co - base alloy composite coating on the 1Cr17Mn6Ni5N stainless steel surface by laser cladding, and found that its increased by 51%. Dai D Q[8]fabricated coatings on the 1Cr12MoV steel surface with Stellie6 and Ni60 alloy powder respectively by laser cladding, and found that hardness and wear resistance of the coating with Ni60 alloy powder are better than that of Stellie6 alloy powder. The above study did not describe such high thickness gradient wear-resistant coating was fabricated with the Ni-based alloy powder by laser cladding.

In this paper, the high thickness Ni-based wear-resisting coating was fabricated with the different kinds of alloy powder successively by laser cladding, and then its microstructure and property were researched..

2. Experimental details

2.1 Materials

In this study, a die cast plates of 20CrMoMn steel was used as target for laser surface melting, of which the size was 50mm×30mm×5mm. Their chemical composition is as follows: 0.17-0.23wt%C, 0.17-0.37wt%Si, 0.9-1.2wt%Mn, 1.1-1.4wt%Cr, 0.2-0.3wt%Mo, 0.03wt%Ni, 0.035wt%P, 0.035wt%Si, 0.03wt%Cu, and Fe in balance.

The composite powder of St6, St12B andNi60+5%w (WC) was used as laser cladding material. The powder particle sizes range from 45μm to 105μm.

2.2 Experimental setup and procedure

Laser cladding experiments conducted on the KUKA robot system, which match HL4006D Nd: YAG laser, the type of powder feeding device is PFL- 2A, the method of synchronous side-injection feeding powder is used, and the shielding gas is argon. The laser parameters: laser power: 800W, coke amount: 10mm, feeding rate: 4.75g/min, scanning speed: 6mm/s, lap rate: 30%. Finally, the 2.4mm thickness of coating was obtained.

2.3 Characterization

Cross-section of the Ni-based gradient wear-resistant coating was sectioned by wire-electrode cutting, mounted in bake lite, polished and etched using 5%Nital solution. The microstructure of the coating was analyzed by optical microscopy (OM). The microhardness measurement was conducted on the cross-sections of the melted zone and as-received using the Vickers Microindentor (HMT-3) with the loads of 100g applied for 10s. The tribological property was measured using a pin-on-disc wear tester (HT-1000) at room-temperature, sliding contact against the GCr15 steel ball (5 mm in diameter, 60–65HRC, and mass fraction: C:0.95%–1.1%, Si:0.15%–0.35%, Mn:0.5%, P:0.025%, Cr:1.3%–1.6%). The test was run at the constant normal load of 200N, the rotation speed and time were 200 r/min and 30min, respectively. The wear resistance was determined by measuring the mass loss and friction of the samples.

3. Results and discussion

3.1 Microstructure

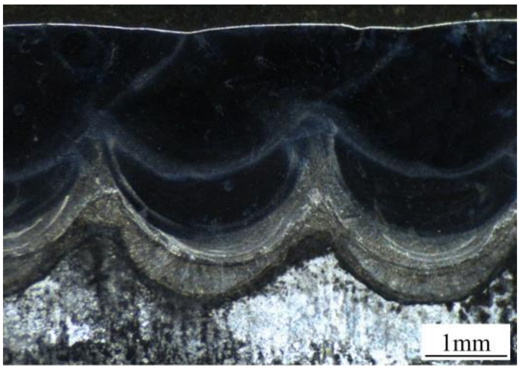

Fig.1 Micromorphology of the gradient wear-resistant coating

Fig. 1 shows the appearance of the Ni60+5%w (WC) gradient wear-resisting coating. Some distinct white bands were found in junctions, and the width became larger and larger from the wear-resistant layer to the transition layer, and then from the bottom layer to the substrate. The analysis suggests that the influence of the heating times and each melted layer with different powder, so this phenomenon occurs. The diffusion of the elements in the melting pool makes the elements of the adjacent coatings sufficiently diffuse and fuse to generate white bands.

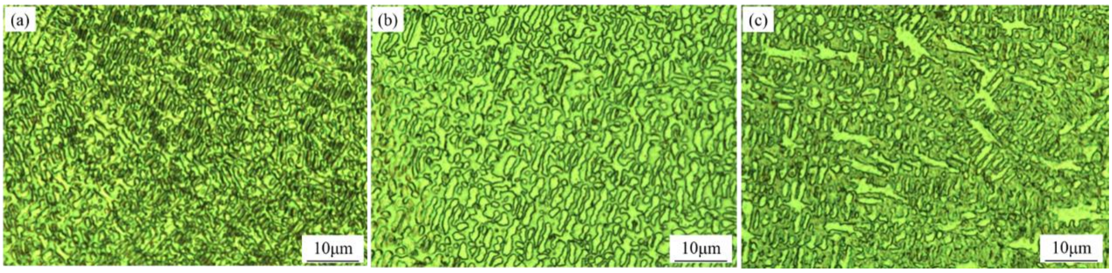

Fig.2 Microstructure of the gradient wear-resistant coating

As shown in Fig.2(a), the crystals and the black hard phase were found in the wear-resisting layer, and the crystals size were small and dense. When alloy powder was heated by laser irradiation, Ni60 and most of the WC elements melt because of its high laser power. Due to the gravity, buoyancy, temperature gradient, and the role of liquid surface tension in the molten pool, the WC and Ni elements appear to spread quickly, and then form a strengthen phase. When the G/Vs[9]value of the wear-resisting layer is small, the dendritic orientation is mainly determined by the anisotropy of crystallography. Due to G value is very large, the crystals could crystallization but it is too late to grow, so the dense equiaxial crystals were formed.

As shown in Fig.2(b), the columnar crystals and a small amount of black reinforcement were discovered in the transition layer. As the decrease rate of VS value is less than G value, G/VS value is larger than the surface. Solidification crystallization process is close to equilibrium solidification, hence it developed well directional property and the good uniformity of columnar crystal. The occurrence of black hard phase is due to the diffusion of the WC and Ni elements in molten pool, and then a strengthen phase is formed.

As shown in Fig.2(c), the columnar crystals and some of the large dendrites were found in the bottom layer. Though G value is very small, VS value tends to zero, so the G/Vs value is even larger, the solidification crystal orientation along the direction of heat flow form columnar crystal growth, and because of the G value is very small, prompts some crystals to keep growing, and then the dendrites are formed.

3.2 Hardness and wear resistance

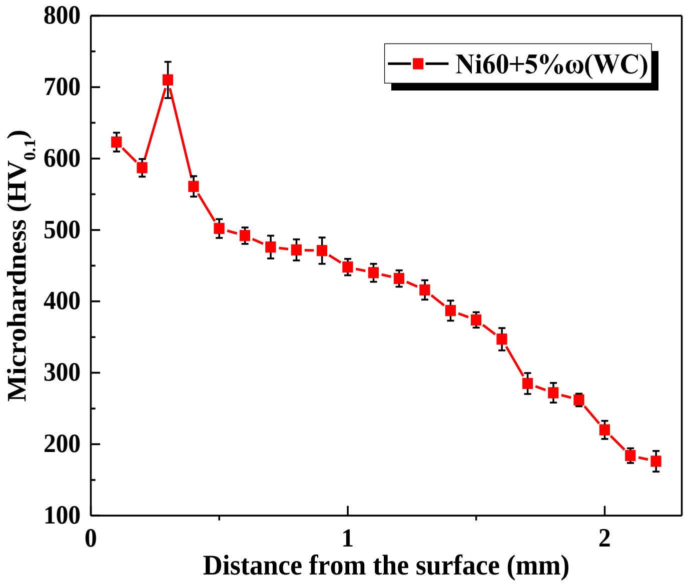

Fig.3 Micro hardness of the gradient wear-resistant coating

As shown in Fig.3, Ni60 + 5%w (WC) of laser cladding powder obtained by gradient coating surface hardness can reach 638 HV0.1. WC compound alloy powder melting point is 2780℃, and Ni60 melting point is 1027℃. When the powder was cladded by laser, the Ni60 melted absolutely and partially WC failed to melt and sank by gravity, caused the hard phase of surface to bring down. The mutation point of microhardness emerged at 0.3mm in which is far from the surface, and the melting point of WC is considered to be higher than that of Ni60, that the unmelted of WC is covered with the Ni60 and then a solid solution is formed.

The wear amount of Ni60+5%w (WC) is 2mg, and then the substrate is 8mg, which increases by 300%, this demonstrates that the wear-resistant coating can be improved by the laser cladding with Ni-based powder.

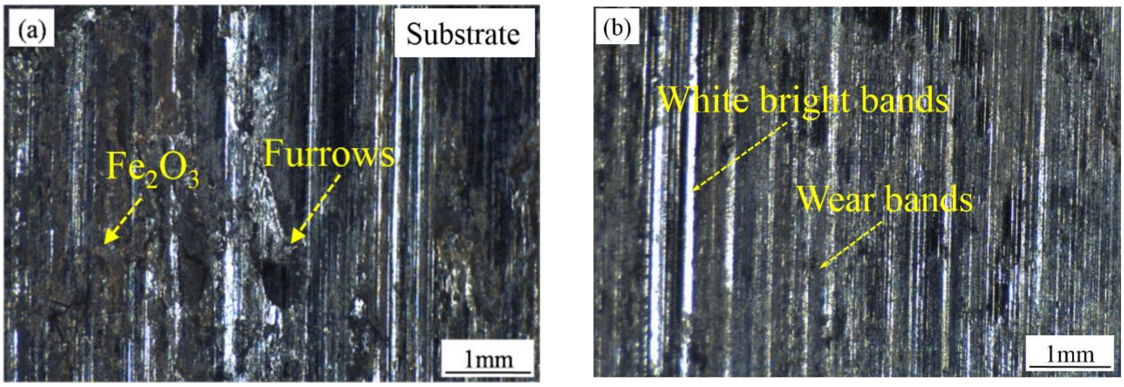

Fig.4 Wear morphologies of the gradient wear-resistant coating

As shown in Fig.4 (a), the surface appears the reddish-brown oxide layer and furrows. In the friction process, the effect of high temperature and moisture in the air caused the oxidation reaction on the surface of 20CrMnMo steel to generate Fe2O3, the partially high Fe2O3 oxide came off to grind the substrate to make it appear furrows.

As shown in Fig.4(b), the surface appears a large scale of flake wear bands and the white bright bands. In the friction process, the surface of GCr15 steel scraped against the wear-resistant layer as the hardness of wear-resistant layer is less than GCr15, and then the white bright bands produced.

4. Conclusion

(1) The 2.4 mm thickness of Ni-based gradient wear-resistant coating was prepared on the 20CrMnMo steel by laser cladding, the surface organization is densification and well-distributed, there is neither porosity nor crack. Then the metallurgical combination is found between the coating and substrate.

(2) In the microhardness test, the microhardness of the Ni-based gradient wear-resistant coating reached 638HV0.1, and the hardness appeared continuously and slowly.

(3) In the friction and wear test, it was found that the gradient wear-resistant coating of Ni60+5%w (WC) could significantly improve wear resistance. In the friction process, the surface of the substrate was oxidized, while the gradient wear-resistant coating of Ni60+5%w (WC) was scratched by the abrasive parts.

Acknowledgements

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