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Fabrication of Ni60+25%WC reinforced steel matrix surface composites by induction cladding

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Fabrication of Ni60+25%WC reinforced steel matrix surface composites by induction cladding

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Abstract: Failure of mechanical parts usually occur on the surface or start from the surface. such as wear, oxidation corrosion and fatigue. This work uses high frequency induction cladding technology to improve the overall performance of stainless steel surface. A layer of WC and stainless steel is coated on the surface of the stainless steel. The effects of different WC material contents and different induction heating current intensities on the cladding were analyzed. After the preparation of the sample, the morphology and properties of the cladding layer were analyzed by SEM, XRD and other test methods. The results show that when the content of WC is 2%-3%, the heating time is 90s and the heating current is 860A-890A. The surface of the cladding layer is most densely formed and there is no obvious over-burning phenomenon and pore generation.

1. Introduction

Induction cladding technology is developed on the basis of induction heating technology. Induction cladding is the pre-preparation of an alloy layer on the substrate of a work piece. The method uses high frequency induction equipment to heat. This cladding technique allows the preformed alloy layer to melt and form a metallurgical bond with the substrate. The cladding layer prepared by the high frequency cladding method is called a high frequency cladding layer. There are two main pre-fabrication methods for the induction cladding alloy layer: a pre-formed powder method and a pre-formed powder block method. High frequency induction cladding is a relatively economical high density energy surface modification technology. This technology adjusts the operating frequency of the device to allow heat to be concentrated in the area where heating is required. Thereby, the

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workpiece and the substrate can be metallurgically bonded. The heat of induction heating is concentrated on the surface layer, and the heat influence on the substrate is small. The induction cladding technology achieves two requirements of small thermal influence and strong bonding force between the substrate and the cladding layer[1-3].

The composite material obtains higher specific stiffness and specific strength, better heat resistance and lower coefficient of thermal expansion. At the same time, the particle reinforced metal matrix composite has good shape, toughness and workability. Particle reinforcement technology is mainly used under working conditions such as wear resistance, heat resistance and corrosion resistance. The ceramic particle reinforced metal-based surface composite material has the characteristics of good metal plastic toughness[4]. The surface cladding layer will also have the advantages of high hardness of ceramic particles and good wear resistance. The surface composite exhibits superior performance unmatched by single metal or ceramic particles. The Ni60+25%WC particles are used as reinforcements for the cladding layer. This is because the high melting point, high hardness, good wear resistance and stable performance[5,6]. WC has good wettability with steel, and the wetting angle between the two is almost zero.

In this work, the mixed Ni60+25%WC/316 stainless steel composite powders was prepared on the surface of 316L stainless steel by induction cladding. The purpose is to improve the mechanical properties of the stainless steel surface such as hardness and friction. Extend the service life of 316L stainless steel. By observing the macroscopic and microscopic morphology of the ball milled powder and the coated coating, the effect of Ni60+25%WC content and induction cladding current on the cladding layer was analyzed. It has certain reference significance for the preparation of stainless steel surface cladding layer.

2. Experiment

The matrix material in this work is 316L stainless steel. The cladding material is WC powder and 316 stainless steel powder. Ni60+25%WC powders with a mass fraction of 1%, 2%, 3%, and 4% were placed in the ball mill jar. The powder was uniformly mixed by ball milling for 1.5 h at a ball to material ratio of 7:1. The base 316L stainless steel was cut into a metal piece with a size of 25 mm × 25 mm × 4 mm. The 316L surface was pretreated with a 600-1500 mesh corundum gauze. The 316L stainless steel was then ultrasonically cleaned with a 98% alcohol solution. A rosin and turpentine mixture in a ratio of 1:3 was used as a binder. The powder of different ratios after the obtained ball mill was mixed and coated on the surface of 316L stainless steel by induction cladding.

3. Results and Discussion

3.1 Effect of different proportions of Ni60+25%WC and 316 stainless steel mixed powder on ball milling

The SEM photographs at different contents of the Ni60+25%WC/316 stainless steel composite powders after milling with content of 1%, 2%, 3% and 4% are in Figure1. As can be seen from the Figure 1, the mixed powder having a Ni60+25%WC content of 2% showed that the ball-milled particles were most uniform. At the same time, the ball dispersion showed the most uniform dispersion of Ni60+25%WC and 316 stainless steel powder. Moreover, there is no obvious bonding phenomenon on the surface of the 316 stainless steel powder. When the Ni60+25%WC content is 1% and 3%, the surface of the 316L stainless steel powder has obvious surface adhesion. The mixed powder particles are irregular in shape. When the content of Ni60+25%WC reaches 4%. The surface of 316L stainless steel powder is seriously damaged. A large amount of bonding occurs in the mixed Ni60+25%WC/316 stainless steel composite powder.

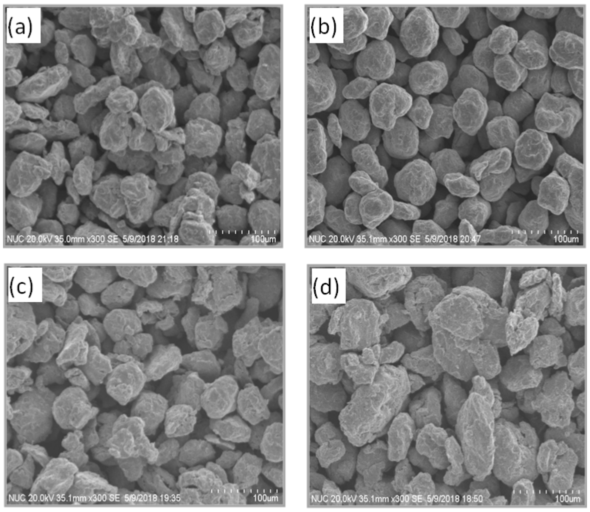

Figure1different contents of the Ni60+25%WC/316 stainless steel composite powders after ball milling

(a) 1%, (b) 2%, (c) 3%, (d) 4%

3.2 Effect of different proportions of Ni60+25%WC mixed powder on the cladding layer

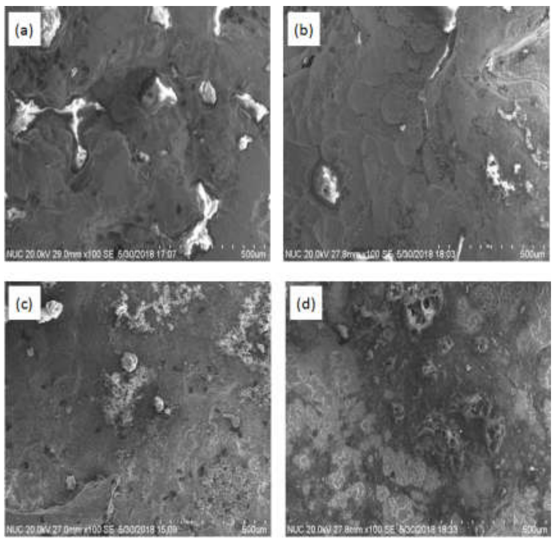

Figure 2 The SEM topography of coating microstructure with different Ni60+25%WC content

(a) 1%, (b) 2%, (c) 3%, (d) 4%

Figures 2 is SEM images of the cladding layer with WC content of 1%, 2%, 3%, and 4%, respectively. It can be seen from the picture that white particles appear in the cladding layers of different Ni60+25%WC content. These white particles are all melted precipitate phases of Ni60+25%WC. The picture shows the different Ni60+25%WC content in the cladding layer. SEM images of 1% and 2%

show that the surface of the cladding layer is relatively flat. There are no obvious holes and cracks on the surface of the cladding layer. And when the content of Ni60+25%WC is higher than 2%, porosity begins to appear on the surface of the cladding layer. The surface of the cladding layer becomes rough. It can be seen from the picture that the Ni60+25%WC content increases from 1% to 4%. The large particles originally formed on the surface of the cladding layer are gradually reduced and dispersed. At the same time they are accompanied by an increase in surface porosity.

In summary, with the increase of Ni60+25%WC content, it will reduce the deposition of WC on the surface of the cladding layer and increase the surface strength of the cladding layer. At the same time, however, it causes thermal agglomeration of Ni60+25%WC particles in the cladding layer. This will create a large number of pores on the surface of the cladding layer. Therefore, under the premise of combining SEM images, the WC content is most suitable at 2%-3%.

3.3 Effect of different induction heating current on cladding layer

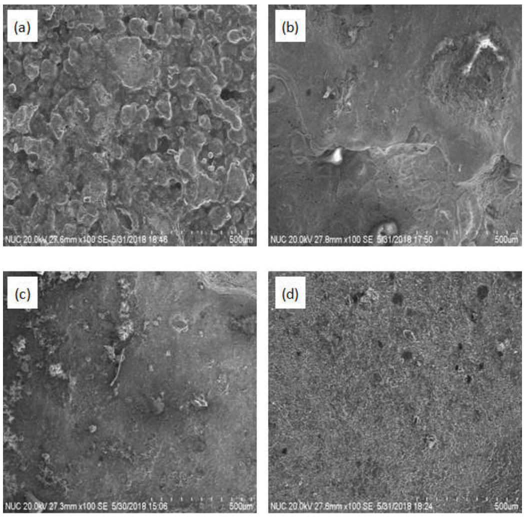

Figure 3 Topography of the cladding layer with different induction heating currents
(a) 830A, (b) 860A, (c) 890A, (d) 920A

Figure 3 shows the topography of the cladding layer with different induction heating currents of 830A, 860A, 890A, and 920A, respectively. When the induction heating current is 830A,a large number of grooves and holes appear on the surface of the cladding layer. The induced current is set to 860A-890A. It can be seen from the SEM image that the surface of the cladding layer is relatively flat. At the same time, there are no obvious defects and cracks on the surface. When heating current reaches 930A, the surface roughness of the cladding layer is increased. The surface produces a large amount of white particles[7,8].

In summary, the induction heating current is higher in a certain range. The resulted cladding layer will be denser and the surface strength will be better. It performs best in the range of induced currents of 860A-890A. When the induction heating current exceeds 890A, over burning may occur. This leads to a decrease in the strength of the cladding layer.. At the same time, it will cause damage to the substrate.

4 Conclusions

In this work, high frequency induction cladding technology is used to clad a Ni60+25%WC and stainless steel composite coating on the surface of stainless steel, in order to improve the comprehensive properties of stainless steel surface. With the increase of Ni60+25%WC content, the deposition of Ni60+25%WC on the cladding layer will be reduced, and the surface strength of the cladding layer will be increased. But at the same time, it will cause the thermal agglomeration of Ni60+25%WC particles in the cladding layer, resulting in a large number of surface pores. Therefore, in combination with the SEM image analysis, the WC content is most suitable for 2%-3%. The higher the induction heating current in a certain range, the denser the surface of the cladding layer and the better the surface strength. When the current is in the range of 860A-890A, the coating performs best. When the induction heating current exceeds 890 A, over burning may occur, which will lead to the decrease of the strength of the cladding layer and the damage to the matrix.

Acknowledgments

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References

[1] Chen X, Qin X, Gao K, et al. 2018 Microstructural Evolution of NiCrBSi Coatings Fabricated by Stationary Local Induction Cladding. Journal of Materials Engineering & Performance, p1-11.
[2] Yin J, Wang D Z, Meng L, et al. 2017 High-temperature slide wear of Ni-Cr-Si metal silicide based composite coatings on copper substrate by laser-induction hybrid cladding. Surface & Coatings Technology, p 325.
[3] Yu H L, Zhang W, Wang H M, et al. 2017 In-situ synthesis of TiC/Ti composite coating by high frequency induction cladding. Journal of Alloys & Compounds, p 244-255.
[4] Pines M L, Bruck H A. 2006Pressureless sintering of particle-reinforced metal–ceramic composites for functionally graded materials: Part I. Porosity reduction models. Acta Materialia, , p1457-1465.
[5] Sui Y, Han L, Jiang Y, et al. 2018 Effects of Ni60WC25 powder content on the microstructure and wear properties of WC p, reinforced surface metal matrix composites. Transactions of the Indian Institute of Metals,p1-8.
[6] Liu S L, Zheng X P. 2009 Microstructure and properties of AC-HVAF sprayed Ni60/WC composite coating. Journal of Alloys & Compounds, p254-258.
[7] Hong S I, Lee K W. 2005 Stress-induced reorientation of hydrides and mechanical properties of Zircaloy4 cladding tubes. Journal of Nuclear Materials, p203-208.
[8] Pinkerton A J, Li L. 2003The effect of laser pulse width on multiple-layer 316L steel clad microstructure and surface finish. Applied Surface Science, p411-416.