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EFFECT OF CeO_2 ADDITION ON HARDNESS OF INDUCTION HEATED Ni-WC COMPOSITE COATINGS

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Getting Ni-WC composite coatings with different rare earth CeO_2 additions on the substrate of 45 steel by induction heating; testing the surface hardness and cross-section microhardness of the coatings with Rockwell hardness tester and microhardness tester; meanwhile analyzing the microstructure and WC morphology of the coatings by scanning electron microscopy (SEM), in order to find the best amount of CeO_2 in the coatings. The results show that the 0,5 / % content of CeO_2 helps to improve the interfusion bonding between the coating and the substrate, and to refine the grain size, homogenize the composition and increase the hardness of the coating.

Keywords: steel, induction heating, CeO2 content, hardness, microstructure

INTRODUCTION

Induction heating alloy coating process is a new technology of modern surface metallurgy [1, 2]. It changes the composition and organization of the working surface of the base material, so that the material can meet the wear resistance, corrosion resistance, resistance to thermal fatigue and other various use requirements of the method [3-6]. The process can overcome some of the shortcomings of thermal spray coating, expand the application of alloy coating, and has been widely used in the exhaust valves of internal combustion engines, turbine engine blades, wire roll and other important positions [7, 8].

TEST CONDITIONS AND NETHODS

Specimen Preparation

The specimen substrate is rolled state 45 steel with the size of 15 / mm × 25 / mm × 10 / mm, the powder is the mix of Ni45B and rare earth CeO_2 according to the proportion of different additions. Chemical composition of Ni45B: C is 0,7 / %, Si is 3,5 / %, B is 3,0 / % Cr is 15 / %, Fe is less than 12 / %. Chemical composition of CeO_2: Cu is less than 0,002 / %, Fe is less than 0,002 / %, Rare earths (except Ce) is less than 0,5 / %.

The coating material is CeO_2 with additions of 0,0 / %, 0,25 / %, 0,5 / %, 0,75 / % and 1,0 / % and Ni45B. The alloy powder is ground and mixed and the 1,5 / mm thickness of powder is pre-placed on the surface of the specimen, and the coating with different CeO_2 additions is fused onto the surface of the substrate using medium frequency induction heating technology.

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Test Method

After dissecting and etching the specimen sections, SEM and EDS were used to observe the coating, matrix and WC microstructure. The distribution of elements in the specimen was measured by energy spectrometer, and the hardness of the coating surface and sections were measured by Rockwell hardness tester and micro hardness tester respectively.

EXPERIMENTAL RESULTS

Surface Rockwell Hardness

The surface slag of the coating with different CeO_2 additions was polished and the hardness of the surface of each coating was determined using a Rockwell hardness tester HR-150DT, the experimental results are shown in Figure 1.

It can be seen from Figure 1 that with the increase of CeO_2 addition, the Rockwell hardness of the coating

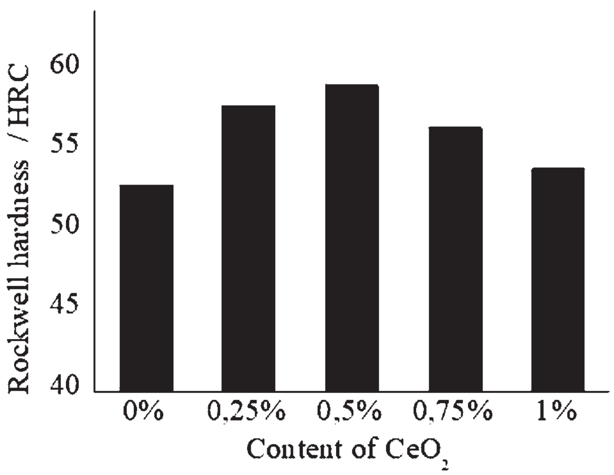


Figure 1 Rockwell hardness of coatings surface

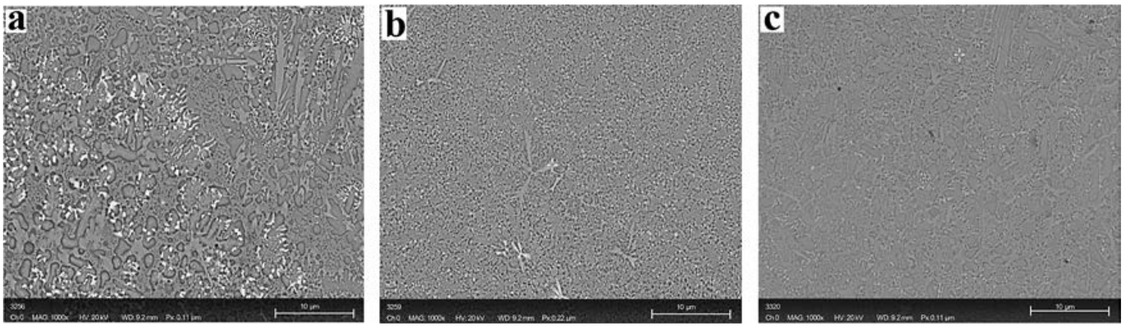
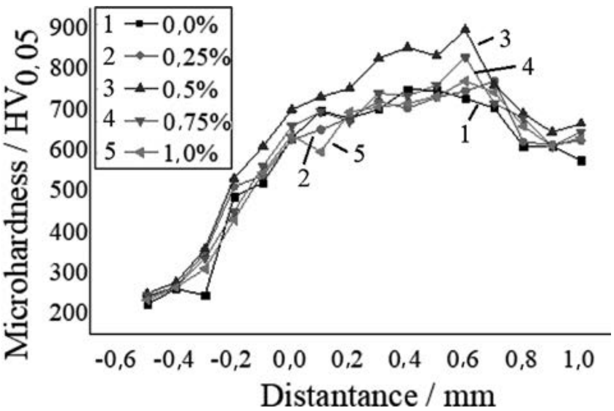


Figure 2 SEM of coatings' surface with different CeO_2 content (a) 0 / % CeO_2 (b) 0,5 / % CeO_2 (c) 1,0 / % CeO_2



Figrue 3 Microhardness linear diagram of coatings

surface increases first and then decreases. The lowest surface hardness of the coating without CeO_2 addition is HRC52,8, when CeO_2 addition is 0,25 / % the surface hardness of the coating increases to HRC57,8, when CeO_2 addition is 0,5 / % the surface hardness of the coating is the highest at HRC59,1, when CeO_2 When the addition amount of CeO_2 is 0,75 / % and 1 / % respectively, the coating surface hardness starts to decrease again to HRC56,5 and HRC53,85. It can be seen from the images that the addition of CeO_2 can improve the coating surface hardness, but there is an optimum value for the addition amount of CeO_2.

To explain this phenomenon more clearly, scanned photographs of specimens with CeO_2 content of 0 / %, 0,5 / % and 1,0 / % respectively are used as examples, as shown in Figure 2.

The surface structure of the coating without CeO_2 is relatively coarse, while after adding 0,5 / % CeO_2, the surface structure becomes obviously fine, thus improving the surface hardness. When excessive addition is made, the coating structure as shown in Figure 2 (c) becomes thicker and defects increase, thus reducing the surface hardness. Therefore, the surface hardness of the coating presents the above change rule.

Coating Cross-sectional Microhardness

Use the micro hardness tester to determine the coating cross-section microhardness. The experimental load is 50 / g, and the holding time is 12 / s. The microhardness is measured every 0,1 / mm from the substrate 0,3 / mm away from the cross section to the highest point of the cladding layer. Take the average of 3 points with small hardness changes at the same coordinate position. The measurement results are shown in Figure 3.

As can be seen from Figure3, the curves of the five different CeO_2 contents do not differ much and show an overall "mountain" shaped distribution, with a corresponding peak area in the range of 0,5 - 0,7 / mm from the bond. This is because the low melting point eutectic phase in the Ni-based alloy melts first at the melting temperature, while the un-melted hard phases containing Ni, high melting point carbide of Cr, borides and silicides float upwards, causing the hard phase content in the transition zone near the interface to drop, while the relatively large hard phase content on the outside of the coating leads to an uneven distribution of the hard phases in the coating and a "bi-polymerisation" of the hard phases on the secondary surface. The hardness maximum is 0,50 – 0,70 / mm from the interface, while it can be seen from the SEM photos that the addition of an appropriate amount of CeO_2 can effectively refine the morphology of the hard phase WC to improve the hardness of the coating, as shown in Figure 4.

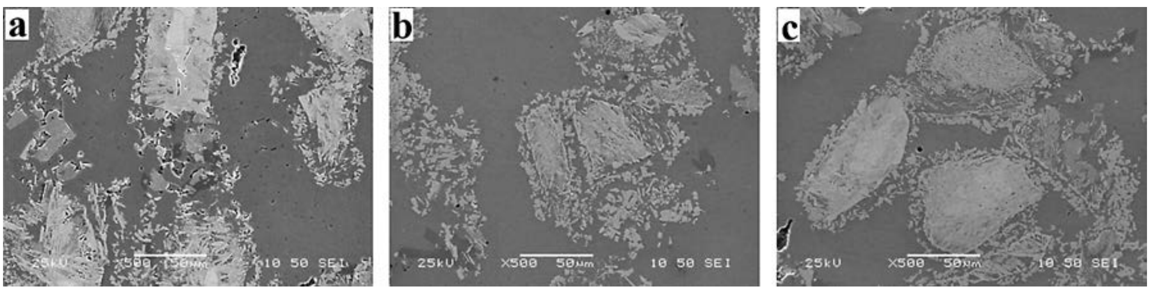


Figure 4 SEM of the coatings' longitudinal section with different CeO_2 content a) 0 / % CeO_2 b) 0,5 / % CeO_2 c) 1, 0 / % CeO_2

Five curves on the matrix side near the bond as the hardness rises near the bond, the hardness value rises from about 250 / $HV_{0,05}$ to about 550 / $HV_{0,05}$, there is no obvious step jump at the bond, which is far different from the hardness distribution of thermal spraying, spray welding and vapour deposition coatings at the interface, this gradient distribution feature of micro hardness is exactly the result of mutual diffusion of alloying elements occurring at the interface, which shows that the bond between the vacuum fusion burned coating and the matrix at the bond is very strong.

CONCLUSIONS

An appropriate amount of CeO_2 addition can effectively enhance the surface hardness of the coating, and 0,5 / % CeO_2 has the highest surface hardness.

The microhardness of the longitudinal section of the coating is “mountain shaped”distribution, with the highest hardness of the coating at 0,5 – 0,7 / mm from the bond.

When the CeO_2 addition is 0,5 / %, the coating structure is the finest and the hardness is the highest, which is the best amount of rare earth CeO_2 addition.

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REFERENCES

[1] I. B. García, J. L. Lerma, G. M. Navarro, Fully automatic smartphone-based photogrammetric 3D modelling of infant’s heads for cranial deformation analysis, ISPRS Journal of Photogrammetry and Remote Sensing, (2020) 166, 268-277.

[2] G. Y. Li, W. M. Jiang, F. Guan, J. W. Zhu, Y. Yu, Z. T. Fan, Improving mechanical properties of AZ91D magnesium / A356 aluminum bimetal prepared by compound casting via a high velocity oxygen fuel sprayed Ni coating, Journal of Magnesium and Alloys, 10(2022)4, 1075-1085.

[3] Su H, Shi T, Shi S H, F G, Algorithm and Implementation of Laser Cladding with Equal Overlapping Ratio on Free-Form Surface, Chinese Journal of Lasers, 47(2020)4, 0402008, 1-7.

[4] Sadaphal V., Prasad B., Kay W., Feasibility of heating metal implants with alternating magnetic fields (AMF) in scaled up models, International journal of hyperthermia : The official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group, 39(2022)1, 81-96.

[5] Cui C, Wu M P, Xia S H, Effect of heat treatment on properties of laser cladding cobalt-based coating on 42CrMo steel surface, Chinese Journal of Lasers, 47(2020)6, 0602011, 1-8.

[6] Zhai J H, Liu Z J, Zhang Y, et al. Laser cladding reparation of inner cylinder piston rods[J]. Laser & Optoelectronics Progress, 54(2017)11, 1114111, 1-8.

[7] Pozhyvatenko V. V, Structural and electronic properties of ternary alloys of alkaline-earth oxides and chalcogenides, Phase Transitions, 95 (2022)1, 19-39.

[8] N. Muhammad, H. Muhammad, H. Altaf, Structural stability, electronic structure, mechanical and optical properties of MAX phase ternary Mo2Ga2C, Mo2GaC and Mo-3GaC2 carbides, Journal of Materials Research and Technology, (2021)14, 521-532.

Note: The responsible translator for English is Yan Wu, University of Science and Technology Liaoning, Anshan, China