Effect of Current Variation on Microstructure and Properties of B₄C Nickel-base Alloy by Plasma Surfacing

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Abstract. In order to study the hardness of nickel-based alloys and the effect of different mass fraction boron Carbide on the microstructure of nickel-based alloys. In this paper, different amounts of boron carbide are added to the nickel alloy powder. A layer of nickel alloy surface layer is welded on the surface of the Q235 steel plate by plasma surfacing technology. The microstructure of the laminate is observed and analyzed by using Caisijinxiang tissue microscope. The hardness of the welding layer was tested by microhardness meter and the influence of boron Carbide on nickel alloy was obtained. The results show that boron carbide and nickel base alloy are well fused. The surfacing layer is mainly composed of fine dendrites and herbaceous eutectic structures. The addition of boron carbide can significantly improve the hardness and fine structure of the surfacing layer. With the increase of the content of boron carbide, the hardness of the surfacing layer first increases and then decreases. The experimental data show that when the mass fraction content of boron carbide is 6% and the current is 110A, the hardness of the welding parts is higher.

1. Introduction

Nowadays, in the process of industrial production and manufacturing, the use and application of iron and steel has always occupied a dominant position. Steel has many excellent characteristics, such as high strength, high toughness, good abrasion, good plasticity and so on. The preparation of composite coatings on the surface of common metal materials can improve the surface properties of materials, prolong the service life of mechanical and electrical products and reduce environmental pollution [1-9]. Because of its characteristics and practical application, it meets people's expectations, and the quality requirements of iron and steel products are also increasing. With the rapid development of industry, people put forward higher performance requirements for iron and steel (mainly wear resistance and corrosion resistance). Therefore, the development of surface property improvement technology is more and more welcomed by everyone. In this paper, Ni60 and boron carbide are surfaced on Q235 steel plate by plasma surfacing technology. The experimental process is completed by adjusting the surfacing current of parameter variables. Microstructure observation and microhardness analysis of alloy surfacing layer were carried out after the experiment. Microstructure observation mainly focused on the study of various microstructures in alloy surfacing layer, while microhardness analysis focused more on the hardness analysis of alloy surfacing layer at different positions under the same load.
Finally, through the analysis of microstructures and hardness of nickel-based alloy, the law and conclusion of performance change were obtained.

2. Experiments and Materials

2.1. Materials and equipment for experiments
The base steel used in the test steel plate is Q235 carbon structural steel plate. The nickel-based alloy powder was Ni60 (B4C with 6% mass fraction). The experimental equipment is PTA-BX-400A plasma powder surfacing device, Shanghai Benxi Mechanical and Electrical Technology Co., Ltd. Cutting equipment is grinding wheel cutting machine. The Choice of metallographic testing equipment is Zeiss metallographic microscope. The microhardness tester is selected as the hardness testing equipment.

2.2. Alloy Composition of Experimental Materials
The composition of the experimental steel plate is shown in Table 1.

|          | C   | Mn  | Si  | S   | P   | Ni  | Fe  |
|----------|-----|-----|-----|-----|-----|-----|-----|
| Composition of Q235 Carbon Structural Steel (mass fraction %) | 0.14 | 0.30 | 0.30 | 0.05 | 0.04 | 0.5 | Others |

The composition of Ni60 surfacing material is shown in Table 2.

| Ni  | Fe  | Cr  | C   | B   | Si  |
|-----|-----|-----|-----|-----|-----|
| Others | 12.13 | 15.85 | 0.46 | 3.11 | 4.45 |

2.3. Pre-welding preparation and sample preparation

2.3.1. Experimental preparation and sample preparation. Before welding, the surface of base steel is polished by angular mill to remove impurities and oxide scales on the surface of base metal, so that the surface of base metal is bright and smooth and easy to weld. The welded specimens were cut into 30 mm x 30 mm x 30 mm cubes by a grinding wheel cutter, and then the cut parts were inlaid with denture base resin to facilitate subsequent grinding and polishing. The abrasive paper with 180 meshes, 240 meshes, 400 meshes, 600 meshes, 800 meshes, 1200 meshes and 15000 meshes was used to polish the polished workpiece with a polishing machine, and then the corrosion was observed. 4% nitric acid alcohol was used as corrosive agent. The sample surface is washed and dried with clean water. After the sample surface is clean, it is corroded with aqua regia for about one minute. The sample surface is observed. After the color changes, the corroded workpiece is washed in clean water immediately. After washing, the corroded workpiece is dried quickly with a blower to ensure that the corroded surface of the welding layer is not oxidized. Finally, the metallographic group is observed and photographed. In the course of observation, we select the parts which are more clear and easy to observe and analyze. The clear parts are observed with 100, 200, 500 and 1000 magnification respectively. At the same time, we take metallographic photographs, mark the scale, and then analyze. Microstructure and hardness of nickel-based alloys with spacing of 0.15 mm were recorded and analyzed by microhardness tester.

2.3.2. Experimental methods. Q235 carbon structural steel plate was used as the base material and boron carbide nickel-based alloy powder was added as the material. After plasma surfacing equipment welding, the metallurgical bonding degree between the two can be reached. Controlling the current
and the content of boron carbide during welding, different samples were obtained, and the conclusion was obtained by observation and test.

2.3.3. Welding. Using plasma surfacing machine, according to the standard welding operation procedure, the Q235 steel plate substrate is placed under the nozzle, and the parameters are set to weld the alloy powder together on the substrate. When it is cooled to room temperature, the welded workpiece is cut into 30 x 30 x 30 mm pieces by a grinding wheel cutter, and the workpiece is mosaic to prepare for the next rough grinding, fine grinding and polishing.

3. Results and Analysis

3.1. Vickers hardness value of experimental sample
We measured 5 points for each group of samples and calculated their average values to obtain data as shown in Table 3.

|   | number | number 1 | number 2 | number 3 | number 4 | number 5 | average |
|---|--------|----------|----------|----------|----------|----------|---------|
| NO.1 | 749.9  | 921.4    | 1032     | 907      | 893      | 900.7    |
| NO.2 | 685    | 818.3    | 782.9    | 632.3    | 628.2    | 707.4    |
| NO.3 | 794.8  | 939.7    | 824.4    | 655.6    | 592.7    | 761.4    |
| NO.4 | 865    | 989.2    | 755.1    | 893.8    | 908.7    | 882.4    |

Sample 1-Sample 4 is the hardness of nickel-based alloy with 6% boron carbide under 110A, 120A, 130A and 140A current, respectively. The hardness of the sample decreases with the increase of current.

3.2. Observe and analyze the microstructure
Fig. 1 shows the metallographic structure of samples with constant mass fraction of boron carbide (B\textsubscript{4}C 6%) and increasing current. In this paper, the mass fraction of boron carbide in samples 1 to 4 is the same as 6%, and the current increases from 110A to 140 A. When the current is 120A and the mass fraction of boron carbide is 6%, the dendritic structure can be obtained by comparing the metallographic photos, and the observation of the metallographic structure of this group is clearer. With the increase of electric current, the structure becomes irregular and the bonding condition at the fusion line becomes worse.

4. Conclusions
In this paper, plasma arc surfacing technology is used to metallurgically bond nickel-based alloy and boron carbide on Q235 structural steel. The changes of microhardness and microstructure of nickel-based surfacing layer were studied. Specific conclusions are as follows: Firstly, adding hard phase (boron carbide) particles can effectively improve the hardness and refine the structure of nickel-based alloys. Secondly, the surfacing layer formed a good metallurgical bond with the base metal. The surfacing layer was composed of fine dendrites and fish bone eutectic, and the phase was finer than that of the base metal. Thirdly, with the increase of current, the effect of current on the hardness of nickel-based alloys increases first and then decreases. Finally, the addition of boron carbide in nickel-based composite surfacing layer has a significant impact on the hardness, wear resistance and fine structure of the surfacing layer. With the increase of boron carbide content, the hardness of surfacing layer increases first and then decreases. When the current is 130A, the structure is more dendritic. The hardness of surfacing layer is higher when the mass fraction of boron carbide is 6%.
Acknowledgement
It is a project supported by Innovation and Entrepreneurship Training Program for College Students (201910222041) and Jiamusi University President Innovation and Entrepreneurship Fund Project (XZYF2019-12) of China.

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