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A new type of wear-resistant overlay welding rod①

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Abstract: By adopting the alloy wire of $Ni_{80}Cr_{20}$ as the welding core and adding the alloy elements of B, Si, Mo and W into the outer-plating covering, a new type of wear-resistant overlay welding rod of Ni-Cr-B-Si was developed. This overlay welding rod has several properties such as low melting point and good fluidity. With low content of W and Mo, the wearability and crack resistance of the overlay welding rod can be increased, and the hardness can be increased to about HRC64. This kind of overlay rod has been applied to the overlay of wearable workpieces, such as the valves of high temperature, high pressure and the side plates of floor-boarding brick-die.

Key words: Ni-Cr-B-Si; wear resistant alloys; overlay; welding rod **Document code: A**

1 INTRODUCTION

The alloy of Ni-Cr-B-Si belongs to Ni-base overlay alloy, being used to manufacture and repair wearable parts at high or room temperatures, among all kinds of overlay alloys, Ni-base alloy has the best property of metal such as friction and wear resistance. This alloy can remain quite high hardness as well as oxidization-resistance and good property of creep-resistance even at high temperature.

However, in the past, this kind of alloy was only used in spray welding in the form of powder. We have ever studied one kind of acetylene welding wire[1], but without its electrode[2]. Analytically, the reason is that with high hardness and great britteness, the alloy could not be drawn into welding core to form electrode. In present research, the Ni-Cr electric furnace wires ($Ni_{80}Cr_{20}$) are used as welding rods core (due to their soft quality and being drawn easily), which can realize and widen the composition of spray welding powder so as to reach or even surpass the deposit performance of powder spray welding.

Compared with the powder spray-welding, using welding rods with Ni-Cr-B-Si electrode has the following advantages. First, the method of manual overlay welding is quite interchangeable, easily operable and flexible, while spray welding requires specially trained welders and special equipment. Second, manual overlay welding requires the cleanliness on the workpiece surface being low relatively, but the surface of spray-welding workpiece needs to be specially treated[3] even if it is made very clean. The oxidation in the process of spray-welding often weakens the joint of the workpiece with spray-welding layer. And the speed of overlay welding is three times or more than that of spray welding, in which the workpiece needs to be preheated and more energy source is consumed. When workpiece is a bit greater the preheated temperature can not rise, and spraying can not be carried out. Especially during spraying, the metal particles fly up apart from the workpiece, making great loss and poor labour conditions and even influencing the welder's health. Furthermore, the alloy components of the electrode are adjustable, then the overlay metals organization, as well as their crack resistance, hardness and wearability, can be easily improved.

2 EXPERIMENTAL

The alloy wire of Ni-20Cr was used as welding rod's core with diameter of 4 mm, coating components of outerface were modulated with diverse materials such as chip-graphite, ferroboron, ferro-silicon alloy, carborundum, ferro-molybdenum and tungsten carbide aluminium magnesium powder. The testing plate was made from A3 steel or 45 steel.

The facilities adopted included TL-25 welding-rod coating unit, ZXG7-300 silicon rectified welder, HR-150 Rockwell hardness meter, MLS-23 wet sand rubber-tyre grain wear testing machine, ordinary optical microscope, S-570 scanning electron microscope, and D/max-3C metallographic phase automatic powder X-ray diffraction meter.

On the small piece of A3 steel plate with thickness of 4 mm, two layers were overlaid under the current being 140 ~ 150 A; when cooled to room temperature, then the plate was cut and smoothed and made into a sample of 57 mm × 25.5 mm × 6 mm. The thickness of the overlay layer should be more than 2 mm.

3 RESULTS AND DISCUSSION

3.1 Content and function of each element

The content of Ni(mass fraction) in the overlay

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metals is 50 % ~ 60 %, while that of Cr is 10 % ~ 20 %, and that of B is 1 .5 % ~ 4 .0 %. If the content of B is more than 4 .0 %, cracks would occur easily in welding bead.

The content of Si in the overlay metals is 2 % ~ 6 %. As the content increases, the hardness of the overlay metals would rise up. But the solvability of Si within Ni is only 6 % at room temperature[4]. Surpassing this value, brittle β phase would form, which makes the toughness of the overlay metals decrease greatly.

Tungsten carbide was added to the welding rod covering W with content of 15 % ~ 25 %. The tungsten carbide has good humidification and tight cohesion with the alloy of Ni, Cr, Bi and Si. The welding rod with tungsten carbide can be used in the overlay of workpieces suffered severe abrasion. But owing to the brittleness of tungsten carbide, when the content is too high, there would be a tendency of crack occurring in the metals.

In the overlay metals the content of Mo is 4 %, which can increase the plasticity of the metals[5]. In order to increase the hardness, wearability and crack resistance of the metals, compared with the common alloy of Ni-Cr-B-Si, this kind of alloy welding rod has increased contents of W and Mo.

3 .2 Hardness of overlay metals

The hardness of usual alloy of Ni-Cr-B-Si is below HRC60[6], while the welding rod under development, owing to the flexible components, the requirement of hardness can be adjusted among HRC20 ~ 65 according to the reality. Suitable quantities of Mo and W added to the welding rod can make the hardness heighten about HRC5. The hardness value in actual measurement of one welding rod were 62, 64, 64, 63, 65, with average value about 63 .6.

3 .3 Wearability of overlay metal

The data of wearability of the overlay metals are shown in Table 1. The contrast samples for wearability test include two, one is hardened and tempered Cr12MoV die steel sample, the other is usual Ni55 Ni-Cr-B-Si powder spray welding sample.

From Table 1, it can be seen that the wearability of this welding rod is higher than those of Cr12MoV and the Ni-Cr-B-Si powder. But Hardness is not the determined index to judge the wearability of overlay metals[7~9].

3 .4 Crack resistance of welding rod

Compared with the alloy of Ni-Cr-B-Si powder spray welding, the crack resistance of the welding rod is better than that of the powder spray welding alloy. In order to improve the crack resistance of the welding rod, the contents of carbon and boron should be controlled, without consideration of other properties, the less, the better. In actual overlaying, according to the size, shape and thickness of the workpieces, when preheated at 300 ~ 600 ℃, the cracks of the alloy can usually be controlled.

3 .5 Microstructure of overlay welding metals

The microstructure of the overlay welding metal is comparably complex. Through usual metalloscope, electron microscope and X-ray structural analyses, it has been preliminarily considered that there exist carbides, borides of Cr, borides and silicides of Ni, in the overlay welding metals. There are also data[10,11] introduced that these carbides and borides are distributed in austenite phase representing network, however, from the metallographic structare of welding rod (Fig.1), we an see that the carbides and borides are in shapes of particles and blocks, which is one of the causes why the crack resistance of the welding rod is better than that of the powder spray welding.

3 .6 Application in production

The red hardness of this welding rod researched in the present paper is comparably good, though it is slightly lower than that of Co-base alloy at 6 5 0 ℃ or

Table 1 Datas of wearability in test

Sample	No	Mass of pre-grinding /g	Mass of post-grinding/g	Absolute mass loss/g	Averaged mass loss/g
Cr12MoV	1	63 .4290	63 .3656	0 .0634	0 .0714
	2	61 .6124	61 .5366	0 .0758	
	3	64 .5653	64 .4903	0 .0750	
Ni55 powder	1	63 .8642	63 .7939	0 .0704	0 .0553
	2	62 .9585	62 .9105	0 .0480	
	3	63 .9079	63 .86021	0 .0477	
Welding rod under research	1	64 .2531	64 .2220	0 .0311	0 .0218
	2	64 .3045	64 .2844	0 .0201	
	3	63 .2485	63 .2342	0 .0143	

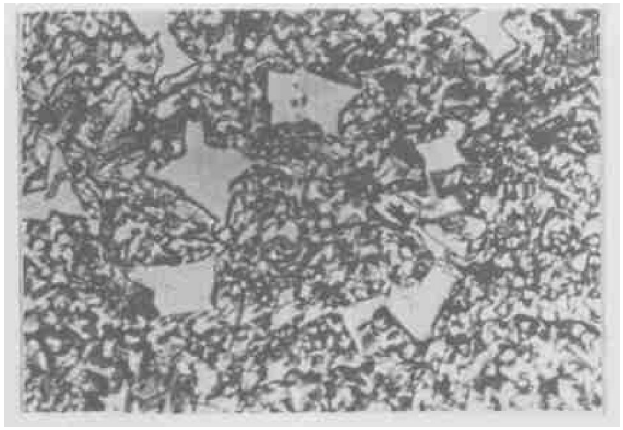

Fig.1 Metallographic organization of the overlaying metals (× 400)

below, and so is the wearability. Therefore the welding rod has been widely applied in overlaying the valves of high temperature and high pressure. During overlaying the side plate of floor-boarding brick-die and the eye-plate of concrete transfer pump, the comprehensive properties of crack-resistance and wearability of this welding rod are superior to any other overlay welding rods nowadays.

4 CONCULSIONS

1) Compared with spray welding powder, the welding rod of Ni-Cr-B-Si, with $Ni_{80}Cr_{20}$ wire being the welding rods core and alloy coating, has flexibly adjustable components, and its hardness can be higher than HRC60.

2) The toughness of the welding rod of Ni-Cr-B-Si can be enhanced with Mo added, and the wearability can be greatly improved with tungsten carbide. But the contents of Cr, B and Si should be controlled so as to avoid the brittleness being too large. By adjusting the components, comminuting crystalline grains and improving primary crystallization, carbides and borides distributing in shape of network can be prevented.

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