Study on the Performance of Laser Cladding Ni/TiC on the Surface of Mold Steel

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Abstract—Mold failure usually starts from the surface. The mold life expectancy can be effectively extended by improving the surface properties and performance of the mold. Laser cladding technology is a new type of materials processing and surface modification technology. Because the advantages of cladding surface abrasion resistance, corrosion resistance, anti-oxidation and base metal metallurgy combination, so widely used. In this paper, 45 steel surfaces are treated by laser cladding using the LWS-500 laser welding. The cladding material is nickel-based alloy powder TiC ceramic particles. Through the observation of microstructure of the cladding layer and measuring the micro-hardness, it analyzes the influence of Ni/TiC ratio on the cladding structure and microstructure hardness of the layer. Results show that the Ni60+20%TiC alloy powder for laser cladding can get the best quality of cladding layer. Deformation of the base metal is very small. It has a large number of applications in engineering practice currently. To improve the quality and the service life of the die has great economic benefit and social benefit.

Keywords-Laser Cladding; Ni/TiC; Microstructure; Micro-hardness; Mold Steel

I. INTRODUCTION

Laser cladding is a high-power laser beam that scans metal surfaces. The high performance material is clothed on the metal surface, forming coating layer with hardness, good abrasive and corrosion resistance etc. characteristics. Laser cladding technology can significantly improve the wear-resisting, corrosion-resisting, heat-resisting, antioxidant and electrical characteristics on the surface of the basal body. It greatly excavates the use of the material and can also save precious rare metal elements. As a kind of advanced surface modification technique, laser cladding technology has a broad application prospect [1-2].

45 steel is commonly used in industry as medium-carbon steel, with excellent mechanical properties, e.g. high strength, toughness, plasticity, etc. It is the main material of the mold, and has been widely applied in the mold industrial production. But in practice, in order to improve the surface performance of 45 steel, laser cladding is often applied on the surface of 45 mold steel [3-4].

The main cladding materials in laser cladding technology include three kinds of self-fluxing alloy powders, namely Ni-, Co-, and Fe-based powders, among which Ni-based self-fluxing alloy powder has better comprehensive performance and value of money with good lubricity, wear resistance, corrosion and oxidation resistance and it is most widely used in laser cladding. However, if all kinds of high-melting-point carbides (e.g. TiC, SiC, B4C, WC), nitride, boride and oxide ceramic particles are added to self-fluxing metals, composite coating will be formed, and thus develop excellent surface properties[5-6]. This thesis mainly studies the adding amount of TiC powder when 45 steel laser cladding with Ni-based alloy powder and the influence on microstructure and the hardening effect on the samples.

II. EXPERIMENTAL MATERIALS AND PARAMETERS

The base material of the experiment is 45 steel with the size of 5 mm * 10 mm * 30 mm. First, the sample is quenched. The sample is heated to 860 ℃ in the furnace for 30 minutes before cooling it down in the water. It is then put into the furnace again and heat to 600 ℃ for 60 min. Open the furnace to cool and finally get the sample after quenching. After grinding and cleaning, the hardness of sample is measured under the MHV2000 micro-hardness meter. The micro-hardness value of the base surface is 310 HV.

This experiment selected nickel base self fluxing alloy powder. The ceramic particles with certain quality scores TiC as hard reinforcing phase. The nickel base self fluxing alloy powder is Ni60 self fluxing alloy powder that it's purity is More than 99%. Ni60 self fluxing alloy powder is a kind of common nickel base alloy powder with wear resistant, corrosion resistance, heat resistance and other characteristics. The main component content is as shown in Table 1. The specification is 150-320 mesh.

TABLE I. TABLE1 TECHNICAL PARAMETERS OF NI60 SELF-FLUXING ALLOY POWDER

component	C	Cr	B	Si	Fe	Ni
content	$\leqslant$3%	12-19%	2.3%	$\leqslant$2%	$\leqslant$6%	others

Figure 1 is SEM photos of the Ni60 self fluxing alloy powder, magnification is 100 times. From the Fig .1, we can see that Ni60 self fluxing alloy powder particles were spherical, irregular size. Most of the diameter is less than 50μm, A few particle size large.

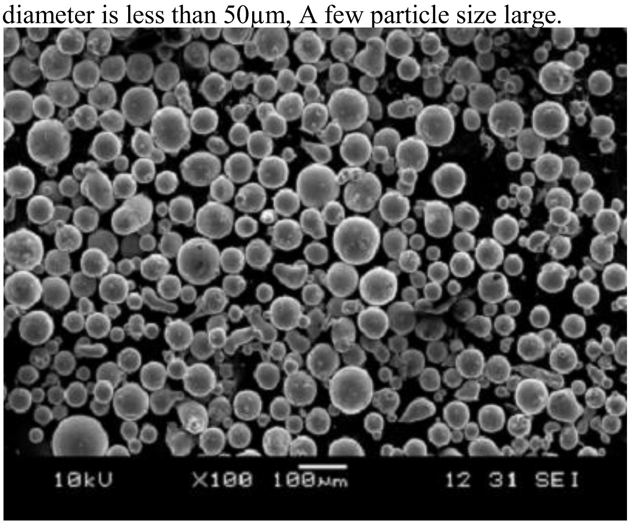


Figure 1. Ni60 self fluxing alloy powder SEM diagram

Because the particle sizes of Nickel-based alloy powder and titanium carbide powder vary, in order to mix the cladding powders evenly, the ball-milling mixed powders are needed. After weighing different groups of cladding-coating powder according to the formula, the powder groups are added to different ball mills for mixing. The rolling speed is set at 200r/min with ball mixing time of 16 hours. After ball-mill mixing, the composite powder is dried for use.

LWS-500YAG laser machine is used for laser cladding experiments, using a MHV2000 micro-hardness meter to measure micro-hardness of the cladding layer and a JSM-6360LA scanning electron microscope to observe the organ of cladding layer cross section. The laser cladding layer alloy uses the Ni60 self-fluxing alloy powder, adding a certain amount of TiC particles as hard phase. There are six groups of cladding powder, Ni60 powder, Ni60 + 10% TiC alloy powder, Ni60 + 15% TiC alloy powder, Ni60 + 20% TiC alloy powder, Ni60 + 25% TiC alloy powder and Ni60 +30% TiC alloy powder respectively. And the variable-frequency planet-type XQM - 0.4L grinding ball mill is used to mix powder evenly.

The laser cladding parameters this experiment adopts are as follows: current 135A, frequency 30Hz, pulse width 3ms and scanning speed 4mm/s. Feeding method is preset. Six groups of powder are prepared on the sample respectively after hardening and quenching. The thickness of preset powder is 1 mm.

III. EXPERIMENT RESULTS AND ANALYSIS

The quality of laser cladding layer include two parts, the macroscopic quality and microscopic quality. The macro quality mainly refers to the shape, thickness, surface roughness, cracks and other properties of the laser cladding layer. Micro quality mainly include the chemical components, microstructure, interface combined of cladding layer. Evaluation of laser cladding micro quality is mainly observed the microstructure of laser cladding layers of tissue density, micro cracks, porosity and other defects.

A. Geometry morphology of laser cladding layer section

The geometric morphology of the laser cladding layer refers to the shape of a cross section [7]. The laser cladding layer can be divided into three parts: cladding zone, combining zone and heat-affected zone. In figure 1, (a) is the geometric topography of cladding layer section by laser cladding Ni60 alloy powder samples; (b) is the geometric topography of cladding layer section by laser cladding Ni60 + 10% TiC alloy powder samples; (c) is the geometric topography of cladding layer section by laser cladding Ni60 + 15% TiC alloy powder samples; (d) is the geometric topography of cladding layer section by laser cladding Ni60 + 20% TiC alloy powder samples; (e) is the geometric topography of cladding layer section by laser cladding Ni60 + 25% TiC alloy powder samples; (f) is the geometric topography of cladding layer section by laser cladding Ni60 + 30% TiC alloy powder samples.

From the Fig .1, we could see that cladding layer properties and the micro density of the sample are good without adding TiC ceramic particles. There are few cracks and pores. But without TiC ceramic particles as enhancement phase, the hardness of sample will be low; the cladding performance and micro density with 10% TiC ceramic particles in the sample are relatively poor; cladding region has defects like having few pores, low content of TiC ceramic particles in the coating, and unclear improvement of hardness. The cladding performance with 15% TiC ceramic particles in the sample is relatively poor because of thinner cladding area and small amount of pores and TiC ceramic particles in cladding area. The cladding performance and micro density of the sample with 20% TiC ceramic particles are relatively good. The cladding zone, combining zone and heat-affected zone can be clearly identified. The thickness of cladding layer is thicker with a flat layer and very few cracks and pores in the cladding area. The TiC ceramic particles are distributed dispersively in the coating, which can have good hardness enhancement effect. The cladding performance with 25% TiC ceramic particles in the sample is poorer with a large number of cracks and pores. The microstructure in the heat-affected zone is better; the black TiC ceramic particles distributed in the cladding zone, the enhancement of hard is good; the cladding performance with 30% TiC ceramic particles in the sample is better. But the cladding region has a few large pores and cracks. There is a higher content of TiC ceramic particles in the coating, making it worse for the cladding layer forming.

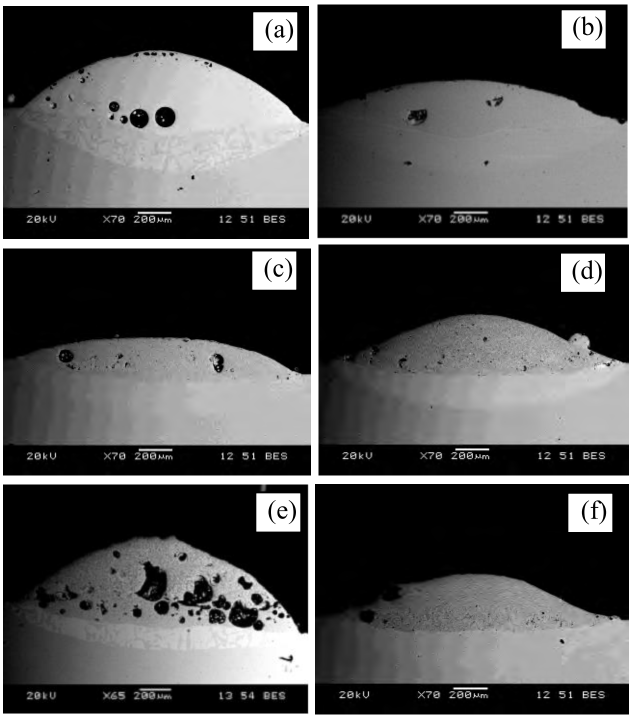


Figure 2. The Geometrical Shape of Sample Piece Cross Section

B. Microstructure of Laser Cladding Layer

The specimens are observed under the scanning electron microscope (SEM)[8]. The microstructure of laser cladding layer in the cladding area is shown in figure 2: (a) the microstructure of laser cladding Ni60 alloy powder in the cladding area; (b) the microstructure of laser cladding Ni60+10% TiC alloy powder; (c) the microstructure of laser cladding Ni60+15% TiC alloy powder; (d) the microstructure of laser cladding Ni60+20% TiC alloy powder; (e) the microstructure of laser cladding Ni60+25% TiC alloy powder; (f) the microstructure of laser cladding Ni60+30% TiC alloy powder. From the figures we can see that the microstructure of the sample with TiC particles has more black particles than the one with only cladding Ni60 fluxed alloy powder. This is because after adding TiC, the heat and mass transfer characteristics have been changed, adding the in homogeneity of the laser cladding layer tissue. The TiC and precipitates in the cladding layer change the micro structure of the cladding layer.

From figure 2 we can see that the microstructure of the sample without adding TiC ceramic has no obvious characteristic. The ceramic particles with 10% TiC distribute unevenly in the cladding area. The ceramic particles with 20% TiC appear like black dendrite particles in the cladding region. From the picture we could see that the TiC particles are distributed evenly in the cladding area. The cladding performance of the sample and the micro structure of the cladding layer have good density. As for sample with 30%TiC ceramic particles, the black TiC particles in the cladding zone is distributed unevenly, with a small amount of enrichment phenomenon.

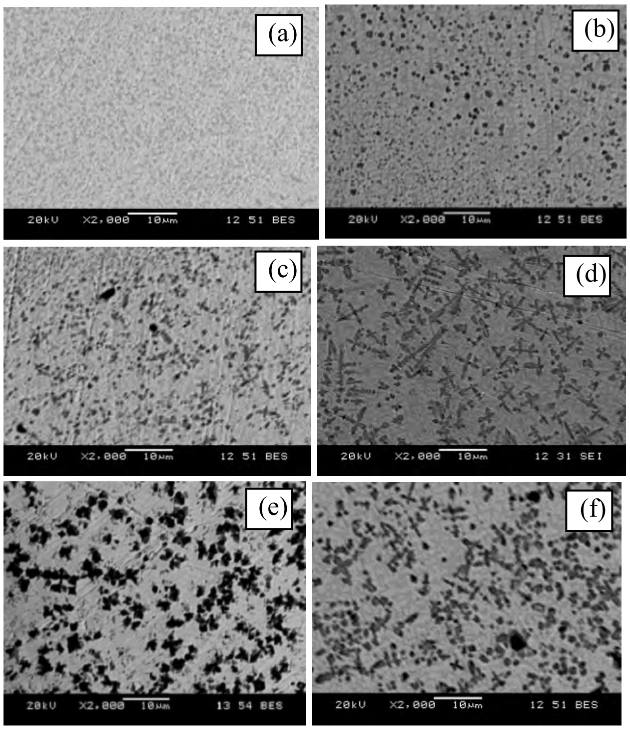


Figure 3. Ni/TiC Microstructure with Different Content of TiC Laser Cladding

Through the experiment we could find that nickel-based alloy composite powder has good cladding performance by adding mass fraction of 20% TiC ceramic particles. The distribution of the cladding layer, combination zone and heat-affected zone is obvious, with relatively high surface smoothness and better density of the microstructure in the cladding area. The coating and base form a good metallurgical bonding, the thickness of which has reached 0.5 mm. There are few tissue defects such as cracks and pores in the cladding region. The black dendrite TiC ceramic particles are dispersed evenly in the cladding region, which has a very good hardness enhancement effect. Therefore, the nickel-based alloy composite powder with the mass fraction of 20% TiC ceramic particles is the most suitable powder formula.

C. Micro-hardness in Laser Cladding Area

Use MHV2000 micro-hardness meter to measure the micro-hardness of the laser cladding layer [9]. The load force is 4.9 N, and the time is 10s. Test the micro Vickers-hardness of the 6 samples with the following mass fractions of TiC ceramic particles: 0% 10%, 15%, 20%, 25% and 30% respectively. Examine five points in each sample and take the average value. The adding TiC ceramic particle mass fraction and calculate its average. Figure 3 shows the relation between the mass fraction of TiC ceramic particles and micro hardness of the laser cladding layer, with the X coordinate representing the mass fraction of TiC ceramic composite powder particles and the Y coordinate representing the micro-hardness of the cladding layer[10].

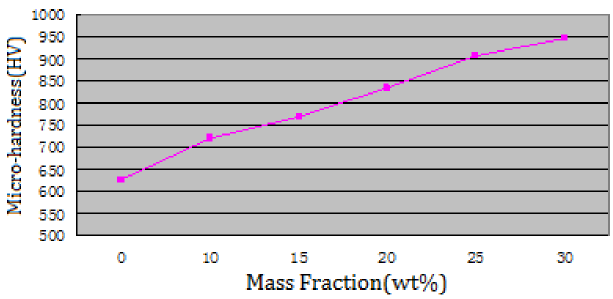


Figure 4. Micro-hardness of Sample

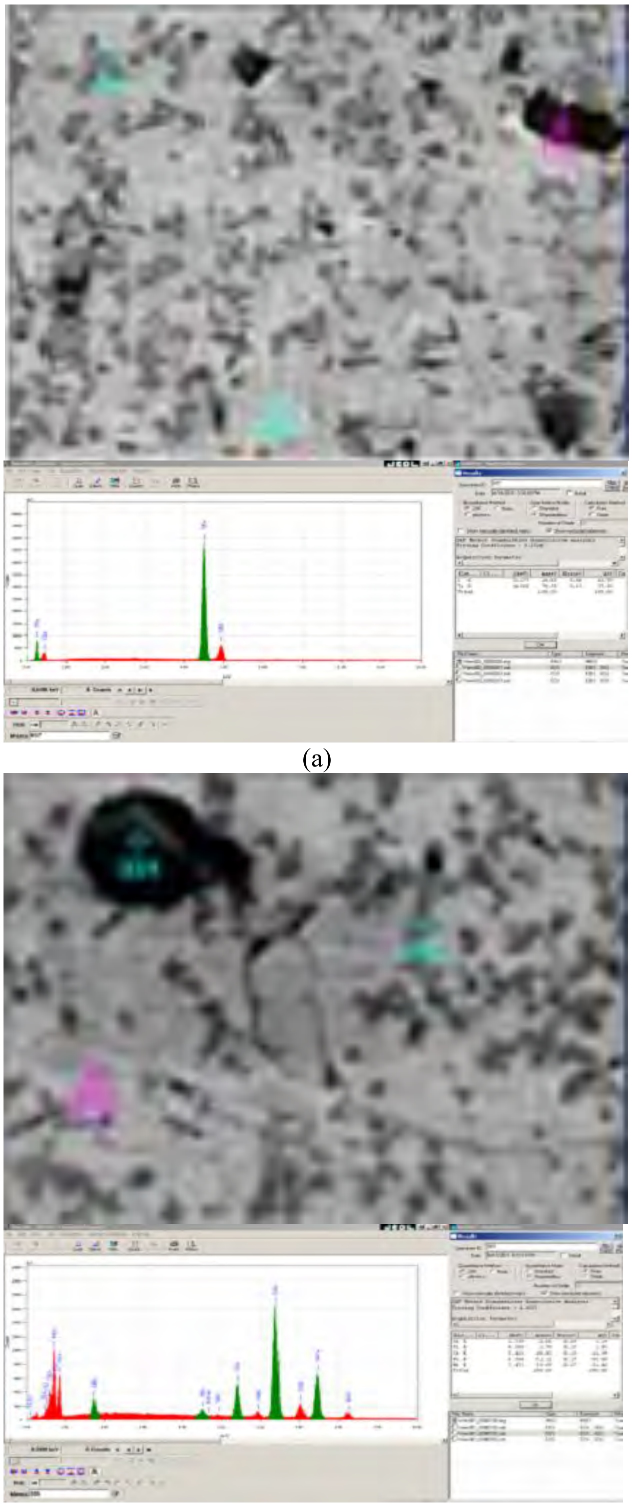
It can be seen from Figure 3 that the micro-hardness of the cladding layer of the sample that has laser cladding with TiC ceramic particles has been increased significantly. With more TiC amount, the hardness of the cladding layer will be improved accordingly. The reason for this is that when doing laser cladding, the TiC in the cladding layer re-melts and creates new carbide with the matrix elements. Then they gather around the un-melted TiC particles. The new carbide and un-melted TiC particles are dispersed in the cladding area to strengthen the hardness, and thus increasing the micro-hardness of the sample with TiC ceramic particles.

The measurements show that it can greatly improve the microhardness of laser cladding layer when the Ni60 self fluxing alloy powder is added in the TiC ceramic particles. With the increase of TiC content, the microhardness of the cladding layer increases.

D. *Analysis of laser cladding components*

Using scanning electron microscopy with energy spectrum analysis function, the EDS fixed point analysis the elements composition of the coating. The cladding materials of laser cladding are mainly nickel base alloy powder and TiC ceramic particles. Ni based alloy is mainly binding phase in the cladding zone. TiC ceramic particles are mainly as hard reinforcing phase. The morphology of nickel base alloys with adding mass fraction of 20%TiC ceramic particles in laser cladding zone is shown in figure 4.

By the EDS fixed point analysis chart can be seen, the main existing black particles and the white area in the cladding region. The black areas of main elements in the cladding region component is C and Ti, the black particles are TiC ceramic particles. The white area of the elements is mainly Ni and Fe, and a small amount of C, Cr, Si and other elements. White areas are nickel based alloy bonding phase.



(a)

(b)

Figure 5. Element Analysis of Coating Microstructure by EDS Fixed Point

(a) Black Grain (b) White Zone

IV. Conclusion

Through the laser cladding of 45 mold steel by using LWS-500 laser welding machine, this paper studies the influence of nickel-based alloy powder with different content of TiC on the performance and micro hardness of laser cladding.

The experiments show that the performance of Ni60 alloy powder with TiC ceramic particles is better with thicker cladding layer, and dense micro structure. Among them, the sample with a mass fraction of 20% TiC ceramic particles has relatively few defects such as pores and cracks in the cladding area and better cladding performance. Compared with the laser cladding specimens without TiC ceramic particles, the ones with TiC particles can greatly improve the micro hardness of the laser cladding layer, and with the increase of TiC amount, the micro hardness increases accordingly. The cladding layer with a mass fraction of TiC ceramic particles has better cladding performance, and the micro-hardness is increased by about 200HV than the ones without TiC.

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