Effect of laser cladding process parameters on the quality of cladding layer in 35CrMoV piston rod

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Keywords: Laser cladding, 35CrMoV, Process parameter, Quality of cladding layer.

Abstract: In this paper, using laser cladding technology on the materials of 35 CrMoV specimen preparation of Ni-WC25 alloy coating. To detect the shape, hardness and coefficient of friction of the layers under different process parameters, and accordingly it to analyze the influence of laser power, scanning speed and powder delivery speed on the quality of cladding layer.

1. Introduction

Generally, wear failure is the most important failure form of metal materials. The data show that about 70% ~ 80% of the mechanical equipment damage is caused by wear failure of metal materials used in the equipment [1]. Therefore, the laser cladding technology in preparation of substrate materials with special performance to make up for the substrate by high performance advantage [2], making it a repair the wear surface or change the surface properties of technology choice. Additional, the nickel base alloy powder has high hardness, good wettability, wear-resisting, corrosion resistance, etc, so that it widely used in axial, valves, plunger, conveyor roller and surface strengthening aspects of pump, shaft sleeve, etc recently [3]. Therefore, using laser cladding technology to repair the parts of piston rod of diamond six-face press not only has significant economic advantages but also can obtain a good quality cladding layer. Part of the research on coating Ni-WC alloy on the workpiece surface shows that: The hardness of the cladding layer increased significantly with the addition of WC [4]. The hardness and abrasion resistance of the cladding layer are many times better than that of the substrate [5]. The cladding layer is distributed with WC particle and the microhardness peak is up to 1000HV[6]. In addition, the research on the parameters of the cladding process shows that: The matching of powder and laser beam is crucial to the forming quality of cladding layer [7-8]. And the process parameters have great influence on the microstructure of the cladding layer [9],and it can be obtained uniformly and in combination with the matrix by optimizing the process conditions. Therefore, it is significantly to explore the influence of technological parameters on the quality of laser cladding.

2. Experiment preparation

The experimental base material is the same material as the piston rod of diamond six-sided press, which is 35CrMoV and the specimen size is: Ø39x100mm. The coating material is Ni-WC25 alloy powder with a particle size of 300 meshes. Use sandpaper to remove the rust on the surface of the matrix in advance and alcohol acetone to remove the grease. The material composition of matrix and powder is shown in table 1. The laser cladding system used in the experiment consists of a lathe rotating actuator, a coaxial powder feeding system and a control panel, and the shielding gas is Ar gas. Use the control variable method to organize experiments for the three parameters, and the specific combination was shown in table 2. Completed cladding specimens processed into specifications for Ø 40 x Ø 20 x 10 mm rings, with the material is GCr15 steel friction pair of friction and wear experiments. Microstructure and hardness testing were also carried out.

Tab.1 Chemical compositions of substrate and cladding material (wt.%).

Material	Cr	Mo	V	Ni	C	W	Mn	Fe
35CrMoV	1.00~1.30	0.20～0.30	0.10～0.20	≤0.030	0.30～0.38	-	0.40～0.70	Bal.
Ni-WC25	15.5	0.1	-	Bal.	0.8	24.2	0.1	

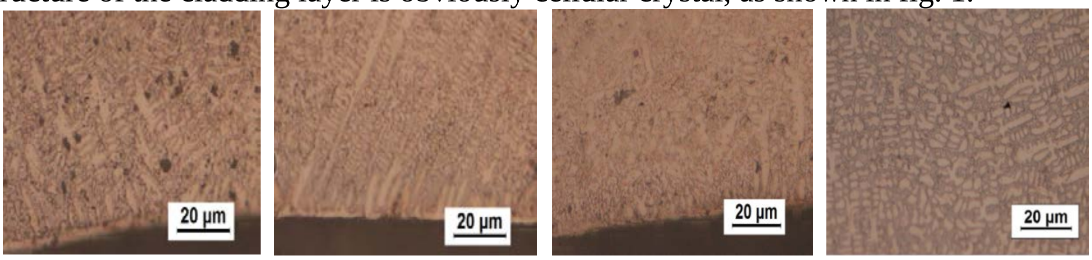
Tab.2 Experimental arrangement of laser power for independent variables.

实验号	激光功率 P/（kW）	扫描速度 Vs/（mm/min）	送粉速度V_f（g/min）
1-4	1.4/1.6/1.7/1.8	100	42.8
5-8	1.8	100/120/140/160	42.8
9-12	1.8	100	40.2/42.8/45.4/47.5

3. Influence of process parameters on the quality of cladding layer

3.1 Influence of process parameters on microstructure of cladding layer

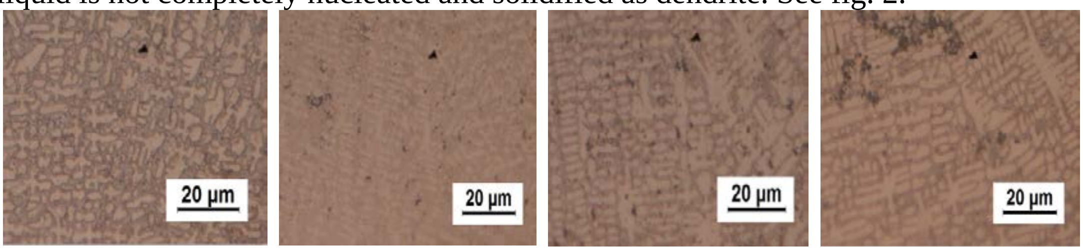
When the laser scanning speed and powder feeding speed are fixed，the depth and width of the molten pool gradually increase with the increase of laser power, and the heat dissipation volume of the molten pool also increases, so the heat dissipation speed of the molten pool is accelerated. In the solidification process, the nucleation speed of nucleation accelerates the growth of nucleation for a short time and no large grains are formed. Therefore, with the increase of laser power, the microstructure of the cladding layer is obviously cellular crystal, as shown in fig. 1.



（a）P=1.4kW （b）P=1.6kW （c）P=1.7kW （d）P=1.8kW

Fig.1 Microstructure morphology of cladding layer under different laser power.

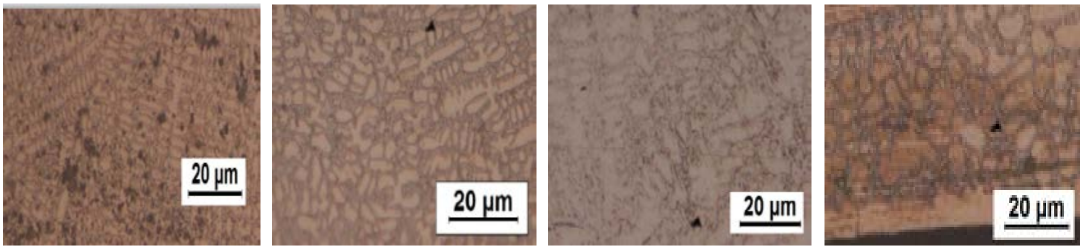
As the scanning speed increases, the microstructure of the cladding layer changes from dense cellular to dense cellular and dendritic. Increasingly the scanning speed, the metal lographic structure of the cladding layer changes from dendritic to discrete cellular crystal. Because the different scanning speed, alloy powder absorption of laser energy per unit time is less, therefore, higher temperature of molten pool during cooling nucleation speed slow, steady process, solidified into a small compact cellular crystal. Increasingly that scanning speed, decrease the laser energy absorbed by the unit time, lowering the temperature of the bath, the cool speed is increased, and the molten liquid is not completely nucleated and solidified as dendrite. See fig. 2.



（a）V=100mm/min （b）V=120mm/min（c）V=140mm/min（d）V=160mm/min

Fig.2 Microstructure morphology of cladding layer at different scanning speeds.

When the laser power and laser scanning speed are fixed, the amount of alloy powder reaching the surface of the matrix increases with the increase of the powder delivery speed and the heat required for melting increases. The laser energy is mostly absorbed by the molten pool, and the melting zone becomes smaller. The reduction of the heating degree of the matrix material accelerates the nucleation speed along with the powder delivery speed in the solidification process. Therefore, the cladding tissue is thickened into cellular crystals with large particles. See fig. 3.



（a）V_f=40.2g/min（b）V_f=42.8g/mim （c）V_f=45.4g/min （d）V_f=47.5g/min

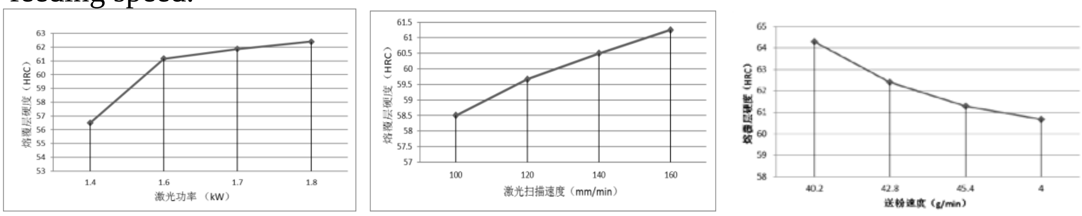
Fig.3 Microstructure morphology of the cladding layer at different feeding speed.

3.2 Effect of process parameters on the hardness of cladding layer

FIG.4(a) shows that the hardness of the cladding layer is positively correlated with the laser power. One hand, the high dilution rate indicates that the alloy molten solution and matrix fuse well to form a close bonding interface, on the other hand, the microstructure of cladding layer is cellular crystal, which is refined with the increase of laser power, and the hardness of cladding layer is improved to provide tissue guarantee.

FIG.4(b) shows that the faster the scanning speed, the higher the hardness of the cladding layer. Because different scanning speed, powder absorption of laser energy per unit time different make fusion of dilution ratio, and Ni - WC25 also different levels of the tungsten carbide particles in the embedded within the cladding layer make the cladding layer hardness. WC particles are embedded in a narrower and shallower pool and deposited at the bottom of a thinner cladding layer, which is more likely to bulge on the surface of the cladding layer and increase its hardness.

FIG.4(c) shows that the hardness of the cladding layer decreases with the increase of powder feeding speed. The hardness of cladding layer mainly depends on the properties, content and distribution of each constituent phase of cladding layer. The increase of powder delivery speed increases the amount of alloy powder delivered to the surface of the matrix within a unit time, and the content of Ni increases accordingly. But too much powder did not melt completely, therefore the dilution rate of cladding layer is reduced, the content of Ni base alloy melt into the substrate decreases and the organization of the cladding layer along the increase of powder feeding speed gradually become rough, thus the hardness of cladding layer decreases with the speeding up of the powder feeding speed.

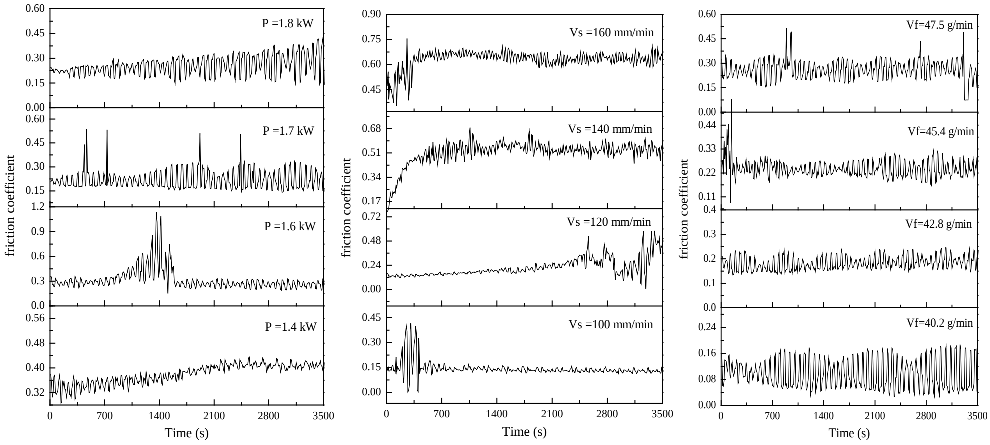


（a） （b） （c）

Fig.4 Hardness of cladding layer under different process parameters.

3.3 Influence of process parameters on friction coefficient of cladding layer

FIG.5(a) shows: when P= 1.4kw, the friction coefficient curve oscillates around 0.3-0.42 and remains stable. When P= 1.6kw, the friction coefficient curve oscillated around 0.25~0.35 and experienced severe shock within a period of 18~24min as there are tiny voids potential in the cladding layer, when it happens that the thickness of wear and tear of cladding layer arrived in pores, long time friction powder into the micro pores, the area of uneven make friction coefficient increases, stomatal grinding stable friction coefficient at ordinary times tend to be the norm and gradually; When P= 1.7kw, the friction coefficient curve oscillates around 0.22~0.30 and there are points with high friction coefficient. When P= 1.8kw, the friction coefficient curve oscillates around 0.20~0.30 and remains stable. In general, the friction coefficient of the cladding layer is small and decreases with the increase of laser power.



(a) (b) (c)

Fig.5 Friction coefficient curves of cladding layer under different process parameters

FIG.5(b) shows: V = 100 mm/min, the friction coefficient of the cladding layer turbulence in the area of the 0.12 ~ 0.15, but the early friction is not stable, because the early wear and tear of powder adhesive on the specimen surface to make the friction coefficient curve appeared rising trend and unstable; When V=120mm/min, within 30min, the friction coefficient of the cladding layer oscillates within the range of 0.12~0.20 and remains stable. After 30min, the friction coefficient curve is unstable and maintains an upward trend: one hand, the powder produced by the cladding layer after a long period of friction is alternately adhered to the surface of the specimen and then detached to make the friction coefficient change at different points of the workpiece. Scanning speed, the other hand, reduce the irradiation of laser energy on powder and cooling speed, reduce the dilution rate and make the cladding layer microstructure coarsening and then organize large spacing cladding layer caused by density difference, lead to rising friction coefficient. When V=140mm/min, the friction coefficient fluctuates in the area of 0.40~0.65 and the initial value is low, but it rises rapidly and keeps a high level continuously. When V=160mm/min, the initial value is low but the fluctuation is large due to the uneven point on the surface of the specimen during the initial wear; with the increase of time, the friction coefficient tends to be stable in the area of 0.60~0.70, which is caused by the poor quality of cladding due to the thick microstructure and poor compactness of cladding layer. Comprehensive analysis: within a certain range, the higher the scanning speed, the higher the friction coefficient of the workpiece, the worse the workpiece wear resistance.

FIG.5(c) shows that when V_f=40.2g/min, the friction coefficient curve oscillates around 0.1~0.18 and remains stable. When V_f=42.8g/min, the friction coefficient curve oscillates around 0.18~0.20 and remains stable. When V_f=45.4g/min, the friction coefficient curve oscillates around 0.20~0.28 and remains stable. At the beginning of the friction phase, the surface of the molten coating is not smooth enough. The surface of the workpiece becomes smooth after a short period of friction, which makes the curve stable quickly. When V_f=47.5g/min, the friction coefficient curve oscillates around 0.26~0.30 and remains relatively stable, during which points with large changes appear. According to the comprehensive analysis, the hardness decreases with the increase of powder delivery speed, leading to the decrease of cladding strength and easy wear. The roughening of metallographic structure weakens the structure foundation of cladding layer and reduces the abrasion resistance of cladding layer. Therefore, the friction coefficient increases with the increase of powder feeding speed.

4. Conclusion

Through a series of experiments of laser cladding ni-wc25 alloy wear resistant layer on 35CrMoV specimens, the following conclusions are obtained:

(1) When the laser scanning speed and powder feeding speed are fixed: the hardness of cladding layer increases with the increase of laser power; the microstructure of the cladding layer is

transformed into cellular crystal and the friction coefficient decreases with the increase of laser power.

(2) When the laser power and feeding speed are fixed: the apparent interstitial space of cladding layer increases; hardness increases with scanning speed; the friction coefficient also tends to increase.

(3) When the laser power is fixed with the laser scanning speed: the microstructure of the cladding thickens gradually, the hardness decreases, and the friction coefficient increases.

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