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ANALYSIS OF FIBER LASER CLADDING OF TITANIUM NITRIDE ON SS304 SUBSTRATE

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ABSTRACT

To improve the surface characteristics of metallic mechanical parts, such as the resistance against wear, laser cladding was performed. Laser cladding coating of TiN and stainless steel304 powder was efficiently synthesized with the help of fiber laser system on a stainless steel304 substrate. The stainless steel304 powder was added to increase the bond strength between clad and the substrate. Poly Vinyl Alcohol was used as a binder for mixing the powders. The microhardness and microstructure was inspected by the vicker hardness test, and Scanning electron microscope (SEM) technique respectively. The microhardness was found to be more than seven times of the substrate hardness. The microstructure of cladding was free of crack and pores. The clad thickness analysis was also done with the help of optical microscope. The wear test was performed on ball on disc friction and wear tester. Laser cladding of TiN had highly results in reducing the wear rate.

Keywords- Microhardness, Microstructure, Stainless steel, TiN cladding, Wear rate.

I. INTRODUCTION

In recent research development composite coating have been demanded by many tribological systems in order to reduce friction and wear [1]. The unique surface properties such as hardness, wear, resistance to oxidation can be achieved by the use of ceramics. Ceramics have high melting points and needed higher laser energy input. Titanium nitride (TiN) is a very hard ceramic material, frequently used as a coating on titanium alloys, steel, carbide, and aluminium components to improve the substrate's surface properties. TiN has a low coefficient of friction, high hardness, resistance to corrosion and adhesive wear [2-3].

Ceramic coatings commonly tend to fail as a result of huge thermal stress at high temperature environment [4,5,6]. Laser cladding technology has been proven a promising method for ceramic coating preparation, due to its low power consumption, short time and high efficiency [7,8,6]. The repeated problem faced by manufacturing industry is wear. Some machine parts fail only due to the slight damage on the surface produce by the wear; hence regular repair and replacement are needed to increase the service life of such components, hence increasing productivity, their wear resistance should be increased. The wear resistance of such components can be improved by using the different methods such as thermal spraying in which layer of hard alloys is fused onto the substrate [9].

Laser cladding is a commonly used technique, as laser radiation is capable to melt a large range of different alloys onto a metallic substrate, and coatings exhibit very low porosity, minimal dilution and a perfect union with the substrate. Additionally, quick solidification generates refined and new microstructures with improved properties [10,11,12].

The extensive feature of laser cladding to synthesize the hard facing layer with high resistance to wear, corrosion, high temperature oxidation has become interesting in research [13,14].

The preplaced powder technique is used in the experiment. Laser cladding with preplaced powder is the ordinary technique. The powder is mixed with a chemical binder to ensure that it will stick to the substrate during the process. As the laser beam passes a melt pool forms in the surface of coating material which extends to the interface with the substrate. A strong fusion bond is attained due to continuous heating. The heat input must be well controlled to anticipate the deep melting of the substrate to achieve a strong fusion bond.

However, the laser cladding coating has some advantages owning to its high hardness and wear resistance [15]. There were few research done on ceramic coatings.There is no information available on the effects of scanning speed and power on TiN coating with fibre laser processing system. This paper describes the experimental results on microstructure, wear behavior and hardness of the TiN coating on stainless steel304 substrate at different scanning speed and power.

II. EXPERIMENTAL

The Stainless steel substrate with 6mm in diameter and 30mm in height was used. Before cladding clad samples were washed with acetone and polished in MECTO machine and cleaned in ultrasonic vibrator. A mixture of TiN and Stainless steel 304 powder with 90% TiN and 10% Stainless steel powder as an additive was prepared. The Stainless steel powder was added as a binder to increase the bond strength between the substrate and clad layer so that there should be no gap and crack generate during the laser cladding process. An organic binder (4% by weight PVA and distilled water solution) was used for mixing the powder to form a layer of approximately 0.9mm thick and kept inside a furnace at 40˚C for 2hr for drying. Slow heating was used to prevent the paste from cracking.

TABLE 1. Experimental parameters selected for cladding

Sample No	Power (w)	Scanning speed(mm/min)	Hardness(HV.5)	Clad thickness(mm)
1	100	180	234.9	0.5
2	100	240	221.6	0.48
3	100	300	253	0.46
4	140	180	301.5	0.56
5	140	240	262.1	0.55
6	140	300	420	0.52
7	180	180	412.2	0.6
8	180	240	380	0.59
9	180	300	481.2	0.58
10	220	180	540	0.63
11	220	240	520	0.6
12	220	300	752	0.58

The binder was used to prevent a powder not be blown away by the shielding gas. After cooling in air laser cladding was done with continuous wave fiber laser processing system with power range 40-400watt.The argon gas was used as a shielding atmosphere with laser power 100-220watt of spot dia 1mm and scanning speed of 180-300mm/min. The process was started with the formation of melt pool as the laser beam passes through the substrate. The complete cladding was observed on the substrate in the area of 6mm diameter. The resulting coating with approximately 0.6mm average thickness was observed.

III. MICROSTRUCTURE CHARACTERIZATION

The microstructure was evaluated by FESEM analysis. Before the characterization all the samples were washed with acetone. FESEM images were taken at 6KX on the top surface. The top surface was examined for the presence of pores, cracks and impurities. The Titanium particles having an irregular conical shape reached deep down to the melt pool due to high density.

In the Fig. 1 it can be seen that a uniform clad on the substrate was achieved. As the power increased, the more uniform cladding was obtained. No pores and crack were observed in the samples.

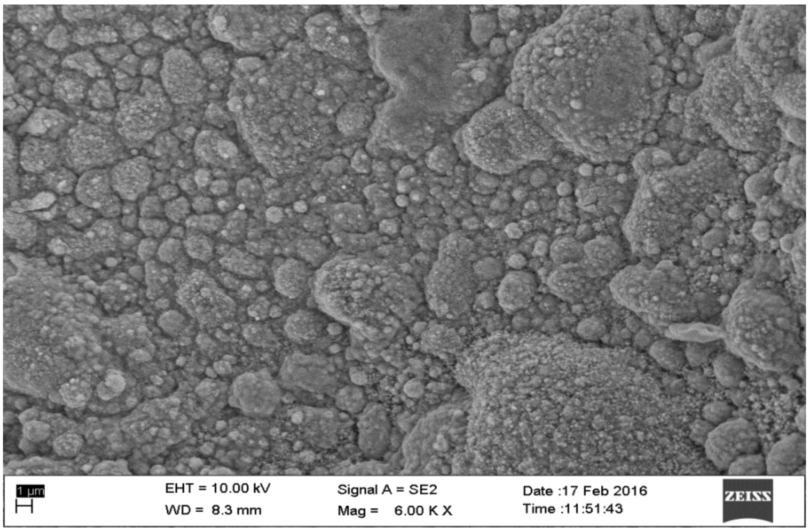

Fig. 1. FESEM image for power 140watt and scanning speed 180mm/min at the top surface.

IV. MICROHARDNES

Before the hardness test samples were polished on polishing machine to make its surface clearly visible during testing. The microhardness of the laser cladding was measured using a vicker hardness machine under 0.5kg load for a dwell time of 10second. Substrate hardness was 121 HV at 0.5 load. The hardness was evaluated at different power and speed as shown in the table. 1.

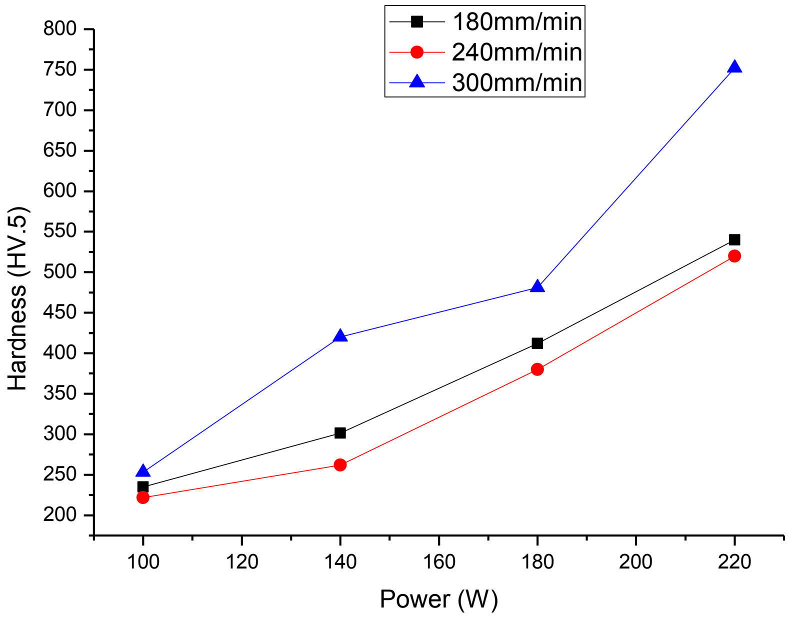

Fig. 2. Microhardness profile of the laser cladding for different process parameters.

The maximum hardness was found with the power of 220 watt with the speed of 300mm/min which was more than seven times of the substrate hardness. As shown in the Fig. 2 given above as the power increases hardness increases. It can be suggested that more heat input may cause the quenching process to take place, resulting in a finer grain structure. Hardness value decreases with speed and then again increases.

V. CLAD THICKNESS ANALYSIS

The clad thickness was examined on optical microscope. It was seen that different thickness of clad was observed at different scanning speed and power.

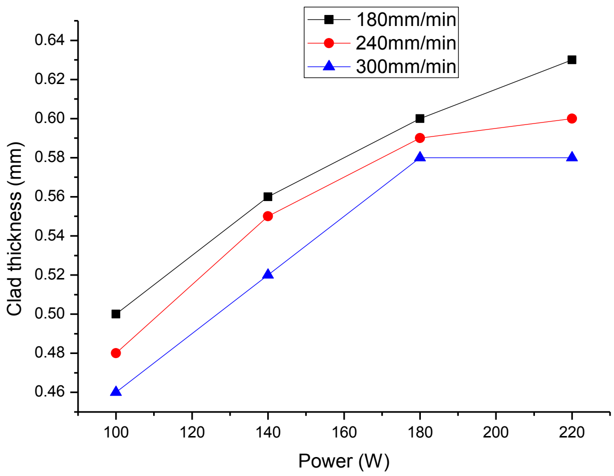

Fig. 3. Variation in clad thickness with power and scanning speed.

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Fig. 3 given above shows that clad thickness is directly dependent on power. As the value of power increased more amount of substrate melts and thickness of the clad increases. The successful cladding was observed in the samples. Some non uniform cladding was observed, but the substrate clad interface was clearly visible. Non uniform cladding was observed due to gas evolution while cladding. No visual pores were present in the clad samples.

VI. WEAR RATE ANALYSIS

A ball on disc friction and wear test was performed to evaluate high temperature friction and wear behavior of the laser cladding coating. The test was carried out at a normal load of 2kgf with a sliding speed of 300rpm for duration 300sec. The wear rate of substrate was measured on mapping profile coupler. All the samples show very good results. Some sample shows the little higher value. The wear rate of substrate was found to be 679.15µm as shown in Fig. 4. Fig. 5 shows the minimum value of wear 39.14µm, which is more than seventeen times better than the wear of stainless steel substrate.

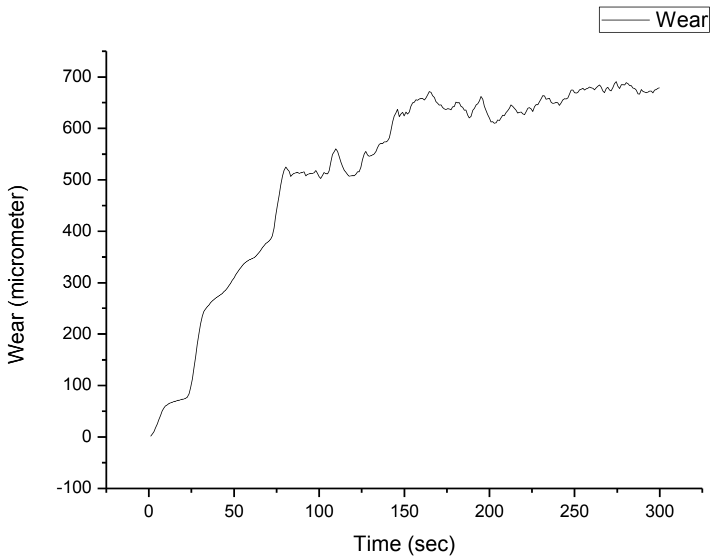

Fig. 4. Variation of wear rate of Stainless steel substrate for 300sec at 300rpm under 2kgf load.

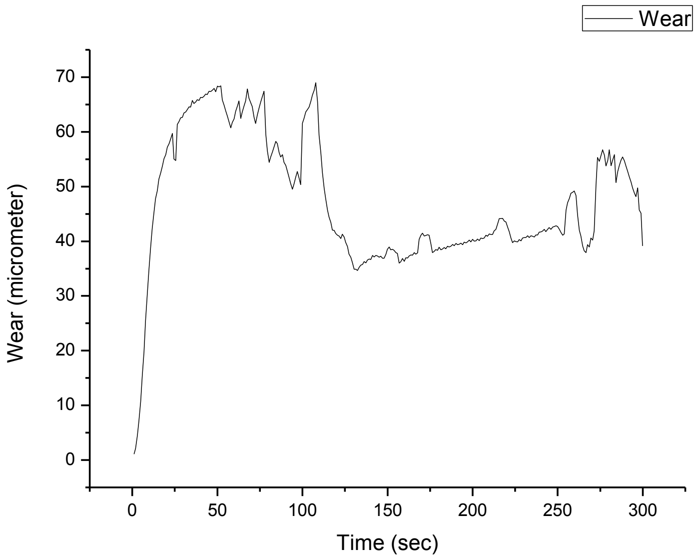

Fig. 5. Variation in wear rate at for 300 sec at 300rpm under 2kgf load with power of 220w and scanning speed 300mm/min.

VII. CONCLUSION

(1) Laser cladding applications include better wear resistance of diesel engine exhaust valves, gas turbine blades and the repair of inserts and dies. The high-quality surface layers that can be generated by laser cladding only, make it an excellent technique.

(2) It can be seen that the laser cladding of TiN results in cladding without any pores, crack and porosity. A uniform clad layer is synthesized in most of the samples by selecting the optimum parameters which can contribute to a satisfactory cladding.

(3) Most of the sample shows the excellent hardness which increases as the power increases. In this research TiN cladding results in improving the wear resistance.

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