Effect of Laser Power on Wear Resistance of Laser Deposited Ti64l6V+W Composites

N. Ndou

***Abstract*— High quality, low weight and exceptional corrosion resistance properties controlled by titanium alloys have prompted an extensive variety of successful applications in aviation, car and power generation. Laser scanning speed on deposits of Ti64l4V+W was studied. The laser metal deposition (LMD) procedure has turned out to be one that is supportable. The results show that low scanning speed has a higher groove depth compared to high scanning speed. The relationship between scanning speed and groove depth correlates with wear performance. The outcomes reveal that scanning speed of the Ti6Al4V/W composite can be controlled successfully. JOEL scanning electron microscopy (SEM) was used to consider the morphology of the wear scar. The tests were performed under various loads for a time of 111 cycles at a frequency 5 Hz.**

***Index Terms*— Heat affected zone, Laser metal deposition**

I. INTRODUCTION

In the present investigation the effect of laser scanning speed on the wear resistance performance of the laser metal deposition on Ti6Al4V/W composites was determined. Because of the generally low density, better quality at high temperatures, good corrosion resistance and exceptional quality to thickness ratio, Ti6Al4V and other alloys are essential in developing most parts utilised in the aerospace and air manufacturing industry [1,2]. Titanium grade 5 alloys are regarded as hard to cut on because of their high chemical activity and low thermal conductivity [2-4]. The chemical reaction of titanium at high temperatures in the cutting zone results in the development of a hard layer, leading to deceasing tool life[5]. Mechanical properties in the aerospace industry parts are hard to machine. The process of laser metal deposition has been utilized for improving the workpiece surface since it fabricates the life expectancy workpiece and reduces the assembly costs[6], while guaranteeing surface hardness[7]. Surface alteration by methods for lasers is intriguing in light of the fact that lasers demonstrate high consistency and are directional, implying that they offer accuracy at a range without damaging any part of the surface[8].

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Recently, it has been exhibited that tungsten particles can be utilized in a titanium matrix, realizing a Ti6AI4V + W coating of great quality[9]

II. EXPERIMENTAL METHODS

A. *Samples preparation and equipment*

Prior to deposition, the substrate was cleaned and sandblast to remove undesirable so as to encourage adequate metallographic joining. The layer of the material was cleaned with acetone to improve the laser control maintenance. The deposition of Ti6Al4V/W particles was performed at the National Laser Centre of the Council for Scientific and Industrial Research (CSIR) in Pretoria, South Africa, utilising a robot arm machine with an extreme intensity of 4 400 W. The powder feeder was loaded with Ti6Al4V and W powders at a stream rate particularly in respect of rotational speed. It is better to use separated double containers than pre-blended powders, as pre-mixed powders are not of a uniform density. Chambers were loaded with argon gas to avoid oxygen contamination on the deposited composite samples. Argon gas were used to keep the sample from oxidising through the procedure, control the gas, the argon gas control the flow of powder and the melted metal in the foreseen direction.

Figure1: Experiment set-up

B. *Experimental procedure*

Ti6Al4V was utilised as the substrate, which was a solid plate with a measurement of 105 x 105 x 7.5 mm3. Before the laser metal process deposition, all undesirable material

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on the solid substrate was detached by sandblasted to allow firm metallurgical bonding from the substrate surface. The Titanium alloy grade 5 and Tungsten particles were sustained through two different hoppers connected directly to the nozzle. The two powders were arranged in various positions in connection to one another. Every container was set by the predefined ratio in the experiment setup. LMD was completed utilising laser power of 800 W, 900 W, 1200 W, 1000 W and 1400 W. The laser scan speed of 0.05 m/s was kept constant for Ti6Al4V+W. The beam diameter of 2 mm was utilised during the trial setup and the focal point beam was set at 15 mm under the surface substrate. The deposited track on the substrate was cleaned with a metal brush to prevent unwanted sparks from forming during the deposition process. All specimens were carefully ground, polished and etched according to the ASTM standard[10]. Figure 2 is a diagram demonstration of the laser cladding method.

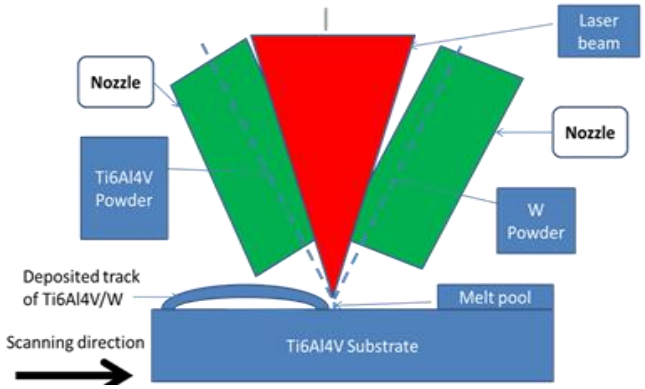

Figure 2: Diagram demonstrating the laser metal deposition process

The coated samples were delivered utilising the laser metal deposition process and produced samples were designated B1 to B5. The hot mounting press machine was utilised to mount all the coated samples.

Table I: Process parameters

Sample Number	Laser Power	Laser Scanning Speed	Feed Rate (unit)		Gas Flow Rate (rpm)
	W	m/min	Ti6Al4V	W	
B1	800	0.5	95%	5%	2
B2	900	0.5	95%	5%	2
B3	1 000	0.5	95%	5%	2
B4	1 200	0.5	95%	5%	2
B5	1 400	0.5	95%	5%	2

C. Microstructures

After the sample preparation, all samples were sectioned. Lecco pressing machine were used to mount the samples using polyfast resin. After mounting of samples, grinding was performed to remove unwanted material on the surface of the coated material. After grinding, the sample was wash with clean water and dry. Polishing disc was applied to smooth the surface and removed undesired scratches on the coated material. The preparation was set up with 3 ml hydrofluoric acid, 100 ml water and 5 ml nitric acid and (30%H2O2, 70% H2O), according to Kroll's reagent. All the coated samples were etched for 15 - 20 s using the Kroll's reagent. The samples were cut, polished carefully, cleaned with acetone, washed with clean water and dried off to reveal the microstructure. Further analyses to the damage structures and morphology of the wear debris generated were characterised utilising microscopy machine.

D. Hardness

The indentation was conducted on the etched sample by utilising the hardness tester, which was accessible at the Tshwane university of technology, Pretoria, South Africa. The dwelling time of 10 s and the indentation load of 500 g was used. The spacing between indentation applied was 100 μm. The microhardness experiment was conducted according to the E384-11el ASTM standard11.

E. Wear resistance testing

Wear testing was performed at the Tshwane University of Technology (TUT) to determine the wear-track surface profile. The wear resistance test was conducted by utilising the UMT-2 CETR tribotester on a dry sliding wear analyser as per ASTMG133-0511. This machine was made accessible at (TUT) campus, Pretoria campus, South Africa. The ball is made of tungsten carbide, at a distance of 10 mm, under a load of 25 N and a reciprocating frequency of 20 Hz and for 1 200 s. To accomplish the load of 25 N, both the frictional power and the typical power were set to 0, with the sample measurements of 24 mm x 14 mm x 14 mm. SEM was utilised to measure the wear surface. Figure 3 shows the wear rule.

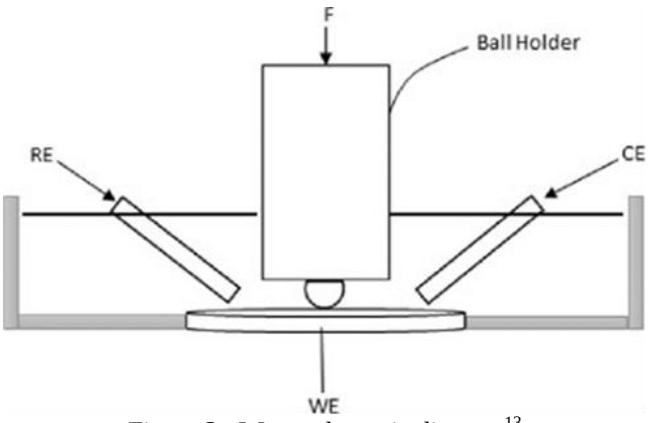

Figure 3: Wear schematic diagram[13]

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According to[14-15], the wear volume loss is calculated by following equation:

$$V_w = L_s\left[r^2\sin^{-1}\left(\frac{w}{2r}\right)-\frac{w}{2}\left(r^2-\frac{w^2}{4}\right)\right]+\frac{\pi}{3}\left[2r^3-2r^2\left(r^2-\frac{w^2}{4}\right)^{\frac{1}{2}}-\frac{w}{4}\left(r^2-\frac{w^2}{4}\right)^{\frac{1}{2}}\right]$$

(3.1)

Where V_w = Wear volume in mm^3
Ls= Stroke length
R = Pitch radius
W = Wear width

III. Results

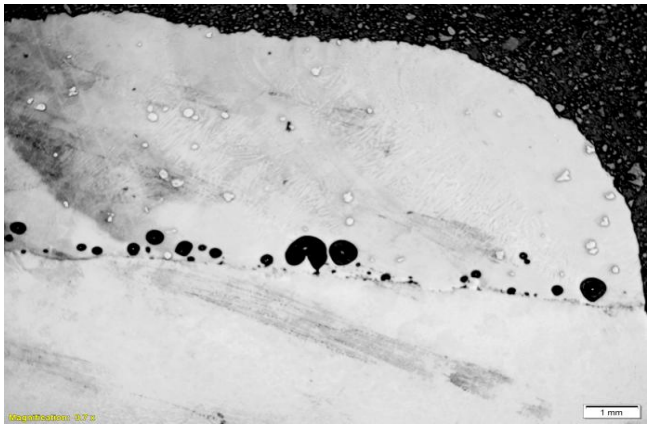
A. Microstructure

The microstructures of the selected samples appear in Figure 4(a) – (c). The deposition process was utilised to produce coated samples with laser power from 8kW to 1.4kW and a 0.05 m/s scanning speed.
Five coated samples were deposited into the substrate and the deposited samples were labelled B1 to B5. Prior to the cladding method, all the substrate material was cleaned by a high-pressure sandblaster machine to take out all undesirable material and to set up the samples for metallurgical bonding. Figure 4(a) shows a coated sample deposited at a 0.05 m/s scanning speed and laser power of 1 200 W. It displays little porosity. The porosity may be caused by insufficient time during the cladding process or insufficient interaction time and the entrapped gas throughout solidification[16]. Figure 4(b) shows a coated sample deposited at a 0.05 m/s scan speed and 1000 W laser power. It shows good bonding with little porosity. The ductility of the composite was improved due to a slow cooling rate. The cooling rate results in a lower scanning speed.
Figure 4(c) demonstrates the heat affected zone (HAZ) and microstructure of the coated material. It also shows the thin strip that was totally secured with W particles. The bonding between the deposited coated layer and the uncoated material is also demonstrated in Figure 4(c).

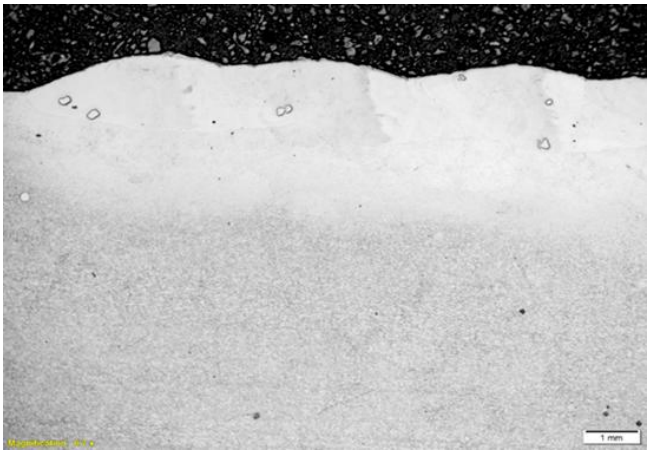
A. Wear resistance testing

The micrograph of the worn surface Ti6Al4V + W composites is demonstrated in Figure 5(a) – (b). The dry sliding wear analyser was used to assessed the wear resistance of Ti6Al4V + W coating, the samples were pressed under a load of 25 N with a distance of up to 2 mm. Figure 5(a) demonstrates that, as scanning speed decreased, the material time connection expanded, and this enhanced wear volume.

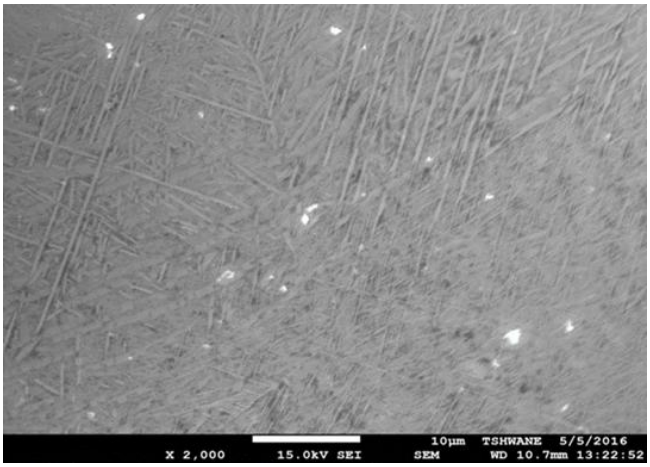
Figure 5(a) displays the micrograph of the wear track of Ti6Al4V + W composite with the debris coming out of the detached materials. It also demonstrates the wear width estimated from the SEM and the wear depth from the wear investigation. Figure 5(b) indicates the wear track acquired during the wear method. A tungsten carbide ball connects with the surface of the coated material, driving the friction activity of the two surfaces. During this friction activity, solid adhesion occurs, leading to a high temperature, which makes debris increase the wear activity.
The impact of the load was seen during the ball-on-flat sliding wear test. Tungsten wear took place under the growing load, and a high deep groove was observed. Different laser power settings from 800 W to 1 400 W were used with a constant scanning speed of 0.05 m/s. 900 W laser power resulted in rise in the wear resistance related to the uncoated substrate.



(a)



(b)



(c)

Figure 4: Etched SEM micrographs showing the coatings deposited at various laser power and constant scanning speed 0.05 m/s: (a) laser power of 1200 W, (b) laser power of 1000 W , (c) laser power of 1000 W

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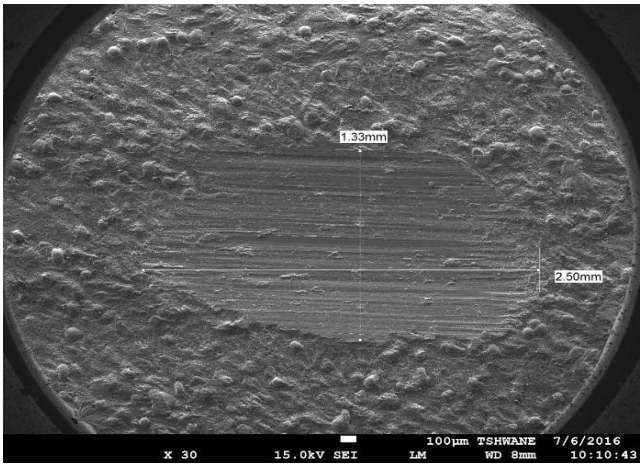

Figure 5(a): Micrograph of wear track at low magnification

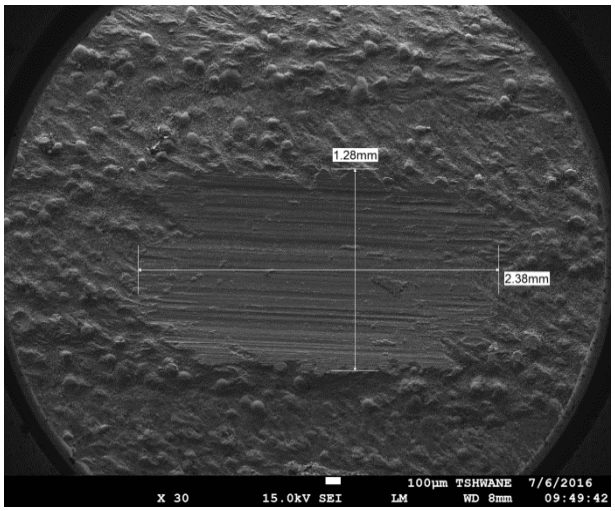

Figure 5(b): Micrograph of wear track at low magnification

The lower scanning speed resulted in more unmelted carbide (UMC). With a high amount of UMC, wear resistance on the ground is strong due to the good support effect of the Ti6Al4V/W powder[15].

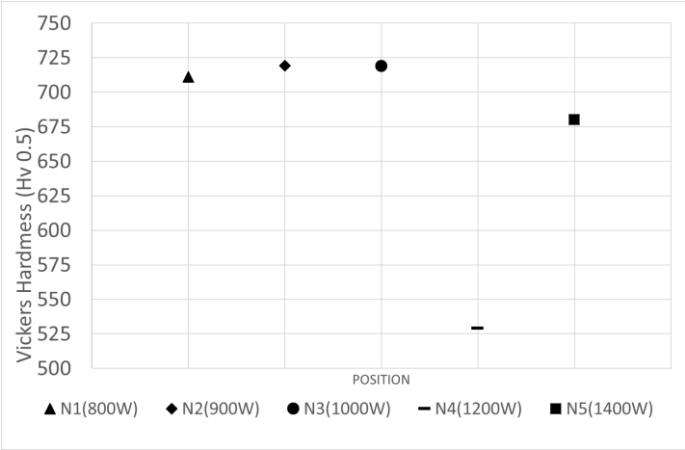

Figure 6: Distribution of hardness

IV. CONCLUSION

The performance of Ti6Al4V/W against the tungsten carbide balls was investigated. The results show that scanning speed has an influence on the performance of wear resistance. The findings of the study are as follows:

- The effect of load pressed under 25 N was observed during wear test
- A better surface finish was achieved with a 0.05 m/s laser scanning speed and laser power of 1000 W was achieved.
- The sample deposited with a laser power of 1000 W shows the highest microhardness values.
- The coating sample performed at a 0.5m/min the scanning speed and the laser power of 1000 W demonstrated increase in the wear resistance compared to the substrate.

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