Influence of Laser Power on the Deposition Ti64l4V/W Composite

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***Abstract*— the influence of laser power on the deposited of Ti64l4V/W composites was investigated. The energy flow rates were varied while every single other parameter were kept at a steady. The evolving microstructure and the hardness of the composites were studied and reported in this study. The study established that the laser metal deposition process is suitable for producing acceptable bonding between a deposited zone and a substrate zone. The hardness values of the deposits varied from 377HV to 719HV. The laser power directly influences the hardness and the microstructure. Scanning electron microscopy (SEM) was utilised to characterise the microstructure of the composite layer formed on the surface of the Ti6Al4V substrate. The microstructure of all the composite layers delivered by the LMD procedure has upgraded properties in connection to that of the Ti64l4V substrate.**

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

I. Introduction

Titanium and other light-weight materials are vital to the improvement of new aviation, motor vehicle and organic applications [1]. Elective assembly strategies assume an exceptionally basic part in these improvements. Laser-based added substance assembling is one of such options. Close net-formed titanium segments can undoubtedly be produced at a greatly decreased expense [2-4].

In the past, numerous systems have been used for creating metal matric composites (MMC) of various Ti combinations [5-9]. Among them, Laser metal affidavit (LMD) is viewed as a suitable arrangement [10-11]. In the laser metal deposition, the laser force is utilised for dissolving the top layer of the metal substrate, while included substance powder is kept in the melt pool in the meantime. The complex composed parts are delivered with the LMD at a significantly lesser expense when contrasted with conventionally created methods, such as turning and framing [12].

The objective of this work is to focuses on the influence of laser power on the deposited composites, microstructure, microhardness, and surface completion of the laser metal deposition of Ti6Al4V/W.

II. Experimental Methods

A. Samples preparation and equipment

Prior to the deposition process, all substrates were sandblasted to remove all unwanted material to facilitate adequate metallographic bonding. Acetone was used to clean the surface so that the laser energy absorption could improve.

Laser system equipment with a maximum power of 4400 Watts was employed for laser cladding using the facility at the National Laser Centre of Council for Scientific and Industrial Research (CSIR), South Africa, Pretoria. Laser metal depositions were achieved by using laser system that uses Kuka robot. The hopper was filled with powder material, such as Ti6Al4V and W powders. Cylinders were filled with argon gas, which is used to stop oxygen contamination on the deposited composite. In addition, an argon shield was utilised to protect deposit from oxidation during the process.

In this experiment, pure nitrogen was used as a powder transporter and a protecting gas In the trial set-up, the metallic powder was infused into the melt pool through a coaxial while all the high powered laser beam melted the cladding material over the substrate or base metal (as shown in Figure 1).

Figure1: Experimental set up

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B. Measurement and method of analysis

A Ti6Al4V specimen measuring 102 x 102 x *7.45 mm^3 was used as the substrate. In this study, two hoppers were used to allow simultaneous deposition of the powder. The laser beam focal point was set at 15mm below the substrate surface, and the beam distance across was kept consistent at 2 mm. The deposited specimens were cleaned so that unmelted powder could be removed. The Ti6Al4V and W powders were fed through two hoses directly to the nozzle from two different hoppers. It may also be better to use two separate hoppers than to use pre-mixed powders, as pre-mixed powders result in different densities. Argon was used to shape gas, to make the powder and to make the melted metal flow in the desired direction. Figure 2 shows two different hoppers. The two powders used were positioned in different positions in relation to each other. Each hopper was set according to the predefined ratio in the experiment set-up. The procedure parameters utilised as a part of this study are presented in Table 1.

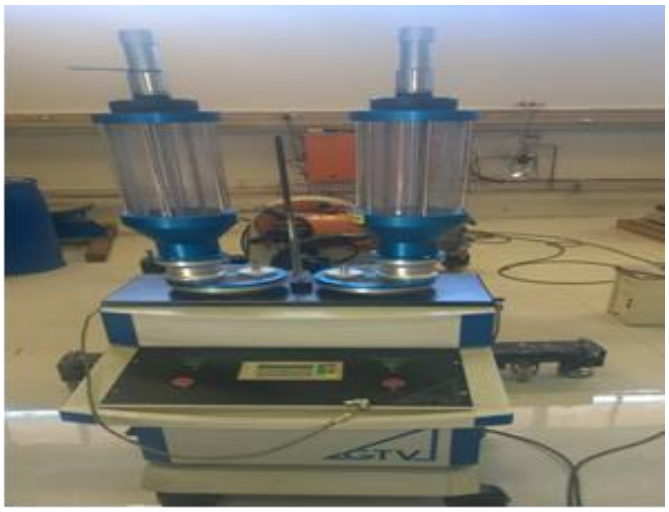

Figure 2: Powder feeder

Five deposits were produced using the laser powers assigned as N1 to N5. The specimens were mounted in polyfast using a hot mounting press

Table 1: Experimental Matrix

Specimen names	Power (W)	Scan speed	Powder rate (rpm)		Gas rate	
			Ti	W	Ti	W
N1	800	0.007	9.5	0.5	1.5	3
N2	900	0.007	9.5	0.5	1.5	3
N3	100	0.007	9.5	0.5	1.5	3
N4	1100	0.007	9.5	0.5	1.5	3
N5	1200	0.007	9.5	0.5	1.5	3

C. Microstructure

After laser process, the deposited materials were section and mounted with polyfast using press mounting. Furthermore, the standard working procedure requires that the titanium substrates are polished by 320 bonded papers. The samples were prepared according to E3-11 ASTM standards [13]. The samples were polish using MD CHEM. Also, the samples were etched for 10 -15 s by means of Kroll's reagent. The reagent was set up with 100 ml of water, 2 ml o hydrofluoric acid and 4 ml of nitric acid and (30%H_2O_2, 70% H_2O). The microstructure was analysed in detail with a BX51M Olympus microscope. Further analyses for microstructure were characterised using JOEL scanning electron microscopy (SEM) with X-ray energy-dispersive spectroscopy (EDS). SEM was utilized to give high resolution and high amplification pictures of the specimen

D. Hardness

The etched specimen were indented using the Vickers hardness machine Metkon micro hardness tester, this equipment was available at the University of Johannesburg, South Africa. The indentation load used was 500 g and a dwelling time of 10 s. Spacing applied was 100µm between the indentations. Moreover, hardness test was done according to E384-11el ASTM standard [14].

III. Results

A. Microstructure

The investigation focused on the deposition of Ti6Al4V and W. The Scanning Electron Microscopy (SEM) powder of the Ti6Al4V is shown in Figure 3 (a), while, the SEM powder of the W is shown in Figure 3(b). The analysis of the Ti6Al4V and W is shown in Figures 3(c) and 3(d) respectively.

Images of scanning electron microscopy are captured from a cleaned cross-section of Ti6Al4V/W coating at 1000 W laser power (See Figure 4). The samples were ground, polished, and etched with Kroll's reagent so that the grain boundaries could be revealed. Figure 4(a) shows the three zones, namely: Heat affected zone (HAZ), deposition zone, and substrate zone. Acceptable bonding between the deposition zone and the substrate are also presented in Figure 4(a). Figure 4(b) demonstrates titanium strips happening with hexagonal particles. Figure 4(c) demonstrates the difference in the microstructure of the deposition and the heat -affected zone. On the bonding interface, the covering was portrayed by a slight strip that was completely secured with a permeable layer. Figure 4(d) demonstrates the micrograph of the HAZ and the substrate bonding between the coating and substrate was acceptable.

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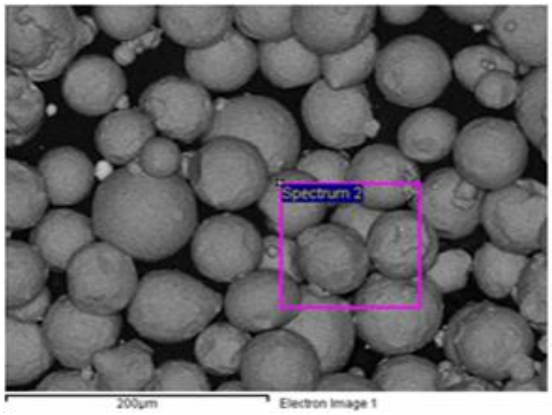
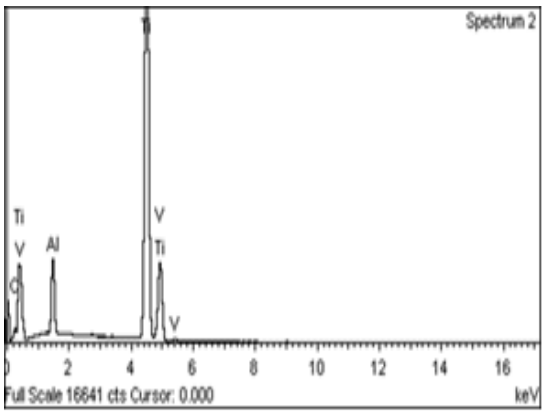


(a)



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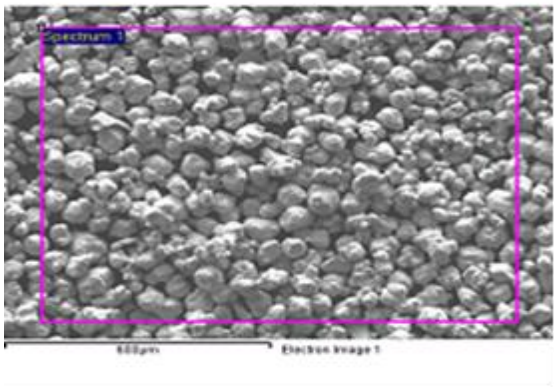
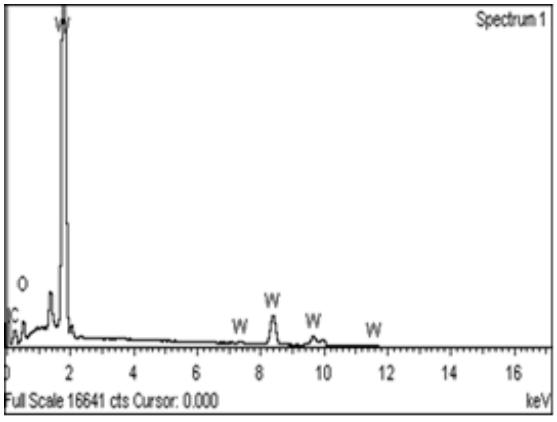
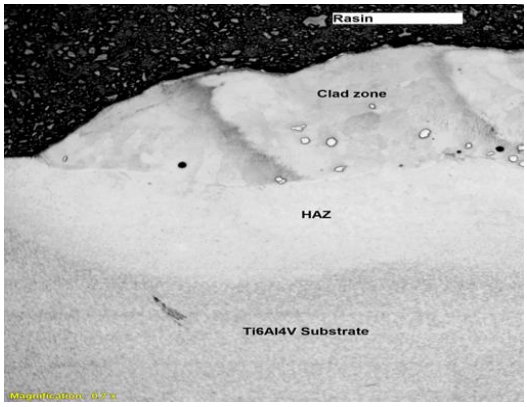


(c)

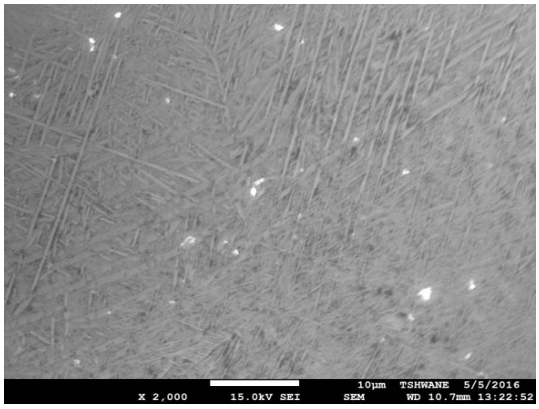


(d)

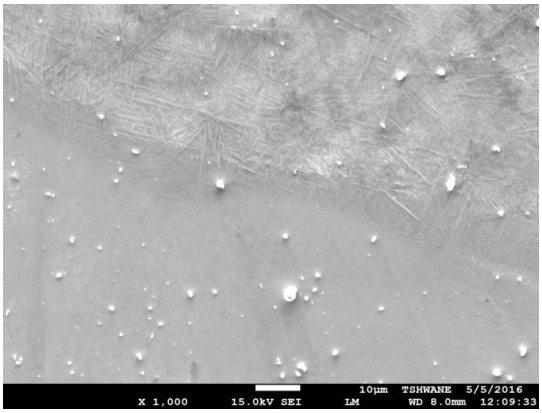
Figure 3 (a) Ti6Al4V powder, 3(b) the analysis of Ti6Al4V powder, 3(c) W powder, 3(d) the analysis of W powder



(a)



(b)



(c)

(d)

Figure 4: scanning electron microscopy (SEM) photos of (a) LMD at 1000W, (b) image of the deposition, (c) image of the deposition and HAZ, and (d) image of HAZ and Ti substrate

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B. *Micro-hardness*

The indentation was done from the highest point of the deposited zone to the fusion zone and up to the substrate. Hardness increment was found in four deposited of LMD processes. Figure 5 show micro-hardness distributions in the composite coatings. The thickness of the hardness composite coatings is it increased with increasing laser power. However, the small scale hardness estimations demonstrate that the most reduced hardness measured was that of the composite coating deposited at 1100W (N4).

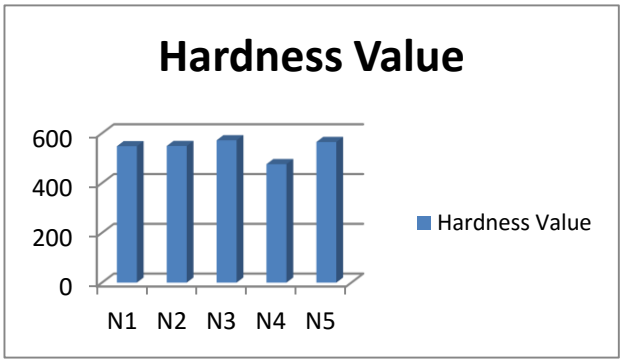

Figure 5: Micro-hardness distributions in the composite coatings

Figure 6 presents the micro hardness profiling of the 1000 W coating. The average hardness values for the deposition zone and the heat affected zone was 430.23 HV. These results show that the coating was strong and without crack or become porous. The hardness between the deposited zone and the substrate was 422 HV. This quality is acceptable and demonstrates the high metallurgical bonding between the substrate and the deposited zone. Since no split or break was made amid the space methodology, it can be presumed that this deposition was strong.

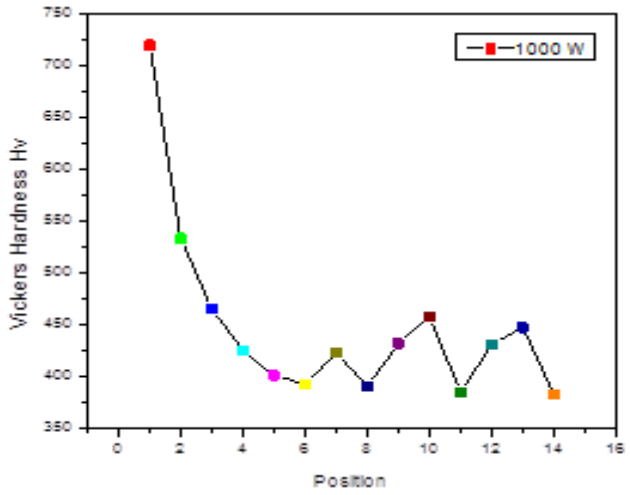

Figure 6: Micro-hardness deposited at the laser power of 1100W

IV. CONCLUSION

The effect of laser power on the microhardness has been studied. The deposition of Ti6Al4V/W coatings on the Ti6Al4V substrate was achieved by LMD processes. The outcomes of this work are summarised as follows:

- LMD processes are suitable for producing acceptable bonding between deposited zones and substrates.
- Sample N3 shows the highest hardness value at the power of 1000W
- Moreover, this study on the impact of laser force rate uncovers that as the laser power expanded, the average micro-hardness diminished.

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REFERENCES

[1] H. Sibum, Titanium and Titanium Alloys—From Raw Material to Semi-finished Products. *Advanced Engineering Materials*, , pp393-398, 2003
[2] R. Vilar, Laser cladding. *Journal of Laser Applications*, 11, pp 64-79,1999.
[3] D.Boisselier and S. Sankaré, Influence of powder characteristics in laser direct metal deposition of SS316L for metallic parts manufacturing. *Physics Procedia*, 39, 455-463, 2012
[4] J. Koch and J. Mazumder, Rapid prototyping by laser cladding. Laser Materials Processing, 556, 1994
[5] B. Kooi, Y. Pei and J.T.M DE Hosson, The evolution of microstructure in a laser clad TiB–Ti composite coating. *Acta Materialia*, 51, 831-845, 2003
[6] Y. J Kim, H. Chung and S.J.L. Kang, Processing and mechanical properties of Ti–6Al–4V/TiC in situ composite fabricated by gas–solid reaction. *Materials Science and Engineering: A*, 333, 343-350, 2002.
[7] R. Banerjee, A. Genc, D. Hill, P. Collins & H. Fraser, Nanoscale TiB precipitates in laser deposited Ti-matrix composites. *Scripta materialia*, 53, 1433-1437, 2005
[8] S. Mridha & T. Baker, Metal matrix composite layers formed by laser processing of commercial purity Ti–SiCp in nitrogen environment. *Materials science and technology*, 12, 595-602, 1996
[9] S. Mridha & T. Baker, Incorporation of 3μm SiC p into Titanium surfaces using a 2.8 kW laser beam of 186 and 373MJm− 2 energy densities in a nitrogen environment. *Journal of materials processing technology*, 185, 38-45, 2007
[10] E. Toyserkani & A. Khajepour, A mechatronics approach to laser powder deposition process. *Mechatronics*, 16, 631-641, 2006
[11] J. Scott, N. Gupta, C. Weber, S. Newsome, T. Wohlers & T. Caffrey, Additive manufacturing: status and opportunities. *Science and Technology Policy Institute, Washington, DC*, 1-29, 2012
[12] R. M. Mahamood, E.T. Akinlabi, M. Shukla & S. Pityana, Effect of laser power on material efficiency, layer height and width of laser metal deposited Ti6Al4V, 2012
[13] Standard, A. 2012. E3-11: Standard Guide for. Preparation of Metallographic Specimens, ASTM International., West Conshohocken, PA.
[14] Standard, A. E384-11E1,—Standard test method for Knoop and Vickers hardness of materials,‖ in ASTM International, West Conshohocken, PA, 2007, DOI: 10.1520/E0384-11E01.