Effect of Laser Power on Surface Finish during Laser Metal Deposition Process

Rasheedat M. Mahamood* and Esther T. Akinlabi.

Abstract— Laser Metal Deposition (LMD) process is an additive manufacturing technology that is used to fabricate complex part through adding of materials layer after layer until the part is completed. Poor surface finish is one of the limitations in additive manufacturing process. In this study, the influence of processing parameters on the surface finish produced on laser metal deposited Titanium alloy was studied. The laser power was varied between 0.8 kW 3.2 The scanning speed was kept at 0.005 m/s and the powder flow rate was kept constant at 2 g/min. The gas flow rate was also kept constant at 2 l/min. The study revealed that as the laser power was increased, the surface finish was increased. The results are presented and discussed fully.

Keywords— Additive Manufacturing Process, Laser Metal Deposition (LMD), Laser power, Surface finish, Ti6Al4V.

I. INTRODUCTION

Ti6Al4V, is an important aerospace alloy and it is referred to the power horse of the industry [1] because of its excellent properties [2]. Despite this, Titanium and its alloys are difficult to machine [3] because of its affinity to the cutting tool materials. The buy-to-fly ratio of small complex aerospace part is very high as a result of material wastage that occurs during the fabrication process [4]. Laser metal deposition (LMD) is an additive manufacturing technology that is capable of producing complex simply by adding materials layer by layer [5,6] as against material removal in the traditional manufacturing process.

LMD can also be for the repair and tooling aerospace and automotive industries [7-9]. LMD is achieved by creating a melt pool on the substrate by the laser beam wherein powder or wire is then fed into the melt pool. This technology can be used to produce functionally graded material [10], both as coatings and as a complex three-dimensional. The complex part is produced directly from the three dimensional (3D) image of the part [11]. One of the drawback of this great technology is that the process is yet to be fully understood and the surface finish of the part produced is poor and it usually requires a secondary finishing operation. A lot of studies have appeared in the literature about effect of processing parameters on surface finish in LMD process [12-15].

Ahn et al., 2009 studied the prediction of surface roughness using data measurement and interpolation [12]. Zhu et al., 2012 [13] studied the benefit of positioning the powder focus below the melt-pool and the quality of the surface finish. This study showed that a melt-pool enlargement was the main contributor to optimum surface finish produced. In another study conducted by Alimardani et al., 2012 [14] was also shown that controlling the melt-pool dimension and temperature could improve the surface finish. This study investigated the effect of increasing the scanning speed and the melt pool dimension on the quality of the surface finish. Influence of particle size on surface quality has also been correlated in a similar study performed by Spierings et al., 2010 [15].

This study investigated the influence of laser power on the surface finish variations in laser metal deposited Ti6Al4V. The laser power was varied from 0.8 kW to 3.2 kw, while the other processing parameters: scanning speed, powder flow rate and gas flow rate were kept constant. The results were analyzed and fully presented.

II. EXPERIMENTAL PROCEDURE

The Ti6Al4V substrate used in this study is of 99.6% pure and of dimension 72 x 72 x 5 mm. The Ti6Al4V powder used is in this study is also 99.6% pure and of particle size ranging between 150 and 200 μm. The substrate was sandblasted and cleaned with acetone in order to roughen the surface so as to improve the laser energy absorption process. The experimental set-up consists of a Kuka robot carrying an Nd-YAG laser head (by Rofin) in its end effector. This experimental set-up is available at the CSIR, National Laser Center, Pretoria, South Africa. To prevent the environmental attack on the deposited samples which can cause scaling of the sample surface as a result of oxidation, a glove box was improvised to prevent contamination of surface finish produced. The glove box was filled with argon gas. The laser metal deposition process was achieved by the laser beam creating a melt pool on the substrate and then the Ti6Al4V powder was then delivered into the melt pool through the coaxial powder nozzles attached to the end-effector. A solid track of Ti6Al4V metal was created upon solidification of the melt pool. The laser power used was between 0.8 and 3.2 kW.

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The experimental set-up is shown in Figure 1. The Ti6Al4V powder flow rate, scanning speed and the gas flow rate are fixed at 2 g/min, 0.005 m/s and 2 l/min respectively. The experimental matrix is presented in Table 1. The laser beam was maintained at a focal distance of 195 mm above the substrate to maintain the laser beam at a constant diameter of 2 mm

Figure 1. Experimental Set-up

Table 1 Experimental matrix

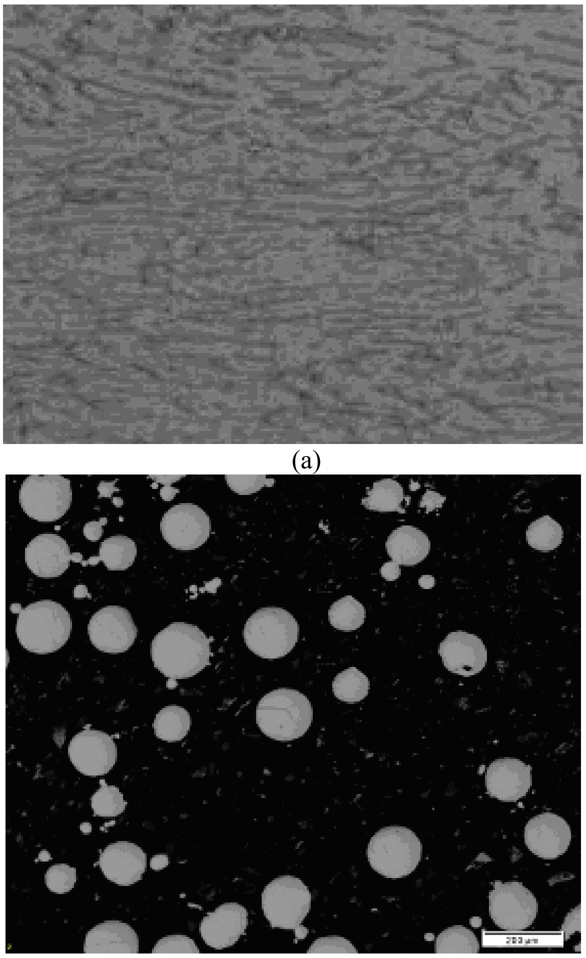
Sample Designation	Laser Power (kW)
A	0.8
B	1.2
C	1.6
D	2.0
E	2.4
F	2.8
G	3.2

After the deposition process, the samples were cleaned with acetone in preparation for surface roughness measurement. The surface roughness measurement was achieved using stylus surface analyzer by Jenoptik, equipped with Hommelmap 6.2 software. The surface analyzer is shown in in Figure 2.. The effective measuring length was kept at 4.8 mm. The cut-off length was maintained at 0.8 mm; and the measuring range was kept at 400 µm. A sliding speed of 0.50 mm/s was also selected. The measuring condition used in the study was according to the „BS EN ISO 4288:1998" standard. Five measurements were taken on each of the samples, and the arithmetic average of the 2D roughness profiles (Ra) was recorded for each samples.

Figure 2 Jenoptik surface profiler

III. RESULTS AND DISCUSSION

The microstructure of the substrate used in this study as observed under the Olympus optical microscope is shown in Figure 3a and the morphology of the Ti6Al4V powder is shown in Figure 3b. The microstructure of the Ti6Al4V is characterized by alpha and beta grain structure. The lighter part in the microstructure represents the alpha grains while the darker parts are the beta grains. The morphology of the powder is characterized by spherical shaped gas atomized powder. The results of the surface finish are presented in Table 2.



(a)

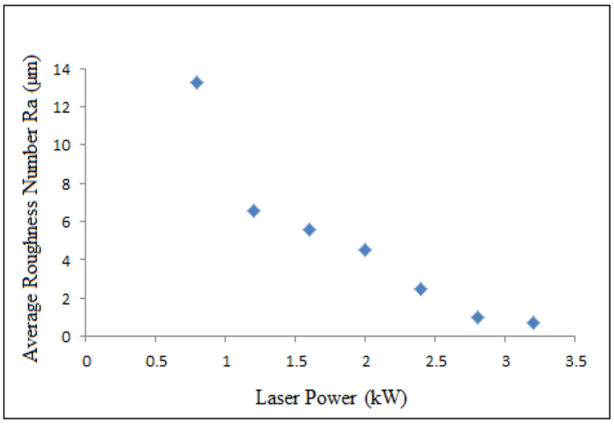
(a)

Figure 3: (a) Micrograph of the substrate (b) Micrograph of the Ti6Al4V powder [16]

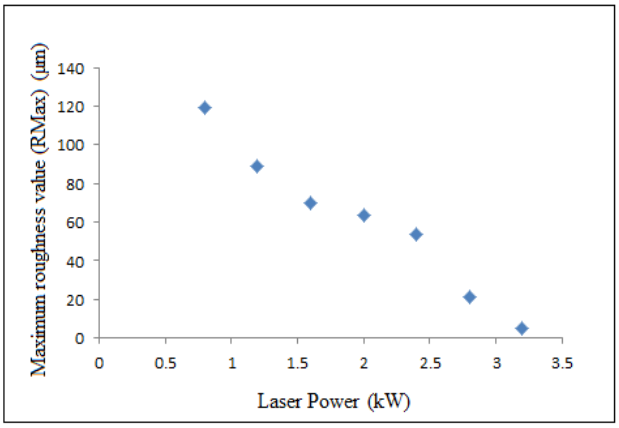
Table 2 Results of surface roughness

Samples Designation	Average Surface roughness value (Ra)	Rmax
A	13.3	119.5
B	6.6	88.8
C	5.6	69.7
D	4.5	63.2
E	2.5	53.7
F	1	21
G	0.7	5.3
Substrate	0.46	4.8

The plot of average roughness value against the laser power is shown in Figure 4a. and the plot of the maximum roughness value against the laser power is also shown in Figure 4b. The graph of surface roughness of the parent material, samples A, B, D, F and G are presented in Figure 5a-5f respectively.



(a)



(b)

Figure 4 The plot of (a) Ra against laser power (b) Rmax against laser power

The surface roughness is found to reduce as the laser power was increased ass seen in Figure 4a. This is because as laser power was increased there is more available power for proper melting of the deposited Ti6Al4V powder. The proper melting of the powder at higher laser power gives rise to smoother a surface thereby reducing the average roughness number. At low laser power, not all the powder delivered by the powder nozzle was fully melted thereby causing some of the unmelted powder particles to cause the higher roughness number observed. Also the maximum roughness number Rmax at low laser power is very high as a result of the unmelted Ti6Al4V powder particles seen at low laser power. These effects are seen properly in Figures 5b – 5f. The high laser power produces high volume of melt pool which is also responsible for the improved surface finish achieves. This result is consistence with the literature [12, 13].

IV CONCLUSSION

Ti6Al4V is an important aerospace alloy and difficult to machine using traditional manufacturing process. Manufacturing complex aerospace part involves various manufacturing processes when produced using the conventional manufacturing process. Additive manufacturing is an excellent manufacturing process capable of producing complex parts in a single manufacturing run, but surface finish is one of the problems of this exciting technology. This study investigates the effect of laser power on the surface finish produces in laser metal deposition process, an additive manufacturing process. Laser power was varied between 0.8 kW and 3.2 kW. The scanning speed, powder flow rate and gas flow rate were kept at constant values of 0.005 m/s, 2g/min and 2 l/min respectively. The study reveals that as the laser power was increased the surface finish was improved. This study shows that a better surface finish can be achieved in laser metal deposition process by using a high laser power. With the right combination of processing parameters and high laser power an improved surface finish is achievable.

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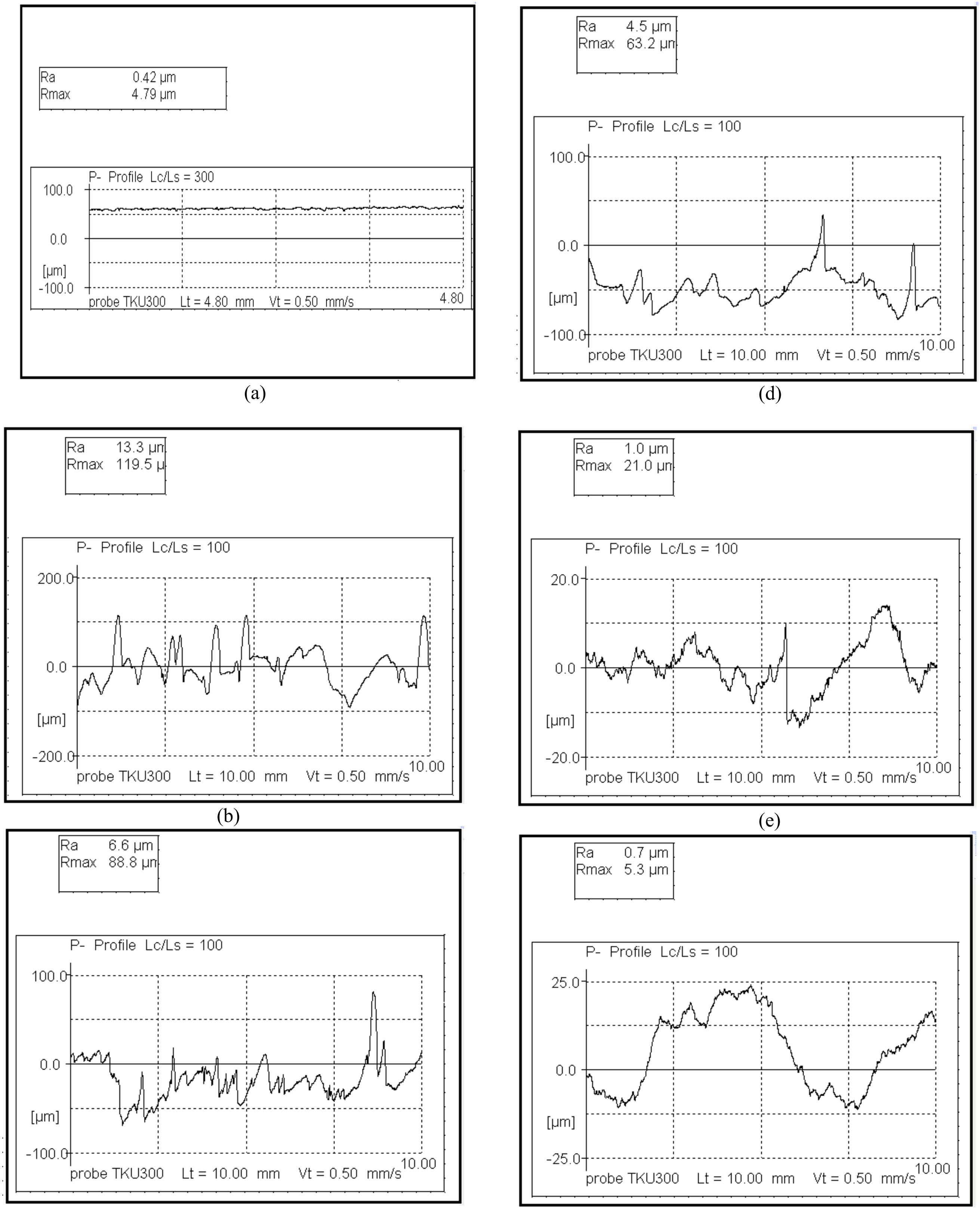

(a) (d)

(b) (e)

(c) (f)

Figure 5 Surface profile of the (a) substrate and sample at laser power of (b) 0.8 kW (c) 1.2 kW (d) 2.0kW (e) 2.8 kW (f) 3.2 kW

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