6th International Conference on Applied Engineering and Natural Sciences

September 25-26, 2024 : Konya, Turkey

© 2024 Published by All Sciences Academy

https://www.icaens.org/

Fiber Laser Peening of Ti6Al4V Alloy Considering the Effects of Laser Power, Scan Speed and Overlap Rate on Surface Morphology and Roughness

Satılmış ÜRGÜN[1*], Sinan FİDAN [2] Mehmet İskender ÖZSOY[3], Mustafa Özgür BORA[2]

[1]*Department of Aviation Electrics and Electronics, Faculty of Aeronautics and Astronautics, Kocaeli University, Turkey*
[2]*Department of Airframe & Powerplant Maintenance, Faculty of Aeronautics and Astronautics, Kocaeli University, Turkey*
[3]*Department of Mechanical Engineering, Faculty of Engineering, Sakarya University, Turkey*

[*]*(urgun@kocaeli.edu.tr)*

Abstract – This research work has been carried out with attention to how the LP technique can change both the surface topography and roughness of the Ti6Al4V alloy by changing some of the most relevant parameters: power of laser, scan speed, and overlap rate. The Ti6Al4V alloy is considered for its exceptionally great strength-to-weight ratio besides being rated for excellent corrosion resistance and biocompatibility. In the experiment, the variation in the laser power varied from 10 to 30 W, the scan speed from 250 to 500 mm/s, and the overlap rate from 20% to 40% using a factorial design method to study the effects on surface texture. The surface morphology was characterized by optical microscopy and profilometry. With higher laser power, the surface is bound to be more irregular with higher valleys and peaks due to the higher material ablation rate, while at bigger scan speeds, the surface tends to be smoother due to lower energy input per unit area. The rate of overlap significantly influenced the uniformity of the surface-the higher the rate, the more homogeneous the texture of the surface would be. It has also been observed from the results that low laser power and high scanning speed combined to form a smooth surface, while a high overlap rate improved uniformity. For this reason, the present results are important for the understanding of the laser processing parameters with respect to surface topography in Ti6Al4V and as such improves its applications in industries where stringent surface modification requirements are required.

Keywords – Laser Peening (LP), Ti6Al4V, Roughness Morphology, Overlap

I. INTRODUCTION

Titanium alloys have a very high strength-to-weight ratio, excellent corrosion resistance and good biocompatibility. Indeed, due to these intrinsic properties, it has suitability for applications in many different sectors, especially biomedical, automotive, aerospace, and marine applications. The rationale for such widespread applications in those particular fields pertains to the fact that hostile conditions may be endured without sacrificing their structural integrity and functional efficiency. Because of this property, the biocompatibility, titanium alloys have found extensive applications in medical implants and equipment. Indeed, all of the properties mentioned above provide a reason for their versatility and engineering importance in many fields. In fact, they are ideal for long-term implantation in the human body owing to their excellent mechanical properties combined with a good strength-to-weight ratio and exceptional biocompatibility and resistance to corrosion [1,2]. Several surface treatment methods have been utilized to attain the required level of surface roughness, such as acid etching, sandblasting, and laser etching. These techniques are essential for increasing a material's surface properties, especially when it comes to enhancing wear resistance, adhesion, and cell integration in biomedical implants [3]. LST is one of the most promising ways of modifying the surface and is one of the well-known surface modification methods due to its

excellent beam quality, efficiency, precision, flexibility, accuracy, and being environmentally sustainable. In this process, a high-energy laser beam is focused on the material's surface, through which a micro-textured pattern is created by localized melting and vaporization of the material [4]. Ding et al. [5] showed that, though the laser can precisely control the size and shape of these patterns, wavelength, pulse duration, frequency, and laser power have such influential factors on the final surface topography that their optimization should be seriously worked out so as to achieve any particular results. The effects of open atmosphere laser polishing on additively built Ti-6Al-4V samples were assessed using ANOVA and statistical analysis. Software for statistical DOE model analysis was shown to provide better stability and applicability for this type of investigation. A detailed investigation was conducted into how different process parameters affected the final surface roughness. The study found that trustworthy mathematical regression models with above 90% prediction accuracy may be obtained using statistical DOE tools like MINITAB and Design Expert. On the other hand, it was discovered that MATLAB was not sufficient to produce precise mathematical formulas for prediction in this specific application [6]. Commercially pure titanium and Ti6Al4V alloy were surface treated by a picosecond laser, obtaining aligned grooves with sub-micrometric depths and micrometric widths and spacing (15-20 μm), hence assuring a mean roughness below 0.2 μm few asperities. The topography of the groove surface was given multiscale features owing to the peculiar micro and sub-micro features introduced by the laser process itself. The multi-scale texture, in applications like biomedical implants where surface features are of vital importance due to the contribution of tissue integration and mechanical performance, has improved surface properties that may lead to enhancement [7]. Yeşil et al. [8] studied the impact of three surface treatment types: SB, TSC, and YFL roughening on surface roughness and shear bond strength between titanium-ceramic on surface roughness using specimens produced with CST, ML, and SLM. The surface roughness was significantly higher ($p<0.01$) for the CST/YFL group at 1.254±0.058 μm, SLM/SB group at 1.294±0.054 μm, and SLM/YFL group at 1.208±0.057 μm. The data demonstrated that both surface treatment methods and manufacturing processes have a significant effect on shear bond strength while excessive roughness impairs bonding performance. Campanelli et al. [9] studied surface roughness and geometry of the shape of the Ti6Al4V parts laser milled by using a nanosecond Nd-laser source. This study focused on the effect of the processing factors of the laser on the machining outcome with the aim of establishing the conditions that are most suitable for the reduction of geometrical defectives and improvement of surface quality. Among the variables considered and analyzed were frequency, scanning speed, and average laser power. We have found that with an average power of 20 W, frequencies between 20 kHz and 35 kHz, and scanning rates of about 300 mm/min, it is possible to obtain roughness values below 2 μm. Rafiee et al. [10] evaluate how the frequency of pulsed Nd-YAG lasers affected the surface topography and biocompatibility of Ti6Al4V alloy. The laser frequency was adjusted within a range of 1 to 20 Hz, while all other parameters stayed fixed. The range of surface roughness was 452 nm to 3.37 μm. We performed additional analysis on the samples with the highest, lowest, and untreated surface roughness. The largest surface roughness was obtained at the optimal frequency of 10 Hz, and this was connected with better biocompatibility. Vs, a critical control parameter for generating different topographies in the irradiated surface, was adopted during the design of the laser surface texturing systems. Changing Vs further generates different geometrical and dimensional features along the texturized tracks. With a view to studying the effect of such features on the wetting behavior of the irradiation layer, the features were characterized, relying on advanced techniques for surface finish assessment. The results showed that as Vs increased, texturing grooves became more pronounced, improving the treated surfaces' hydrophobic qualities [11]. Maressa et al. [12] determine a first exploration into the use of a pulsed fiber laser to texturize Ti6Al4V alloy in order to improve surface adherence for bonding. The surface roughness measurements for the different treated surfaces are investigated. When sandblasted surfaces are compared to untreated surfaces, the average roughness changes very little, with Ra values of about 1 μm and Rz rising from 5 to 10 μm. By sharp contrast, the surface roughness of the dimpling textures has increased very much because of their repeated microstructures. Moreover, the surface roughness is highest for grid and chaotic textures since massive voids have formed on the surface. The average Ra value is approximately around 25 μm, Rq is 34 μm, and Rz is up to 130 μm.

This work presents a novel method for examining how laser peening affects the surface texturing of Ti6Al4V alloy. This research, in contrast to earlier works, focuses on generating unique surface textures through manipulation of the laser's strength, overlap rate, and scan speed. 3D optical profilometry and optical microscopy analyses are used to quantify the surface roughness of these laser-induced patterns. The results demonstrate the substantial influence of varying laser parameters on the surface topography, offering valuable perspectives for enhancing surface properties.

II. Materials and Method

A. *Material*

Grade 5 or Ti6Al4V, is among the popular titanium alloys characterized by a high strength-to-weight ratio, excellent intensification of corrosion resistance, and excellent biocompatibility. In fact, the alloy is a combination of titanium alloyed with 6% aluminium and 4% vanadium. The application of the alloy covers aerospace, biomedical (implants), automotive, and marine industries. The primary mechanical properties include: tensile strength, while it has highly durable applications. Due to its main density of 4.43 g/cm³, it is about 40% lighter than steel and preferred for light and durable structural material. The alloy has a thermal conductivity of 6.7 W/m K and a modulus of elasticity of about 114 GPa, thus giving it good thermal and structural stability [13-15].

B. *Laser Surface Texturing Process*

Figure 1 shows a simplified picture of Ti6Al4V material processing with fiber laser. Table 1 shows the Ti6Al4V laser surface sintering parameters obtained by the factorial experimental design method. In this experimental study, surface modification was performed on Ti6Al4V alloy using fiber laser, and the experimental design was made with the factorial method. Three main factors were taken into account in the experimental design: overlap rate, laser power, and scan speed. Each factor was adjusted at different levels, and the changes to the material's surface were examined.

All experimental factors and levels were combined using factorial design. Three different levels (20%, 30%, 40%) were determined for overlap rate, three levels (10 W, 20 W, 30 W) for laser power, and two levels (250 mm/s and 500 mm/s) for scanning speed. This design considers a holistic approach in which the effect of each factor on surface morphology and roughness will be studied. Each combination has been conducted with the view that the determined parameters will go ahead and affect the surface of the material during the process in which it is being laser-processed. The factorial experimental design allows the determination of optimum parameters by systematically examining the combinations of all factors. This method provides important data to understand which parameters are more effective on the outputs, such as roughness, deformation, and surface quality, on the Ti6Al4V surface processed with fiber laser.

.

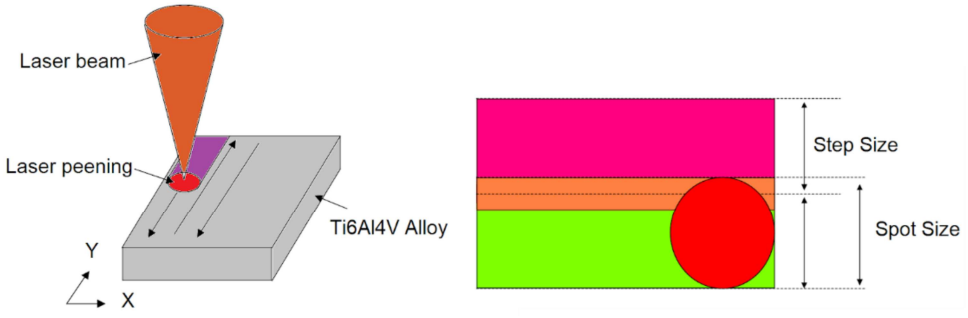

Fig. 1 Laser surface texturing schematic of Ti6Al4V

Table 1. Laser surface sintering parameters of Ti6Al4V

Exp. No.	Overlap Rate (%)	Laser Power (W)	Scan Speed (mm/s)
1	20	10	250
2	20	10	500
3	20	20	250
4	20	20	500
5	20	30	250
6	20	30	500
7	30	10	250
8	30	10	500
9	30	20	250
10	30	20	500
11	30	30	250
12	30	30	500
13	40	10	250
14	40	10	500
15	40	20	250
16	40	20	500
17	40	30	250
18	40	30	500

The overlap rate is an important parameter during fiber laser peening because it indicates how much the laser spots overlap and directly affects the surface properties of the processed material. In fiber laser processing of Ti6Al4V alloy, overlap rate controls the amount of energy applied to a region of the laser beam, which has a significant effect on the surface morphology and roughness. A high overlap rate means that the laser spots lap on each other largely, hence allowing more energy to be transferred to the surface. Overlap rate is one of the most critical parameters that provide a balance between the method of application by laser and material surface quality. So, choosing the right overlap rate is very important for fiber laser processing of Ti6Al4V alloy in order to get the desired surface roughness and morphology during the process. Overlap rate (OR) was calculated with the formula given in Equation 1.

$$OR = \left(1 - \frac{step\ size}{spot\ size}\right) X\ 100 \qquad (1)$$

Spot size: The diameter of the laser beam, often measured in micrometers or millimeters. Step size: The distance between laser tracks (the distance from one track to the subsequent track).

C. *Optical Microscope Surface Characterization*

Surface characterization of Ti6Al4V was performed using the Evident-Olympus BX 53 MRF model microscope. This high-performance optical microscope, which had been used to record high-resolution images of great quality, also enabled detailed analyses of microstructural features present on the laser-textured surfaces. The BX 53MRF model offers a variety of magnification options, including the examination of precise surface morphologies, the identification of grain structures, the determination of surface roughness, and the identification of laser-induced micro-defects. By performing surface morphological image characterizations, the effect of laser parameters can be visually explained.

D. *Roughness Characterization*

The surface topography of the Ti6Al4V was determined using an LST and a non-contact laser profilometer named Nanovea PS50. This technology enabled the visualization of the exactness of surface roughness parameters without any need for physical contact with the material. The data in the raw state were analyzed by using the DigitalSurf application-only version 6.2.7487, provided by Mountains Technology. This consequently allowed the generation of three-dimensional surface topography representations according to the specifications laid by the ISO 25178 standards. Moreover, the images that were required for carrying out the analysis of the laser-induced surface topographies were generated in

accordance with what was stipulated under the ISO 4287 standards. The laser profilometer allowed a thorough overview of all the LST surfaces by scanning the sample surfaces, which have been hit with various laser settings across an area of 1 mm x 1 mm. The present analysis will be taken from samples exposed to texturing, as one may observe theoretical laser-scanned area factors and power levels from the given table. It aimed to precisely characterize surface changes induced on Ti6Al4V with 20%, 30%, and 40% overlap rates.

III. RESULTS AND DISCUSSIONS

A. Surface Optical Microscope Characterization

Figure 2 presents the surface morphology for the Ti6Al4V alloy produced with a fiber laser at different power and scan speed settings, all with a 20% overlap rate. Figure 2-a shows the surface subjected to 10 W laser power operating at 250 mm/s scan speed. This results in a fairly smooth topography that is marked by linear laser tracks with fewer surface distortions. The low treatment power coupled with a moderate speed ensured a soft interaction of the laser with the material, thus reducing the surface roughness. Figure 2-b: Application of the same value laser power at an increased scan speed of 500 mm/s resulted in a far finer texture. The laser traces are visible but less pronounced. This is because of the higher speed, which provided reduced energy input per unit area, yielding a smoother surface with reduced roughness. Figure 2-c represents the increase in laser power to 20 W while maintaining the scan speed constant at 250 mm/s. This is much rougher, with higher peaks and deeper valleys, a feature consistent with the increased laser energy ablating more material and causing surface deformation. It yields a coarser morphology with the laser tracks more pronounced and deeper. Figure 2-d shows what happens to this power level (20 W) as the scan speed is increased to 500 mm/s. The surface morphology also shows features that are finer compared to Figure 2-c. The higher the scanning speed, the lower the energy density of the laser and hence less aggressiveness of the material removal process was performed, leading to a smoother surface with lower roughness, even with higher power. Figure 2-e was made for a laser power of 30 W and a scan speed of 250 mm/s. The morphology of the surface is much coarser compared to the other images, with marked irregularities and a chaotic appearance. The much higher power input greatly increased the amount of energy inputted into the material with an increase in material removal rates and hence much more pronounced surface deformation. Peaks and valleys are deeper, showing that the surface profile is highly rough. Finally, in the case of Figure 2-f, the same laser power of 30 W was applied, but with a higher scanning speed of 500 mm/s. The surface is still comparatively rough; however, compared to Figure 2-e, the irregularities are less striking. Greater scanning speed reduces the interaction time, hence leading to a more controlled ablation process. The laser tracks are now much less discernible, although the surface is still quite rough, and there is evidence of both removal and localized melting of material. In general, all these results provide evidence that an increase in laser power promotes a rougher surface with more pronounced material deformation, whereas an increase in scan speed generally tends to decrease the surface roughness due to a reduction in the input of laser energy per unit area. All these experiments were done with a 20% overlap rate that contributes to the observed surface patterns for the continuity of surface texture through partial overlying of adjacent laser passes.

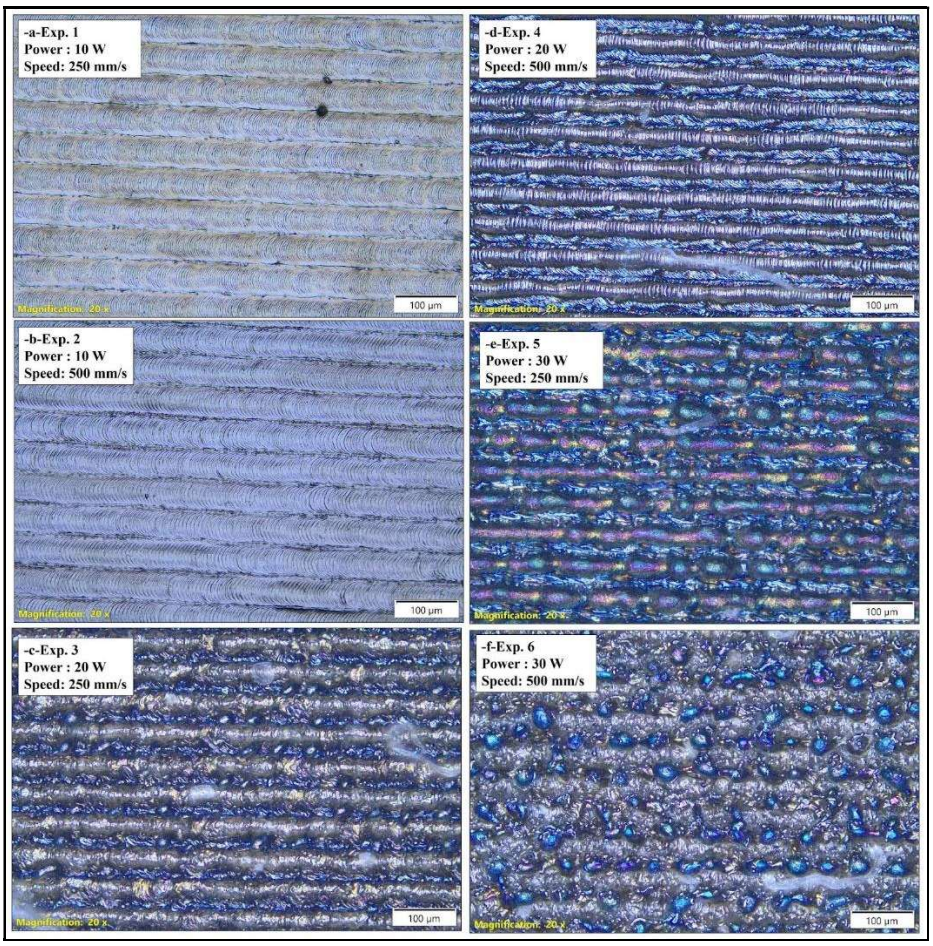

Fig. 2 Laser textured Ti6Al4V surfaces with 20 % overlap rate

Optical microscope images for Ti6Al4V surfaces processed by laser with 30% overlapping are demonstrated in Figure 3. The sample in Figure 3a was machined using a laser power of 10 W and scanning rate of 250 mm/s. Then, the sample presented a smooth flat surface, clearly illustrating at a certain place the laser traces without a surface deformation. Such is the case of the effect changing, but now at an increased scan speed of 400 mm/s, with the same laser power input of 10 W, a more fine and smooth surface texture. Increased speed simply resulted in lower energy input per unit area, which led to refinement of the laser tracks to lower surface roughness. In Figure 3-c, as the laser power was increased to 20 W, the surface appears with wider peaks and deep valleys depicting higher material removal and deformation of the surface, implying changes towards roughness. Figure 3-d at 500 mm/s scanning speed for 20 W shows a further smoothened surface texture compared to Figure 3-c. The reason lies in the fact that higher the speed, the lower will be the energy density, hence the lesser ablation of material, and consequently the reduced surface roughness. It can be noticed in Figure 3e that at 30 W with 250 mm/s scanning speed, the surface is very rough, having irregular peaks and valleys-that is, due to the higher energy input, with very intense machining material removal and deformation. It can be observed from Figure 3-f that, even at 30 W and 500 mm/s, it is still rough, though with less disturbance compared to Figure 3-e, due to the fact that the increase in scan speed decreases the interaction time, and therefore the material removal is less. Taken in combination, these experiments revealed that increased power led to rougher surfaces, with swells of higher amplitude, but that scan speed worked in some sort of counteraction against the development of surface roughness through the reduction in energy available to be input into the material per unit area. All the experiments were further performed under a 30% overlap rate, which influences the consistency of the surface texture over the part through increasing the overlap between consecutive runs of the laser.

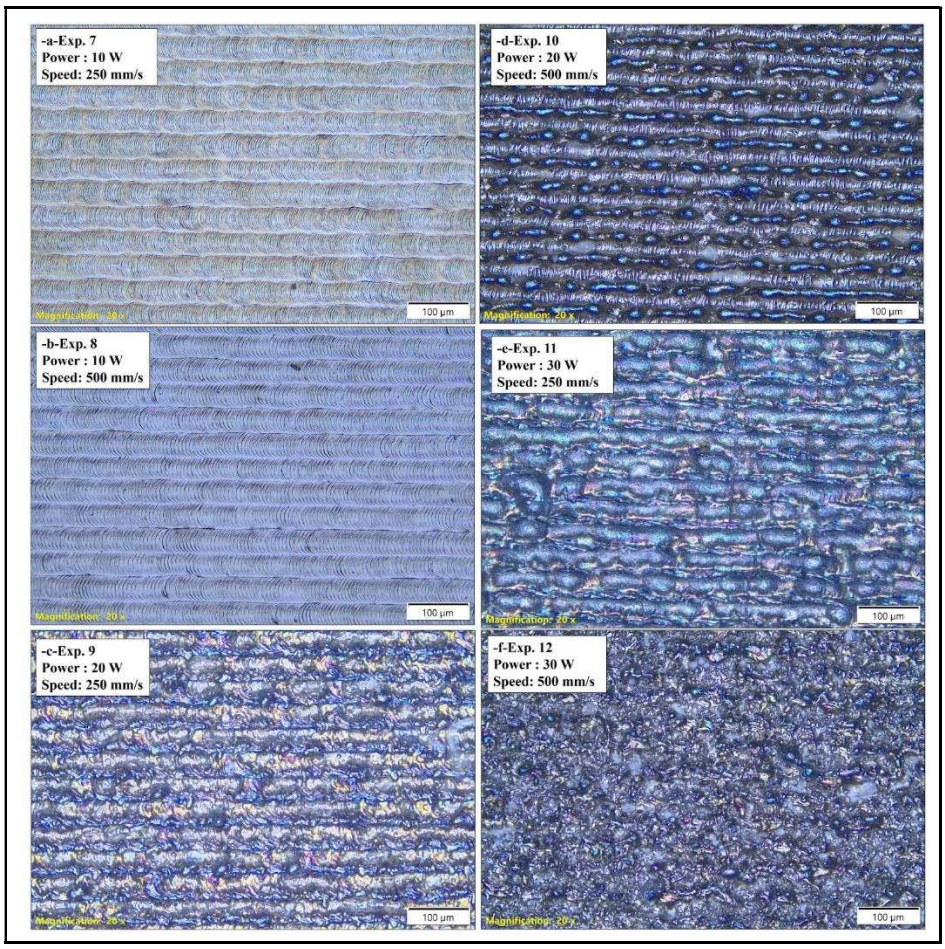

Fig. 3 Laser textured Ti6Al4V surfaces with 30 % overlap rate

Figure 4 presents the surface morphology of a Ti6Al4V alloy processed by a fiber laser, using different parameters of power and scan speed, but with all of them at an overlap rate of 40%. Figure 4-a (Exp. 13): 10 W power and 250 mm/s as the scan speed. The resulting surface is relatively smooth and homogeneous, with visible clear laser tracks and low surface roughness. The low-power moderate-speed interaction yielded a well-defined texture. Figure 4-b (Experiment 14) shows how increasing the scan speed to 500 mm/s - while keeping the same power of 10 W-clear laser tracks are still distinguishable on the surface, but the texture is a bit finer since the higher speed reduces the energy input per unit area, thus giving a smoother profile to the treated surface. Figure 4-c (Exp. 15) is for increased laser power at 20 W with a scan speed of 250 mm/s, where the surface has more pronounced peaks and valleys because the greater material removal is reflected with a higher degree of roughness due to higher energy input. However, at the same power but at a higher scanning speed of 500 mm/s, Fig. 4-d (Exp. 16) shows a smoother surface in relation to Fig. 4-c (Exp. 15). It could be explained by the increase in scanning speed that reduces energy density, clearly decreasing the material ablation aggressiveness, yielding a coarser surface. In Figure 4-e (Exp. 17), the surface was treated with an input power of 30 W and a scan speed of 250 mm/s. Under this condition, a surface with significant irregularities was obtained, including marked ones, due to the higher power favoring a greater removal of material and deformation on the surface. Last but not least, Figure 4-f (Exp. 18) was processed at 30 W, with a higher scanning speed at 500 mm/s, also showing a rough surface. The higher the scanning speed, the less severe it is in comparison to Figure 4-e. Increased speed minimizes interaction time, reducing material removal slightly, which is still enough to keep a highly textured surface. These images altogether depict that the surfaces are getting rougher with more pronounced deformation as the laser power increases, whereas a higher scanning speed generally reduces the surface roughness due to the lower energy input per unit area. The 40% overlap rate in these experiments leads to greater overlap between laser passes, enhancing the uniformity in the surface topography and affecting the overall roughness of the processed surfaces.

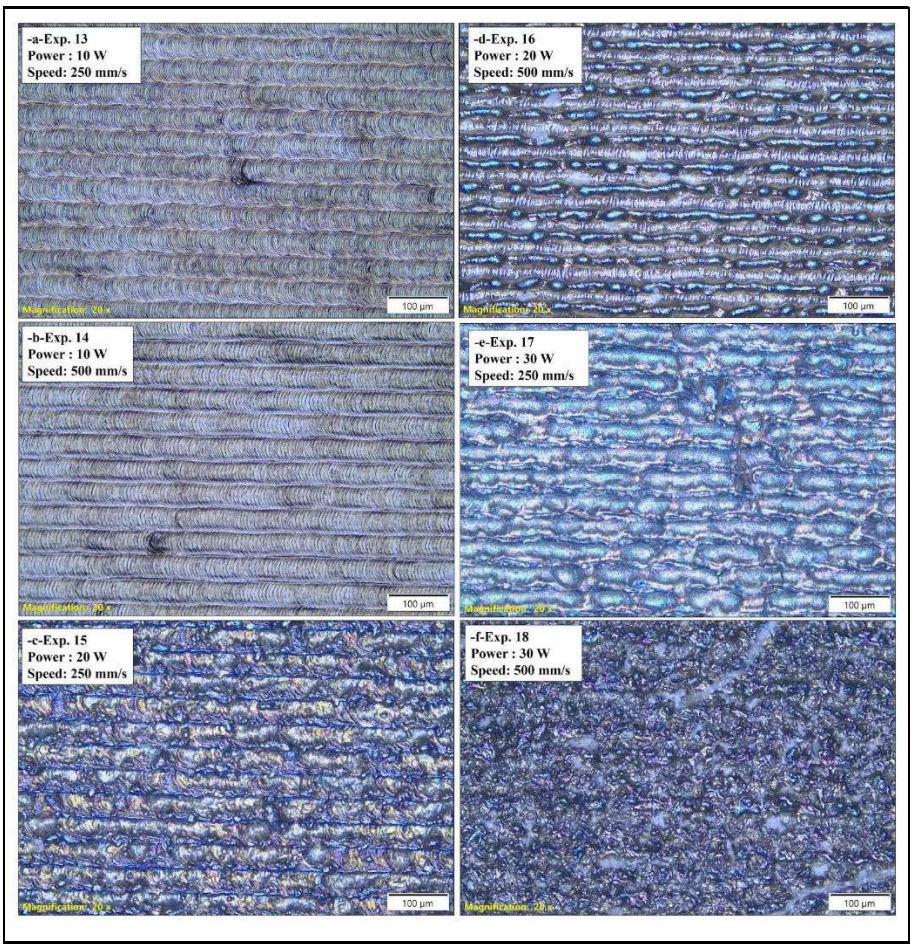

Fig. 4 Laser textured Ti6Al4V surfaces with 40 % overlap rate

Figures 2, 3, and 4 depict the laser texturing of the Ti6Al4V surface at 20%, 30%, and 40% overlap rates, respectively. It can be observed from these three figures that an increase in the overlap rate, besides laser power and scan speed, modified the shape of the surface; with the increase in overlap rate, the surface gets progressive and uniform, with a view of more consistent laser tracks at lower laser powers. Greater overlap is related to improving the uniformity of the surface because of increased coverage from one verge of the laser passage to the other. Higher laser powers up to 30 W expose the surface to deformation and material removal, while higher scan speeds do reduce this. In general, the 30% and 40% overlap rates give smoother surfaces at medium power levels and scanning speed, thus providing a better-controlled texturing process.

B. Roughness Characterization

Figure 5 compares the Sa values of the arithmetical mean height for Ti6Al4V surfaces processed with laser texturing, using three overlap rates: 20%, 30%, and 40%. The trend of the variation in surface topography as a function of the overlap rate and processing parameters is well reflected in the graph. In the graphs for the 20% overlap rate, Sa ranges from very low values of ~2 µm for Exp. 1 to moderate values of ~20 µm for Exp. 6; this reflects that the surface texture should be relatively controlled, showing a gradual increase in surface height by changing laser power and scan speed. The highest value of intensity, Sa, is obtained in Exp. 6, which has the highest power and fastest scan speed for removing a lot of material. Values in the group with an overlap rate of 30% were lower (from ~5 µm to 15 µm) and more consistent. Finer and smoother surface texture is thus indicated as compared to the group with 20% overlap rate because of higher overlap of laser passes. The lower Sa values that were observed in experiments 7 to 12 thus point to a smoothening effect of increased overlap so that extreme topographic fluctuation may become less likely even for higher laser powers. Indeed, even at a 40% overlap rate, Sa values are well higher, while for Exp. 16 it even passes 100 µm, indicative of a significantly rougher surface, probably due to the higher laser power of 20 W applied with a slower scan speed-a combination that generally guarantees more aggressive

ablation of material and deformation of the surface. Experiments 17 and 18 yield slightly lower values of Sa, and this confirms that the 40% overlap rate tends to increase the variation in surface height, but that effect may be reduced by a gain in scan speed. In general, this graph shows that increasing the overlap rate from 20% to 30% generally decreases the Sa values, while increasing the latter to 40% may lead to significantly higher values of Sa under conditions of high laser power and slower scan speeds.

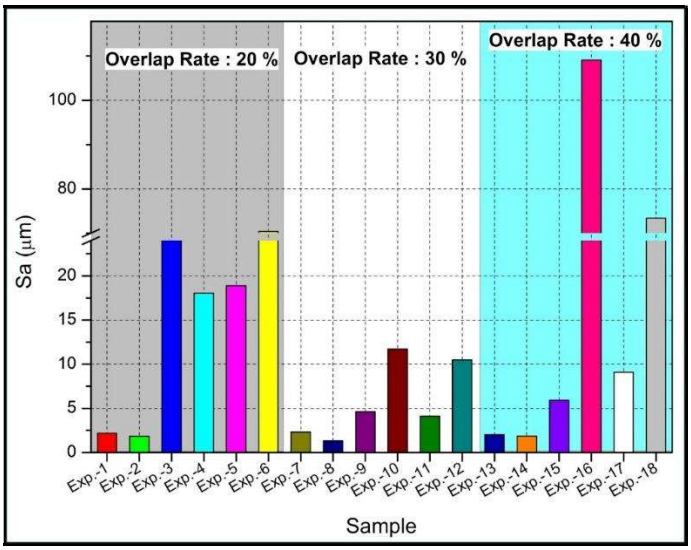

Fig. 5 Roughness Sa values comparison according to overlap rate of laser textured Ti6Al4V surfaces.

Figure 6 shows the maximum and minimum values of Sa for laser-textured Ti6Al4V surfaces processed with 40% and 30% overlap rates. Thus, for an overlap rate of 40%, in Figure 6-a, for the sample with processing parameters of power 20 W and scan speed of 500 mm/s, which corresponds to the experiment number Exp. 16, the maximum recorded Sa value is 109 µm. The profile of this 3D surface topography shows sharp and deep valleys and high peaks, proving great surface irregularity with marked material ablation and surface deformation. The high value of Sa and its correspondent line profile confirm the very rough and irregular character of the surface related to the higher aggressiveness of the laser treatment at the increased overlap rates. The sample treated with a 30% overlapping percentage (Exp. 8) could be seen for comparison in Fig. 6b under the power of 10 W and scanning rate of 500 mm/s that produces a minimum value of Sa, 1.3 µm. In the 3D surface profile, there is a smooth surface with less topography variation. It can be seen from the line profile that the surface lies nearly flat, with minor undulations. That means the effect of the lower power and reduced overlap rate to a more uniform and controlled surface morphology, with lesser material deformation. This is an indication, if these two compared overlap rates are considered, high overlap rates of 40% give higher surface roughness with pronounced texturing, whereas low overlap rates of up to 30% in moderate power settings give smoother and more repetitive surface finishes.

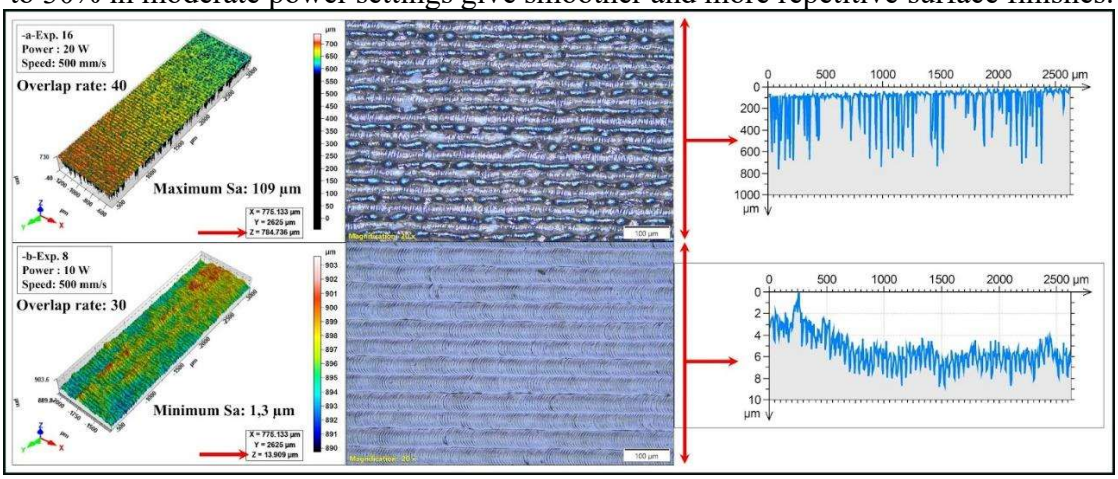

Fig. 6 Maximum and minimum Sa comparison according to overlap rate of laser textured Ti6Al4V surfaces (a) 40% (b) 30%

IV. CONCLUSION

In the present work, the surface morphology and roughness of the Ti6Al4V alloy after laser peening were studied by systematically changing three important processing parameters-laser power, scanning speed, and overlap rate. Using the design of experiments on the basis of a full factorial, it was possible to study 18 experimental conditions that comprehensively describe the influence of these variables on the surface properties.

The experimental results revealed that the variation of laser power has much influence on surface morphology. Increased surface roughness with an increase in laser power is recorded, so is the establishment of pronounced peaks and valleys, owing to increased energy input that results in aggressive material removal and surface deformation. While increasing the scanning speed led to a smoother surface, reducing the laser energy input per unit area allows less material ablation and more controlled surface texturing. On the contrary, the overlap rate was another critical factor that preceded the uniformity of the surface: the increase in the overlap rate made the laser tracks more consistent, reflecting in a smoother surface texture, especially for medium laser power.

The data on roughness characterization confirm these observations. The values of Sa, representing the arithmetic average height of the surface, were found to increase with increased laser power input and with the slowing down of scan speed, while the increased overlap rate tended to decrease surface roughness. The maximum roughness, Sa = 109 μm, was reached at the maximum power of the laser, 20 W, together with the high scanning speed, 500 mm/s, and an appropriate overlap rate of 40%, and the minimum roughness, Sa = 1.3 μm, was achieved using the low laser power, 10 W, with the same scanning speed, 500 mm/s, and an overlap rate of 30%. These results reflect that optimization of the overlap rate, in combination with the right scan speed, can reduce surface roughness that may be induced by high laser power.

In the present work, evidence has been obtained that surface topography of the Ti6Al4V alloy is controllably modulated by well-controlled parameters in laser processing. Optimal adjustment of laser power, scan speed, and overlap rate is expected to achieve an optimum balance between surface roughness and uniformity, which will cater to applications in aerospace all the way to biomedical implants. The present work may be looked upon as a starting point for further investigations into laser peening mode optimizations targeting improvement in surface properties with enhanced performance of the above-mentioned Ti6Al4V alloy components.

ACKNOWLEDGMENT

This work was supported by the Kocaeli University Scientific Research Projects Coordination Unit [Project No: FBA-2024-3704].

REFERENCES

[1] Şefika KASMAN, Burak BÜYÜKER, Sertan OZAN, Machining of Ti–6Al–4V alloy by fiber laser: Determining the effects of parameters on surface roughness, Sigma J Eng Nat Sci, Vol. 41, No. 4, pp. 770−780, August, 2023, DOI: 10.14744/sigma.2023.00087

[2] Brezinová, J.; Hudák, R.; Guzanová, A.; Draganovská, D.; Ižaríková, G.; Koncz, J. Direct Metal Laser Sintering of Ti6Al4V for Biomedical Applications: Microstructure, Corrosion Properties, and Mechanical Treatment of Implants. Metals 2016, 6, 171. https://doi.org/10.3390/met6070171

[3] Berivan Dündar Yılmaz, İbrahim Halil Tepe, Remzi Nigiz, Zelal Seyfioğlu Polat, Server Mutluay Unal, Effect of Yb: Fiber Laser on Surface Roughness and Wettability of Titanium, Balk J Dent Med, 2022;52-57, 10.5937/bjdm2201052D

[4] Francisca Melo-Fonseca, Bruno Guimarães, Michael Gasik, Filipe S. Silva, Georgina Miranda, Experimental analysis and predictive modelling of Ti6Al4V laser surface texturing for biomedical applications, Surfaces and Interfaces, Volume 35, 2022, 102466, ISSN 2468-0230, https://doi.org/10.1016/j.surfin.2022.102466.

[5] Q. Ding, L. Wang, L. Hu, 16 - Tribology optimization by laser surface texturing: from bulk materials to surface coatings, Editor(s): J. Lawrence, D.G. Waugh, In Woodhead Publishing Series in Electronic and Optical Materials, Laser Surface Engineering, Woodhead Publishing, 2015, Pages 405-422, ISBN 9781782420743, https://doi.org/10.1016/B978-1-78242-074-3.00016-7.

[6] Tolgahan Ermergen, Fatih Taylan, Investigation of DOE model analyses for open atmosphere laser polishing of additively manufactured Ti-6Al-4V samples by using ANOVA, Optics & Laser Technology, Volume 168, 2024, 109832, ISSN 0030-3992, https://doi.org/10.1016/j.optlastec.2023.109832.
[7] S. Ferraris, A. Cochis, A.C. Scalia, A. Tori, L. Rimondini, S. Spriano, Laser surface texturing of Ti-cp and Ti6Al4V alloy for the improvement of fibroblast adhesion and alignment and the reduction of bacterial adhesion, Journal of Materials Research and Technology, Volume 29, 2024, Pages 5464-5472, ISSN 2238-7854, https://doi.org/10.1016/j.jmrt.2024.03.033.
[8] Yeşil H, Ezmek B, Sipahi CO. Effects of surface treatment methods on shear bond strength of ceramic to cast, milled and laser-sintered titanium frameworks. Gulhane Med J. 2022 Dec; 64(4):307-314. doi:10.4274/gulhane.galenos.2022.53244.
[9] Campanelli, S.L.; Lavecchia, F.; Contuzzi, N.; Percoco, G. Analysis of Shape Geometry and Roughness of Ti6Al4V Parts Fabricated by Nanosecond Laser Ablation. Micromachines 2018, 9, 324. https://doi.org/10.3390/mi9070324
[10] Kimia Rafiee, Homam Naffakh-Moosavy, Elnaz Tamjid, The effect of laser frequency on roughness, microstructure, cell viability and attachment of Ti6Al4V alloy, Materials Science and Engineering: C, Volume 109, 2020, 110637, ISSN 0928-4931, https://doi.org/10.1016/j.msec.2020.110637.
[11] Vazquez-Martinez, J.M.; Salguero Gomez, J.; Mayuet Ares, P.F.; Fernandez-Vidal, S.R.; Batista Ponce, M. Effects of Laser Microtexturing on the Wetting Behavior of Ti6Al4V Alloy. Coatings 2018, 8, 145. https://doi.org/10.3390/coatings8040145
[12] Maressa, P., Anodio, L., Bernasconi, A., Demir, A. G., & Previtali, B. (2014). Effect of Surface Texture on the Adhesion Performance of Laser Treated Ti6Al4V Alloy. The Journal of Adhesion, 91(7), 518–537. https://doi.org/10.1080/00218464.2014.933809
[13] Boyer, R., Welsch, G., & Collings, E. W. (1994). Materials Properties Handbook: Titanium Alloys. ASM International, ISBN-13: 978-0-87170-481-8.
[14] Leyens, C., & Peters, M. (2003). Titanium and Titanium Alloys: Fundamentals and Applications. Wiley-VCH, ISBN: 978-3-527-60211-7.
[15] Donachie, M. J. (2000). Titanium: A Technical Guide. ASM International, Michigan University, ISBN: 9780871706867.