

# Parameter optimization for selective laser melting of TiAl6V4 alloy by CO<sub>2</sub> laser

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**Abstract.** TiAl6V4 alloy is one of the widely used materials in powder bed fusion additive manufacturing technologies. In recent years selective laser melting (SLM) of TiAl6V4 alloy by fiber laser has been well studied, but SLM by CO<sub>2</sub>-lasers has not. SLM of TiAl6V4 powder by CO<sub>2</sub>-laser was studied in this paper. Nine 10x10x10 mm cubic specimens were fabricated using different SLM process parameters. All of the fabricated specimens have a good dense structure and a good surface finish quality without dimensional distortion. The lowest porosity that was achieved was about 0.5%.

## 1. Introduction

Selective laser melting (SLM) is powder bed additive manufacturing technique that makes it possible to fabricate near net shape parts from metal powder. Now SLM is widely used in aerospace industry [1-3] and medicine [4, 5] for production of parts with complex shapes such as fuel injectors, cooling combustion chambers, and surgical and dental implants [6-8]. TiAl6V4 is one of the most used materials for SLM fabrication due to its high strength, corrosion resistance, low density, and high biocompatibility [9-11]. In recent years, SLM of TiAl6V4 alloy by fiber laser has been well studied [12-16], but SLM by CO<sub>2</sub>-lasers has not. Laser energy absorption by metal powder material is strongly wavelength dependent, for titanium alloy absorptance of CO<sub>2</sub>-laser energy is lower than for fiber laser [17]. The aim of this study is determine of SLM parameters for the fabrication of high density TiAl6V4 alloy parts by CO<sub>2</sub>-laser.

## 2. Experimental setup

The Sinterstation<sup>®</sup> Pro DM125 SLM system from 3D Systems was used within this investigation for TiAl6V4 porosity optimization. The Sinterstation<sup>®</sup> Pro DM125 SLM system is equipped with a 200 W CO<sub>2</sub>-laser with 35 µm beam diameter on the powder surface, an automatic powder spreading system, an inert argon gas protection system, and a powder bed preheating system.

Nine 10x10x10 mm cubic specimens were manufactured for porosity optimization in an argon atmosphere by using different process parameters. Point distance (PD), hatch space (HS), and layer thickness were fixed to 50 µm, the oxygen content in building chamber was limited to 500 ppm, and powder bed preheating was not used. Laser power (P) and exposure time (ET) values are presented in table 1. All specimens were fabricated using an "alternating" scanning strategy, wherein each new layer is rotated by 90° in relation to the preceding layer [18].

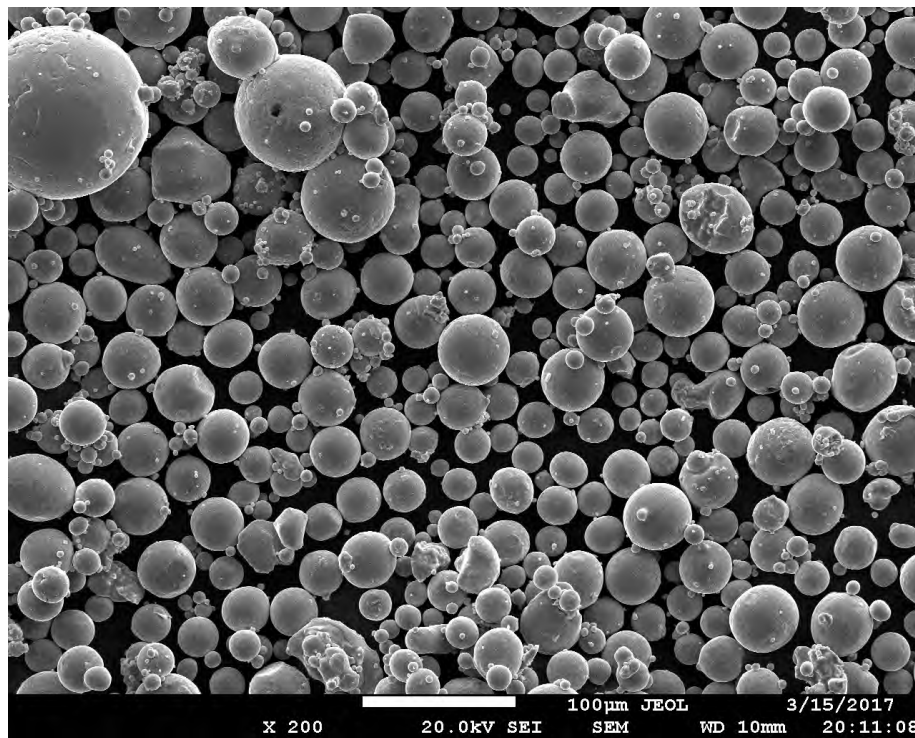


**Table 1.** Parameters of SLM.

№	1	2	3	4	5	6	7	8	9
P, (W)	200	200	200	150	150	150	100	100	100
ET, (μs)	100	50	150	100	50	150	100	50	150

TiAl6V4 powder with 20-63 μm particle size from MTT Technologies GmbH was used within this investigation. The mean particle size of TiAl6V4 powder is  $d_{50}=44\mu\text{m}$ . The mean ISO Roundness of powder particles by volume is 63.74%. Optical granulomorphometer Occhio 500nano was used for determination of powder particle size and ISO Roundness. The flowability of powder is 19 s/50 g, the apparent density is 2482 kg/m<sup>3</sup>.

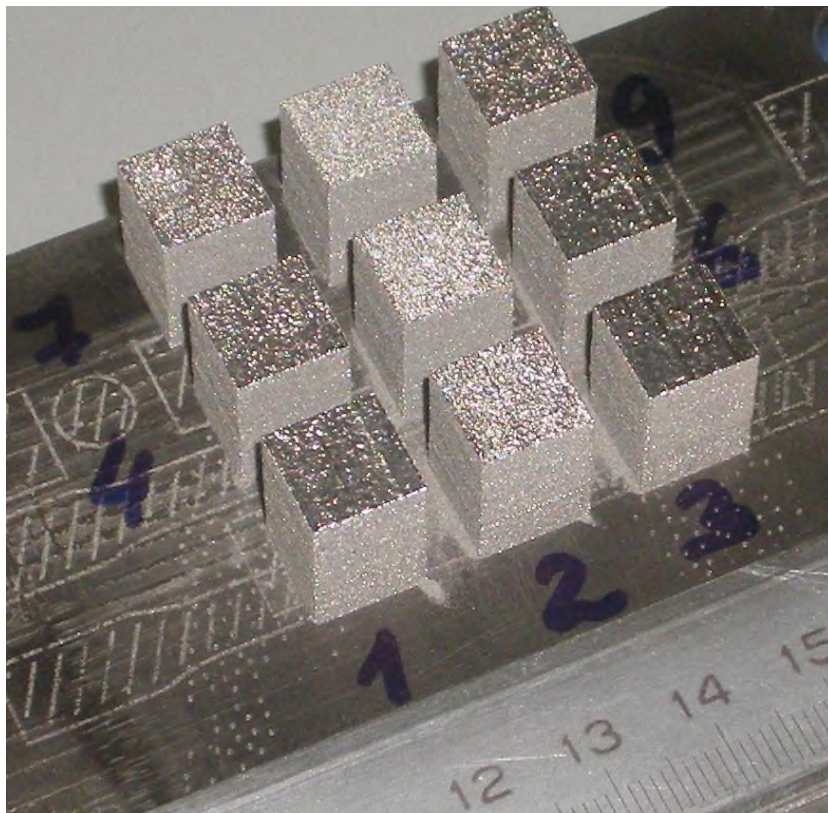
An SEM image of TiAl6V4 powder is presented in figure 1. As can be seen, most powder particles have a regular spherical morphology and there are some irregular particles formed in atomization.

**Figure 1.** Morphology ofTiAl6V4 powder.

The porosity of the fabricated 10x10x10 mm cubes was determined through microscopy analysis by the cross-sections method [19]. For each specimen, two cross-sections were prepared (parallel and perpendicular to the building direction) by cutting. Each specimen was mounted in bakelite, then grinded and polished by standard procedures. Images of the cross-sections were analyzed by GIMP 2.8.22 software to determine porosity.

### 3. Results and discussion

SLM fabricated TiAl6V4 specimens are shown in figure 2. All of the specimens have a dense structure and a good surface finish quality without dimensional distortions.



**Figure 2.** SLM-fabricated TiAl6V4 specimens.

In figure 3, porosity evolution in TiAl6V4 samples was processed using different combinations of laser power and exposure time. The 8th specimen has the highest porosity - 22.6%, its cross-section is located in the top left corner of figure 3 on low laser power and low exposure time zone. It can be seen that the pores of specimen №8 have an irregular shape and large size. Such pores are called keyhole pores and arise due to insufficient energy for the full melting of powder layer [16].

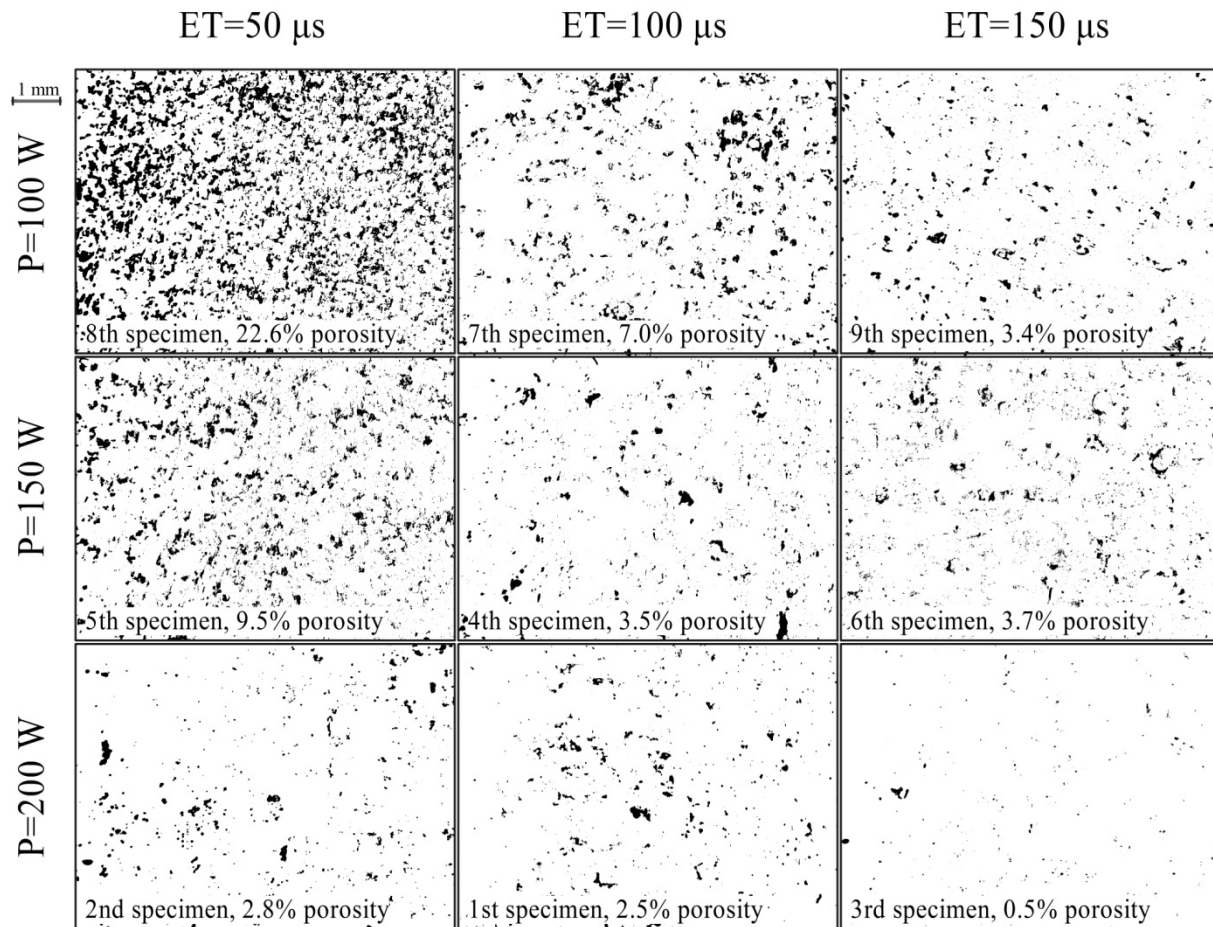
With increasing of exposure time (7th specimen) and laser power (5th specimen), the number of pores reduced, but the morphology and size of pores almost was not changed. This demonstrates that laser energy is still insufficient for full melting of the powder layer. With further increase of exposure time and laser power (1st, 2nd, 4th, 6th, and 9th specimens), the number of keyhole pores further reduced, however, there were other type of pores with spherical shape and small size. Such pores are called metallurgical pores and arise from gases trapped within melt pool [18].

The 3rd specimen has the lowest porosity (about 0.5%) and is characterized only by metallurgical pores. Since the metallurgical pores are created due to gases dissolved in powder for the fabrication of low porosity materials by SLM, it is necessary to use a powder with low dissolved gases content.

#### **4. Conclusion**

Selective laser melting of TiAl6V4 powder using a CO<sub>2</sub>-laser was studied in this paper. Nine 10x10x10 mm cubic specimens were fabricated using different SLM process parameters. All of the fabricated specimens have a good dense structure and a good surface finish quality without dimensional distortion. The lowest porosity that was achieved is about 0.5%.





**Figure 3.** Porosity evolution in TiAl6V4 samples processed using different combinations of laser power and exposure time.

### Acknowledgements

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