Proc. of the 9th Intl. Conf. of Asian Society for Precision Engg. and Nanotechnology (ASPEN 2022)
15–18 November 2022, Singapore. Edited by Nai Mui Ling Sharon and A. Senthil Kumar
doi://10.3850/978-981-18-6021-8_OR-01-0315

A Novel 2μm Fiber Laser Setup for Evaluating the Sintering Ability of Polymeric Powder for Selective Laser Sintering

Eugene Kok[1], Baicen Li[2], Feng Lin Ng[1,#]

1 Singapore Institute of Manufacturing Technology (SIMTech), 2 Fusionopolis Way, Singapore 138634, Singapore
2 Department of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798, Singapore
Corresponding Author / Email: ngfl@simtech.a-star.edu.sg, TEL: +65-67938959,

KEYWORDS: Selective Laser Sintering, SLS, Polymer Powder

Selective Laser Sintering (SLS) is a powder bed fusion additive manufacturing process involving the use of polymeric powders. Typical SLS systems utilizes either CO_2 laser, at 10.6μm or traditional diode fiber lasers (Nd-YAG, Yb), at 0.8-1.07 μm. In this work, a 2μm Tm fiber laser was setup to evaluate the sintering ability of polyamide-12 (PA2200) powder and compared with commercial SLS system in terms of mechanical performance, thickness of sintered layer and surface roughness. In-house lasered samples using 2μm laser showed higher strength (+37%) and larger thickness (+210%) as compared to EOS P395 printed sample with similar print properties. The higher thickness layer set the basis for a possible high speed SLS printing process.

NOMENCLATURE

CO_2 = Carbon Dioxide
Nd-YAG = Neodymium-doped Yttrium Aluminum Garnet
Tm = Thulium, chemical element atomic no. 69
Yb = Ytterbium, chemical element atomic no. 70
f-θ = f-theta, type of lens for laser processing
PA2200, PA12 = Polyamide-12 powders (EOS GmbH)

1. Introduction

Selective Laser Sintering (SLS) is a powder bed fusion process involving the use of polymeric powders. It is a type of additive manufacturing process which utilizes laser as the source of heat to fuse powders in a layer-by-layer manner, to form a desired 3D structure. [1] The main benefit of using SLS as compared to other additive manufacturing processes is the ability of this process to produce parts with complex features and geometry without the need for support structures. Conventional SLS systems consist of either CO_2 laser at 10.6μm or common solid-state diode laser (Yb and Nd-YAG), at 0.8-1.07 μm. However, there are weaknesses in using these types of lasers for SLS. When compared with fiber laser, CO_2 lasers requires warm up time, process up to five times slower than fiber laser in half the operating costs, requires regular beam path maintenance and alignments (unlike that of fiber laser) and is not a consistent beam (as compared to fiber laser) [2]. In addition, Girdu. et al. has reported that fiber laser are more efficient in terms of laser energy delivery and energy consumption compared to CO_2 laser [3]. In recent years, there are commercial SLS manufacturers supplying SLS systems with solid-state diode lasers, in the wavelength between 0.8-1.07 μm. However, these lasers require laser-absorbing additives, and are typically in grey or black appearance. Table 1 below showed a list of SLS systems with the laser used. In this work, a novel 2μm Tm fiber laser was setup to evaluate the sintering ability of polyamide-12 (PA2200) powder and compared with samples printed from commercial SLS system in terms of mechanical performance, thickness of sintered layer and surface roughness. PA2200 is inherently white in appearance.

Table 1: List of common commercial SLS systems and type of laser used

	Brand/Model	Laser type	Powder Color	Source
1	EOS GmbH / P395	CO_2, 10.6μm	White, etc.	[4]
2	3D Systems / ProX 6100	CO_2, 10.6μm	White, etc.	[5]
3	Sinterit / Lisa Pro	Diode, 0.8μm	Grey / Black	[6]
4	Sintratec / S2	Nd: YAG, 1μm	Grey / Black	[7]

5	SIMTech's Tm Laser	Tm, 2µm	White, etc.	-

2. Methodology and Results

2.1 Setup and materials

A setup using existing laser with galvanometer scanning head, f-θ lens, computer with laser control interface, heating plate and glassware and tools were used to devise the SLS setup for laser sintering of single layer of polymeric powder. Setup was as shown in Figure 1. Surface temperature on the center of the powder bed was determined by measurement using a non-contact infrared temperature. PA2200 (Polyamide-12) powder (56 µm average grain size) from EOS GmbH, refreshed 50%, was used in the study. Parameter sets with different conditions were used and tabulated in Table 2. Strips of size 60 x 15 cm were sintered, with five replicates for repeatability study. The samples were lasered in the loading direction of the tensile pull.

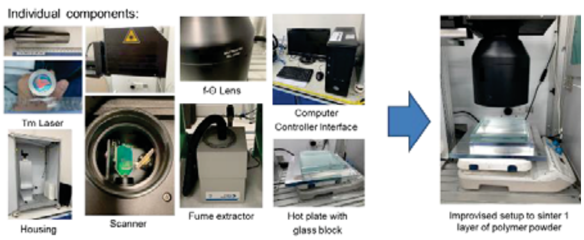

Figure 1: Assembly of individual components to improvise a setup for SLS

Table 2: Label of SLS laser parameter sets

Label		Laser energy density input (W/mm^2)	Surface temperature on the center of t he powder bed (°C)
B	Tm laser	0.4	100
G	Tm laser		120
E	EOS P395	Black box parameter (parameter key for PA2200, 150um)	172
F	EOS P395	Black box parameter (parameter key for PA2200, 100um)	172

2.2 Results and Discussion

Lasered single layer samples using Tm laser and EOS P395 (for benchmarking) were subjected to mechanical, geometry and roughness measurement for comparison purposes. Mechanical testing was conducted using Instron 5548 with 1kN load cell. Modified ISO 527-1 standard was used, with crosshead speed of 1 mm/min. Sample dimensions of strips of 60x15cm had to be small due to current limitation of the Tm laser's work area. From Fig 2, the UTS of the sample set G (lasered with Tm laser) was highest as compared to both E and F (lasered with P395). This indicated high strength in the single layer laser-sintered part. Sample set B had lower UTS when compared to the rest (Sample set G, E, F). One possible reason could be due to the lower surface temperature. The higher the surface temperature of the powder, the higher will be the UTS. Further work can be conducted at higher surface temperature to understand the trend. When comparing between sets G with E and F, the main differences were the build temperature and laser type. The higher UTS seen in set G could be due to several factors such as laser wavelength (1.94µm in Tm laser vs 10.6µm in EOS P395), beam shape and size. Follow up work will be to look at microstructure and understand the laser-particle interaction, how fusion occurs from exposure to different types of laser wavelength. Sample set G also had the largest thickness for a single layer exposure (Fig. 3). This gives an indication that the use of this laser can enable deep penetration of the powder bed, potentially setting the ability to sinter larger layer and hence higher speed (build rate) of part forming. One downside to this ideology will be the lacked of z-axis resolution of the part. Nevertheless, not all sections of the part need high resolution, hence, this method can serve as a precursor to the creation of an SLS system with high build rate. In addition to mechanical performance and thickness measurement, surface roughness measurement was conducted using Taylor-Hobson Stylus Profilometer. Both top side and underside of the sample were measured three times on each side and taken average, with the results tabulated in Fig. 4. The top side refers to the side that was exposed to the laser. The surface roughness of sample set G, E and F were comparable in terms of roughness data (Ra), ranging from 11 to 15 µm. This indicated that the sintered part produced from in-house Tm laser had similar surface roughness data and consistency as the part produced from commercial SLS EOS P395 (set E and F).

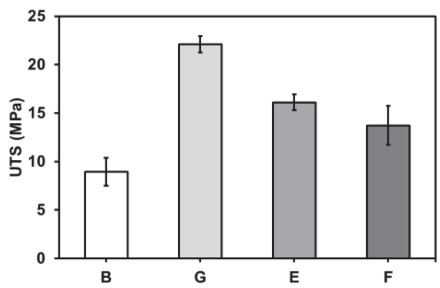

Fig 2. Comparison of ultimate tensile strength of single layer lasered samples using in-house improvised setup (sample sets B and G) and commercial SLS system, EOS P395 (sample sets E and F)

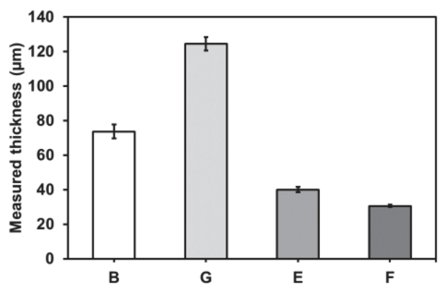

Fig 3. Comparison of measured thicknesses of single layer lasered samples using in-house improvised setup (sample sets B and G) and commercial SLS system, EOS P395 (sample sets E and F)

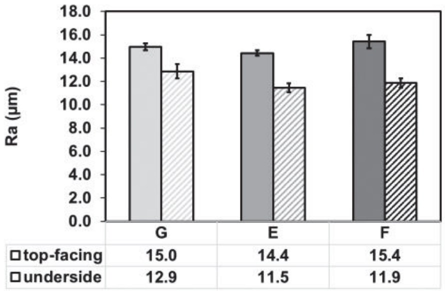

Fig 4. Comparison of surface roughness of single layer lasered samples using in-house improvised setup (sample set G) and commercial SLS system, EOS P395 (sample sets E and F)

3. Conclusions

In-house lasered samples showed higher strength (+37%) and larger thickness (+210%) as compared to EOS P395 printed sample of set E and F. Sample E had higher UTS than F as the default laser parameter key used for sample E was meant for 150 µm layer thickness whereas for sample F it was for 100µm. It is possible that the laser parameters for sample set E has higher laser energy input in order fused a larger layer step height. This also meant that sample set G can potentially accommodate a larger layer thickness (seen in Fig. 3), which set the basis for a possible high speed SLS printing process. To have a fair comparison, both all sample sets (B, G, E, F) were printed in the same hatch spacing and all were lasered in the loading direction of tensile pull. In this study, same batch of PA 2200 materials were used. Evidently, in this study in-house laser (Tm laser) has demonstrated a possible alternative laser setup for the SLS processing of functional components. Strength between layers can be further improved through proper recoating and heating setup design.

ACKNOWLEDGEMENT

The authors would like to thank Singapore Institute of Manufacturing Technology (SIMTech), Agency of Science, Technology and Research (A*STAR) for the funding and support in this work.

REFERENCES

1. M. Schmidt, D. Pohle, T. Rechtenwald, “Selective Laser Sintering of PEEK”, CIRP Annals, vol. 56, No. 1, pp. 205-208, 2007.
2. Arteaga, F., “CO2 vs Fiber Laser Technology: Which is right for you?”. Available from: bystronicusa.com/en/news/technical-articles/130204_CO2-vs-Fiber-Laser.php# [Accessed 30 July 2022]
3. Girdu, C. C., and Gheorghe, C., "Energy Efficiency in CO2 Laser Processing of Hardox 400 Material,” Materials, vol 15, No. 4505, pp. 1-27, 2022.
4. Materflow, “EOSINT P395”. Available from: https://www.materflow.com/wp-content/uploads/2020/07/technical-information-p395.pdf [Accessed 30 July 2022]
5. 3D Systems, Inc., “ProX® SLS 6100 3D Printer User Guide”. Available from: http://infocenter.3dsystems.com/product-library/sites/default/files/printers/ProX_SLS_6100/76-D020_ProX_SLS_6100_User_Guide_Rev_B.pdf [Accessed 30 July 2022]
6. Sinterit SP ZOO, “Lisa PRO open SLS 3D printer”. Available from: https://sinterit.com/3dprinters/lisa-pro/ [Accessed 30 July 2022]
7. Sintratec AG, “Sintratec S2 Operating Manual”