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# Optimization of Laser Power to Avoid the Thermal Stress in The Metal Am Process to Avoid Lift Off of the Build Part

**Mr. K. Sai Vinay*, Mr. D R K Subrahmanyam*, Mr. V Tarun Kumar*, Mr. K Meher Venkat*, Mr. DVVUB Dvijesh*, Mr. VVN Sarath**, Ms. M Amrutha****

***UG students, **Faculty, Department of Mechanical Engineering College, Pragati Engineering College (A)**

**ABSTRACT: This investigation uses a complex geometry which combines both straight edges and a rounded feature, allowing for the in-depth analysis of the effects of laser power on Ti-6Al-4V alloy parts produced by additive manufacturing. The printing study was carried out using the laser beam powder bed fusion technique (SLM 280 HL). The laser power was altered in the range of 500 to 600 W, in order to evaluate the effects of changing the input energy received by the powder particles on the as-built parts. The impact of changing laser power was investigated based on printed part dimensions, displacement, plastic strain, von-mises stress, nodal temperature, temperature. It was determined that laser power has a direct influence on dimensional accuracy, displacement, plastic strain, parts printed at the higher power. The laser power optimized at 550 W where the minimum displacement, plastic strain, von-mises stress and minimum temperature are getting minimum values.**

***Key words: Optimization, Laser Power, Thermal stresses, Plastic strain,, Von-misses stress***

## I. INTRODUCTION

Selective Laser Melting (SLM) is a metal additive manufacturing (AM) process wherein a laser beam is used to melt and fuse metal powder layer by layer to create a part. This technology is considered to be one of the upcoming techniques to manufacture near net shape components for industries like automobile, aerospace, defence and biomedical. Further, due to layer by layer building approach, this process enables to fabricate components with complex shapes using volume optimization techniques like topology optimization (TO). Brackett et al. (2011) reviewed the feasibility of implementation of topology optimization to additive manufacturing techniques. They reported that TO designs can be effectively employed to manufacture products using AM with a significant improvement in TO methods. Furthermore, Brandt et al. (2013) employed the SLM technique to fabricate an optimized design of an aerospace bracket. They described various strategies to improve the manufacturability of the 2 optimized designs using the SLM process. However, to realize the full potential of TO, the AM processes have to be fully optimised, as reported in detail by Zegard and Paulino (2016).

Till date, most of the studies have been carried out to assess the feasibility of SLM printability of a variety of engineering materials. Yap et al. (2015) reviewed different materials that were being employed in the SLM process along with their applications. They reported that most engineering materials like aluminium, steels, cobalt- and nickel-based superalloys, and titanium alloys are being studied for printability using SLM. However, to fabricate functional parts using SLM process, considerable research is required to obtain fully dense metal components by selection of optimum process parameters. For example, Yasa and Kruth (2011) printed single layers of 316L stainless steel to study the effect of SLM process parameters on density and microstructure. They reported that even though SLM process is capable of producing parts with densities of 98-99%, the remaining porosity of even 1-2% would render the as-built SLM parts not suitable for high strength and load bearing applications in aerospace and defence industries. Therefore, it is vital that a comprehensive understanding of the SLM process is developed to achieve desired properties. SLM is a complex additive manufacturing process that involves understanding the interaction between various parameters relating to materials, machine, as well as fabrication aspects. Irrinki et al. (2016) found that the powder parameters like particle size and shape along with powder atomization process affect the density and mechanical properties of SLM printed parts. Moreover, Attar et al. (2015) studied the influence of particle morphology on the density of in-situ Ti-TiB composite material parts fabricated via SLM. The relative density of the samples produced using spherical particles was 99.5% when compared to samples printed

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using irregular shaped particles having a relative density of about 95%. On the contrary, powder characteristics are external parameters as they are usually supplied by either the machine manufacturers or powder-manufacturing suppliers. Furthermore, SLM machine parameters like laser type, maximum laser power and laser wavelength are machine dependent parameters and are restricted in terms of improving the properties of as-built SLM parts. Hence, the possibility of enhancing the performance of SLM-built products is through optimising the process parameters in order to obtain fully dense components.

## II. LITERATURE REVIEW

Kruth et al. (2004) showed strong relevance of scanning strategy on densification and mechanical properties of iron-based powders. Further, Thijs et al. (2010) studied the influence of three different scanning strategies on microstructure of SLM printed Ti-6Al-4V parts and found that using an optimum scanning strategy, an isotropic microstructure was obtained. Furthermore, Aboulkhair et al. (2014) showed that the application of alternate scanning strategy along with optimised process parameters could remove porosities and obtain about 99.8% dense AlSi10Mg parts.

17-4PH is a martensite phase dominant precipitation hardened stainless steel. The material finds its applications in components of aerospace and defence industries, like stator parts of engines, fitting gears, compressor impeller and fasteners, due to its high hardness and strength. Averyanova et al. (2012) have studied the influence of primary process parameters, laser power, scanning speed, hatch spacing and layer thickness on the build characteristics of 17- 4PH single tracks and layers using design of experiments approach. The authors proposed use of a complex objective function to determine the printability of single track and layer. Similarly, Makoana et al. (2016) studied the influence of high laser power (100-300W) and bigger spot size (80μm) along with varying scanning speeds, on the geometric features of single tracks. The study found geometric defects in the tracks using higher laser powers densities. These studies (Averyanova et al. (2012) and Makoana et al. (2016)) defined the process parameter window on the basis of dimensions of the printed single tracks.

Further, Gu et al.) studied the effect of energy density (by varying laser power and scanning speed) on porosity and microstructure of 17-4PH SLM parts. This study reported that even at a constant energy density with different laser power and scanning speed, there was a significant variation in percentages of porosity. In a recent study, Hu et al. (2017) studied the influence of varying input parameters, like scanning speed, layer thickness and hatch distance, at maximum laser power on density and hardness of the built parts. They reported that scanning velocity and layer thickness govern the density of the fabricated part while all process parameters have significant influence on the hardness. Moreover, they also observed that the heat-treated samples had increased hardness in comparison to the as-fabricated samples. Yadollahi et al. (2015) and Yadollahi et al. (2016) reported the effect of part build orientation on the tensile and fatigue properties of 17-4PH samples, respectively. Further, they also reported that different build orientation and heat treatment yields different microstructural phases of 17-4PH parts fabricated which was responsible for different mechanical properties. Irrinki et al. (2016) studied the influence of powder shape and size along with laser power and scan speed for densification of 17-4PH fabricated parts. The study found that the application of gas-atomised powder improved the density and mechanical properties of 17-4PH SLM parts when compared to parts made using water-atomised 17-4PH powders.

Although a number of research works have reported the influence of various process parameters on the printability, densification and mechanical performance of SLM-printed 17- 4PH parts, there is limited literature that investigates the effect of various scan strategies on the 4 physical and mechanical properties of 17-4PH components. Averyanova et al. (2012) have mentioned that laser re-melting scanning strategy produces highly dense single layer of 17- 4PH processed using SLM. Therefore, the primary objective of this study is to explore the effect of two distinct scan strategies on the density and metallurgical properties of 17-4PH stainless steel samples printed by SLM. Furthermore, the variation in hardness and microstructures of the heat-treated samples in relation to the as-built parts is also reported in this paper.

## III. EOS 3D PRINTING MACHINE

**SLM 280 Machine**

Ideal for medium to high volume metal part production and prototypes, the robust second generation SLM®280 2.0 selective laser melting system offers a 280 x 280 x 365 mm build envelope and patented multi-beam laser technology with up to two fiber lasers exposing the build field via a 3D scan optic. Multi-laser systems can achieve build rates 80% faster than a single laser, and patented bi-directional powder recoating minimizes manufacturing time by reducing the number of passes required to lay fresh powder during a build.

Outfitted with a standard PSM powder sieve, overflow bottles transfer material between sieve and machine reducing operator contact with loose powder. PSM sieves and powder change kits allow users material flexibility while maintaining powder quality in an inert atmosphere.

**Solid works modelling**

SolidWorks is a solid modeler, and utilizes a parametric feature-based approach which was initially developed by PTC (Creo/Pro-Engineer) to create models and assemblies. The software is written on Parasolid-kernel.

Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters

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can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allows them to capture design intent.

Design intent is how the creator of the part wants it to respond to changes and updates. For example, you would want the hole at the top of a beverage can to stay at the top surface, regardless of the height or size of the can. SolidWorks allows the user to specify that the hole is a feature on the top surface, and will then honor their design intent no matter what height they later assign to the can.

Finally, drawings can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed. The drawing module includes most paper sizes and standards (ANSI, ISO, DIN, GOST, JIS, BSI and SAC).

Features refer to the building blocks of the part. They are the shapes and operations that construct the part. Shape-based features typically begin with a 2D or 3D sketch of shapes such as bosses, holes, slots, etc. This shape is then extruded to add or cut to remove material from the part. Operation-based features are not sketch-based, and include features such as fillets, chamfers, shells, applying draft to the faces of a part, etc.

Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside the sketch.

In an assembly, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, assembly mates define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies. Solid Works also includes additional advanced mating features such as gear and cam follower mates, which allow modelled gear assemblies to accurately reproduce the rotational movement of an actual.

## IV. RESULTS AND DISCUSSIONS

**3D printing simulation result for 500 W**

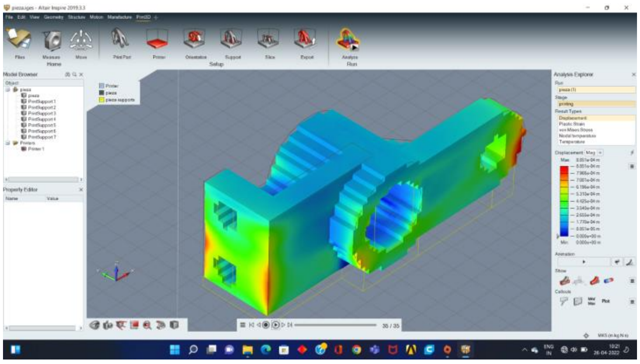

Fig 1: Displacement of pieza ejercicio for 500 W laser power

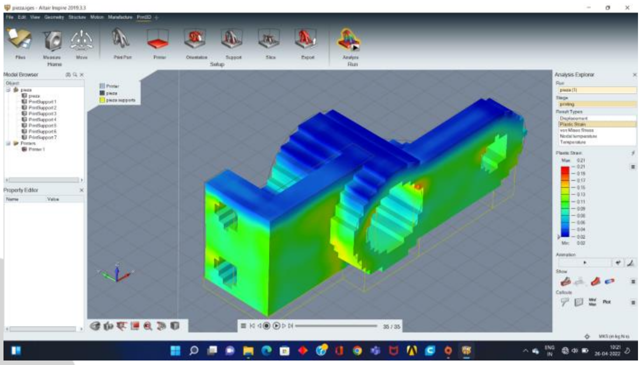

Fig 2: Plastic strain of pieza ejercicio for 500 W laser power

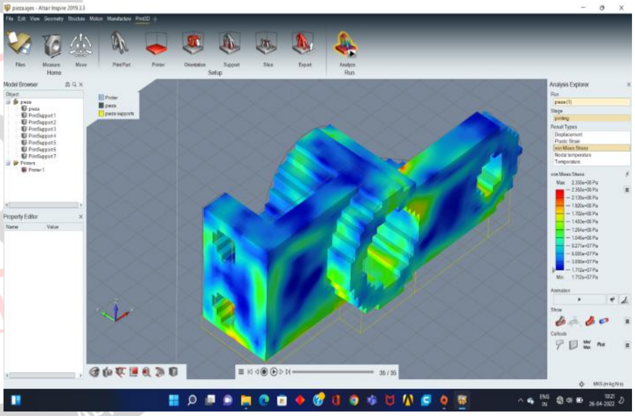

Fig 3: Von mises of pieza ejercicio for 500 W laser power

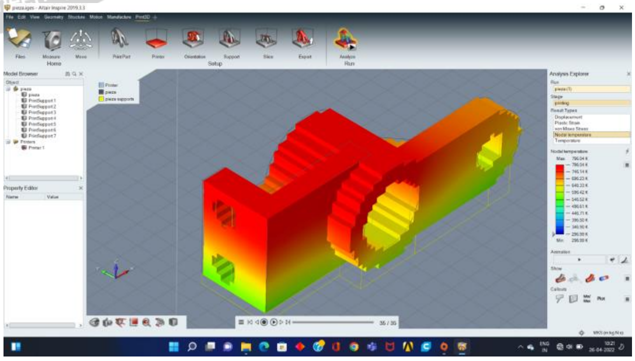

Fig 4: Nodal temperature of pieza ejercicio for 500 W laser power

**3D printing simulation result for 550 W**

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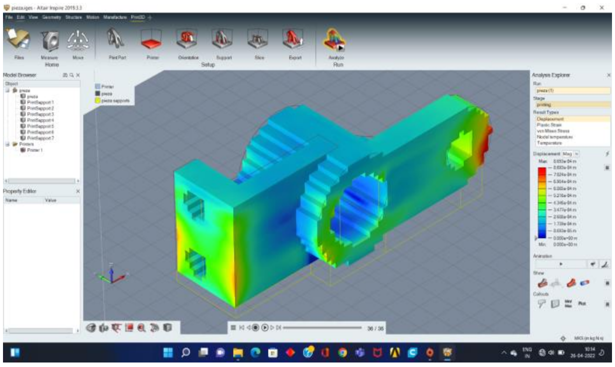

Fig 5: Displacement of pieza ejercicio for 550 W laser power

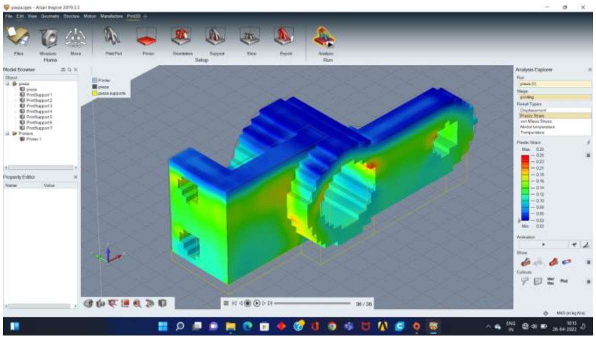

Fig 6: Plastic strain of pieza ejercicio for 550 W laser power

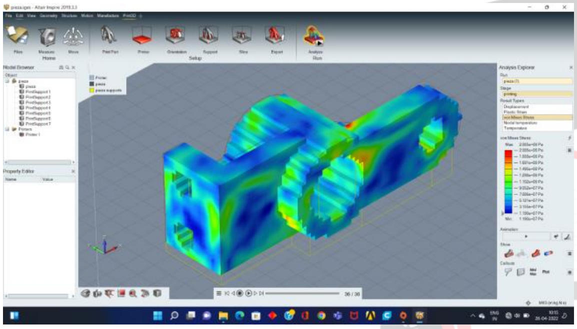

Fig 7: Von mises of pieza ejercicio for 550 W laser power

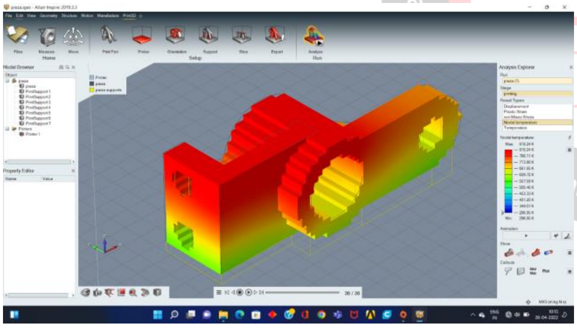

Fig 8: Nodal temperature of pieza ejercicio for 550 W laser power

**3D printing simulation result for 600 W**

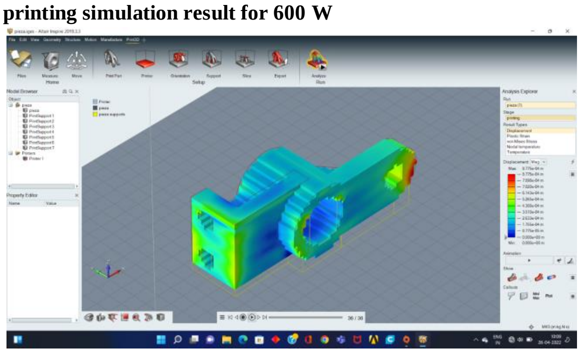

Fig 9: Displacement of pieza ejercicio for 600 W laser power

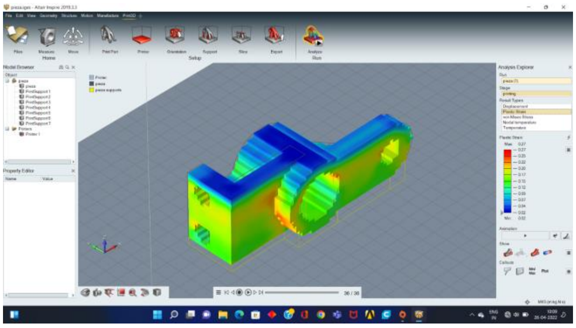

Fig 10: Plastic strain of pieza ejercicio for 600 W laser power

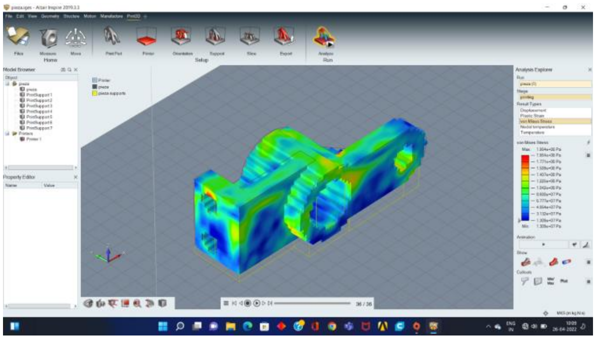

Fig 11: Von mises of pieza ejercicio for 600 W laser power

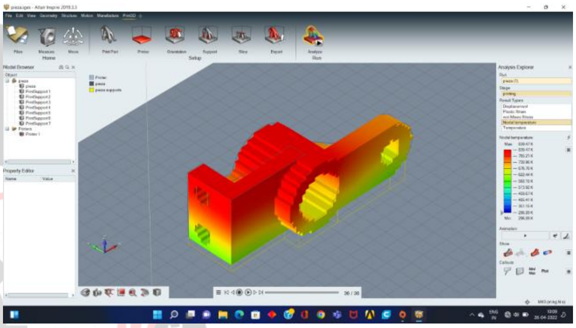

Fig 12: Nodal temperature of pieza ejercicio for 600 W laser power

## V. CONCLUSIONS

By performing the simulation of engine head for different laser powers 500 W, 550W, 600W we can conclude that

As the laser power increasing the displacement of the component increasing but at 550W we get the optimized displacement values. Similarly, as the laser power increasing it unstable the melt pool and improper cooling rate and decreases the dimensional accuracy. Also, increase the surface roughness As the laser power increasing von mises stresses also increasing in the final component.

As the stresses in the component increasing, it causes in increasing the residual stresses in the final component. Due to increase in von mises stresses it causes residual stresses which directly effect the life of the component. Positive compressive residual stresses are increase the life of the component and negative residual stresses will decreases the life of the component. to reduce the residual stresses, we can go for heat treatment

The nodal temperature in the final component increasing consciously which might be the reason for larger


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displacement. To avoid the nodal temperature, we need give more cooling time.

By conducting the simulations, we can conclude that pieza ejercicio can be print with 550 W laser power where the optimized.

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