Optimization of Support Structures to Avoid the Lift Off of Printing Component for Renishaw Am 240 Machines

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ABSTRACT: Additive manufacturing is rapidly growing technology in the field of production and research. AM is perceived as an environmentally friendly and sustainable technology and has already gained a lot of attention globally. The potential freedom of design offered by AM is, however, often limited when printing complex geometries due to an inability to support the stresses inherent within the manufacturing process. Additional support structures are often needed, which leads to material, time and energy waste. Research in support structures is, therefore, of great importance for the future and further improvement of additive manufacturing. This paper aims to review the varied research that has been performed in the area of support structures. To study the effect of support structures we have taken three different types of support structures to optimize the best support structure. Optimizing the perfect support support structure will give better results on the final build component. Support structure will help in improving the better mechanical properties also. The dimensional accuracy and surface roughness are also depending on the support structure geometry.

Key words: Optimization, AM240, simulation, circular support structures, Temparature

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 SLMprintability 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.

The RenAM 240 optical system features dynamic focusing, enabling all lasers to precisely address the entire bed simultaneously. This flexibility ensures build times are minimised by enabling the laser energy to be optimised over the entire powder bed.

The system uses a monolithic water-cooled additively manufactured galvanometer mounting, designed and manufactured in-house by Renishaw. Unlike separate mountings found on other multi-laser AM systems, the RenAM 240 series design features tight alignment of the optics and internal conformal cooling channels. This is a key enabler for precision laser control. Harnessing Renishaw's industry-leading metrology technology, the RenAM 240 series features a RESOLUTE™ optical encoder with a 1 nm z-axis resolution for high accuracy positional sensing.

The kinematic recoated mounting ensures rapid and repeatable positioning of the powder spreading recoated blade. Together, these features help maintain a precise relationship between the optical system and the working plane, which is vital for accurate part manufacture. The

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flexible recoated blade is forgiving for both solid and lattice geometry manufacture.

III. RESULTS AND DISCUSSIONS

3D print simulation of default support structure

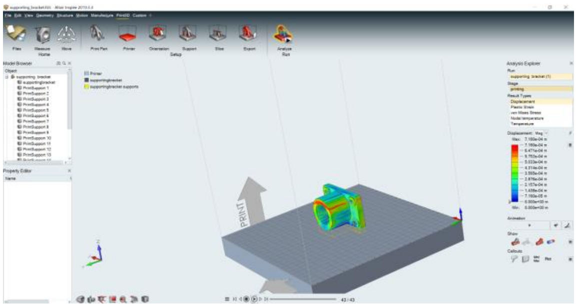

Fig.1 displacement of bracket for default support structures

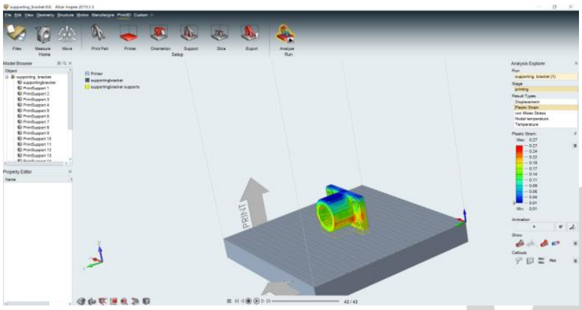

Fig.2. plastic strain of bracket for default support structures

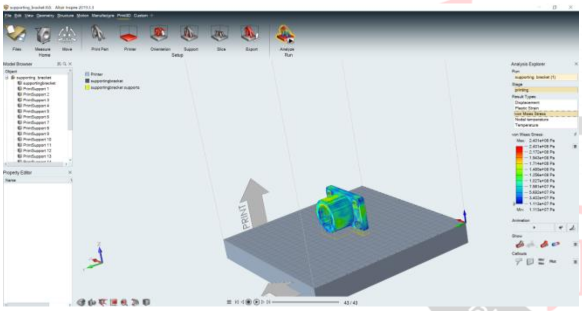

Fig.3. vonmises of bracket for default support structures

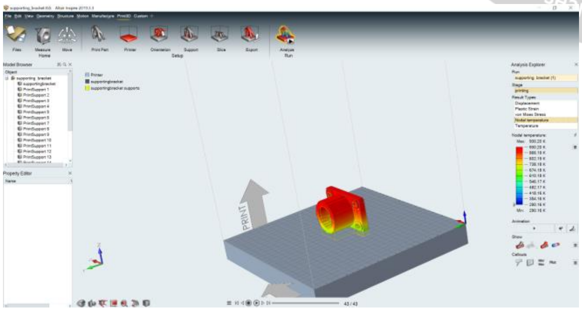

Fig.4. nodal temperature of bracket for default support structures

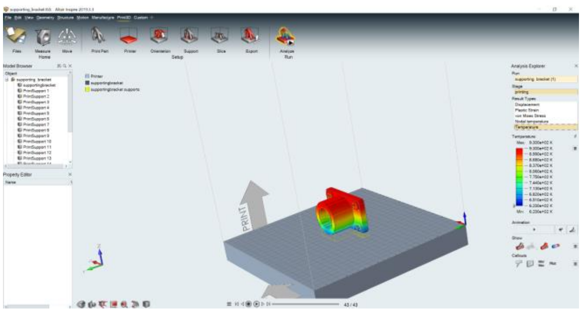

Fig.5. temperature distribution of bracket for default support structures

3D print simulation of circular support structure

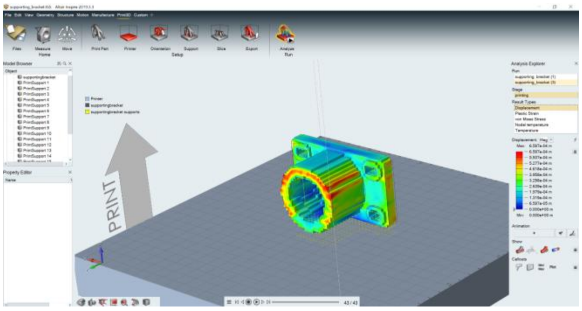

Fig.6. displacement of bracket for circular support structures

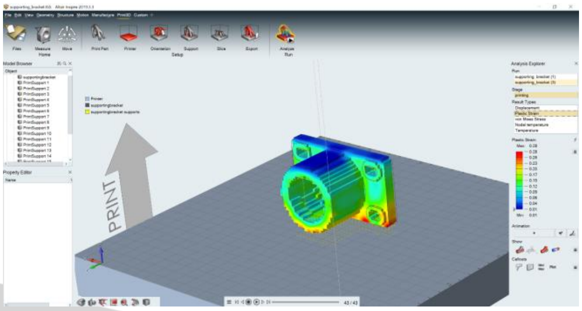

Fig.7. plastic strain of bracket for circular support structures

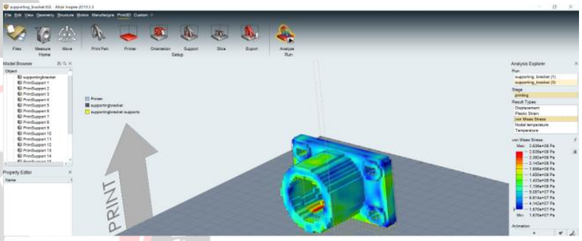

Fig.8. vonmises of bracket for circular support structures

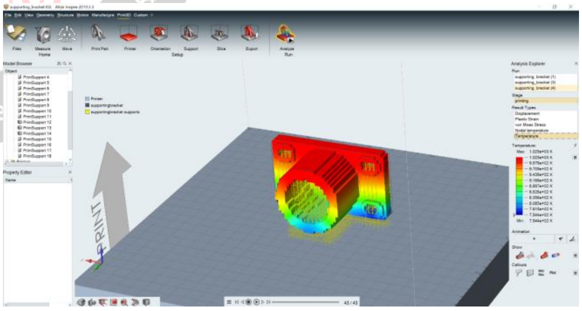

Fig.9: temperature distribution of bracket for hollow support structures

SUPPORT STRUCTURE	DISPLACEMENT (e-04 m)	PLASTIC STRAIN	STRESS (e+08 Pa)	NODAL TEMPERATURE (K)	TEMPERATURE (e+02 K)
DEFAULT	7.19	0.27	2.401	930.20	9.300
CIRCULAR	6.597	0.28	2.639	1011.15	1.011
HOLLOW	7.041	0.30	2.475	1025.09	1.025

Table 1. Support Structure Stats

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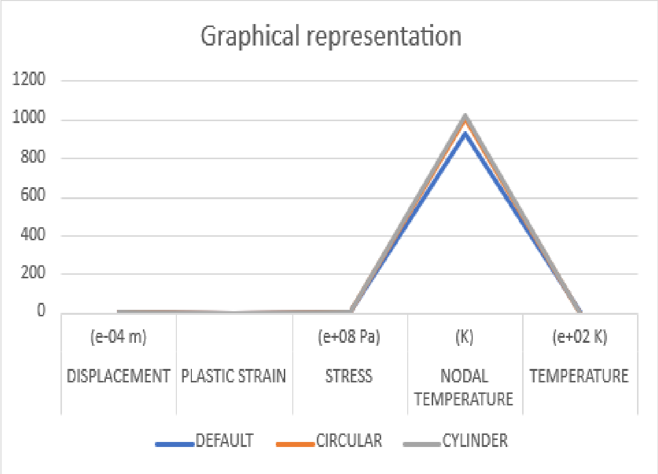

Fig 10**.** Graphical representation of support structures

IV. Conclusion

3D printing process is very advanced manufacturing process. In this laser parameters plays major role in building the component. Majorly the quality of the final part depends on the laser power, scanning speed, support structure, hatch distance, scanning strategy etc.… as the support structure varies the displacement in the final part also changes. Here we performed different case studies for different support structures. From the results we an conclude that

1. We have performed the simulation for different support structures to study the optimize the support structure default support structures have more displacement when compare to other two support geometries.
2. When comparing the plastic strain default support structure gives less plastic strain when compare to other two plastic strains. Plastic strain is directly tells us the final deformation rate in the build component.
3. The stresses developed in different support structures compared and the least stresses developed in the default support structures when compare to other two plastic strains. The less the stresses more will be the life. These stresses will directly affect the fatigue life of the component
4. The nodal temperature is gradually increasing for different support structures default support structure giving us the least nodal temperature. Less the nodal temperature less will be the thermal stresses. More will be the life of the component
5. Similarly, temperature is gradually increasing for different support structures for default is less than circular is less than hollow support structures. Temperature distribution is overall temperature in the component after print. this temperature needs to be cooled in the machine itself. If the part removed immediately oxidation and shrinkage will takes place.

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