International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-08, Special Issue, MAY 2022

Optimization of Support Structures to Minimize the Displacement of Standard ASTM E8 Tensile Specimen

Mr. V. Sandeep*, Mr. P. Pavan Kumar*, Mr. I. Akshay*, Mr. K. Vinay Kumar*, Mr. K. Sweet Babu*, Mr. VVN Sarath, Mrs. P Gayatri****

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

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

ABSTRACT - The purpose of this study is to study the influence of the laser power and the scanning speed on the surface hardness, and top surface and side surface roughness of Ti-6Al-4V metal specimens fabricated via the selective laser melting (SLM) technique. The laser power was varied between 150 and 300 W while the scan speed was varied between 800 and 1400 mm/s. Response surface methodology (RSM) in the Design Expert 11 software environment was used for the design of experiment and results analysis. The distance for surface indentations were targeted at 10–20 µm for the top surface and 60–80 µm for the side surface while the surface hardness profiling was studied using an indenter with the indentation performed at a load of 500 gf and at a dwelling time of 15 s. The study revealed that as the laser power was increased, the surface hardness increases, while the top surface and side surface roughness reduces. Then, when the scanning speed increased, the surface hardness, and top surface and side surface roughness were found to also increase. The optimum range of the process parameters selected are laser speed 300 W and scan speed 1400 mm/s. This produces a minimum surface roughness of 13.006µm for the top surface roughness and 62.166 µm for the side surface roughness with a corresponding hardness value of 409.391 HV. The findings of this study will assist manufacturers in the process design of the SLM of titanium alloy for aerospace applications.

Key words: Optimization, ASTM E8, RSM, SLM, Titanium alloy

I. INTRODUCTION

The laser power and scan speed played contradicting roles in the resultant roughness and porosity. An appropriate increase in laser power and decrease in scan speed could reduce the surface roughness and simultaneously improve the density and dimensional accuracy. Additive Manufacturing (AM) is defined as the manufacturing process to build three dimensional objects by adding layer-upon-layer of material. The process starts with a computer-aided-design (CAD) file that includes information about how the finished product is supposed to look. The material can be plastic, metal, concrete or even human tissue. AM is achieved using an additive process, where successive layers of material are laid down in different shapes. It is also considered different from traditional machining techniques that mostly depend on the removal of material by subtractive processes like milling or lathing. All AM technologies involve a series of steps that move from the virtual three-dimensional geometric representations to the physical resultant part. Due to variety of the product demands and the level of complexity, AM involves in process development in different ways and different degrees. Furthermore, in the early stages of product development of small and relatively simple products AM is used for a simple fabrication of visualization model while in later stages the larger and more complex parts require certain technology and possible post processing activities for the final form of the product. Regardless the case, the construction process of all AM technologies follows to some degree at least the same principle generic process sequence.

According to Gibson (2010) eight key steps can be defined as the generic process of AM:

- Conceptualization and CAD
- Conversion to STL
- Transfer and manipulation of STL file on AM machine
- Machine setup
- Build
- Part removal
- Post processing of part
- Application

All AM parts must begin from virtual model designed on software describing the external geometry in detail. The output of the first step should be an STL file format given information of the external surface and the basic calculations of the slices of the part. At the next stage the part is transferred to an AM process software where is been

 DOI : 10.35291/2454-9150.2022.0221

manipulated accordingly to the AM technology restrictions and a machine code sequence is generated. As following, the products are carried out layer by layer and according to the occasion some finishing operation is needed. The total procedure is indeed not necessarily a "rapid" process however AM involves to reduction of the development product time and thought the flexibility to decrease the number of required steps, it success a more economic but richer in variation of products and materials production. Nowadays Rapid Prototyping (RP) comprises AM and other non-additive methods for manufacturing physical objects at usually high speed and mostly for test purposes and not as a final part. Although, the American Society for Testing and Materials (ASTM) is standardizing the AM field by creating a new 3D generic file format for it called (*.amf) to substitute STL and others (IGS, STEP etc.). Consequently, new parameters are provided so that new AM machines can come to light and exploit their multiple capabilities. Nevertheless, AM is a very large division of RP and since RP was synonym of additive or layered manufacturing, nowadays they are still used as synonyms of each other in practice. The AM is also popularized with the term 3D printing, to make it more familiar and reachable to the public. In this thesis the term AM is used. The AM is not a new technology. It emerged with the invention of the first system, the stereolithography or SLA. It is a method that involves the use of a pool of a photopolymer resin where the successive layers are solidified and bonded to the previous ones by a UV laser that cures the liquid resin according to the required part geometry to produce 3D parts and it was developed by Charles Hull in 1984. The idea was patented in 1986. Then the invention of Selective Laser Sintering or SLS followed in 1987, a process that involves the melting powder substances to create an object via laser (again, find a more concise way of explaining SLS please). Later, the invention of "Three Dimensional Printing" (3DP) came out in 1993 by the Massachusetts Institute of Technology and the Z402 printer was introduced by Z Corp in 1996. During the next years several systems launched and the term "3D printing" was popularized. Today the AM has gained and earned its momentum. It can replace the traditional ways of manufacturing to meet the actual requirements of the industries. In addition, AM is available, nowadays, even for the households with the prosumer (producer- consumer) AM machines. Just in 2012, the AM has become more affordable and available for office, residential and academic purposes due to MakerBot together with RepRap that stormed the market. Moreover, AM can be applied in numerous fields. One of the applications of the AM products is the creation of moulds for sand casting made by SLS technology, that they can be used for casting patterns in the lost wax method or even as medical models for the visualization process to plan a surgery. Therefore some other most current and interesting applications in medical and dental fields can be the hearing aid shells, the dental aligners, or the orthopedical and craniomaxillofacial implants. Furthermore, there are more applications in the aeronautical industry, the artistic and design field or in the academic level and research. Hot topics on AM are the biomaterials (tissue and organ printing), the new design principles and software, the adaptation of available materials and the addition of new materials for AM, the new, faster and less costly processes and the fact that bigger and metallic machines are about to be launched. Some can be wondering if there is a demand for AM from the industry. The AM technology has already been tried back in the 90s and RP is still used when it is needed. The materials are not so good compared to conventional manufacturing but in some cases the rough surfaces and pores in metallic AM are actually very beneficial for prostheses. AM is slow for real manufacturing, more expensive and the technologies are not that precise with the production of poor surfaces, but if one needs a product that requires customization then the AM is the only way to produce it with an affordable cost comparing to conventional machining. On the other hand, AM today offers the freedom to create new geometries, materials with excellent properties and a variable composition, as well as the recycling of the material. As a result, a lot of research is being focused on AM since all the above characteristics, including the intense customer demands, force the companies to look for better responsiveness through better methods and improvements. AM is advantageous for customer-based production which is the key for a company in this competitive market.

1.1 Overview of Plastictechnologies:

1.1.1 Stereolithography Apparatus (SLA)

1.2.2 Fused Deposition Modeling (FDM)

Fused Deposition Modeling (FDM) involves feeding a thermoplastic filament (typical thickness 1.75 – 3 mm) into a heated extrusion nozzle that moves in the X and Y axes that form the horizontal plane by convention. So the direction of Z axis is the vertical plane where the building of the part is done. The heated extrusion head melts and deposits the thermoplastic material on a table that moves on the z axis building the model. The molten thermoplastic is channeled through an extrusion nozzle which reduces it to a fine bead or deposition onto a substrate material. After depositing each bead, the model is built up layer by layer. Layer thickness of industrial machines is typically between 125 μm to 330 μm. As it is deposited the molten thermoplastic material is just slightly above its melting point so that solidification can occur immediately after extrusion as the material welds to previous layers. Additionally, post-processing techniques are required for support removal.

DOI : 10.35291/2454-9150.2022.0221

Figure 1: MakerBot mixtape printed using FDM.

In FDM technology there is a wide range of materials that is used such as ABS, ABSi (Methyl methacrylate/Acrylonitrile/Butadiene/Styrene/Copolymer) that is beneficial for monitoring material flow and light transmission, ABS-ESD7 (Acrylonitrile Butadiene Styrene – Electrostatic Dissipative) that will not produce a static shock or cause other materials like powders, dust and fine particles to stick to it, ABS-M30 that gives stronger, smoother and with better feature detail parts, biocompatible ABS-M30i, PC, PC/ABC, ULTEM (lightweight and flame-retardant thermoplastic) and PPSF (Polyphenylsulfone).

1.1.3 Binder Jetting

1.1.4 PolyJet Printing

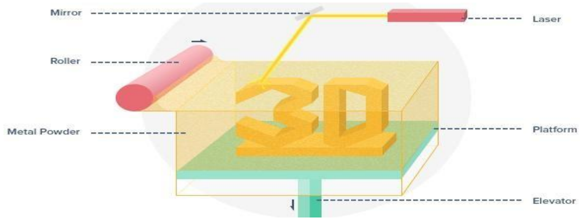
1.1.5 Selective Laser Sintering (SLS)

1.1.6 Digital Light Processing (DLP)

1.2 Metallic Technologies:

(a) Direct Metal Laser Sintering (DMLS)

Direct Metal Laser Sintering also known as DMLS is an additive manufacturing technology that creates metal parts directly from 3D CAD data without the use of tooling. DMLS utilizes a variety of metal and alloy materials to create strong durable parts and prototypes. DMLS is a great choice for functional metal prototypes, high temperature applications and end-use parts. The process begins with the same way as the other layer additive manufacturing technologies. The 3D CAD model of the metal part is divided into 2D cross sections. Then the information is transferred to the DMLS machine. A recoater/roller dispatches material powder from the powder supply to create a uniform layer over the base bed. A laser then draws a 2D section on the surface of the material through heating and fusing it. Once a single layer is complete the base bed is lowered in a distance that is equal to the size of the thickness of a single layer. The raw material is again spread evenly on the previous sintered layer. The DMLS machine continues to sinter layer upon layer as a result the building of the part from the bottom up. During the build process, support structures are added to give supplemental strength to find features and overhanging surfaces. The completed part is then removed from the base bed and treated with a heat treating process to be further hardened. Any support structures are also removed at this time.



(a) How DMLS works.

DMLS parts can be used in highly cosmetic applications with post processing techniques such as surface treatment and hand polishing actions that are available through many providers. Typical uses for DMLS include tools, small integrated structures, surgical implants and aerospace parts The range of alloy powders now available for DMLS included stainless steels, cobalt-chrome, cobalt and nickel-base superalloys (IN 625, IN 718), maraging steels, dental alloys, Ti and Ti alloys (EOS Ti64), Al and EOS AlSi10Mg. The following table indicates some of the specifications of the DMLS machine EOSINT M 280 provided by EOS.

DMLS technology

Building Volume	250mm x 250mm x 325mm
Build Rate	2 – 8 mm^3/s
Laser Power	200 W or 400 W
Scan Speed	Up to 7.0 m/s
Layer Thickness	20 – 60 µm
Accuracy	+/- 50 µm
Power Supply	32 A
Power Consumption	Max 8.5 kW/ typical 3.2 kW
Price	422 k€[2]

Table 1: EOSINT M 280 specifications.

(b) Selective Laser Melting (SLM)

Selective laser melting (SLM) is an additive manufacturing process that uses 3D CAD data the energy of a high powered laser beam (usually an ytterbium fiber laser) to create three-dimensional metal parts by fusing fine metallic powders together. The process starts with the introduction of a 3D model into software that slices the file into to 2D cross sections and sends it to the printer. The energy of a high power CO2 laser is used to fuse particles of metallic powder together. The same idea of AM happens also in this process. The recoater or roller sweeps a layer of the fine material powder and makes it ready for the laser to fuse them according to the 2D cross section under a controlled inert environment. With each successive layer scan, the platform bed is lowered incrementally. This process is repeated one slice at a time until the part built height is completed. Part support is accomplished by the unsintered powder that surrounds the parts during processing. Complete mechanical assemblies can be made mechanically functional simply by removing the unsintered powder. The result is a wide range of durable, high precision and functional end-use parts and prototypes. The main advantage of the SLM process is the possibility to build

DOI : 10.35291/2454-9150.2022.0221

thin wall parts to a high resolution which extends its manufacturing capabilities. However many processing issues arise due to the use of a high power laser to fuse the material from a powder bed. High heat input often causes an increase in material vaporization and spatter generation during processing. Surface roughness is another SLM issue that is influenced by particle melting; melt pool stability and re-solidifying mechanisms.

Figure 2: A pump manufactured by SLM3

Material powders used in SLM include; stainless steel powder of size 25-50 µm (named as CL20ES supplied by Concept Laser GmbH) that is recommended for the production of acid- and corrosion- resistant parts or tool components for preproduction tools; tool steel powder of size 20-50 µm (named CL50WS and supplied by Concept Laser GmbH) which is recommended for the production of parts with characteristics similar to hot-work steel 1.2343 as well as tool components of plastic injection moulds; stainless steel powder of average size 25 µm (named as EOS Stainless Steel 17-4PH and supplied by EOS GmbH); Ti-6Al-4V and Ti-6Al-7Nb powder of size 25-45 µm (obtained from Concept Laser GmbH and its trade name is CL 40Ti); Co-Cr-Mo powder of average size of 50 µm; Cobalt chrome (ASTM75); Aluminum Al-Si-12; Inconel 718 and 625.

The Table 2 includes specifications of the SLM machine AM250 provided by Renishaw.

Building Volume	250 x 250 x 300 mm
Build Rate	1 – 6 mm^3/s
Laser Power	200 or 400 W
Scan Speed	Up to 2.0 m/s
Layer Thickness	20 – 100 µm
Accuracy	+/- 50 µm
Power Supply	230 V 1 PH, 16 A
Price	750 k€[4]

Table 2: Renishaw AM250 specifications

(c) Electron Beam Melting (EBM)

Electron beam melting (EBM) is a type of additive manufacturing for metal parts. It is similar to Selective Laser Melting (SLM) with the main difference being that EBM melts the metal powder with the use of an electron beam in a high vacuum. When a layer is finished, the powder platform moves down, and an automated powder arm adds a new layer of material which is melted to form the next section of the model. Repeating this process builds up the object one layer at a time. When printing is completed, the build chamber, including the model and excess material inside, is left to cool. The leftover material is then recovered and recycled, leaving the final model behind. EBM takes place at such a high temperature that it produces parts that are practically free from residual stress and distortion at a micro level, eliminating the need for heat treatment post-processing. However, due to high temperatures in the build chamber, the object can be subject to some thermal stress or warping as it cools. Unlike some metal sintering techniques, the parts are fully dense, void-free, and extremely strong.

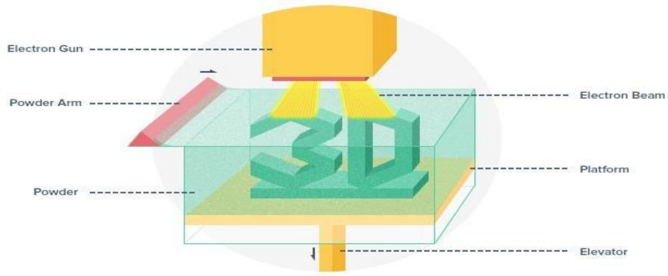


Figure 3: How EBM works.

EBM printers can use various forms of titanium in addition to cobalt chrome. Due to the vacuum environment at high temperature, EBM can produce objects comparable to wrought material with better mechanical properties than cast titanium and cobalt chrome. Organizations can take advantage of this technology to produce both prototype and manufacture high-quality objects with great durability. Biocompatible implants have also been built by EBM. The table below shows some specifications of the EBM machine QA2X provided by Arcam.

Building Volume	200 x 200 x 380 mm
Build Rate	45 – 66 mm^3/s
Laser Power	50 – 3000 W
Scan Speed	Up to 2.0 m/s
Layer Thickness	50 µm
Accuracy	+/- 0.2mm
Power Supply	3 x 400 V, 32 A, 7 kW
Price	975 [5]

1.3.4 Electron Beam Direct Manufacturing (EBDM)

Direct manufacturing is a process used exclusively by Sickay, Inc. in 2009 that melts metal wire as feedstock used

 DOI : 10.35291/2454-9150.2022.0221

International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-08, Special Issue, MAY 2022

to form an object within a vacuum chamber. During the EBDM process the energy from an electron beam gun is used to melt a metallic material that is usually wire. The electron beam head is controlled by a computer to melt the material and build up the object on a movable table. An advantage of this process is the fact that the electron beam is an efficient power source that can be precisely focused and deflected using electromagnetic coils and with the combination of the contamination-free environment of the vacuum chamber there is no need for additional inert gases (commonly used with laser and arc based processes). EBDM can produce very large end-use objects quickly. However, EBDM is not as precise as other processes since the parts produced have a very coarse surface that requires extensive machining after building is complete.

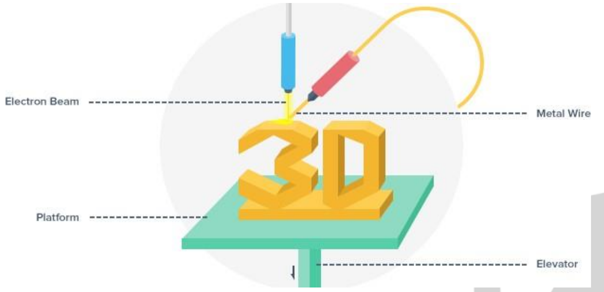


Figure 5: How EBDM works

Sciaky's EBDM process has a standard build envelope of 48.3 cm x 10.2 cm x 10.2 cm (L x W x H), allowing manufacturers to produce very large parts and structures, with virtually no waste. A wide variety of materials are available for use. Materials include titanium, tantalum, stainless steel, Inconel, aluminum alloys, nickel-based alloys, titanium aluminides, and Metal Matrix Composites (MMCs) (including titanium matrix composites). There is now growing interest in strong steels such as Vascomax and 15-5 PH.

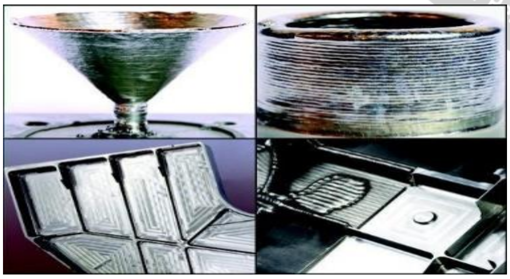


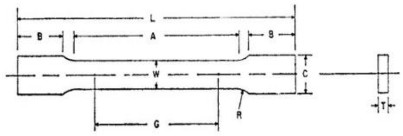
Figure 6: A sample of titanium parts created with Sciaky's direct manufacturing technology, which combines an electron beam welding gun with wire feed additive layering.6

1.3 OVERVIEW OF METALLIC MATERIALS OF AM:

1) Pure metals powder
2) Ti- based alloys
3) Ni- based alloys
4) Fe- based alloys
5) Al-based alloys
6) Cu-based alloys
7) Metal matrix composites (MMC)

II. DESIGN METHODOLOGY

2.1 E8 specimen design



Dimensions			
	Standard Specimens		Subsize Specimen
	Plate-Type, 40 mm [1.500 in.] Wide	Sheet-Type, 12.5 mm [0.500 in.] Wide	6 mm [0.250 in.] Wide
	mm [in.]	mm [in.]	mm [in.]
G—Gage length (Note 1 and Note 2)	200.0 ± 0.2 [8.00 ± 0.01]	50.0 ± 0.1 [2.000 ± 0.005]	25.0 ± 0.1 [1.000 ± 0.003]
W—Width (Note 3 and Note 4)	40.0 ± 2.0 [1.500 ± 0.125, -0.250]	12.5 ± 0.2 [0.500 ± 0.010]	6.0 ± 0.1 [0.250 ± 0.005]
T—Thickness (Note 5)		thickness of material	
R—Radius of fillet, min (Note 6)	25 [1]	12.5 [0.500]	6 [0.250]
L—Overall length, (Note 2, Note 7, and Note 8)	450 [18]	200 [8]	100 [4]
A—Length of reduced section, min	225 [9]	57 [2.25]	32 [1.25]
B—Length of grip section (Note 8)	75 [3]	50 [2]	30 [1.25]
C—Width of grip section, approximate (Note 4 and Note 9)	50 [2]	20 [0.750]	10 [0.375]

Fig E8 specimen design

NOTE 1—For the 40 mm [1.500 in.] wide specimen, punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the reduced section. Either a set of nine or more punch marks 25 mm [1 in.] apart, or one or more pairs of punch marks 200 mm [8 in.] apart may be used.

NOTE 2—When elongation measurements of 40 mm [1.500 in.] wide specimens are not required, a minimum length of reduced section (*A*) of 75 mm [2.25 in.] may be used with all other dimensions similar to those of the plate-type specimen.

NOTE 3—For the three sizes of specimens, the ends of the reduced section shall not differ in width by more than 0.10, 0.05 or 0.02 mm [0.004, 0.002 or 0.001 in.], respectively. Also, there may be a gradual decrease in width from the ends to the center, but the width at each end shall not be more than 1 % larger than the width at the center.

NOTE 4—For each of the three sizes of specimens, narrower widths (*W* and *C*) may be used when necessary. In such cases the width of the reduced section should be as large as the width of the material being tested permits; however, unless stated specifically, the requirements for elongation in a product specification shall not apply when these narrower specimens are used.

NOTE 5—The dimension *T* is the thickness of the test specimen as provided for in the applicable material specifications. Minimum thickness of 40 mm [1.500 in.] wide specimens shall be 5 mm [0.188 in.]. Maximum thickness of 12.5 and 6 mm [0.500 and 0.250 in.] wide specimens shall be 19 and 6 mm [0.750 and 0.250 in.], respectively.

NOTE 6—For the 40 mm [1.500 in.] wide specimen, a 13 mm [0.500 in.] minimum radius at the ends of the reduced section is permitted for steel specimens under 690 MPa

 DOI : 10.35291/2454-9150.2022.0221

[100 000 psi] in tensile strength when a profile cutter is used to machine the reduced section.

NOTE 7—The dimension shown is suggested as a minimum. In determining the minimum length, the grips must not extend in to the transition section between Dimensions *A* and *B*, see Note 9.

NOTE 8—To aid in obtaining axial force application during testing of 6-mm [0.250-in.] wide specimens, the overall length should be as large as the material will permit, up to 200 mm [8.00 in.].

NOTE 9—It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips. If the thickness of 12.5 mm [0.500-in.] wide specimens is over 10 mm [0.375 in.], longer grips and correspondingly longer grip sections of the specimen may be necessary to prevent failure in the grip section.

NOTE 10—For the three sizes of specimens, the ends of the specimen shall be symmetrical in width with the center line of the reduced section within 2.5, 0.25 and 0.13 mm [0.10, 0.01 and 0.005 in.], respectively. However, for referee testing and when required by product specifications, the ends of the

12.5 mm [0.500 in.] wide specimen shall be symmetrical within 0.2 mm [0.01 in.].

NOTE 11—For each specimen type, the radii of all fillets shall be equal to each other within a tolerance of 1.25 mm [0.05 in.], and the centers of curvature of the two fillets at a particular end shall be located across from each other (on a line perpendicular to the centerline) within a tolerance of 0.2 mm [0.01 in.].

NOTE 12—Specimens with sides parallel throughout their length are permitted, except for referee testing, provided: *(a)* the above tolerances are used;

(b) an adequate number of marks are provided for determination of elongation; and *(c)* when yield strength is determined, a suitable extensometer is used. If the fracture occurs at a distance of less than 2 W from the edge of the gripping device, the tensile properties determined may not be representative of the material. In acceptance testing, if the properties meet the minimum requirements specified, no further testing is required, but if they are less than the minimum requirements, discard the test and retest.

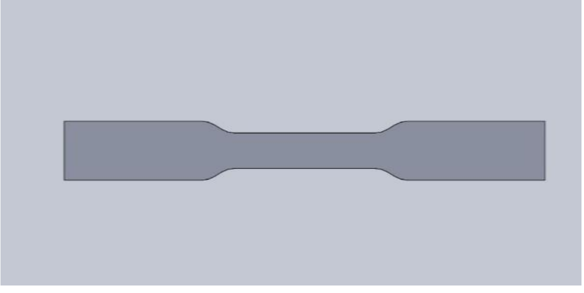


Fig E8 specimen design front view

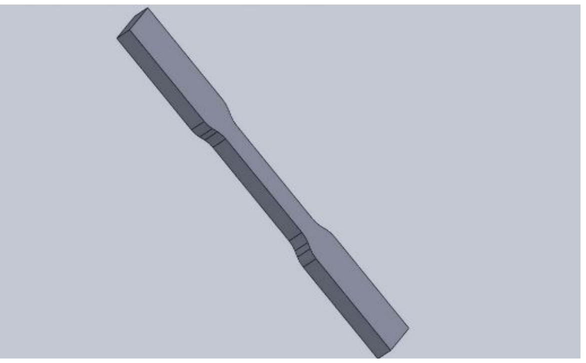


Fig E8 specimen design isometric view

2.2 3D printing simulation to optimize the laser power

Altair Engineering Inc. is an American multinational information technology company headquartered in Troy, Michigan. It provides software and cloud solutions for simulation, IoT, high performance computing (HPC), data analytics, and artificial intelligence (AI). Altair Engineering is the creator of the HyperWorks CAE software product, among numerous other software packages and suites. The company was founded in 1985 and went public in 2017. It is traded on the Nasdaq stock exchange under the stock ticker symbol ALTR. Altair Engineering was founded in 1985 by James R. Scapa, George Christ, and Mark Kistner in Troy, Michigan. Since the company's outset, Scapa has served as its CEO (and now chairman). Initially, Altair started as an engineering consulting firm, but soon branched out into product development and computer-aided engineering (CAE) software. In the 1990s, it became known for its software products like Hyper Works, Opti Struct, and Hyper Mesh, which were often used for product development by the automotive industry. Some of Altair's early clients included the Ford Motor Company, General Motors, and Chrysler. Its software also aided in the development of the Young America and America One racing yachts, the former of which was used to compete in the 1995 America's Cup. Its software also found uses in other sectors, including aerospace (NASA), aviation (Airbus), consumer electronics (Nokia), and toy manufacturing (Mattel), among others. In 2002, Altair software aided in the design of the Airbus A380 by weight optimizing the aircraft wing ribs. That year, the company moved into a new headquarters in Troy, Michigan. It maintained separate offices in Allen Park, Michigan. Also in 2002, Altair opened offices in Seongnam, South Korea and Shanghai, China, adding those locales to its international footprint alongside India where it had begun investment in 1992. In addition to its software production, Altair continued hiring out engineering consultants to its corporate clientele. Its consultancy services accounted for the majority of the company's revenue until 2004, when the sale and licensing of software overtook that. In October of that year, General Atlantic invested $30 million in Altair. Also in 2004, Altair partnered with General Motors and the United States Department of Défense on the design and

DOI : 10.35291/2454-9150.2022.0221

construction of a new military vehicle. Altair also branched out into the life sciences, finance, and pharmaceutical industries with its high-performance computing software, PBS Pro, which it had acquired the rights to in 2003. In June 2006, Altair acquired the French CAE software company, Mecalog, and its Radios technology suite. In 2007, it spun off a new wholly-owned subsidiary called ilumisys, which would focus on light-emitting diode (LED) lamps designed to be used as direct replacements for fluorescent light tubes. Ilumisys' operations were moved to Michigan in 2011, and it was rebranded as TOGGLED in 2012. In the early 2010s, Altair's product design division (Altair Product Design) began creating prototypes of various vehicles including a hydraulic hybrid transit bus known as BUSolution and an electric concept car called the Avant GT. By 2013, the company had offices in 19 countries worldwide and 1,800 employees. That year, it also bought out General Atlantic's equity stake in the company. On November 1, 2017, Altair went public with an IPO on the Nasdaq stock exchange and began trading under the stock ticker symbol ALTR. The company raised $156 million with share prices starting at $13. In the years leading up to the IPO, Altair acquired 11 different companies with strategic assets and expertise in fields like material science, electronics, industrial design, rendering, and others. By 2019, the company had acquired a total of 30 businesses or business units. It also began making efforts to incorporate artificial intelligence technology into its new software packages. That year, it opened a new office in Greensboro, North Carolina after acquiring the data analytics company, Datawatch, which had offices in the area. In June 2020, the company announced that it would be providing software updates for all of its products. The updates were implemented to improve workflows and provide access to a broader set of tools for data analytics, machine learning, and physics. In January 2021, Altair announced that it would collaborate with Rolls-Royce Holdings on a project that would use AI and machine learning to facilitate the design process. Fig Inspire software interface

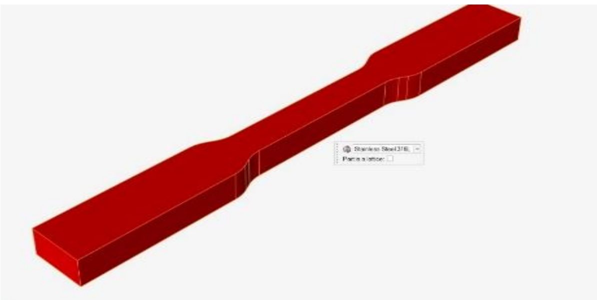


Fig defining material

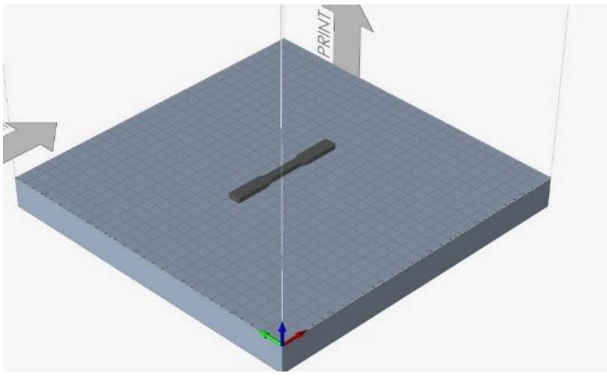


Fig defining machine

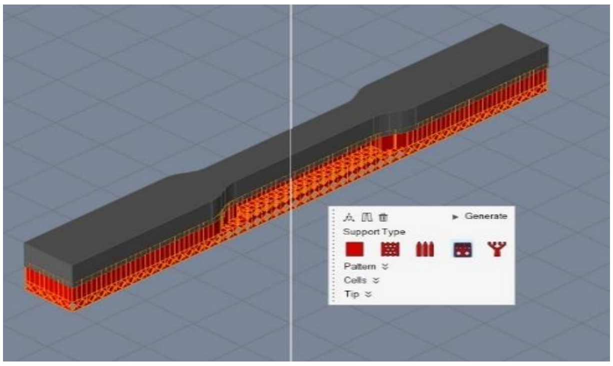


Fig generating support material

III. RESULTS AND DISCUSSIONS

4.1 3D printing simulation result for circular support structure

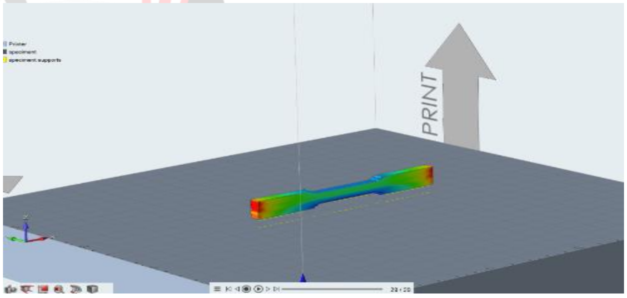


Fig displacement result for circular support structure

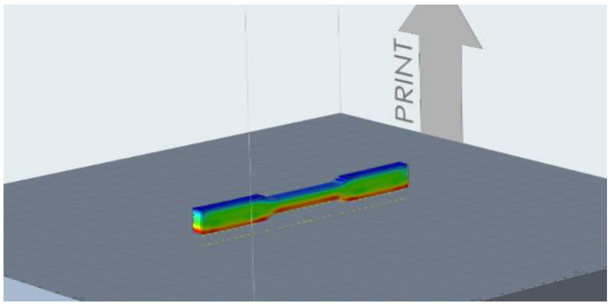


Fig plastic strain result for circular support structure

DOI : 10.35291/2454-9150.2022.0221

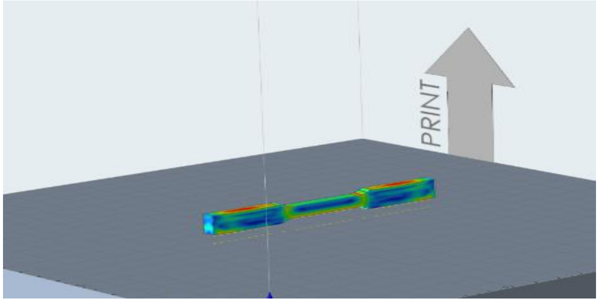


Fig von mises stress result for circular support structure

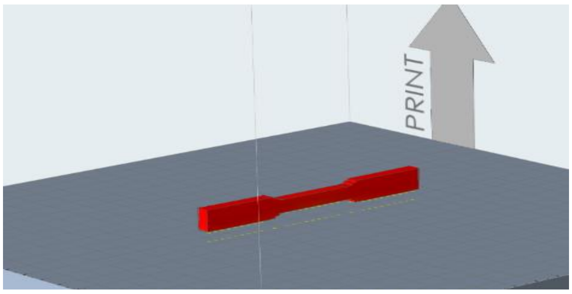


Fig nodal temperature result for circular support structure

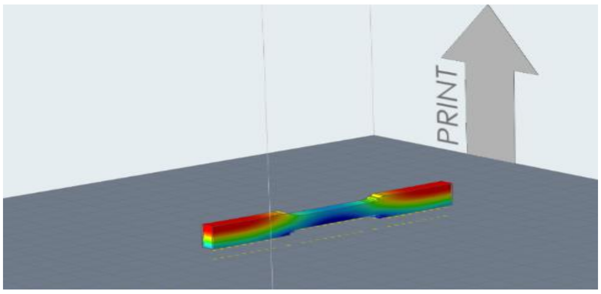
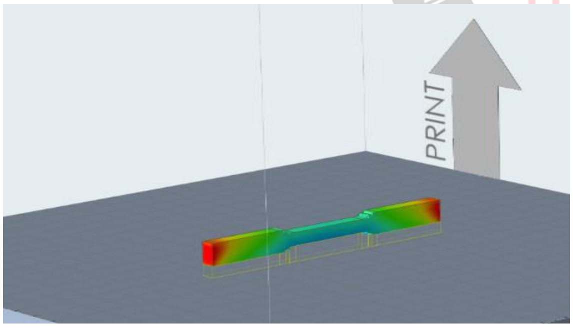


Fig temperature distribution for circular support structure

4.2 3D printing simulation result for bar support structure



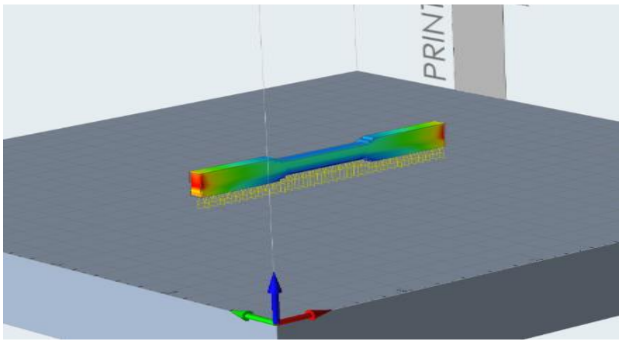


Fig displacement result for hollow support structure

Fig displacement result for bar support structure

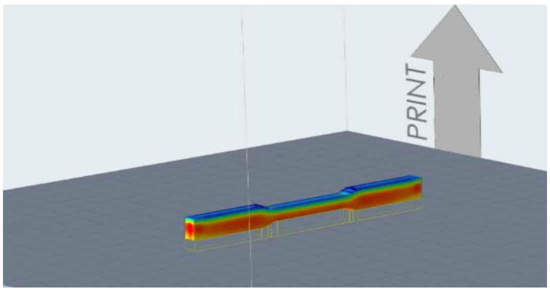


Fig plastic strain result for bar support structure

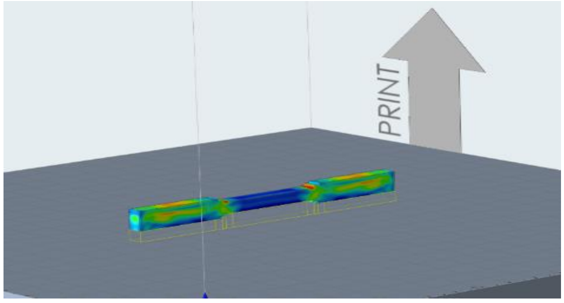


Fig von mises stress result for bar support structure

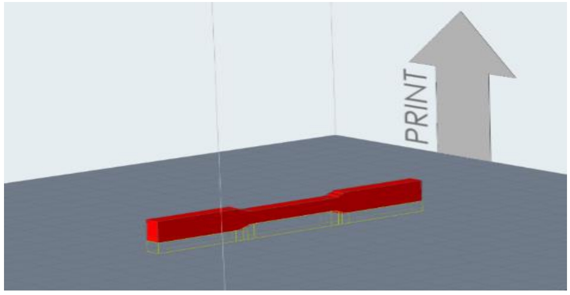


Fig nodal temperature result for bar support structure

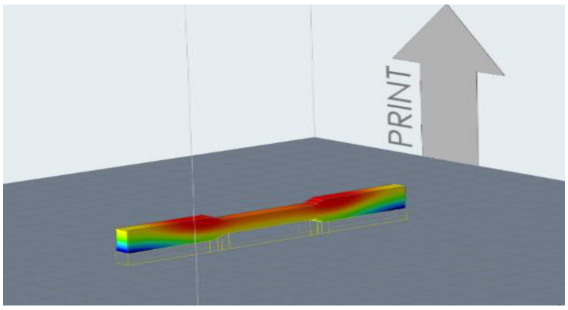


Fig temperature distribution for bar support structure

4.3 3D printing simulation result for hollow support structure:

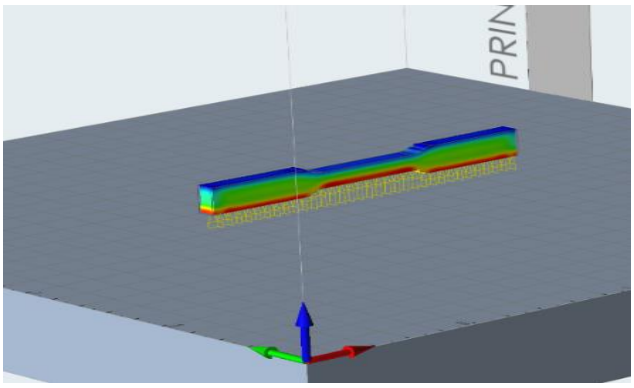


Fig plastic strain result for hollow support structure

DOI : 10.35291/2454-9150.2022.0221

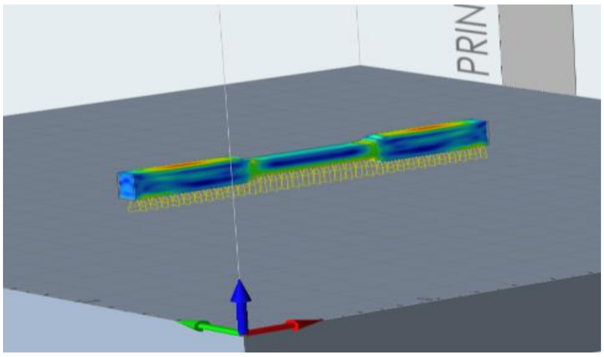


Fig von mises stress result for hollow support structure

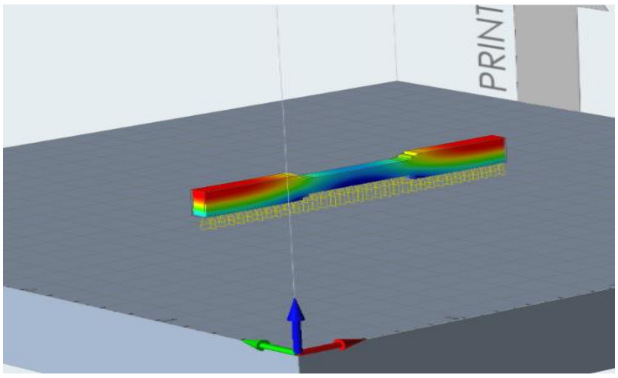


Fig nodal temperature result for hollow support structure

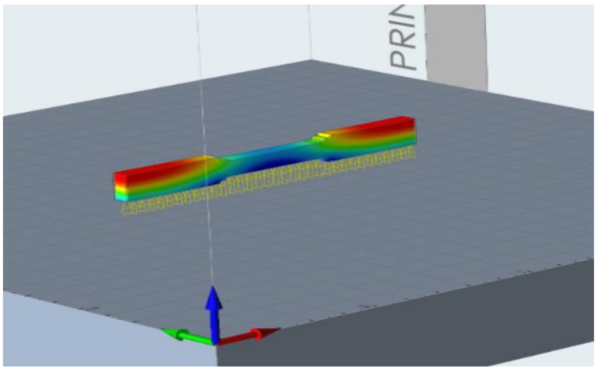


Fig temperature distribution for hollow support structure

IV. CONCLUSION

3D printing technology is advanced manufacturing process in the field of production and rapid prototyping. The quality and dimensional accuracy of the 3D printed depends on the so many factors depend on the geometrical conditions of the component. To study that we have simulate the analysis for ASTM E8 specimen for different support structures. The ASTM E8 sample is for conducting standard tensile test to study the mechanical properties of the particular material and machining process. From the simulation results we can conclude that

1. Bar support structures gives better results when compare to circular pin and hollow supports. The displacement of the bar support structure is very less when compare to other two support structure.

2. The plastic strain of the bar support structure is less when compare with other two support structure. We can observe more plastic strain in the circular pin support structure it is because of end contact of the pin is very less. To reduce this plastic, we can increase the contact point of circular pin.

3. The vonmises stresses are varying and it exhibits very low for circular pin. The bar support structure shows optimized von mises stresses.

4. The nodal temperature is low for bar support structure when compare to other two support structure. Due to this the cooling time will take more for other two support structure when compare to bar support structure.

5. The temperature distribution also exhibits very less for bar support structure.

From the above results we can conclude that bar support structures give better results and to confirm this experimental studies need to be done confirm with the simulation results

REFERENCES

[1] EXOne. (2013). ExOne-Rapid Growth of Additive Manufacturing (AM) Disrupts Traditional Manufacturing Process. Available: http://additivemanufacturing.com/2013/06/06/exone- rapid-growth-of-additive-manufacturing-am-disrupts-traditional-manufacturing-process/. Last accessed 14th Feb 2014.

[2] Klas Boivie, Additive Manufacturing: A brief overview by SINTEF Raufoss Manufacturing AS, lecture notes distributed in Not Just CAD at KTH Royal Institute of Technology, Stockholm on 19th November 2012.

[3] Robots and Androids. (2013). History of 3D Printing. Available: http://www.robots-and-androids.com/history-of-3d-printing.html. Last accessed 14th Feb 2014.

[4] Laser Prototypes Europe Ltd. (2012). Stereolithography – The Materials. Available: http://www.laserproto.com/services/stereolithography-2/stereolithography-sla-materials- used. Last accessed 3rd Feb 2014.

[5] 3D Systems Inc. (2014). Stereolithography (SLA) Material Selection Guide. Available: http://www.3dsystems.com/files/downloads/3D-Systems-SLA-material-selection-guide- 0813-USEN.pdf. Last accessed 3rd Feb 2014.

[6] Materialize NV. (2014). FDM: Materials & datasheets. Available: http://manufacturing.materialise.com/fdm-materials-datasheets-0. Last accessed 3rd Feb 2014.

[7] RedEye Copyright©. (2013). FDM Thermoplastics. Available: http://www.redeyeondemand.com/PPSF.aspx. Last accessed 3rd Feb 2014.

 DOI : 10.35291/2454-9150.2022.0221

[8] Thre3D. (2013). HOW BINDER JETTING WORKS. Available: https://thre3d.com/how-it-works/binder-jetting. Last accessed 11th Mar 2014.

[9] Stratasys Ltd. (2014). PolyJet Technology. Available: http://www.stratasys.com/3d-printers/technology/polyjet-technology. Last accessed 11th Mar 2014.

[10] 3D Systems, Inc. (2014). Selective Laser Sintering (SLS). Available: http://www.3dsystems.com/quickparts/prototyping-pre-production/selective-laser- sintering-sls. Last accessed 3rd Feb 2014

[11] C. Simoneau, P. Terriault, B. Jetté, M. Dumas, V. Brailovski, Development of a porous metallic femoral stem: Design, manufacturing, simulation and mechanical testing, Mater. Des. 114 (2017) 546-556.

[12] S. Alvi, K. Saeidi, F. Akhtar, High temperature tribology and wear of selective laser melted (SLM) 316L stainless steel, Wear 448-449 (2020) 203228.

[13] X.Q. Wang, L.N. Carter, B. Pang, M.M. Attallah, M.H. Loretto, Microstructure and yield strength of SLM-fabricated CM247LC Ni-Superalloy, Acta Mater. 128 (2017) 87-95. [14] J.N. Li, X.L. Wang, W.J. Qi, J. Tian, S.L. Gong, Laser nanocomposites-reinforcing/manufacturing of SLM 18Ni300 alloy under aging treatment, Mater. Charact. 153 (2019) 69-78.

[15] Z.H. Hu, H.H. Zhu, H. Zhang, X.Y. Zeng, Experimental investigation on selective laser melting of 17-4PH stainless steel, Opt. Laser Technol. 87 (2017) 17-25.

[16] M. Ghayoor, K. Lee, Y.J. He, C.H. Chang, B.K. Paul, S. Pasebani, Selective laser melting of 304L stainless steel: Role of volumetric energy density on the microstructure, texture and mechanical properties, Addit. Manuf. 32 (2020) 101011.

[17] J. Sander, J. Hufenbach, L. Giebeler, H. Wendrock, U. JUHN, J. Eckert, Microstructure and properties of FeCrMoVC tool teel produced by selective laser melting, Mater. Des. 89 (2016) 335-341.

[18] R. Rashid, S.H. Masood, D. Ruan, S. Palanisamy, R.A. R. Rashid, M. Brandt, Effect of scan strategy on density and metallurgical properties of 17-4PH parts printed by selective laser melting (SLM), J. Mater. Process. Technol. 249 (2017) 502-511.

[19] Y.N. Song, Q.D. Sun, X.B. Wang, J.W. Liu, J. Sun, Effect of scanning strategies on the microstructure and mechanical behavior of 316L stainless steel fabricated by selective laser melting, Mater. Sci. Eng. A 793 (2020) 139879.

[20] L. Zhou, S.Y. Chen, M.W. Wei, J. Liang, C.S. Liu, M. Wang, Microstructure and properties of 24CrNiMoY alloy steel prepared by direct laser deposited under different preheating temperature, Mater. Charact. 158 (2019) 109931.

[21] W. Xiong, L. Hao, Y. Li, D.N. Tang, Q. Cui, Z.Y. Feng, C.Z. Yan, Effect of selective laser melting parameters on morphology, microstructure, densification and mechanical properties of supersaturated silver alloy, Mater. Des. 170 (2017) 107697.

[22] X.L. Kang, S.Y. Dong, P. Men, X.T. Liu, S.X. Yan, H.B. Wang, B.S. Xu, Microstructure evolution and gradient performance of 24CrNiMo steel prepared via laser melting deposition, Mater. Sci. Eng. A 777 (2020) 139004.

[23] X. Tang, S. Zhang, X. Cui, C.H. Zhang, Y. Liu, J.B. Zhang, Tribological and cavitation erosion behaviors of nickel-based and iron-based coatings deposited on AISI 304 stainless steel by cold.

 DOI : 10.35291/2454-9150.2022.0221