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Laser Speed Effect on Quality Prototype Fabrication Operation: Selective Laser Sintering

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ABSTRACT

This document reports an inclusive set of theoretical research and industrial applications of computers aided rapid manufacturing technology in various areas for high integrity components. The advancements in layer additive manufacturing technologies have enabled the manufacture of functional 3D products directly from Computer-Aided Design data. The aim of this paper is to compose the knowledge about the laser speed affects the quality of part production, the part merit depends on the effect of scan speed on processing time we also discuss the distinctive part orientation in AM process. We discuss current research and application examples using rapid manufacturing for advanced illustration.

***KEY WORDS**: Rapid manufacturing, Additive manufacturing, Orientation. Part Building*

1. INTRODUCTION

Present day market is characterized by a keen global competition. In such a competitive, global environment, it is a buyer's market, and is very favorable to the consumers. People able to purchase goods with quality and values[1]. For a company to have sustained growth and earnings, it needs to build customer loyalty by creating high cost products in this very aggressive global market. This means that the products need to be low in cost and high in quality. The global competitive environment changed the product development system. It is required the world-class manufacturing to fulfill consumers requirement. The product can be designed and developed by the engineers is to be within the cost, quality, time, and function constraints. Such a global environment has placed numerous burdens on researchers and engineers. Product prototyping is a critical job it works as a role of concept or an idea to be produces a quality product. However, prototyping often is very costly and time consuming, thus it becomes the bottleneck of the product development process [2]. Customers need to produce products cheaper in cost and of good quality and they want it deliver within time, this is a challenging task to be an engineer. Fortunately, the current technologies offer good leverage to overcome some of the issues. As prototyping activities can often be very expensive in terms of time and cost, it is critical to plan them well and use state-of-the-art technologies, such as rapid prototyping and virtual prototyping tools. The modern tools of digital prototyping and digital manufacturing using the CAD/CAM technologies to prototyping overcome the conventional manufacturing such as material removal methods and it can be produced functional products by additive manufacturing methods [3]. Rapid manufacturing technology stands for group of techniques used to produce quickly a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. RP is a generic term as layer over layer additive method, reverse engineering, solid free form fabrication, Rapid Manufacturing (RM), Additive Fabrication, Freeform Fabrication (FF), Additive Manufacturing, Direct Manufacturing, e-Manufacturing, Freeform Manufacturing (FFM), Digital Manufacturing, Digital Fabrication [4].

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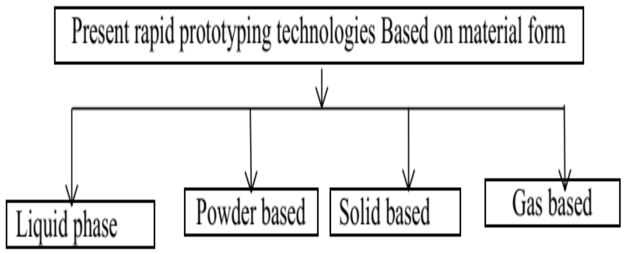
2. ADDITIVE MANUFACTURING

AM is an umbrella word given to all technologies that processes parts joining material in layers, as apposed removing material in conventional subtractive processes. The ASTM F42 Technical Committee defines AM as the "method of fuse materials to get articles from 3D model data, usually one sheet up on another sheet, as opposed to conventional manufacturing processes" [5]. Initially AM technologies used to produce models and prototypes leading to the widely accepted term, RP, which was for many years a term used to refer to all layer additive manufacturing processes [6, 7]. Currently advances in materials, processes and machine hardware meant that parts could be produced with sufficient mechanical properties to allow end user products which led to the term RM being adopted to differentiate the fully functional nature of the parts being manufactured from the previous RP models and prototypes. Now, AM is the general term used and RP and RM are used to describe the respective application of AM technologies. There are more technologies which employ this method of manufacturing products, some of them widely used based on materials such as solid, liquid, powder and gas based [8]. The present RP techniques available are as follows:



- Stereo lithography
- Laminated object manufacture
- Fused deposition modeling
- Solid ground curing
- Multi Jet Modelling
- Laser Engineered Net Shaping
- Selective Laser Sintering
- Three Dimensional Printing

3. RAPIDPROTOTYPINGTECHNIQUES

a. STEREO LITHOGRAPHY (SLA)

3D systems was founded in 1986, stereo lithography started the rapid prototyping revolution. This technique produces three-dimensional models of liquid-based polymers which solidify when exposed to ultraviolet radiation. As shown in the picture below, the model is built on a platform just below the container surface with a liquid epoxy or acrylic resin. The powerful, low-power UV laser follows the first layer and strengthens the cross section of the model while leaving excess fluid surfaces [9].

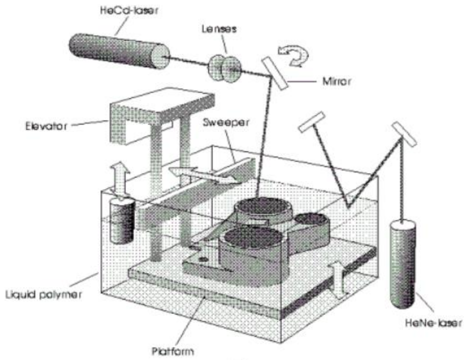


Fig 1: Schematic Diagram of SLA Process

Then the plate is poured into a capillary polymer. The wiper again coats the next layer of resin on the surface. The laser is a bit pulling another layer. This process continues building the work from the bottom up until the system completes the component. It is then possible to use and clean with excess polymer. Prototypes in early stereographic lithographs were relatively fragile and susceptible to corrosion-induced cylindrical pages and deformations, but recent adjustments largely corrected these problems.

b. LAMINATED OBJECT MANUFACTURE

This technique was developed by Helisys or Torrance. In this process, thin layers of adhesive-coated material are continuously joined to each other and individually cut by a CO2 laser beam to obtain a prototype. The actual material contains paper laminated with heat activated adhesive and rolled onto cylindrical rollers. As shown in FIG. 2 below. The charging and feeding mechanism of the roller moves it onto the building platform and then, after the heated roller exerts pressure to attach the paper to the base [10].

The computer generates exact calculations, which guides the laser beam to cut the cross sectional outline, the crosshatched and the model's perimeter. While making the build the excess material gives the better support the overhangs and thin- walled sections. After the first layer is cut the platform descends and new material is advances. Then the platform ascends to slightly below the previous height, the heated roller laminates second layer to the first one and laser cuts the second layer. This process repeated until build the part, which would have a wood like texture. The models made of paper; they must be sealed and finished with pointer or varnish to prevent moisture damage. Potentially any sheet material with adhesive baking can be used in LOM. Cubic technologies have developed plastics, metals and ceramic tapes. The main powers of LOM technologies are wide variety of materials, fast build time, and high precision. The deficiency of LOM is accurate power adjustment must be maintain, the fabrication thin walled parts should take adequate precautions. In the post processing phase the part has to be removing with woodcarving tools, it is time consuming process.

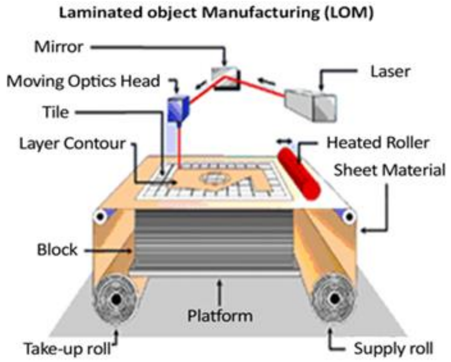


Fig 2: The Schematic Diagram of LOM

c. FUSED DEPOSITION MODELING (FDM)

The fundamental of the FDM is based on the surface chemistry, thermal energy and layer manufacturing technology. The material is in the form of a filament (cartridge or reel). The tip of filament is move in the x-y plane fed into an extrusion head and heated to a semi-fluid state and then set down in extremely thin layers from the FDM head, one layer each time. Due to the air around the head is maintained at a temperature lower than the melting point of the material, the exiting thermoplastic gently hardened. After the platform lowers, the extrusion head set down a second layer upon the first. The model is build layer by layer till the product produced. Stratus's, of Eden Prairie, MN makes a different types of FDM machines vary from rapid concept modelers to low speed, high-precision machines. Materials used in FDM system include ABS (standard and medical grade), elastomeric polycarbonate, polyphenol sulfone, and investment casting wax. The schematic diagram of FDM is shown below in fig 3[11]. The soundness of the FDM is fabrication of functional parts, minimum wastage; support removal is simple, easy of material change, large scale build volume. Drawbacks are inadequate accuracy, slow process, and unpredictable shrinkage. The models of FDM can be used in the common areas such as (a) models for conceptualization and presentation, (b) Prototypes for design, analysis, and functional testing, (c) patterns and masters for tooling, FIG (3) the schematic diagram of FDM shown below. [12].

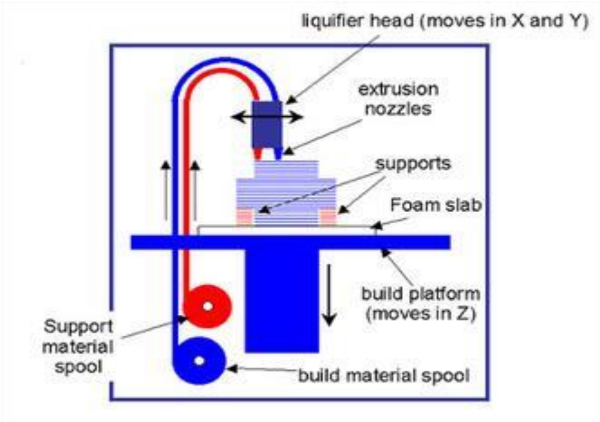


Fig 3: The Schematic Diagram of FDM

d. SOLID GROUND CURING

This technology started by Cubical, solid ground curing (SGC) is resembles to stereo lithography (SLA) in that both use ultraviolet light to selectively solidify photosensitive polymers. Dissimilar to SLA, SGC cures an entire layer at a time. Figure 4 shows solid ground curing, it is also known as the solider process. Initially, photosensitive resin is sprinkle on the build platform. After, the machine develops a photo mask (like a pattern) of the layer to be built. This photo mask is printed on a glass plate over the build platform using an electrostatic process alike to that of in photocopiers. Then the mask exposed to UV light, which only passes through the transparent portions of the mask to selectively set down the shape of the present layer. Solidify the shape of the present layer. Next the layer is hardened; the machine cleans up the surplus liquid resin and sprinkles wax in its place to support the model during the build. The top surface is pulverized flat, and then the process repeats to build the next layer. After the part is completed, it must be dewaxed by dipping into a solvent bath. FIG (4) the schematic diagram of SGC shown below. [13].

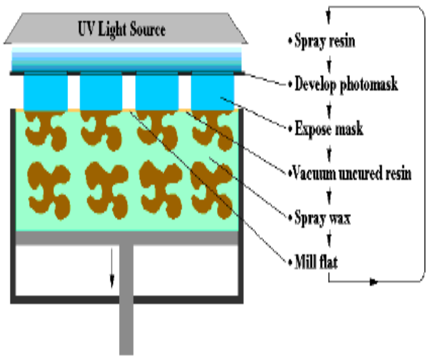


Fig 4: Schematic Diagram of Solid Ground Curing

e. MULTI JET MODELING (MJM)

A print head consists of 96 very small nozzles (or jets) in a linear order passes into the X-y plane on a platform. A jet distributes a droplet of a thermos-plastic polymer where the material is set down. Any number of the 96 jets can be actuated at a time giving a rapid supply rate of when all jets are actuated. The hot droplets of material joined to the earlier slice of the part that has just been printed. Thin support columns should be able to build up layer by layer in the same material where they are required.[14] When the present layer of the part (plus layer of the support column) is completed, the plat form is descends relative to the print head and the next layer is printed. When all the layers have been completed, the part has taken out from the machine and the support structure is broken off. FIG (5) the schematic diagram of MJM SYSTEM shown below.

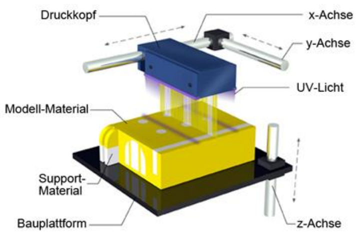


Fig 5: Schematic Diagram of Multi jet modeling system

f. LASER ENGINEERED NET SHAPING (LENS)

The laser engineered net shaping (LENS) method is advanced by Sandia National Laboratories. Optomec delivered its first commercial system to Ohio State University. In this method metal parts manufactured directly from the Computer Aided Design (CAD) solid models using a metal powder spread over a liquid puddle created by an intense, laser beam. At the same time, the sheet on which the deposition is running is scanned under the beam/powder interaction zone to manufacture the desired cross-sectional part. Consecutive layers are one by one deposited, thereby producing a 3D metal component. Soundness of this process is capable of producing fully dense metal products; metal parts of complex geometry can be produced, drawbacks are limited materials, high power consumption. Fig (6) the schematic diagram of LENS shown below. [15]

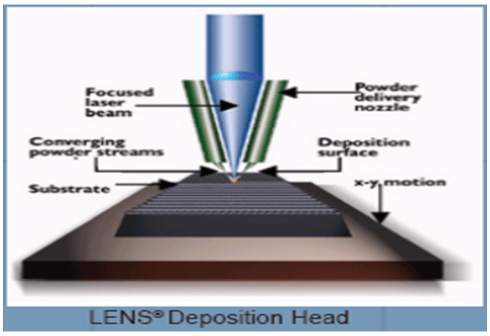


Fig 6: The Schematic Diagram of LENS.

g. SELECTIVE LASER SINTERING (SLS)

This technology, developed by Carl Deckard for his master's degree at the University of Texas, became selective laser sintering patented in 1989. By this method a thin layer of thermoplastic powder is spread of a sweeper on the surface of the cylinder and just under heating of melting point at a CO2 laser at the sintering station. CAD data files in the STL file format are transferred to the sintering station systems where they are cut. Then a laser beam finds out the area of one layer of the part. When the laser beam is pointed on the powder the affected particles sintered combined. The first melted layer goes below one object layer, the roller spreads out the next layer of the powder, and this process continued until the product complete. The powder not melted during the process or fused acts as built-in support structure. Thus the supports are not required separately, and when part is complete the non-fused powder material can completely remove off. Fig (7) the schematic diagram of SLS shown below. Advantages of SLS technology are good part stability, no need to part supports. Drawbacks are high power consumption, poor surface finish.[16]

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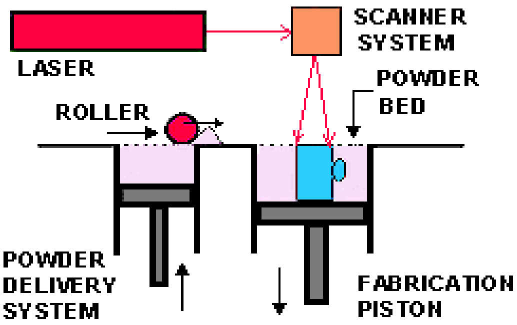

Fig 7: The Schematic Diagram of SLS

h. THREE DIMENSIONAL PRINTING

The 3-DP technology has invented and patented by Massachusetts Institute of technology (MIT), USA. In this process, the principle of inkjet technology is used to build parts in layers. Each layer began with the spread of a powder over the bed of surface. The object is formed by the binder material selectively joins the powder particles using the ink-jet technology. Then after the bed is lowered a fixed length, with a roller mechanism Powder is then deposited and distributed evenly across the bed and second layer is built. This process is continued until the prototype is complete. The unprocessed powder is brushed out. FIG (8) the schematic diagram of 3-DP shown below. [17]

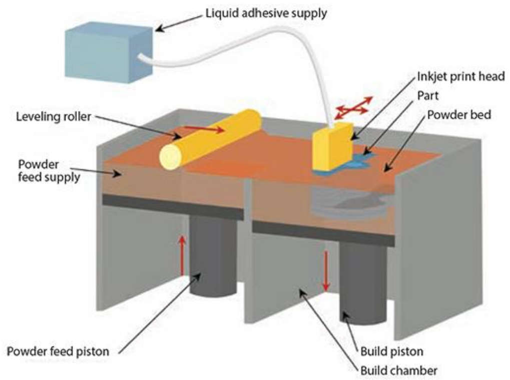

Fig 8: The Schematic Diagram of 3-DP.

4. PROTOTYPE OF HOOKE'S JOINT

A universal joint, U joint, Cardan joint, Hardy-Spicer joint, or Hooke's joint is a joint in a rigid rod that allows the rod to 'bend' in any direction, and is commonly used in shafts that transmit rotary motion. It consists of a pair of hinges located close together, oriented at 90° to each other, connected by a cross shaft [18].

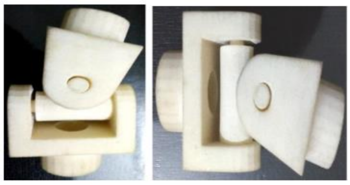

Fig 9: Hooke's Joint by using the EOS RP-Tools

5. PROCEDURE OF DATA PREPARATION

Good data preparation is a prerequisite for the correct function of the building process. Poor data or data errors can cause a job to crash or result in poor parts quality. The following schematic diagram shows the basic sequence for data preparation.

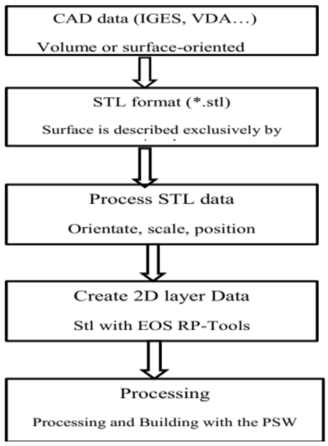

Fig 10: Sequence for Data preparation.

6. PREPARATION OF THE PART

The part designed must first be aligned and positioned in an R P software package, e.g. Magics RP. There are some special aspects that must be taken into account for the laser sintering process. In the initial stage of the data preparation process the component that is to be prototyped is imported into the Magics RP software which is then suitable for converting into STL format with suitable modifications on it. Fig 5.7 shows the component imported and converted into STL. After this, the part data is transformed into layer data using the EOS RP-Tools.

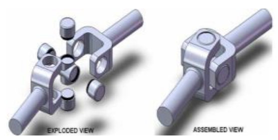

Fig11: Product design for conventional processes

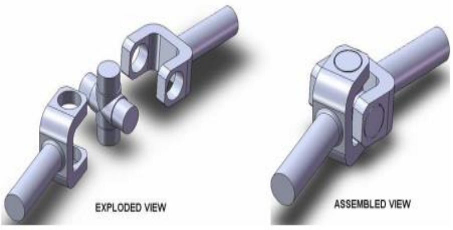

Fig 12: Product design for additive manufacturing process

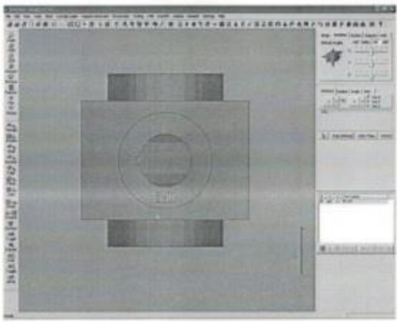

Fig 14: Generation of Label in Magics RP

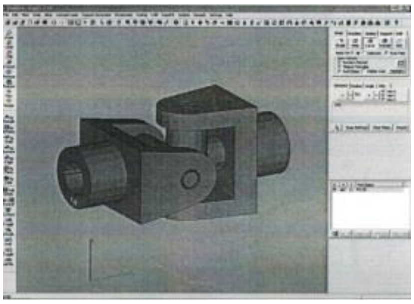

Fig. 13: STL file loaded at an orientation of 0^0 in Magics RP

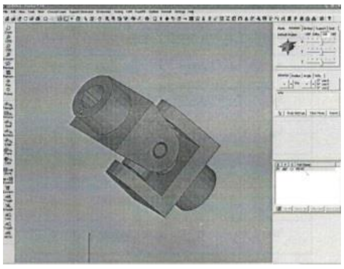

Fig 15: STL file loaded at an orientation of 45^0 in Magics RP

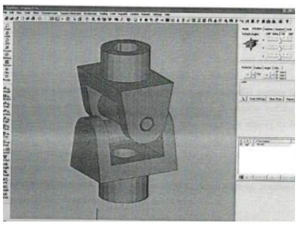

Fig 16: STL file loaded at an orientation of 90^0 in Magics RP

The component is suitably labeled as shown which makes the ease of prototype recognition while the components are made into experimental investigations. Figures 13, 14, 15, 16, show the corresponding orientation of 0^0, 45^0 and 90^0 with respect to the work bed that is XY axis of coordinate system.19]

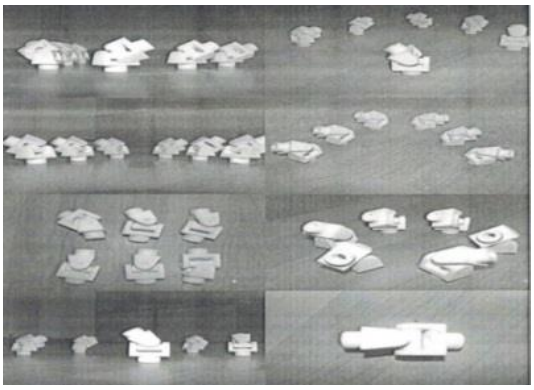

Fig 17: Prototypes of universal Coupling produced using FORMIGA P100, with the material PA2200.

7. EFFECT OF LASER SPEED ON BUILDING TIME

In Selective Laser sintering, the speed of the laser during sintering is critical as it can affect the density and strength of the prototype. The optimization of the sintering process parameters showed that the speed and the sintering strategy have the biggest impact onto the quality of the sintered prototypes, besides the laser power and the hatch distance. Slower scan speed leads to a higher particle density by a lower roughness. A 90^0 rotation of the scan direction at every other layer leads to an increase in strength and a decrease in porosity compared to the alternate scanning (no rotation). The minimum porosity can be achieved. A sliced layered interface file is considered for which building time is calculated using Desktop PSW varying the laser speed. The fig. shows that the maximum building time is for less laser speed and for higher laser speeds, the building time as expected is less. However considering the factor of optimum building time and also the maintaining the density and other mechanical properties of the prototype, an optimum laser speed of 1500mm/sec can be suggested which is supported by previous research studies on laser sintering of metals [18, 19].

Table 1: Effect of Laser speed on building time

S.No	Laser speed (mm/sec)	Building Time
1	50	3.46
2	100	3.30
3	150	3.26
4	200	3.22
5	250	3.21
6	300	3.19
7	350	3.19
8	400	3.19
9	450	3.19
10	500	3.19
11	1000	3.19
12	1500	3.19

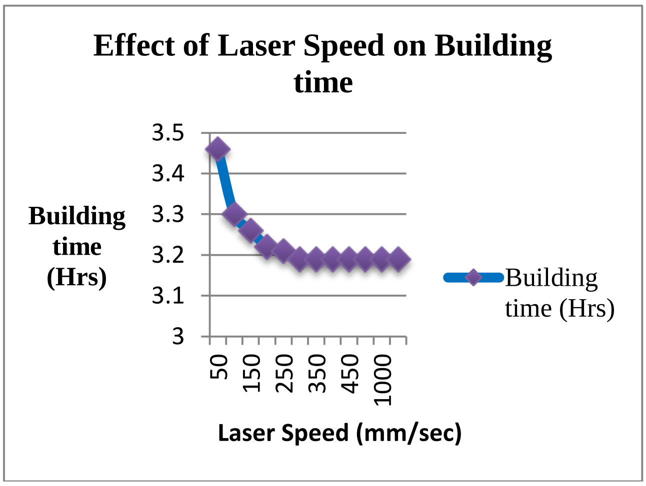

Fig18: Effect of Laser speed on building time

8. CONCLUSIONS

It is proposed that a 90^0 rotation of the scanning direction at each second layer leads to an increase in the strength and a decrease in porosity compared to the alternative scan (no rotation). The slightest porosity can be achieved. The maximum construction time is for less laser speed and higher laser speeds, since the construction time is as expected. However, taking into account the factor for optimal construction time and maintaining the density and other mechanical properties of the prototype, an optimal laser speed of 1500 mm / sec can be proposed.

REFERENCES

1. ASTM Committee F42 on Additive Manufacturing Technologies. http://www.astm.org/COMMITTEE/F42.htm
2. "The status, challenges, and future of additive manufacturing in Engineering" , Wei Gao a,, Yunbo Zhang a, Devarajan Ramanujan a, Karthik Ramani a,b, Yong Chen c, Christopher B. Williams d, Charlie C.L. Wang e, Yung C. Shin a, Song Zhang a, Pablo D. Zavattieri, Computer-Aided Design journal homepage: www.elsevier.com/locate/cad
3. Thompson MK, et al. Design for Additive Manufacturing: Trends, opportunities, considerations, and constraints. CIRP Annals - Manufacturing Technology (2016), http://dx.doi.org/10.1016/j.cirp.2016.05.004
4. Global Journal of Computer Science and Technology Graphics & Vision Volume 13 Issue 4 Version 1.0 Year 2013, Review of Rapid Prototyping-Technology for the Future By Prof. D.V. Mahindru & Prof. Priyanka Mahendru SRMGPC, Tewari Ganj, Lucknow
5. 'The Center for Responsible Nanotechnology: "Beyond RP/RM — Molecular Manufacturing" in issue 14.4 of The TCT Magazine.
6. Nannan GUO, Ming C. LEU, "Additive manufacturing: technology, applications and research needs" Front. Mech. Eng. 2013, 8(3): 215–243 DOI 10.1007/s11465-013-0248-8
7. .Review of Rapid Prototyping-Technology for the Future By Prof. D.V. Mahindru & Prof. Priyanka Mahendru Global Journal of Computer Science and Technology Graphics & Vision Volume 13 Issue 4 Version 1.0 Year 2013.
8. Nannan GUO, Ming C. LEU, Additive manufacturing: technology, applications and research needs, Front. Mech. Eng. 2013, 8(3): 215–243, DOI 10.1007/s11465-013-0248-8.
9. Yong Huang, Ming C. Leu. Frontiers of Additive Manufacturing Research and Education Report of NSF Additive Manufacturing Workshop July 11 and 12, 2013
10. International Scholarly Research Network ISRN Mechanical Engineering Volume 2012, Article ID 208760, 10 page, doi:10.5402/2012/208760, "A Review of Additive Manufacturing" Kaufui V. Wong and Aldo Hernandez.
11. Berman, B., 2012. 3-D printing: The new industrial revolution. Business Horizons, 55(2), pp.155–162. Available at:http://dx.doi.org/10.1016/j.bushor.2011.11.003.
12. Bellini, A. & Güçeri, S., 2003. Mechanical characterization of parts fabricated using fused deposition modeling. Rapid, Prototyping Journal, 9(4), pp.252–264.

13. Răzvan UDROIU, “Applications of additive manufacturing technologies for aerodynamic tests”, Academic Journal Of Manufacturing Engineering, VOL. 8, ISSUE 3/2010
14. Xue Yan and P Gu, Review of rapid prototyping technologies and systems: Comtwier-AidedLksian. Vol. 26, No. 4, PP. 307-316. 1996
15. Anoop Kumar Sood,” Study on Parametric Optimization Of Fused Deposition Modelling (FDM) Process”, NATIONAL INSTITUTE OF Technology, ROURKELA - 769008, INDIA May – 2011.
16. Kaufui V. Wong and Aldo Hernandez, A Review of Additive Manufacturing, ISRN Mechanical Engineering ,Volume 2012, Article ID 208760, 10 pages doi:10.5402/2012/208760
17. Zarringhalam H, Majewski C, Hopkinson N. Degree of particle, melt in Nylon-12 selective laser-sintered parts. Rapid Prototyping, Journal, 2009, 15(2): 126–132
18. Agnes Bagsik, Volker Schöppner, Kunststofftechnik Paderborn, Mechanical Properties of Fused Deposition Modeling Parts Manufactured With Ultem*9085 “ANTEC 2011, Boston,DMRC.
19. Jagan R Rajan, Kristin L Wood, Experimental Study of Selective Laser Sintering of Parmax®,