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Effect of Layer Height and Printing Speed on Print Time Estimation and Cost Analysis

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ABSTRACT: The 3D printing process is a kind of additive manufacturing, that the basic principle of this process is adding material layer by layer to form a product. The purpose of this research was to study the effect of layer thickness and printed speed on CNC cutting tool for making casting replica. In this we are varying the layer thickness and printing speed on material consumption and printing speed. In this study by varying the layer thickness and printing speed time also varying. As the layer height increasing printing time decreasing similarly, as the printing speed increasing printing time decreasing. But by increasing the layer height dimensional accuracy of the final printed part is decreasing. Similarly, as the printing speed increases the bond between the layers is decreases. In same way by increasing the layer height and printing speed surface roughness increasing.

Key words: Printing speed, print time, CNC, layer height, surface roughness

I. INTRODUCTION

3D printing or additive manufacturing (AM) is any of various processes for making a three-dimensional object of almost any shape from a 3D model or other electronic data source primarily through additive processes in which successive layers of material are laid down under computer control. A 3D printer is a type of industrial robot. Early AM equipment and materials were developed in the 1980s. In 1984, Chuck Hull of 3D Systems Corp, invented a process known as stereo lithography employing UV lasers to cure photopolymers. Hull also developed the STL file format widely accepted by 3D printing software, as well as the digital slicing and infill strategies common to many processes today. Also, during the 1980s, the metal sintering forms of AM were being developed (such as selective laser sintering and direct metal laser sintering), although they were not yet called 3D printing or AM at the time. In 1990, the plastic extrusion technology most widely associated with the term “3D printing” was commercialized by Stratasys under the name fused deposition modelling (FDM). In 1995, Z Corporation commercialized an MIT-developed additive process under the trademark 3D printing (3DP), referring at that time to a proprietary process inkjet deposition of liquid binder on powder. AM technologies found applications starting in the 1980s in product development, data visualization, rapid prototyping, and specialized manufacturing. Their expansion into production (job production, mass production, and distributed manufacturing) has been under development in the decades since. Industrial production roles within the metalworking industries achieved significant scale for the first time in the early 2010s. Since the start of the 21st century there has been a large growth in the sales of AM machines, and their price has dropped substantially. According to Wohlers Associates, a consultancy, the market for 3D printers and services was worth $2.2 billion worldwide in 2012, up 29% from 2011. Applications are many, including architecture, construction (AEC), industrial design, automotive, aerospace, military, engineering, dental and medical industries, biotech (human tissue replacement), fashion, footwear, jewellery, eyewear, education, geographic information systems, food, and many other fields.

1.1 3D PRINTER

3D-Printer is a machine reminiscent of the Star Trek Replicator, something magical that can create objects out of thin air. It can “print” in plastic, metal, nylon, and over a hundred other materials. It can be used for making nonsensical little models like the over-printed Yoda, yet it can also print manufacturing prototypes, end user products, quasi-legal guns, aircraft engine parts and even human organs using a person’s own cells. We live in an age that is witness to what many are calling the Third Industrial Revolution. 3D printing, more professionally called additive manufacturing, moves us away from the Henry Ford era mass production line, and will bring us to a new reality of customizable, one-off production. 3D printers use a variety of very different types of additive manufacturing technologies, but they all share one core thing in common: they create a three-dimensional object by building it layer by successive layer, until the entire object is complete. It’s much like printing in two

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dimensions on a sheet of paper, but with an added third dimension: UP. The Z-axis. Each of these printed layers is a thinly-sliced, horizontal cross-section of the eventual object. Imagine a multi-layer cake, with the baker laying down each layer one at a time until the entire cake is formed. 3D printing is somewhat similar, but just a bit more precise than 3D baking. In the 2D world, a sheet of printed paper output from a printer was “designed” on the computer in a program such as Microsoft Word. The file - the Word document which contains the instructions that tell the printer what to do. In the 3D world, a 3D printer also needs to have instructions for what to print. It needs a file as well. The file, a Computer Aided Design (CAD) file is created with the use of a 3D modelling program, either from scratch or beginning with a 3D model created by a 3D scanner. Either way, the program creates a file that is sent to the 3D printer. Along the way, software slices the design into hundreds, or more likely thousands, of horizontal layers. These layers will be printed one atop the other until the 3D object is done. 3D Printing technology could revolutionize the world. Advances in 3D printing technology can significantly change and improve the way we manufacture products and produce goods worldwide. An object is scanned or designed with Computer Aided Design software, then sliced up into thin layers, which can then be printed out to form a solid three-dimensional product. 3D printing can have an application in almost all of the categories of human needs as described by Maslow. While it may not fill an empty unloved heart, it will provide companies and individuals fast and easy manufacturing in any size or scale limited only by their imagination. 3D printing, on the other hand, can enable fast, reliable, and repeatable means of producing tailor-made products which can still be made inexpensively due to automation of processes and distribution of manufacturing needs.

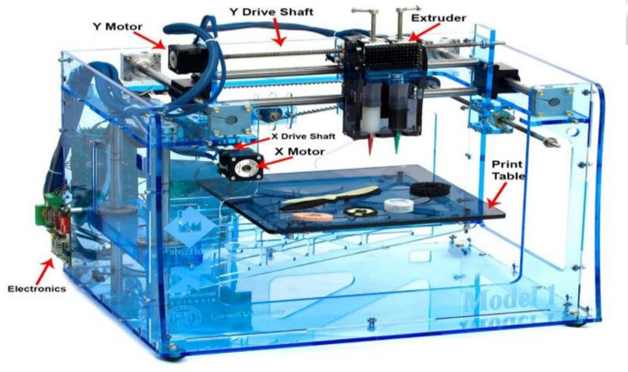

Fig 1.1: Construction of 3d printer

The picture shows the structure of a typical 3D printer. The print table is the platform where the objects for printing has been situated. It provides the basic support for manufacturing objects layer by layer. The extruder is the most important part of a 3D-Printer. As the extruders in the normal paper printers, this extruder is also used to pour ink for printing. The movement of extruder in various dimensions create the 3D print. For printing a 3d object, the extruder has to access X, Y and Z coordinates. For achieving this, many techniques are used according to the printer specification required for various applications. If the 3D-Printer is a desktop printer, the Z axis movement of the extruder can be avoided and that function can be transferred to the print table. This will avoid complexity in 3D printing as well as time consumption. When the STL file is input to the printer, the microcontroller extracts each layer from it and also extracts each line segment from each layer. Then it gives controls to the movement of the extruder at required rate. The X-direction movement of extruder is made possible by the X-motor. When the X motor rotates, the shaft also rotates and the extruder moves in X direction. The Y-direction movement of extruder is made possible by the Y-motor. When the Y motor rotates, the shaft also rotates and the extruder moves in Y direction. The X direction movement is made by the print table. In the case of desktop printers, the printing ink is usually plastic wire that has been melted by the extruder at the time of printing. While printing, the plastic wire will melt and when it falls down to the printing table. Consider printing larger objects like house using 3D printer. There will not be any X motor or Y motor in that case. An extruder which can pour concrete mix is fixed on the tip of a crane. The crane is programmed for the movement of extruder in X, Y and Z axis. The concept and structure of 3d printer changes according to the type, size, accuracy and material of the object that has to be printed. Generalizing the facts, the extruder needs to access all the 3 coordinates in space to print and object. The method used for that doesn’t matters much.

1.1.1 BENEFIT OF USING 3D PRINTING AS A MANUFACTURING TECHNIQUE OVER HAND TOOLS AND HAND DRIVEN MACHINERY

With less time needed to manufacture parts and less stringent design restrictions, 3D printing allows designers to rapidly design and improve their prototypes. Traditional methods can require a significant time investment before you can get a physical prototype in hand. Traditional manufacturing processes require complex tooling. 3D printing eliminates the need to build molds and other tooling before production. The flexibility of 3D printing processes allows multiple SKUs to be produced on a single 3D printing manufacturing line. The main perk of 3D printing is primarily the speed at the rate of which the parts are generally produced in comparison to the traditional manufacturing approaches. The CAD model allows intricate designs to be uploaded and printed in a handful of hours

1.1.2 PROS OF 3D PRINTING

1. Flexible Design
2. Print on Demand
3. Strong and Lightweight Parts

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4. Fast Design and Production
5. Minimizing Waste
6. Cost Effective
7. Ease of Access
8. Advanced Healthcare

1.1.3 CONS OF 3D PRINTING

1. Limited Materials
2. Restricted Build Size
3. Post Processing
4. Large Volumes

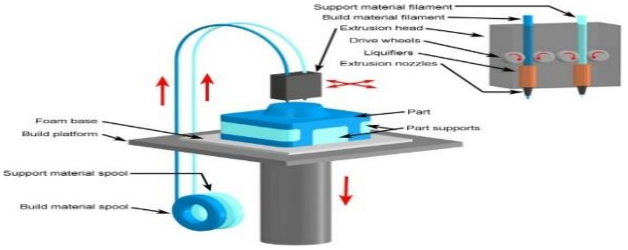

Fig 1.2: Basic Method of FDM Technology

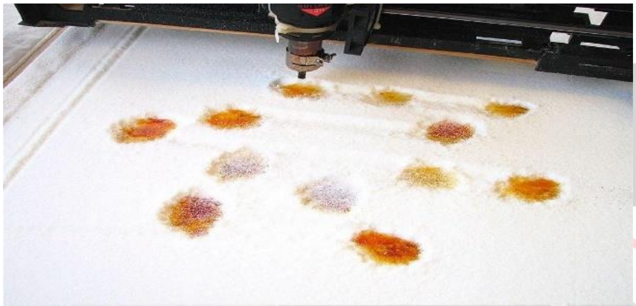

Fig 1.3: Granular material binding

Fig 1.4: Illustration of granular material

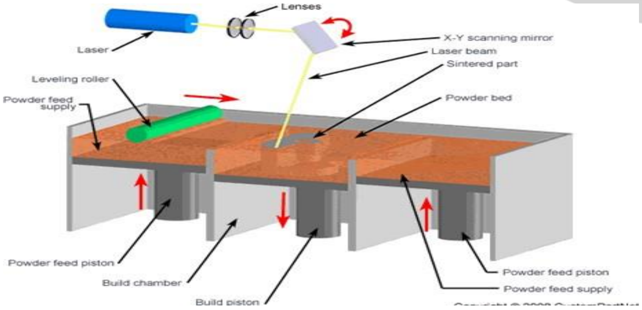

Fig 1.5: Selective Laser Sintering Citation Process

Fig 1.6: Illustration of a Blue Printer Citation

Fig 1.7: A model created by Blue Print Citation

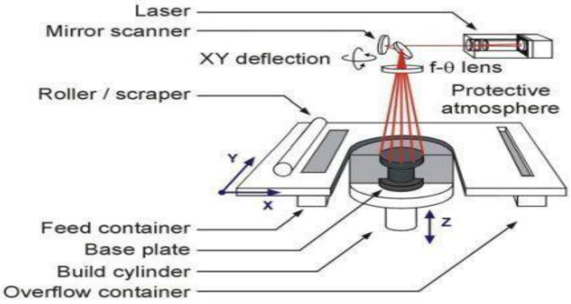

Fig 1.8: Illustration of selective laser melting method

Fig 1.9: Selective laser melting in action

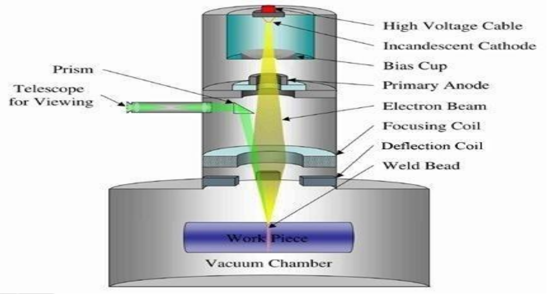

Fig 1.10: Illustration of an EBM process citat

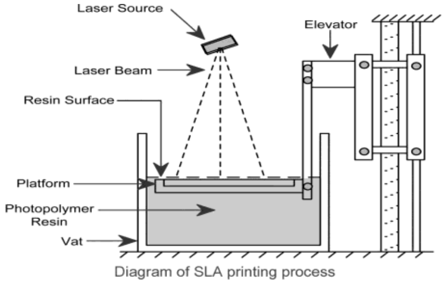

Fig 1.11: Illustration of Stereo Lithography process

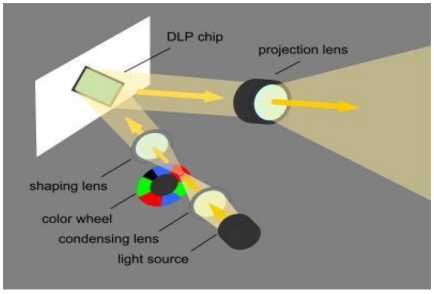

Fig 1.12: Illustration of DLP Projection

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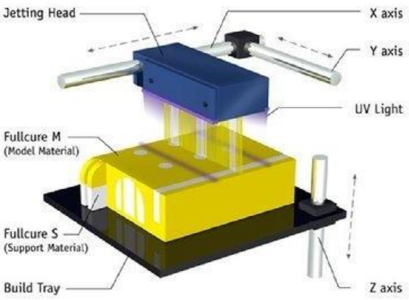

Fig 1.13: Illustration of material jetting process citation

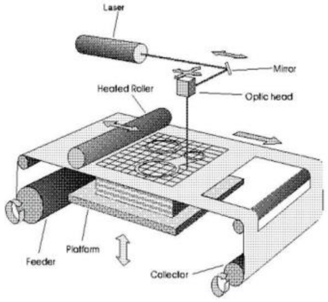

Fig 1.14: Depiction of Laminated Object Manufacturing process

fig.10

Fig 1.16: Rapid Prototyping

II. MASS CUSTOMIZATION

Mass customization, in marketing, manufacturing, call centers and management, is the use of flexible computer-aided manufacturing systems to produce custom output. Those systems combine the low unit costs of mass production processes with the flexibility of individual customization.

Fig.11

Mass customization is the new frontier in business competition for both manufacturing and service industries. At its core is a tremendous increase in variety and customization without a corresponding increase in costs. At its limit, it is the mass production of individually customized goods and services. At its best, it provides strategic advantage and economic value. Mass customization is the method of "effectively postponing the task of differentiating a product for a specific customer until the latest possible point in the supply network." (Chase, Jacobs & Aquilano 2006, p. 419). Kamis, Koufaris and Stern (2008) conducted experiments to test the impacts of mass customization when postponed to the stage of retail, online shopping. They found that users perceive greater usefulness and enjoyment with a mass customization interface vs. a more typical shopping interface, particularly in a task of moderate complexity. From collaborative engineering perspective, mass customization can be viewed as collaborative efforts between customers and manufacturers, who have different sets of priorities and need to jointly search for solutions that best match customers' individual specific needs with manufacturers' customization capabilities (Chen, Wang & Tseng (2009)). With the arrival of 3D printer, we are able to customize any products we want. Consider you are in a shop to buy a spectacle. The only choice you have is to select a model from the shop. If you didn't like any model, you will probably go to another shop. By the implementation of 3d printed spectacles, you are provided with power for creating any spectacle in the world with just the CAD model. Many implementations of mass customization are operational today, such as software-based product configurators that make it possible to add and/or change functionalities of a core product or to build fully custom enclosures from scratch.

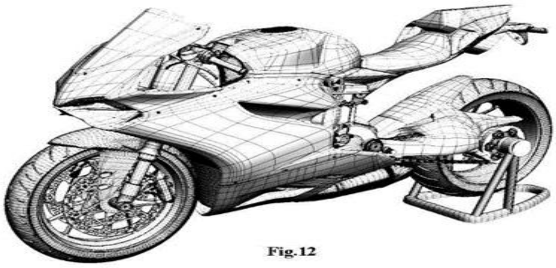

Fig.12

Fig 1.17 3D CAD model of a bike

FDM is a complex process with a large number of parameters that influence product quality and material properties, and the combination of these parameters is often difficult to understand [5], [13]. Printing parameters such as build orientation, layer thickness, raster angle, raster width, air gap, infill density and pattern, and feed rate, among others, have a substantial effect on the quality and performance of FDM printed parts [1], [14], [4], [5], [15], [16], [17], [18], [19], [20]. Since mechanical properties are crucial for functional parts, it is absolutely essential to examine the influence of process parameters on mechanical performance [21], [17], [22], [23], [24]. Thus, further research is required to determine printer parameters such as build orientation, layer thickness and feed rate, particularly since the literature on the mechanical properties of parts processed by low-cost 3D printers is somewhat scarce. This applies to the PLA material used in this study that, unlike ABS material, has not been extensively analyzed [18], [1], [25]. Furthermore, the analysis of the effects of FDM process parameters on mechanical performance are of special interest for the fabrication of continuous reinforced fiber 3D printed structures [2], [3], [16], [11], [26], [27]. To date, a number of studies have highlighted the impact of build orientation on aspects such as surface quality, geometric accuracy, build time and overall manufacturing cost [20]. In addition, build orientation has a major role on the structural properties of FDM parts. Build orientation refers to how and which direction a sample is placed on the 3D printing platform. This is often observed in the form of anisotropically printed objects, making structural performance highly dependent on build orientation in a similar way to composites laminates [28], [29], [30]. The effects of build orientation on mechanical performance of FDM parts have been previously studied [24], [15], [1], [4], [5], [31], [32], [33], [6]. These authors agree that the strongest printing orientation is obtained when the fused filament deposition coincided with the pull direction. However, a range of orientations may be found along this pull direction, which have not been analysed in other studies. A more controversial parameter is layer thickness (Lt). Rankouhi et al. [6] stated that although layer thickness has been studied extensively, it should be further analysed due to the disparity of results. For examples, Sood et al. [15] concluded that tensile strength first decreased and then increased as layer thickness increased for Lt = {0.127, 0.178, 0.254} mm. Tymrak et al. [1] stated that the lowest thickness had the highest tensile strength for Lt = {0.2, 0.4} mm. However, the authors concluded that PLA specimens showed greater variability between parameters. Lanzotti et al. [18] inferred that as the number of shell perimeters increased, the variation of tensile strength with the layer thickness was slightly significant in PLA samples. Ahn et at. [32] deduced a low level of significance of the effect of layer thickness on the final material properties of ABS samples. Finally, Vaezi and Chua [17] reported that for flat oriented samples, a decrease from Lt = 0.1 mm to Lt = 0.087 mm increased the tensile strength and decreased flexural strength. Furthermore, the effect of feed rate on the mechanical performance of PLA samples has not been extensively studied [13]. For example, the results of Ning et al. [16] and Christiyana et al. [34] have shown that tensile and flexural strength decreased as the feed rate increased. This process variable is also directly related to build time, and consequently, to manufacturing.

III. DESIGNING USNG CAD

Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. CAD software for mechanical design uses either vector-based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions. CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space. CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals, often called DCC digital content creation. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry. The design of geometric models for object shapes, in particular, is occasionally called computer-aided geometric design (CAGD). Unexpected capabilities of these associative relationships have led to a new form of prototyping called digital prototyping. In contrast to physical prototypes, which entail manufacturing time in the design. That said, CAD models can be generated by a computer after the physical prototype has been scanned using an industrial CT scanning machine. Depending on the nature of the business, digital or physical prototypes can be initially chosen according to specific needs.

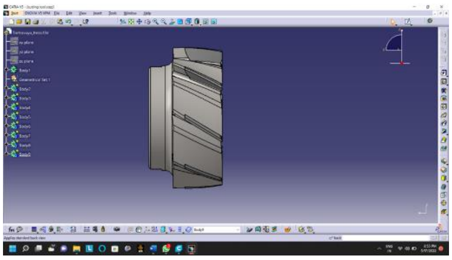

Fig 3.1: front view of milling cutter

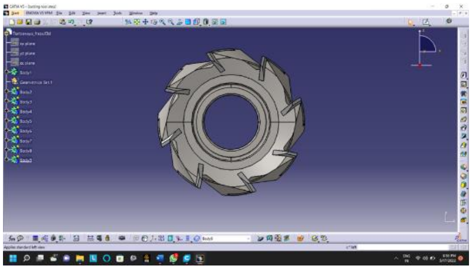

Fig 3.2: front view of milling cutter

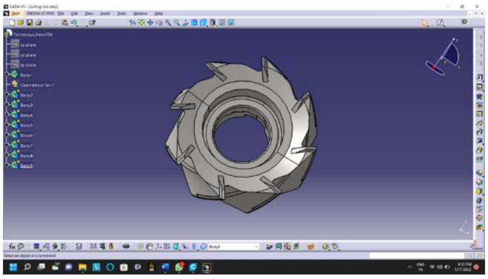

Fig 3.3: isometric view of milling cutter

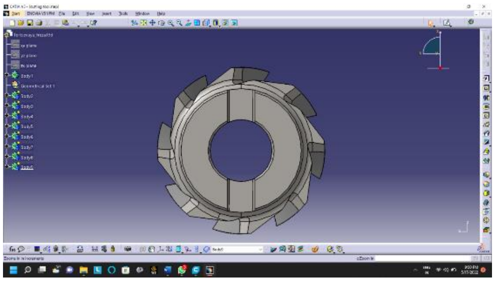

Fig 3.4 side view of milling cutter

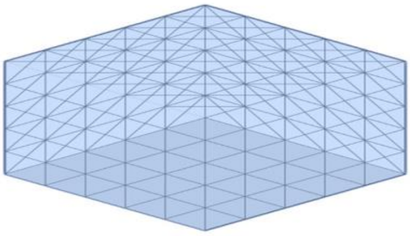

Fig 3.5: Typical STL View

SLICING FEATURES

At the heart of Ultimaker Cura is its powerful, open-source slicing engine, built through years of expert in-house development and user contributions.

- Intent profiles print specific applications at the click of a button
- Recommended profiles tested for thousands of hours ensure reliable results
- ‘Custom mode’ gives over 400 settings for granular control
- Regular updates constantly improve features and printing experience

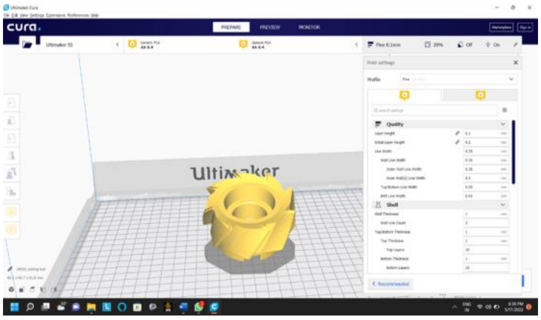

Fig 3.7: loading cutting tool

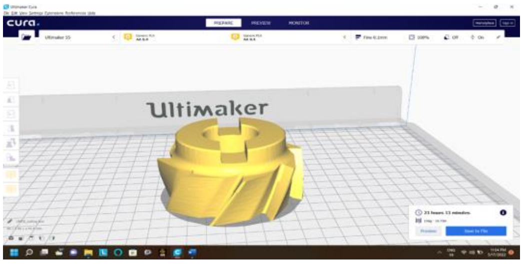

Fig 3.10: layer height 0.1mm layer view with 40mm/s speed

IV. RESULTS AND DISCUSSIONS

4.1 Results

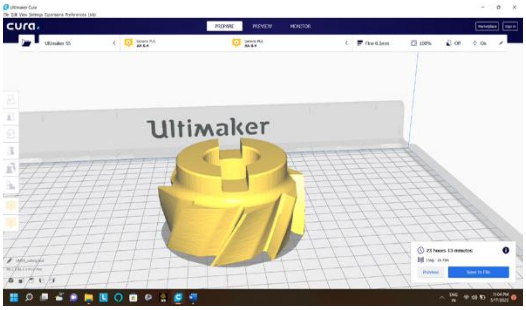

Fig 4.1: printing time and material consumption when layer height (LH) 0.1mm

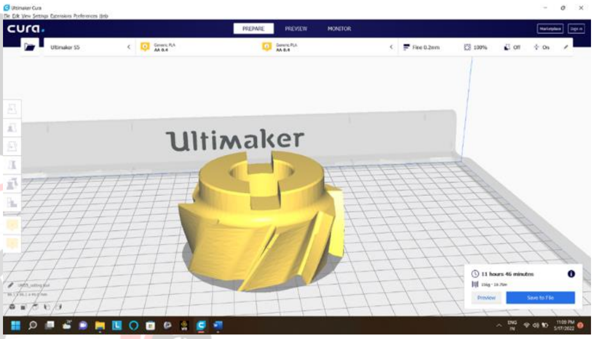

Fig 4.2: printing time and material consumption when layer height (LH) 0.2mm

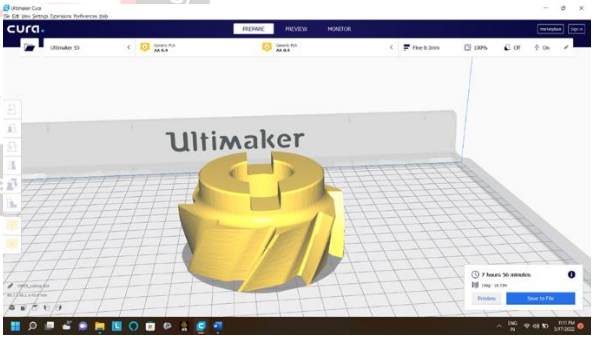

Fig 4.3: printing time and material consumption when layer height (LH) 0.3mm

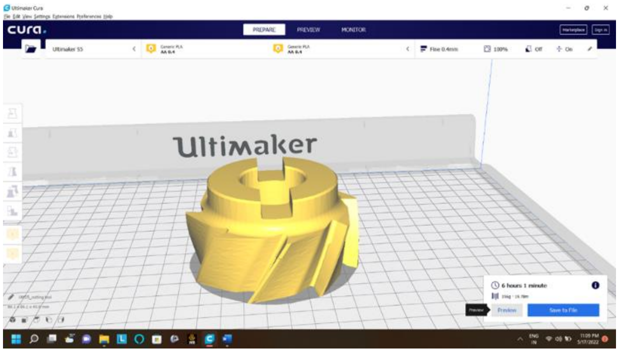

Fig 4.4: printing time and material consumption when layer height (LH) 0.4mm

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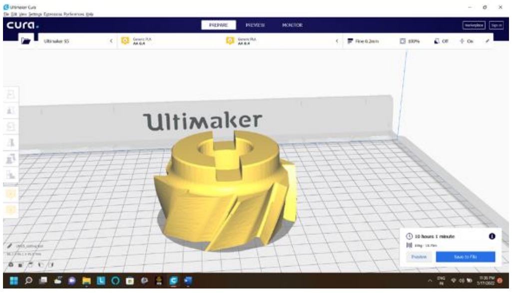

Fig 4.5: printing time and material consumption when layer height (LH) 0.2mm and printing speed 50mm/s

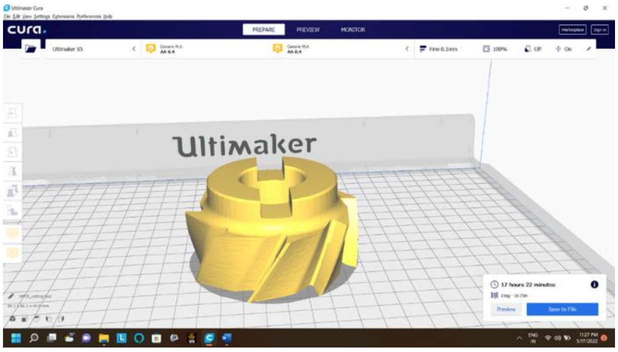

Fig 4.6: printing time and material consumption when layer height (LH) 0.1mm printing speed 60mm/s

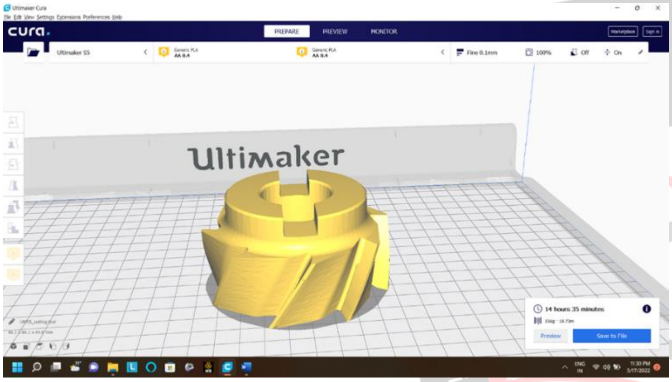

Fig 4.7: printing time and material consumption when layer height (LH) 0.1mm printing speed 80mm/s

4.2 Cost Estimation:

Cost of CNC milling tool is less when compare to other manufacturing process or when compare to other 3d printing process i.e. metal 3d printing, resin based printing process and ceramic based printing.

Total material consumption for CNC milling tool manufacturing is 156 grams

Total time for manufacturing the CNC milling tool is 23 hours 33 minutes

Based on per hour charge with PLA material is Rs 100/-

Per gram material consumption is Rs 6/-

The total cost is for printing the CNC milling tool is Rs 3,269 /-

V. CONCLUSION

From the above results we can conclude that ,As the layer height (LH) increase printing time is decreasing .As the printing speed is increasing printing time is decreasing .Printing time is inversely proportional to LH and print speed .By increasing the layer height surface roughness of the component increases and strength also increases .By increasing the printing speed the bond between the layers detoriates because there is no sufficient cooling time for previous layer .By increasing the layer height the dimensional accuracy of the component decreases .

VI. REFERENCES

[1] Alexander, P., Allen, S., Dutta, D., 1998. Part orientation and build cost determination in layered manufacturing. Comput. Des. 30, 343e356.

[2] Barrett, T.W., Pizzico, M.C., Levy, B., Nagel, R.L., 2015. A review of university maker spaces. In: 122nd ASEE Annual Conference and Exposition. Seattle, WA.

[3] Baumers, M., Tuck, C., Wildman, R., Ashcroft, I., Hague, R., 2011. Energy inputs to additive manufacturing: does capacity utilization matter? In: Solid Freeform Fabrication Symposium, pp. 30e40. Austin, TX.

[4] Baumers, M., Tuck, C., Wildman, R., Ashcroft, I., Rosamond, E., Hague, R., 2013. Transparency Built-in: energy consumption and cost estimation for additive manufacturing Baumers et al. Energy and cost estimation for additive manufacturing. J. Ind. Ecol. 17, 418e431.

[5] Bourell, D.L., Leu, M.C., Rosen, D.W., 2009. Roadmap for Additive Manufacturing: Identifying the Future of Freeform Processing. Austin, TX.

[6] Cheng, W., Fuh, J.Y.H., Nee, A.Y.C., Wong, Y.S., Loh, H.T., Miyazawa, T., 1995. Optimization of part-building orientation in stereolithography. Rapid Prototype. J. 1, 12e23.

[7] Das, P., Chandran, R., Samant, R., Anand, S., 2015. Optimum part build orientation in additive manufacturing for minimizing part errors and support structures. Procedia Manuf. 1, 343e354.

[8] CES Edupack. Granta Design Limited, 2016.

[9] Faludi, J., Bayley, C., Bhogal, S., Iribarne, M., 2015. Comparing environmental impacts of additive manufacturing vs traditional machining via life-cycle assessment. Rapid Prototyp. J. 21, 14e33.

[10] Ford, S., Despeisse, M., 2016. Additive manufacturing and sustainability: an exploratory study of the advantages and challenges. J. Clean. Prod. 137, 1573e1587.

[11] I. J. Solomon, P. Sevvel and J. Gunasekaran, A review on the various processing parameters in FDM, Materials Today: Proceed

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