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Analysis of Effect of Process Parameters On Fused Deposition Modeling (FDM) Technique

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ABSTRACT: Rapid prototyping is a manufacturing process in which a computer-aided design (CAD) model is used to fabricate a physical model without the use of fixtures, tools, and human intervention. The prototype is made by deposition of material in layers. The major advantage of this manufacturing process is that it can fabricate complex part quickly with minimum loss of material. There are many rapid prototyping techniques available commercially. Fused deposition modelling (FDM) is one of the most widely acceptable methods in industry due to its simplicity of operation and ability to fabricate parts with locally controlled properties. However, the surface of the FDM parts shows a very low surface finish. In order to find out the effect of important factors that influence the process parameters on surface quality of spiralise contour and printing time and material consumption here we have done software runs to find the better printing parameters. Spiralise contour majorly used to prepare the casting patters and covering bodies of electronic gadgets and many more application. Here we are studying the process parameters effecting the quality of the print and printing time and consumption of material has been studied. The spiralise contour makes the solid print to outer layer print with constant increment in Z axis. Due to spiralise print the model majorly wall count, shell thickness, print speed will be effected directly. To control the quality of the final print part layer thickness, wall count, line width, print speed will play major role. Fused deposition modeling (FDM) is one of the RP techniques in which a plastic filament is melted in the extruder of the 3D printer and deposited on the build platform of the 3D printer to form the object layer by layer. Part quality and mechanical properties of the FDM fabricated parts extensively depends on process variable parameters such as layer thickness, raster angle, part orientation, raster width, air gap. Hence, selection and optimization of FDM process parameters is vital. The aim and objective of this article is to study and determine the influence of these parameters on processed part through the research work carried out so far. A number of optimization techniques and designs of experiments for the determination of optimum process parameter have been studied.

Key words: Rapid prototyping, FDM, 3D Printing, Optimization, DOE, CAD.

I. INTRODUCTION

The potentials of additive manufacturing (AM) to produce the parts for various applications including prosthetics, automotive, intelligent structure and defence show its increasing recommendations. It is able to fabricate the parts using a variety of materials ranging from plastics to metals. Many AM systems are commercially available such as stereolithography apparatus (SLA), selective laser sintering (SLS), Fused Deposition Modeling (FDM) and three-dimensional printing (3DP) for advanced applications. Among all available AM systems, FDM technology is the most widely used process for polymeric material. The major advantages of FDM technology are material availability, material diversity, cheaper, compact size and low working temperature. Based on the literature survey many studies also revealed some disadvantages of FDM technology such as surface properties, slow process and limits of dimensions. Researchers also performed the optimization of process parameters for avoiding limitations of FDM process.

In every manufacturing process, the cost of process depends upon the material and energy consumption per part. Since 3d printing is advancing rapidly in manufacturing process, the material consumption per part varying depend on the process parameter like infill density, wall count, infill pattern, support material, support infill and brim count etc. The cost of 3D printed part is varying depends upon the complexity of the geometry. If the complexity of the

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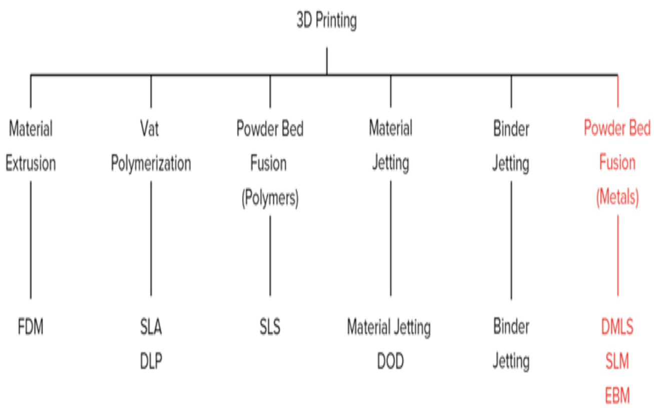
geometry of the increases cost also increases & vice versa. Since 3d printing is layered manufacturing process the, material consumption per each layer varies because material each layer contains cross sectional details of the geometry. The area of each cross section varies continuously and material and energy also consumption also varies. Compared with conventional manufacturing (CM), this unique fabricating approach largely simplifies and accelerates the production process without the requirements of moulds, dies and tools. Its feature of rapid prototyping provides users with an efficient manufacturing environment with higher material utilisation and lower time consumption. As opposed to subtractive manufacture (SM) such as CNC machining, AM is conducive to both thin-skin and light-weighted production with an alternative infill density and a higher material usage efficiency, rather than solid fabrication. The design freedom with limitless geometric constraints offers AM a broad application into customised productions, which allows users to personalise the processing parameters. To produce complex designs, AM avoids the tooling-related constraints with the assist of support structure, especially for the consolidation of assemble parts. Since AM implements fabrication in terms of pre-defined path-planning code, it drives the production mode into mass customisation of high-differentiated products.

Due to the outstanding competitiveness, AM has profound impacts on numerous domains such as medicine, architecture, mechanics, aeronautics, chemical industry, education, food and social culture. It has been expanded into a wide variety of branches based on material feed and material process systems, ranging from powder bed fusion to material extrusion, from material deposition to sheet lamination, from thermal melting to light polymerisation. Many manufacturers have dedicated to developing AM mechanism and its supporting software to provide consumers an easy-to-use, high-dominated, and customised operation environment. However, this emerging production mode still has weaknesses in manufacturing speed, energy and material consumptions.



II. PRINTING METHODS

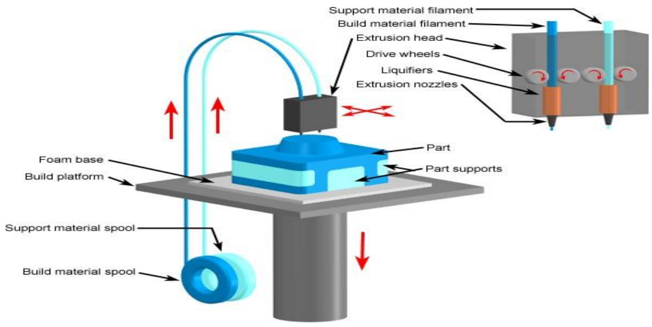


Fig 1.2: Basic Method of FDM Technology

Fig 1.3: Granular Material Binding

Fig 1.4: Illustration of granular material

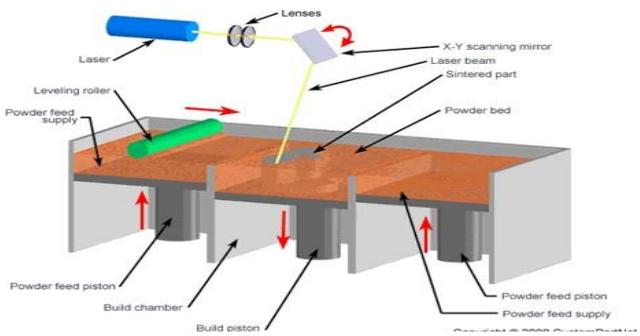


Fig 1.5: Selective Laser Sintering Citation Process

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Fig 1.6: Illustration of a Blue Printer Citation

Fig 1.7: A model created by Blue Print Citation

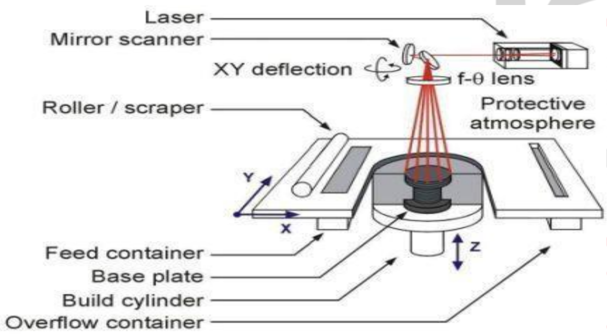

Fig 1.8: Illustration of selective laser sintering method

Fig 1.9: Selective laser sintering in action

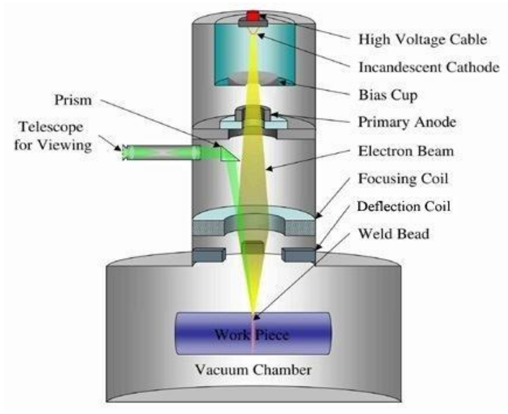

Fig 1.10: Illustration of an EBM process citation

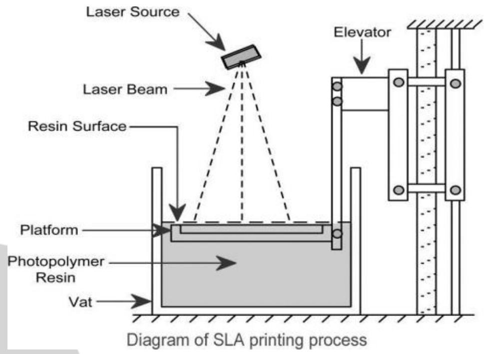

Fig 1.11: Illustration of SLA Process

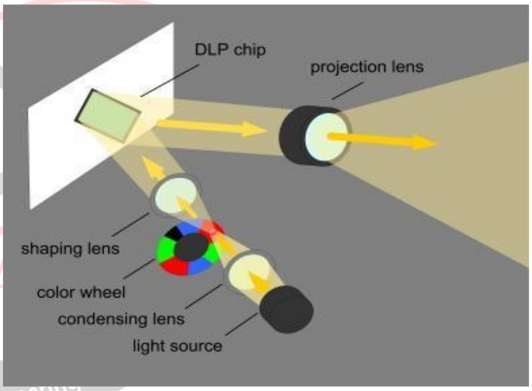

Fig 1.12: Illustration of DLP Projection

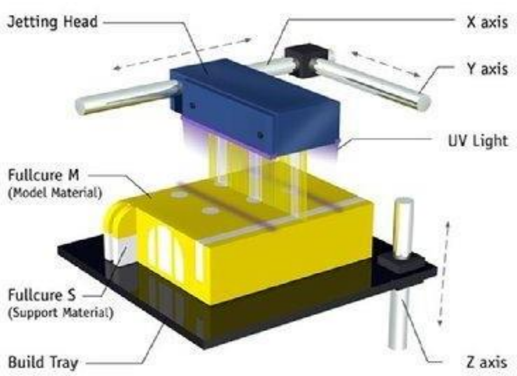

Fig 1.13: Illustration of material jetting process citation

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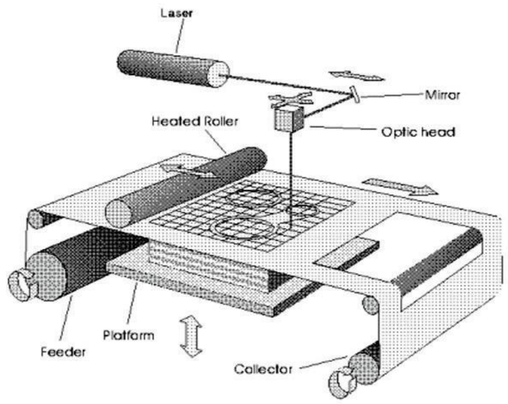


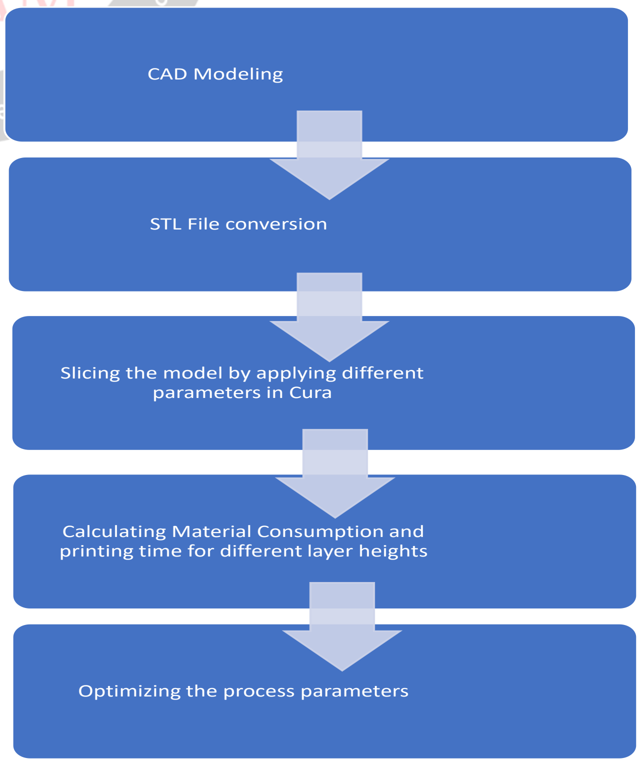
Fig 1.14: Depiction of Laminated Object Manufacturing process

3D printing materials and Application:

1. PLA (Polylactic Acid)
2. ABS (Acrylonitrile Butadiene Styrene)
3. PETG (Polyethylene Terephthalate Glycol)
4. TPU (Thermoplastic Polyurethane)
5. ASA (Acrylonitrile Styrene Acrylate)
6. PEI (Polyetherimide)

Whether AM is veritable as called "rapid prototype" is still doubtable. For mass customised production, AM mechanism is a limited factor itself as it consumes certain times on nozzle travelling, component heating and cooling down as well as its "job by job" mode. Against this issue, a relaxation scheme proposed by (Fok K et al., 2016) developed a path optimiser to shorten the extruder traversing time of each layer. Simulation results proved that the optimiser could significantly reduce the average time consumption in prefabricating and printing processes by nearly 10%. Another study in (Li et al., 2017) proposed a production planning model to estimate production time and cost of specific AM machines by considering multiple factors, including design geometry, task and machine allocation, machine characteristics. Energy sustainability has become an important topic in recent decades. A related study outlined available research on the environmental performance of AM, including the analyses of energy and resource consumptions. Detailed statistics on various AM processes compared with CM were performed. The results confirmed that AM system had a higher electrical energy demand and less material consumption and wastage of material, in which the energy required for direct metal deposition, direct laser deposition, FDM and selective laser melting (SLM) was higher than the average level (Kellens et al., 2017). From the perspective of material consumption, research by (Watson J and Taminger K M, 2015) proposed a decision-support model for comparing energy and material consumptions between AM and SM. A volume faction was obtained as a critical value to judge AM's feasibility. The result confirmed the weakness of AM, for instance, the poorly recycled material from the products with higher usage ratio of support. The move from subtractive manufacturing processes can minimize material waste (Huang et al., 2013), but are currently prone to various human errors. Under ideal conditions, the only material waste for FDM is support material. In practice, however, 3D printers may be used similarly to conventional printers in offices and result in high usage error. Since many users of commercial FDM printers are inexperienced in 3D printing operation, the actual material waste could be larger than that under ideal operating conditions without human or printer error. The quantity of support material changes with part orientation and other settings of the printer or design. Failure could increase both the material and energy consumption, which undermined the environmental benefits of FDM. Failed prints might be produced due to various reasons such as insufficient preheating time, inappropriate geometry of parts or printer malfunctions (Grieser, 2015). When evaluating the material waste from FDM, most studies only consider the support material generation, in other words, the production under ideal conditions without failures. Existing slicer software provides users with customised process parameters, such as layer thickness, support structure, product infill pattern, infill density, etc. Users may optimise both design and parameters to reduce consumed indicators. However, how to accurately model consumptions based on 3D design, machine characteristics and processing parameters; how to determine the most appropriate parameters to achieve the optimal consumptions require to be solved. Therefore, this study proposed a flexible and modular method to reduce the material consumption of AM task at prefabrication stage. It aims to benefit the improvement of design part and assist users in customised selection of process parameters. To achieve a high-precision prediction, the initial model can be upgraded in terms of machine characteristics.

METHODOLOGY



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The prediction method is expected to be applied in practical AM environment which is suitable for other related manufacturing techniques using numerical control (NC) programming.

CAD modelling of bottle for spiralise contour:

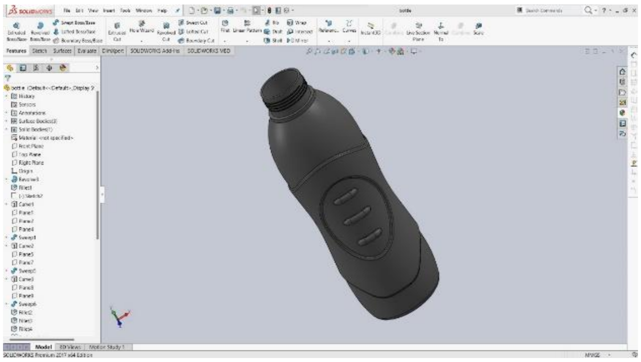

Fig 4.1: Isometric view of bottle

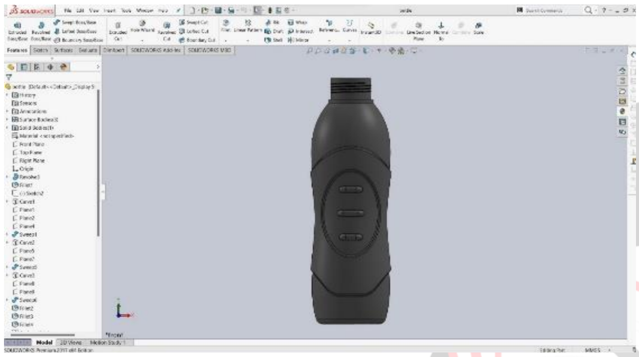

Fig 4.2: Front view of bottle

The bottom/top thickness is the outer shell thickness on the top and bottom. For example,

when printing a simple cube, this square thickness that are put down. Increasing this will make a stronger part, and depending on your model, it will make for better solid tops. Cura fills the internal parts of your model with a structure. This grid is made for strength and to support the top layers. The amount of infill you want is influenced by this setting. More infill produces stronger parts that take longer to print. If strength is not a requirement, then this setting could be put on 5% for a low-density infill that can still support the upper layers.

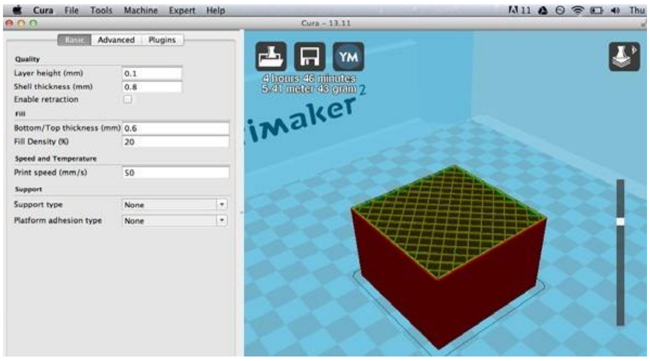

Fig 4.3: Interface of Cura

III. SLICING THE MODEL

Cura is an open-source slicing application for 3D printers. It was created by David Braam who was later employed by Ultimaker, a 3D printer manufacturing company, to maintain the software. Cura is available under LGPLv3 license. Cura was initially released under the open source Affero General Public License version 3, but on 28 September 2017 the license was changed to LGPLv3. This change allowed for more integration with third-party CAD applications. Development is hosted on GitHub. Ultimaker Cura is used by over one million users worldwide and handles 1.4 million print jobs per week. It is the preferred 3D printing software for Ultimaker 3D printers, but it can be used with other printers as well.

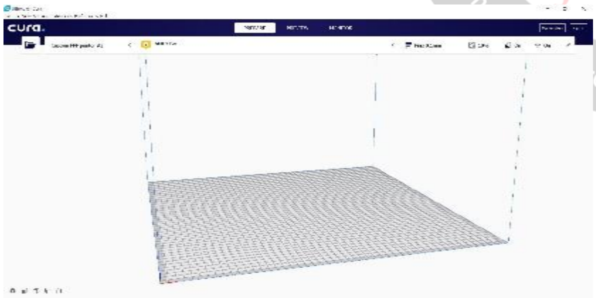

Fig 5.1: CURA Software interface

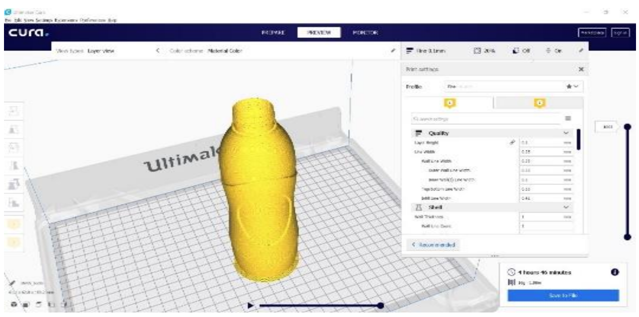

Fig 5.2: spiralise print with 0.1 mm LH

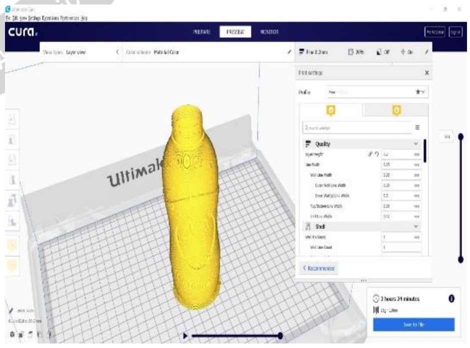

Fig 5.3: spiralise print with 0.2 mm LH

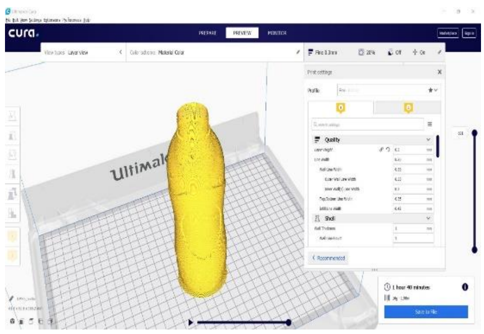

Fig 5.4: spiralise print with 0.3 mm LH

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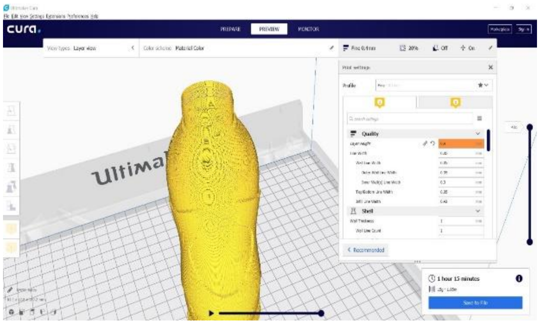

Fig 5.5: spiralise print with 0.4 mm LH

IV. RESULTS AND DISCUSSION

Printing Time Estimation for Different Spiralise Contours

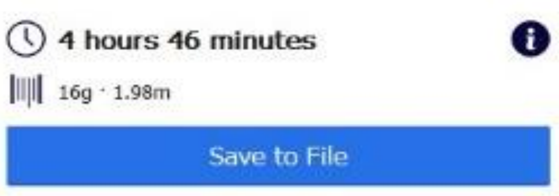

Fig 6.1: printing time and material consumption for 0.1mm LH

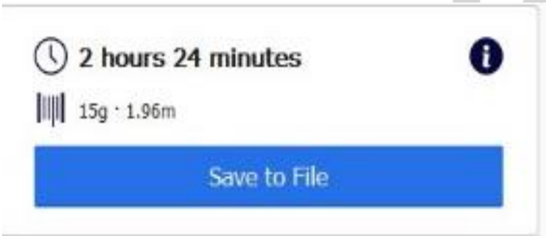

Fig 6.2: printing time and material consumption for 0.2mm LH

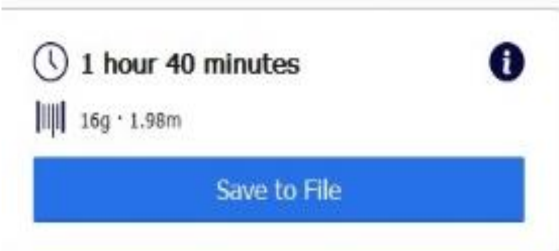

Fig 6.3: printing time and material consumption for 0.3mm LH

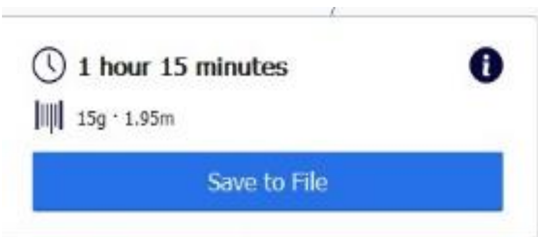

Fig 6.4: printing time and material consumption for 0.4mm LH

V. CONCLUSION

For Objects to be manufactured by Blow moulding process, by using Cura software we can enhance the mechanical properties of the object before manufacturing and reduce the manufacturing time.

From the results obtained we can conclude that by increasing the layer height printing speed can be reduced. Material consumption also depends on the Layer height and Infill Density. Tensile strength decreases with increase in the Layer height.

Better Surface Roughness and better mechanical properties can be obtained by increasing the wall count and reducing Infill density below 50% and also Surface Roughness increases with the increase in Layer height. When printing with FDM printer so many process parameters will affect the printing time, quality and material consumption etc. FDM printer also have special mode printing options to print the part. When printing with spiralize, it smooths out the Z move of the outer edge. This will create a steady Z increase over the whole print. This feature will turn a solid model into a single walled print with a solid bottom. This feature should only be enabled when each layer only contains a single part.

This feature will affect the

1. Wall line count
2. Travel speed
3. Travel acceleration
4. Travel jerk

Spiralize contour will reduce the lot of printing time and material consumption. This feature mainly used in developing the casting patterns and outer surfaces. In this particular feature only, the outer body will trace out.

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