Experimental Investigation on Effect of Layer Width on Dimensional Accuracy of FDM Build Parts

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ABSTRACT: 3D printing is emerging technology in advance manufacturing process. The main moto of the 3D printing is to achieve the most complex geometries accurately without effecting the features of the object within less time compare to conventional manufacturing. To build any component we need material and power source. Materials used in 3d printing are polymers, metals powders, ceramic powder etc… Material consumption is one of the important factors, here we are trying to optimize the consumption of material without effecting the features of the object before going for printing. most of the parameters effecting the material consumption and printing time among all the parameters like layer height, infill density, print speed and shell thickness etc... are majorly effecting parameters. Among these parameters line width or layer width also playing major role in consumption of material. Layer width in directly proportional to the material consumption which means increasing line width increases the material consumption and decrease in layer width decrease the material consumption. This line width directly effecting the printing time, bond strength and surface quality. Rapid increment and decrement of line width causes failure of print. In this study we are trying to optimize the material consumption and printing time by varying the line width for a constant layer height at different infill densities.

Key words: FDM, Density, 3D Printing, strength, surface quality.

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 modelling (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 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

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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

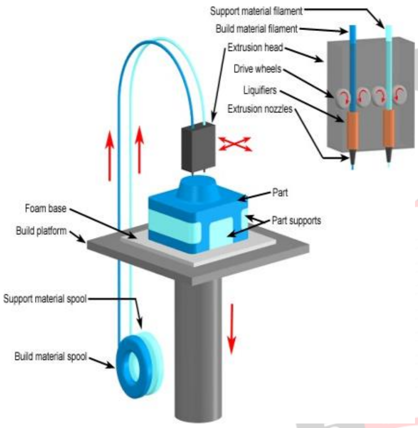

Fig 1.1: Basic Method of FDM Technology

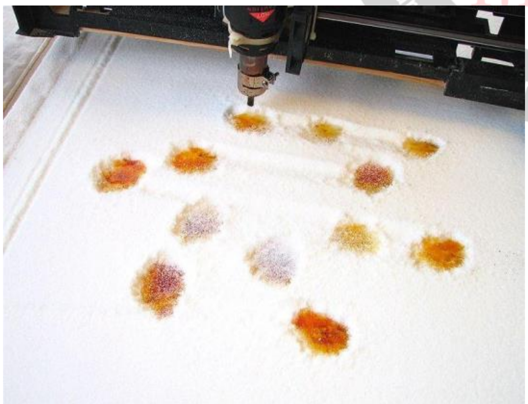

Fig 1.2: Granular material binding

Fig 1.3: Illustration of granular material

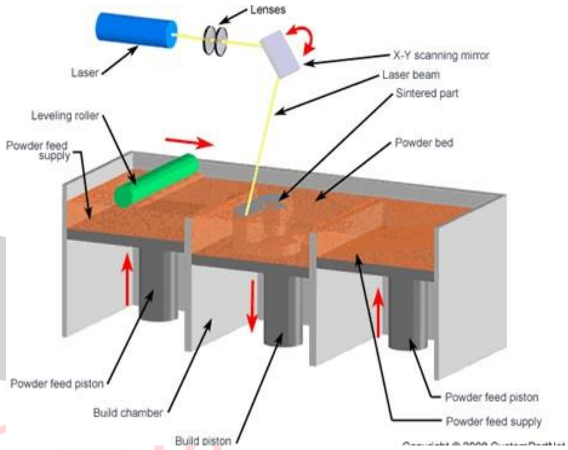

Fig 1.4: Selective Laser Sintering Citation Process

Fig 1.5: Illustration of a Blue Printer Citation

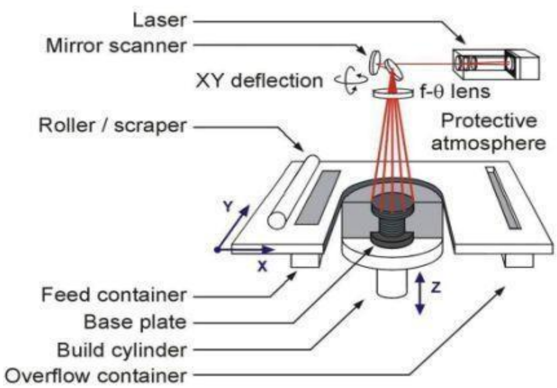

Fig 1.7: Illustration of selective laser sintering method

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Fig 1.8: Selective laser sintering in action

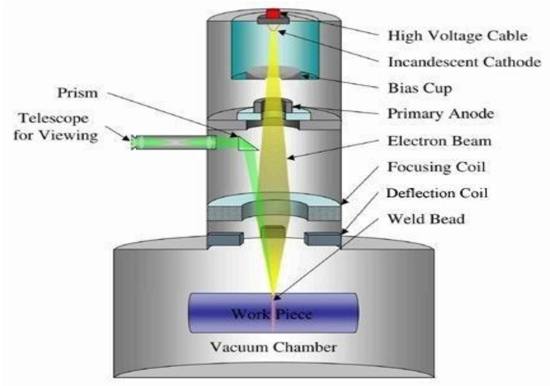

Fig 1.9: Illustration of an EBM process citation

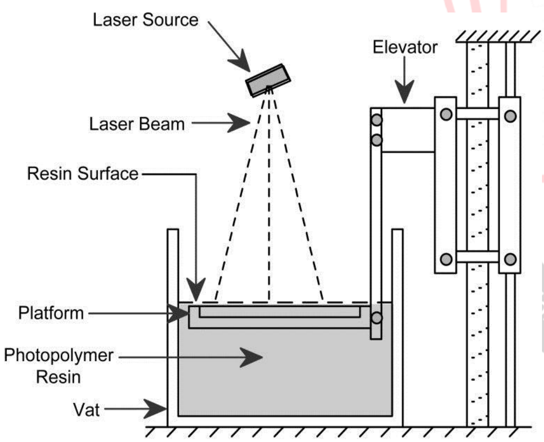

Diagram of SLA printing process

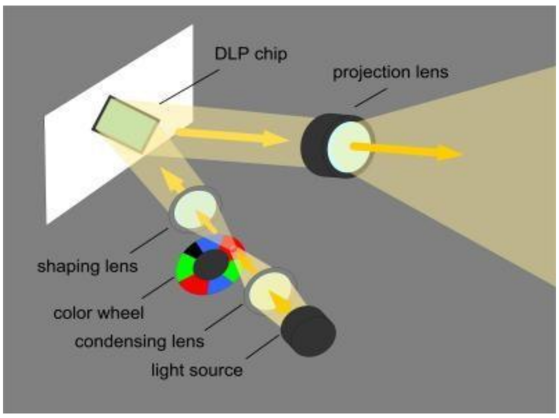

Fig 1.10: Illustration of DLP Projection

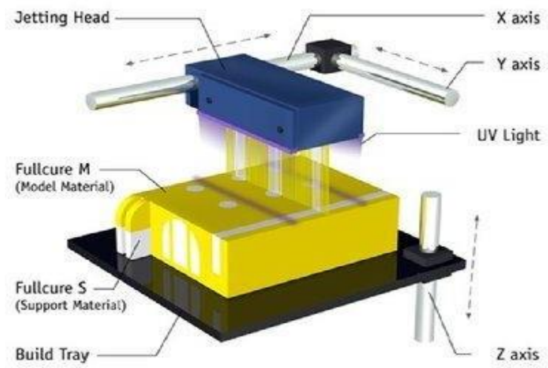

Fig 1.11: Illustration of material jetting process citation

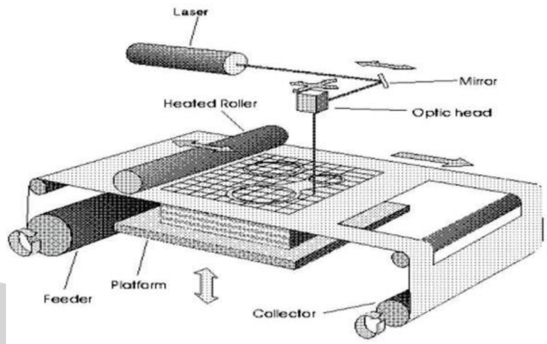

Fig 1.12: Depiction of Laminated Object Manufacturing process

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, a 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

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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.

To build any component raw material plays major role. To build the component raw material is subtracted or added to build the component. Similarly, in the 3d printing process raw material is added layer wise to build the component. In 3d printing process material consumption is controllable when compare with subtractive manufacturing. Quality and material consumption per part depend upon different slicing parameters. The main moto of this study is to study the material consumption per print by varying the layer line width without effecting the geometrical details of the component. The cross section of the layer width is elliptical in shape. The output material from the nozzle in Circular cross section when the nozzle prints one layer over the other, due to gap between the nozzle and the previous layer, material will be compressed. The line width of the layer is depending upon the gap between the nozzle and the bed. The line width of the layer is directly affecting the consumption of material. Material consumption is depending on various parameters as we mentioned earlier infill density and support structures etc... but layer line width will affect the infill pattern, infill patrician thickness and wall thickness of the printed part.

All dimensions are in mm

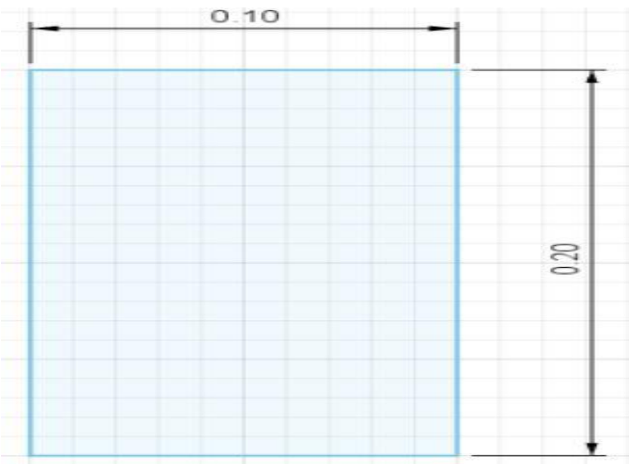

Fig : a

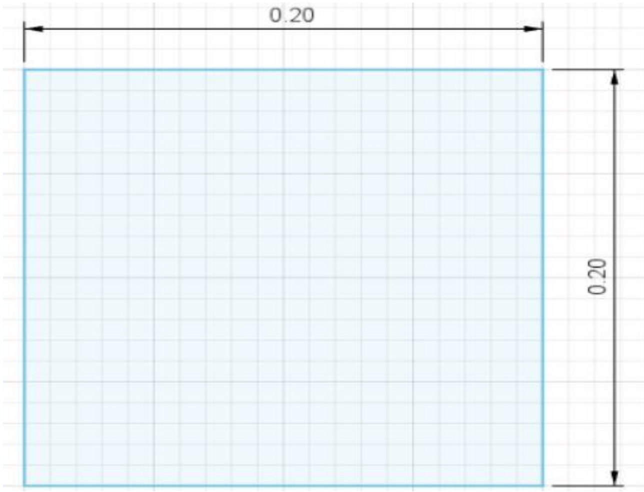

Fig: b

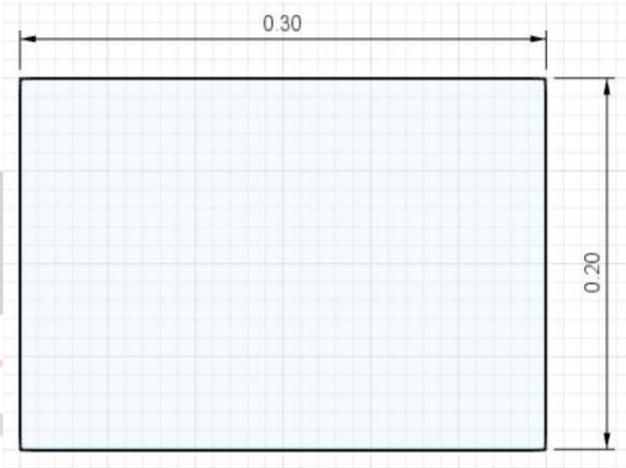

Fig : c

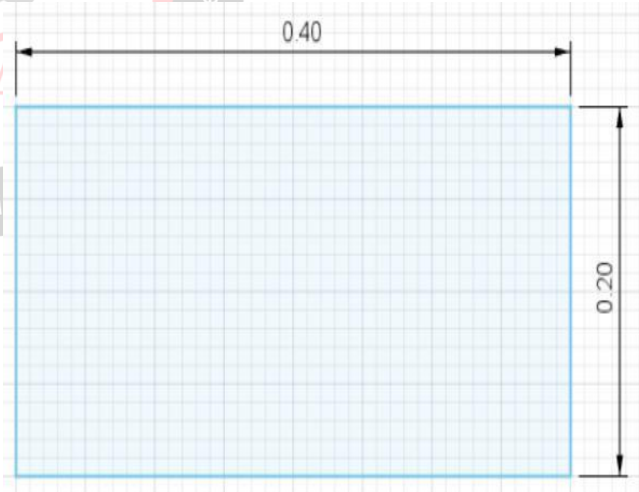

Fig : d

Fig 3.1: a) shows the layer height 0.2 and layer width 0.1 b) shows the layer height 0.2 and layer width 0.2 c) shows the layer height 0.2 and layer width 0.3 d) shows the layer height 0.2 and layer width 0.4

The material consumption is varying depends on the width of the cross section varies. Here we are studying the consumption of material by keeping the infill density constant. In the Fig 3.1, we can see the different layer

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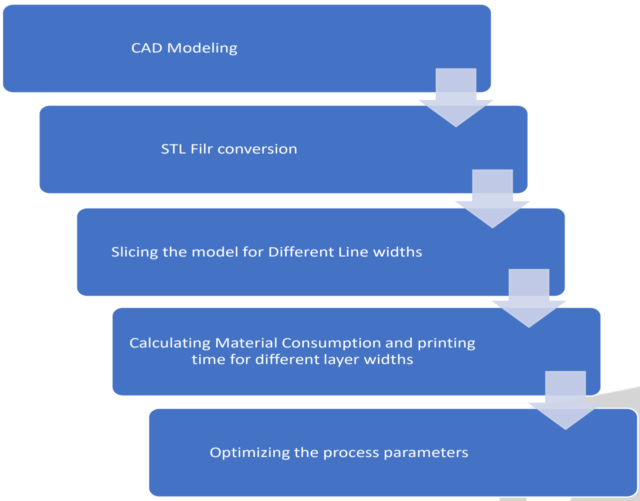
widths from 0.1 to 0.4 mm with constant layer height 0.2mm. This variation in line width directly effecting the surface quality of the component and mechanical properties of the final printed component. Here we are trying to explore the significance of the layer width parameter in slicing and study how it will affect the final printed component.

METHODOLOGY



III. DESIGNING OF CAD MODEL

To study the effect of layer width wee have designed 20 x 20 x 20 mm3. The design carried out in solid works software. Cube allows easy study of material consumption and energy consumption.

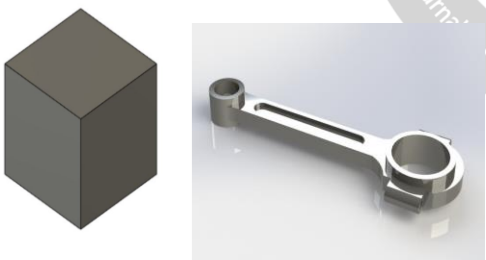


Fig 5.1: Simple basic model of cube and connecting rod assembly

Slicing in Ultimaker CURA Software:

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.[3] 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.

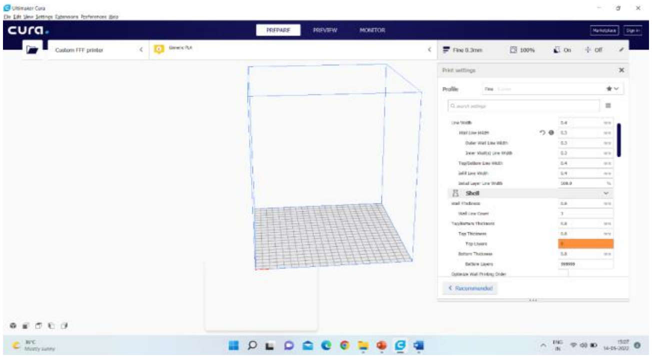


Fig 5.6: Slicing software Interface

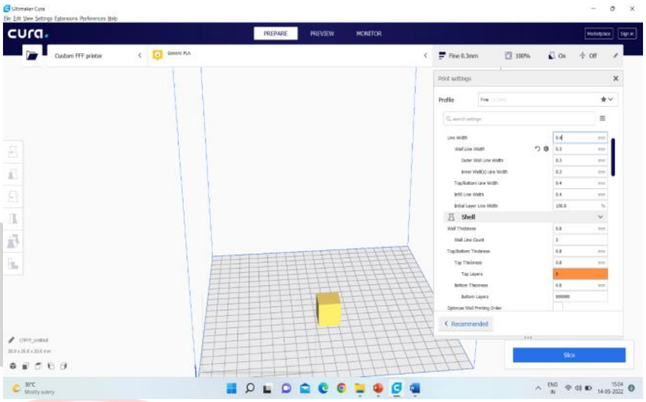
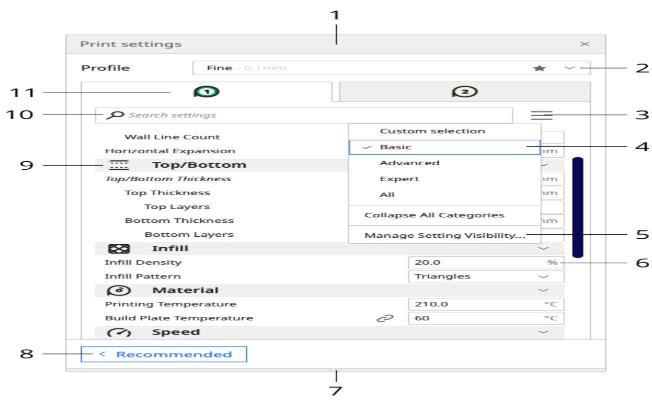


Fig 5.7: loaded stl file in slicing software

The designed typical stl model is loaded into the slicing software. After loading the stl model the component will be shown as designed model. In the Fig 4 shows the interface of the cura slicing software interface. By clicking the file symbol on the right top side we can load the design typical loaded simple cube shown in Fig 5.

SETTING UP Overview

Ultimaker Cura indicates relations between custom settings with icons that indicate their relation. Settings visible to the user can be linked, automatically calculated, unavailable or hidden. This is the full list of icons and indicators used in the custom mode.



1. Linked setting - Settings with this icon are linked between extruders, the setting will always be equal between all extruders

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2. Greyed out setting - This setting is overwritten by a child setting. Reset the child setting to alter this setting

3. Gear icon - Opens the setting visibility preferences

4. Information icon - Shows a hidden setting influences the printing strategy. This only occurs when you accidentally change a setting and hide it afterward

5. Categories - Can be collapsed to hide them temporarily when focusing on different aspects.

6. Reset icon - Resets the value to its default or parent setting.

7. Calculated icon - Indicates the setting is normally calculated from a parent setting.

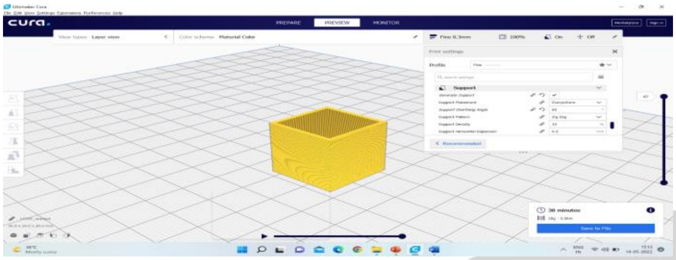

Fig 5.8: preview of sliced component

Fig: Different sizes of nozzle to achieve required layer width

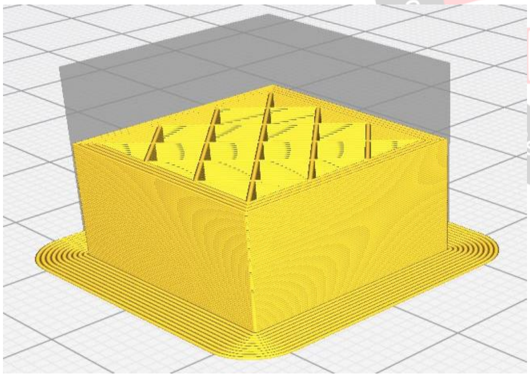

Fig 5.9: infill view of the sliced component

IV. RESULTS AND DISCUSSIONS

While slicing the CAD model we have observed that, when we are slicing the model with different layer line width by keeping the layer height constant, the consumption of material and printing time varies.

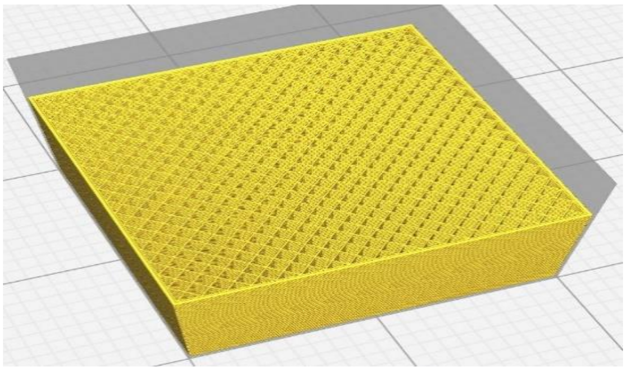

Fig a

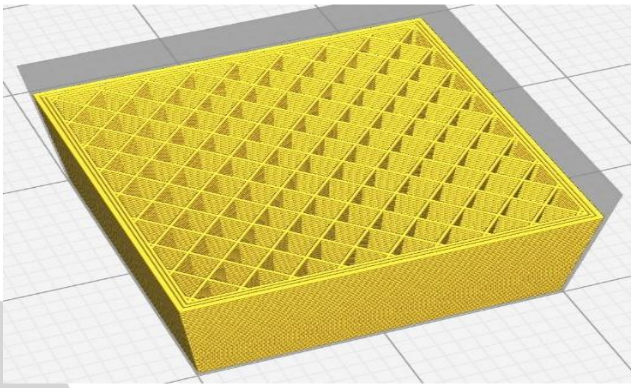

Fig c

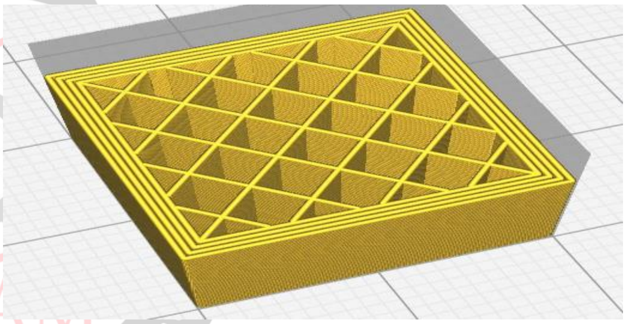

Fig d

Fig 6.1: shows that a) Sliced view of the cube with layer height 0.2 and layer width 0.1 b) Sliced view of the cube with layer height 0.2 and layer width 0.2 c) Sliced view of the cube with layer height 0.2 and layer width 0.3 d) Sliced view of the cube with layer height 0.2 and layer width 0.4

In the below tables we can see the material consumption and printing time for different layer widths

Table 1: The below table shows that material consumption and printing time for different layer widths for 20 x 20 x 20 mm3 cube at 100% infill and later height 0.2

case 1 100% infill and LH 0.2		
Layer Width(mm)	Material Consumption(grams)/ length of wire(meters)	Print Time(minutes)
0.4	10/3.33	46
0.3	10/3.33	61
0.2	10/3.33	89
0.1	10/3.33	174

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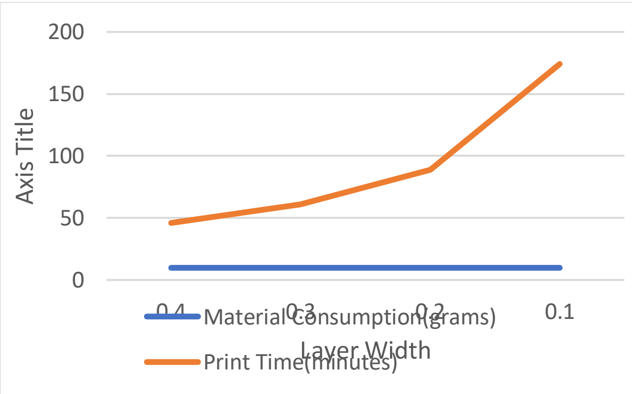
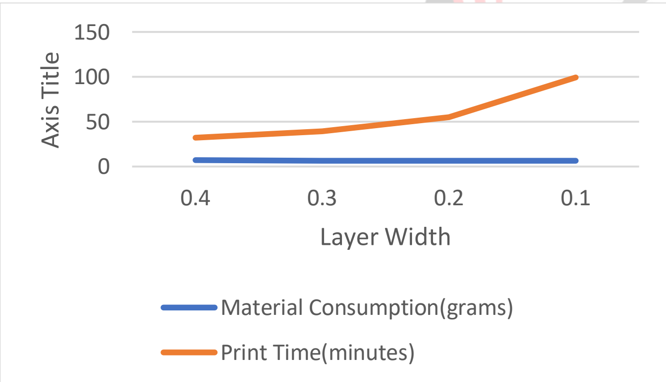
Table 2: The below table shows that material consumption and printing time for different layer widths for 20 x 20 x 20 mm3 cube at 50% infill and later height 0.2

case 2 50% infill and LH 0.2		
Layer Width(mm)	Material Consumption(grams)/ length of wire(meters)	Print Time(minutes)
0.4	7/2.21	32
0.3	6/2.10	39
0.2	6/1.98	55
0.1	6/1.86	99

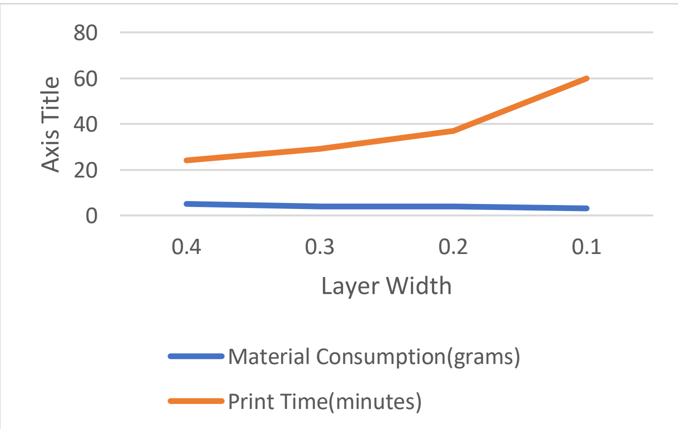
Table 3: The below table shows that material consumption and printing time for different layer widths for 20 x 20 x 20 mm3 cube at 25% infill and later height 0.2



Graph 2: shows that effect of layer width on material consumption and printing time at 50% infill



Graph 3: shows that effect of layer width 0.2mm on material consumption and printing time at 25% infill



case 3 25% infill and LH 0.2		
Layer Width(mm)	Material Consumption(grams)/ length of wire(meters)	Print Time(minutes)
0.4	5/1.65	24
0.3	4/1.48	29
0.2	4/1.3	37
0.1	3/1.12	60

Form the above tables we can clearly observe that effect of layer width on printing time and material consumption.

Graph 1: shows that effect of layer width 0.2mm on material consumption and printing time at 100% infill

Table 4: The below table show the material consumption and printing time for different layer widths for a 20 x 20 x 20 mm3 cube at 100% infill and later height 0.3

case 1 100% infill and LH 0.3		
Layer Width(mm)	Material Consumption(grams)/ length of wire(meters)	Print Time(minutes)
0.4	10/3.34	31
0.3	10/3.34	40
0.2	10/3.34	60
0.1	10/3.34	116

Table 5: The below table show the material consumption and printing time for different layer widths for a 20 x 20 x 20 mm3 cube at 50% infill and later height 0.3

case 2 50% infill and LH 0.3		
Layer Width(mm)	Material Consumption(grams)/ length of wire(meters)	Print Time(minutes)
0.4	7/2.25	21
0.3	6/2.13	27
0.2	6/2.02	37
0.1	6/1.9	67

Table 6: The below table show the material consumption and printing time for different layer widths for a 20 x 20 x 20 mm3 cube at 25% infill and later height 0.3

case 3 25% infill and LH 0.3		
Layer Width(mm)	Material Consumption(grams)/ length of wire(meters)	Print Time(minutes)
0.4	5/1.69	16
0.3	5/1.53	19
0.2	4/1.35	25
0.1	3/1.17	41

From the tables we can observe that by changing the layer width irrespective of the layer height, layer width is directly affecting the printing time, material consumption and energy consumption. Layer width is directly proportional to the material consumption and indirectly proportional to the print time. Here we related the print time with energy consumption. If print time increases energy consumption also increases.

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Table 7: Shows the final weight of the Cube with different layer width at 100% infill and 0.2mm layer height

case 1 100% infill and LH 0.2, PLA density 1.24 g/cm3		
Line Width	Material Volume (cm3)	Weight (grams)
0.4	8.0095	9.93
0.3	8.0095	9.93
0.2	8.0095	9.93
0.1	8.0095	9.93

Table 8: Shows the final weight of the Cube with different layer width at 100% infill and 0.2mm layer height

case 2 50% infill and LH 0.2, density 1.24 g/cm3		
Line Width	Material Volume (cm3)	Weight (grams)
0.4	5.316	6.591
0.3	5.051	6.2632
0.2	4.62	5.904
0.1	4.473	5.546

Table 9: Shows the final weight of the Cube with different layer width at 100% infill and 0.2mm layer height

case 3 25% infill and LH 0.2, density 1.24 g/cm3		
Line Width	Material Volume (cm3)	Weight (grams)
0.4	3.968	4.9203
0.3	3.559	4.413
0.2	3.126	3.8762
0.1	2.693	3.339

Table 10: Shows the final weight of the Cube with different layer width at 100% infill and 0.3mm layer height

case 1 100% infill and LH 0.3, density 1.24 g/cm3		
Line Width	Material Volume (cm3)	Weight (grams)
0.4	8.033	9.9609
0.3	8.033	9.9609
0.2	8.033	9.9609
0.1	8.033	9.9609

Table 11: Shows the final weight of the Cube with different layer width at 100% infill and 0.2mm layer height

case 2 50% infill and LH 0.3, density 1.24 g/cm3		
Line Width	Material Volume (cm3)	Weight (grams)
0.4	5.411	6.7096
0.3	5.123	6.352
0.2	4.858	6.023
0.1	4.57	5.66

Table 12: Shows the final weight of the Cube with different layer width at 100% infill and 0.3mm layer height

case 3 25% infill and LH 0.3, density 1.24 g/cm3		
Line Width	Material Volume (cm3)	Weight (grams)
0.4	4.064	5.039
0.3	3.68	4.563
0.2	3.247	4.026
0.1	2.814	3.489

From the above tables we can observe that the when the layer width decreasing the volume of consumption of material is also decreasing.

V. CONCLUSION

3D printing is more effective way to achieve the complex geometries without effecting the dimensional accuracy. But the consumption of material and energy are the biggest constrain in any manufacturing process. The consumption of material less when compare to conventional machining and consumes more energy when compare to conventional machining. To optimize the material consumption, we are more focused on printing parameters. Majorly line width effecting the material consumption for a constant a layer thickness. By decreasing the line width, the consumption of material is decreasing but consumes more power. Similarly, by increasing the line width consumption of material increases but less energy consumes but the quality of the printed part decreases when compare to less layer width. The less the line width more the dimensional accuracy and better surface finish and vice versa.

1. Here the main observation is only we changing the layer width parameter remaining parameters are constant. Let's consider table 3 shows that material consumption and printing time for different layer widths for 20 x 20 x 20 mm3 cube at 25% infill and later height 0.2. where the percentage of infill is constant in that case the weight of the final part should be same but here the weight of the final part is decreasing.

2. As the infill percentage decreasing at different layer width for decreasing infill percentage the variation in the weight of the final part also more. If observe in the table 1, 2 and 3, at different infill percentages for different layer widths the variation in the final weight of the part increasing.

3. In this study we designed simple cube of 20 x 20 x 20 mm3 block since the block is very small if we print any large component the consumption of material for different layer widths will be very high. Similarly, printing time will be more and consumes more energy.

4. At 100% infill the consumption of material is remains same but the printing will be high as the layer width reduces. In the table 1 and 4, we can notice that at 0.2 and 0.3 layer width the consumption of material is same but as the layer width reduces it causes increase in printing time. The main reason for increase in printing time when layer width reduces the extruder travel time increases.

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

 DOI : 10.35291/2454-9150.2022.0224

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 Prototyp. 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.

 DOI : 10.35291/2454-9150.2022.0224