INVESTIGATION OF NON-PLANNER ADDITIVE MANUFACTURING SYSTEM FOR SMOOTH SURFACE GENERATION AND STRENGTH IMPROVMENTS: A REVIEW

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Abstract

The 3D printing (Additive Manufacturing) is an upcoming technology for layered manufacturing with distinct advantages. Various processes like FDM, SLA and SLS have been used to obtain desired results. Among these three processes FDM is far better than the other processes due to inherent material capabilities and low cost. Although there are few disadvantages of FDM process like surface finish of printed part, mechanical properties etc. Stair stepping effect reduce the surface quality of 3D printed objects, especially when the slope is close to horizontal. Previous researchers showed that nonplanar surfaces could reduce these effects. So, this can be eliminated by using non planner additive manufacturing process, that includes 3d printing of single layer with variation in dimensions of z axis for uneven surfaces of any object.

The prime review is to identify different non-planner additive manufacturing system based on FDM process to identify the key process parameters that affect the non-planner additive manufacturing

***Key Words**: Additive manufacturing, FDM, 3D Print*

1.INTRODUCTION

There is major two types of manufacturing processes

1. **Subtractive Manufacturing -**

Subtractive manufacturing is a process by which 3D objects are constructed by successively cutting material away from a solid block of material.
Subtractive manufacturing can be done by manually cutting the material but is most typically done with a CNC Machine.

2. **Additive manufacturing –**

refers to technologies that create objects through sequential layering.
Additive manufacturing (AM), also known as 3D printing, is a transformative approach to industrial production that enables the creation of lighter, stronger parts and systems

Additive manufacturing, also known as 3D PRINTING, is a manufacturing process where a 3D printer creates three-dimensional objects by deposition materials layer by layer in line with the object's 3D digital mode.
“additive manufacturing” references technologies that grow three-dimensional objects one superfine layer at a time. Each successive layer bonds to the preceding layer of melted or partially melted material. Objects are digitally defined by CAD software that is used to create .stl files that essentially "slice" the object into ultra-thin layers.
The path of a nozzle precisely deposits material upon the preceding layer. As materials cool or are cured, they fuse together to form a three-dimensional object.

1.1 TYPES OF ADDITIVE MANUFACTURING

Fused Deposition Modelling (FDM) or **Fused Filament Fabrication (FFF**), is an additive manufacturing process that belongs to the material extrusion family. In FDM, an object is built by selectively depositing melted material in a pre-determined path layer-by-layer. The materials used are thermoplastic polymers and come in a filament form.

Stereolithography is a 3D Printing process which uses a computer-controlled moving laser beam, pre-programmed using CAM/CAD software. SL is an excellent choice for rapid prototyping and project designs that require the production of very accurate and finely detailed parts. Stereolithography (SLA) resins are liquid UV-curable photopolymers used in this process.

Selective laser sintering (SLS) is an additive manufacturing (AM) technology that uses a laser to sinter powdered plastic material into a solid structure based on a 3D model. SLS 3D Printing has been a popular choice for engineers in product development for decades

2. Recent studies

Ahlers, (2019) Explored that additional processes of production are inherently discretized. The quality of the surfaces of printed 3D objects, especially when the surface slope is close to horizontal, is impaired for many of the technology. In this paper, we propose a new approach to Fused Deposition Modelling (FDM) which combines non-planar and planar layers, enhances printing quality and creates smoother, stronger object surfaces. The slicing algorithm automatically detects the parts of the object to be printed with nonplanar layers and uses a printer and extruder geometric model to create toolpaths with no collision. based on the famous Slic3r tool our open-source implementation can be used on all common 3D printers with three axes. Typical print results are presented and surface quality, slices and printing times are compared with conventional and adaptive planar slicing.

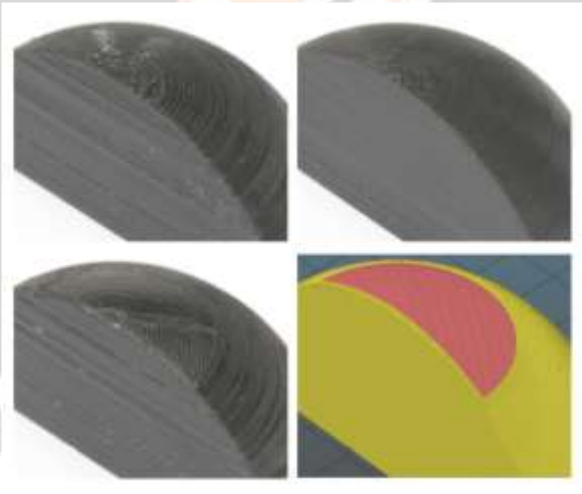

Figure 1 A quarter-sphere to visualize the surface smoothing on its top and the ability to combine planar and nonplanar layers in a single shell.

Alsoufi, (2018-19) Represent that an experimental platform for investigating the surface roughness quality of FDM 3D printed parts made from various filament materials, including PLA, PLA+, ABS, and ABS+, as well as the dimensional accuracy of the parts. both printed parts' length, height, and width. The consistency of the surface roughness and the accuracy of FDM 3D printed parts was investigated.

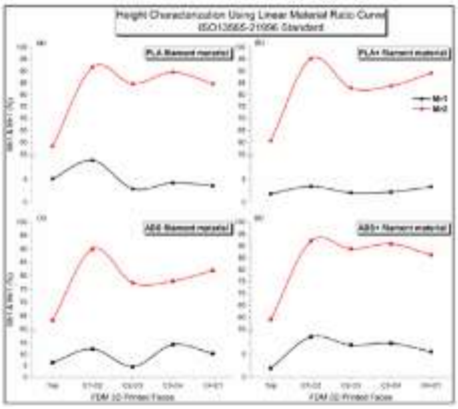

Figure 2 Material ratio assessment (Mr1& Mr2) of (a) PLA; (b) PLA+; (c) ABS and (d) ABS+.

The top face (middle) of all four surfaces (C1-C2, C2-C3, C3-C4, C4-C1) has a high value, with Ra, Wa, and Pa being identical. ABS has an irregular distribution of roughness, shock, and primary surface rugosity on all four sides, including the top face, with no discernible pattern. The ABS Rvk (steep valleys) has a significantly lower highest value than the Rk (flat tops) The authors believe that the findings of this study would aid in the development of thermoplastic filament materials for use in low-cost FDM 3D personalized/desktop printers.

Abdullah T. Alsharhan et al. (2017) Represented that an extrusion based non-planar additive manufacturing process. Test specimens were fabricated using the developed process as well as a commercial planar 3D printer. They noted that on the basis of their observations, Non-planar deposition led to higher stiffness, higher peak load, and sudden structural failure. Planar deposition resulted in higher compliance and lower peak load. the method of making of thin wall structures with unfilled PLA material filament is advantageous in this paper.

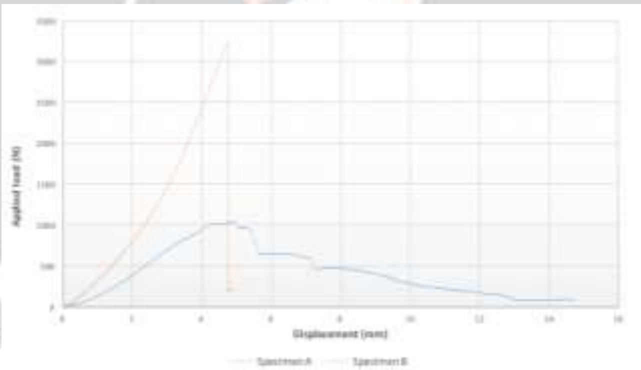

Figure 3 Applied load vs. frame displacement in loading configuration

Donghong Ding, (2016) Define that One of the major challenges in additive fabrication is the creation of a robust algorithm that divides CAD models into layers that demand a minimum of support structures. this paper describes the definition and implementation of a modern multi-level slicing strategy of STL-format CAD models. this study introduces a decomposition regrouping technique, differing from established multi-direction slicing methods that concentrate primarily on finding an optimal decomposition strategy.

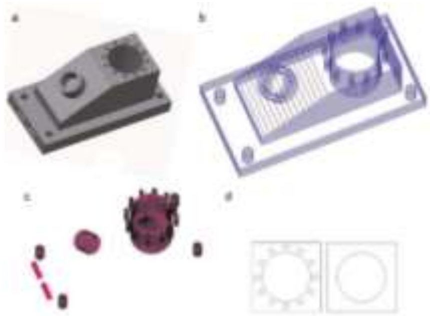

Figure 4 An engineering part; (b) slicing results; (c) all the detected holes; (d) further simplification of slices.

Using a simple curvature-based volume decomposition process, the CAD model is first decomposed into sub-volumes. Then a profound-tree structure is implemented to merged into ordered cuts groups, based on topology knowledge. Moreover, before decomposition of the CAD model, a model simplification step is added to substantially improve the capacity of the proposed multi-direction strategy. In different test pieces, particularly geometrics with a large number of hole components, the strategies proposed are simple and effective.

Grimm, Explored that choosing the right rapid prototyping method can be difficult. It can be difficult to determine a technology's strengths and limitations without firsthand experience. However, knowing this information is crucial when choosing the right tool for the job. Stereolithography (SLA), Selective Laser Sintering (SLS), and PolyJet were the three technologies discussed in a previous reserch. Another leading technology, fused deposition modelling (FDM), is viewed from the user's perspective to add to this body of knowledge. FDM will make selection much more difficult when used in an assessment. For two reasons, this is right. First, FDM introduces a new set of assessment standards, as the technology has evolved.

		FDM Maxum				FDM Titan			Prodigy Plus		
	Nominal	Actual	Deviation	%	Actual	Deviation	%	Actual	Deviation	%
A	3.000	3.000	0.000	0.00	3.000	0.000	0.00	2.995	0.005	0.17
B	1.000	1.003	0.003	0.30	1.004	0.004	0.40	1.006	0.006	0.60
C	6.000	6.000	0.000	0.00	5.995	0.005	0.08	6.000	0.000	0.00
D	0.100	0.099	0.001	1.00	0.100	0.000	0.00	0.100	0.000	0.00
E	3.000	2.998	0.002	0.07	2.995	0.005	0.17	2.997	0.003	0.10
F	4.000	3.999	0.001	0.02	3.993	0.007	0.18	3.996	0.004	0.10
G	1.000	1.003	0.003	0.30	1.004	0.004	0.40	1.006	0.006	0.60
H1	0.500	0.497	0.003	0.60	0.498	0.002	0.40	0.494	0.006	1.20
H2	0.500	0.497	0.003	0.60	0.499	0.001	0.20	0.494	0.006	1.20
I	0.500	0.499	0.001	0.20	0.500	0.000	0.00	0.497	0.003	0.60
J	0.250	0.253	0.003	1.20	0.258	0.008	3.20	0.255	0.005	2.00
K	0.500	0.499	0.001	0.20	0.503	0.003	0.60	0.503	0.003	0.60
			Minimum	0.00			0.00			0.00
			Maximum	1.20			3.20			2.00
			Average	0.37			0.47			0.60

Figure 5 Dimensional accuracy data for the Maxum, Titan and Prodigy Plus. All test parts were constructed with 0.007 in. layers. All dimensions are listed in inches.

Physical properties, organizational limitations, and expected implementations are all factors to consider when choosing the right method. This paper addresses each of these issues. A comparative analysis will be used to determine the best technology for the project using this knowledge.

John C.S. McCaw et al. (2018) Presented that this method shows a high degree of variability, both in parametric geometry and in the structure of the lattice contained therein. The auxetic contempt for energy absorption would therefore be possible. This method also makes it possible to find high-performance shells in highly explored, highly permuted areas of the design. it offers a study of design applications and the growth of a new group of interrupted materials. It is not only exploring the open conditions of the Bezier, but also the growth of the "false" and the "trends" and the "spunky" look.

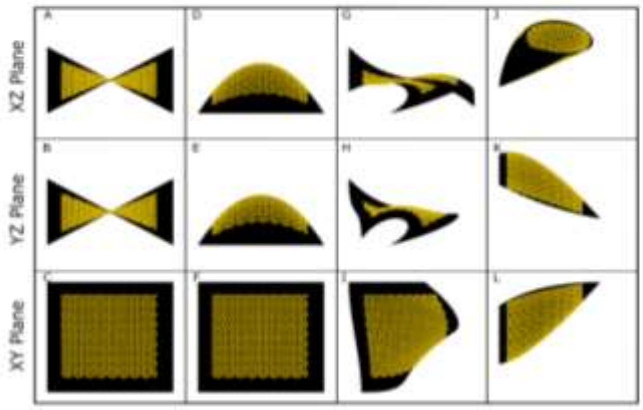

Figure 6 A–C: ‘Saddle’ surface, D–F: Convex Surface, G–I: ‘Draping’ Surface, J–L: ‘Cone’ Surface

N. N. Kumbhar et al. (2016) Explored that the literature of different surface finishing techniques was reviewed in this work. Various methods for improving the surface finish of the components were found. Studying various post-treatment works shows that the systematic use of the post-treatment technique can improve surface finishing. Many assumptions were thus taken, such as the abrasive dimension, HCM feed rate, abrasive flow rate and Laser power.

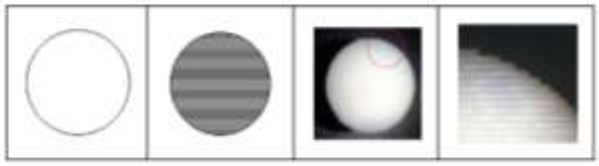

Figure 7 An illustration of the layer-based additive manufacturing processes and related stair-stepping effect.

Halle, Germany et al. (2019) Introduced that under certain printing conditions, current 3D printing applications in dentistry may be inappropriate. The study looked at the surface quality of the form 2 SLA printer models. The results have shown that a curve and suitable knowledge are necessary in dental applications to optimize 3D printing processes. The research was published in 2010 in the journal "Dental Architecture." It was included in 3D printed dental products series of the European Academy of Dental Surgery, the European Dental Journal

Printing Parameters	Selected Settings
Printing speed (layer thickness)	0.025 slow (layer thickness: 25 μm) [S1]
	0.05 standard (layer thickness: 50 μm) [S2]
	0.1 fast (layer thickness: 100 μm) [S3]
Inclination (support structure)	0° (without support structure)
	15° (with support structure)
	(canine up, molar down)
Model structure	hollow body [H]
	solid (full) body [F]

Figure 8 Printing parameters and selected (user-defined) settings

Hany Hassanin et al. (2018) Explored that AM surface improvement technology having a promising future ahead of it, allowing for the production of high-quality AM metal parts. The results show that the surface roughness obtained does not meet the surface requirements of many niche applications, including aerospace and biomedical applications. Chemical and electropolishing are also likely to produce unfavorable chemicals and contaminations. The two methods are equally true, and research into the current AM process will continue.
The final chapter states that AM polishing or surface modification of AM products research is still in its early stages, and that many efforts will be needed to complete it

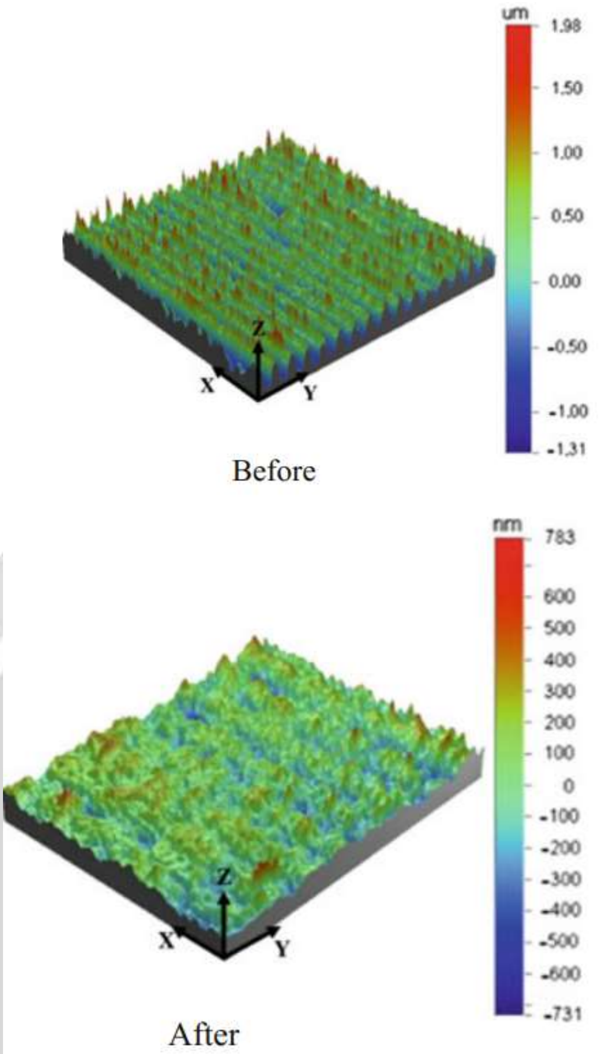

Figure 9 Surface topography before and after LP

Mohammad S. Alsouf et al. (2017) Represented that Six successful 0 percent infill density printed parts were measured using a precision measuring instrument in this work using the desktop low-cost FDM 3D printer. The printed pieces were not polished after they were printed. We assume that the solidification phase during the manufacturing process made the inner faces of 0 percent perspectives rougher than the outer faces of printed pieces. When the nozzle diameter and layer height were 0.5 mm and 0.3 mm, respectively, the lowest surface roughness behavior was 1.350.27 mm (part no.1) at 0° measuring direction. At 45° measuring direction, the highest surface roughness behavior was 34.941.04 mm.

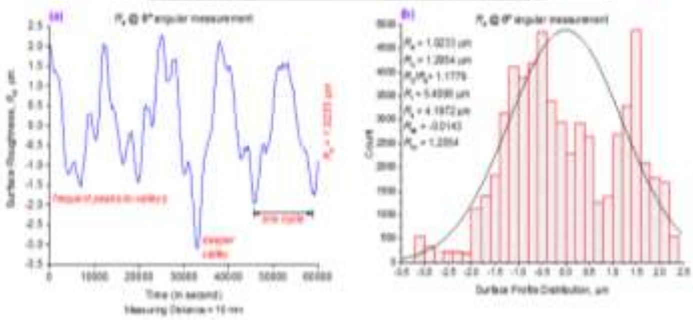

Figure 10.1 Surface roughness @ 0° (a) height profile and (b) distribution profile

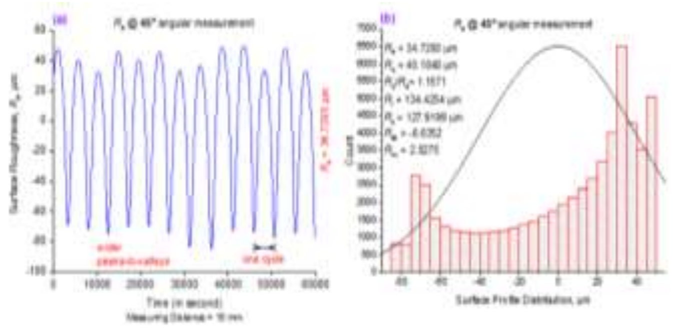

Fig-10.2: Surface roughness @ 45° (a) height profile and (b) distribution profile

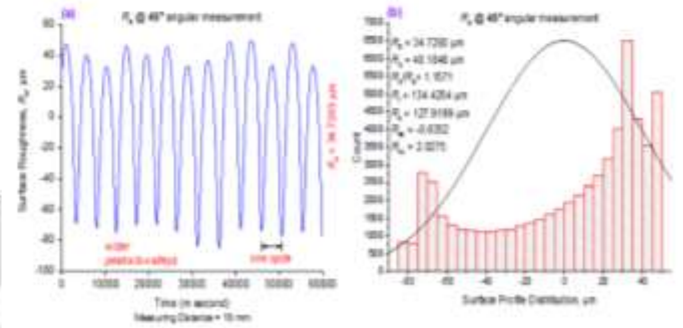

Fig-10.3: Surface roughness @ 90° (a) height profile and (b) distribution profile

D Chaidas et al. (2016) Reserch that the current study looks into the surface roughness of 3D printer models. All models were created through the addition of solid material, a process known as fused filament fabrication (FFF) The influence of the temperature factor on surface roughness was investigated. All surface roughness parameters Ra, Rz, Rt, and Rsm decreased (smoother surfaces) as the temperature increased from 210 °C to 230 °C.

The surface texture parameters measured during this examination were the following:

Ra (µm): the arithmetic mean surface roughness (arithmetical mean of the sums of all profile values). Ra is by far the most commonly used parameter in surface finish measurement and for general quality control. Despite its inherent limitations, it is easy to measure and offers a good overall description of the height characteristics of a surface profile.

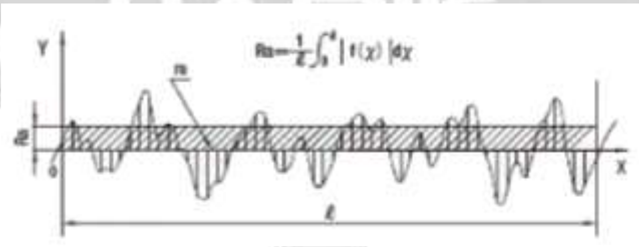

Figure 11.1 Surface texture parameters

Rz (µm): surface roughness depth. It is the arithmetic mean value of the single roughness depths of consecutive sampling lengths.

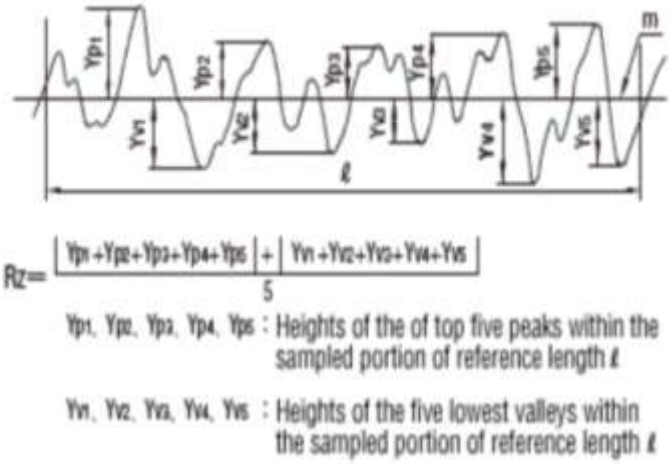

Fig-11.2: Surface texture parameters

Rt (µm): total height of the roughness profile, i.e., the vertical distance between the highest peak and the lowest valley along the assessment length of the profile. This parameter is very sensitive to the high peaks or deep scratches.

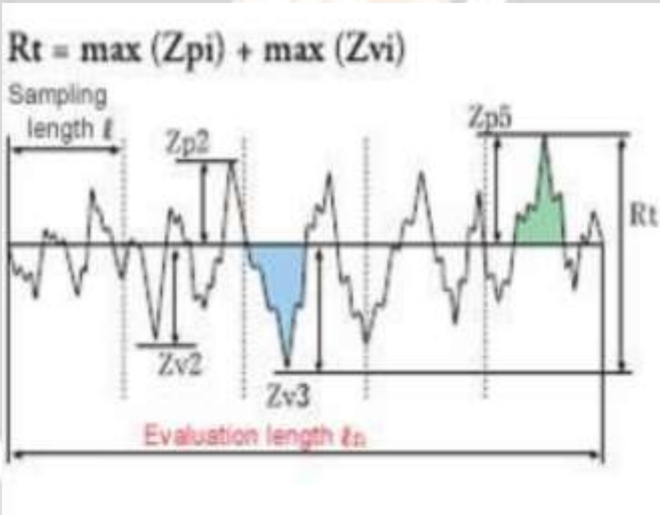

Fig-11.3: . Surface texture parameters

Kovan V. et al. (2018) Explored that the effect of the surface roughness on layer thickness and printing temperature of PLA samples fabricated with FDM was studied. Increasing layer thickness at higher printing temperatures in upright printing direction increases surface roughs. The application of various printing parameters for different materials will contribute to the development of engineering designs.

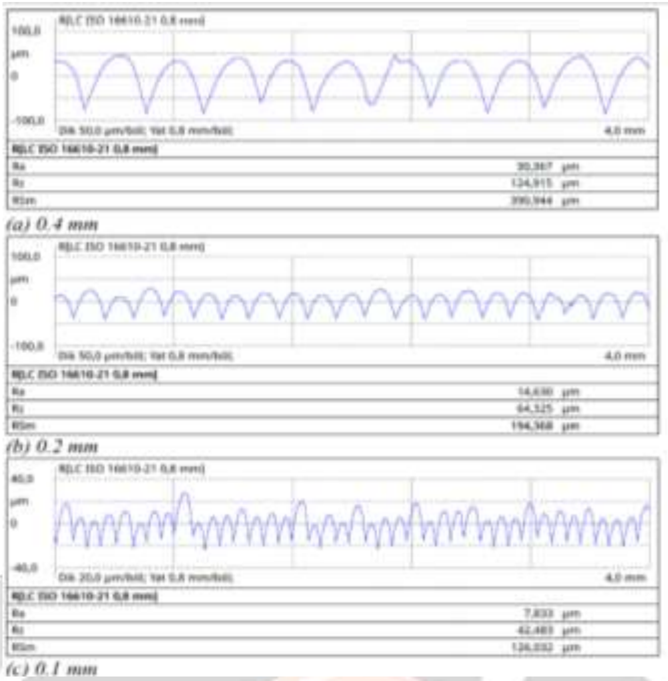

Figure 12 Surface profiles for different layer thickness at 210 °C

Ahmed Elkaseer et al. (2020) Shows that 3D printer can improve surface quality at a low tilt angle by adding unplanned layers on top of a planar surface. The common layer-based technique better prints higher angles. This seems to be mainly because the extruder axis is not perpendicular to the printing direction and the tip of the dust is scratched. Another topic that requires further research is the impact of varying dose height on surface quality. The effect of print speed on surface ruggedness is also a subject that must be studied further.

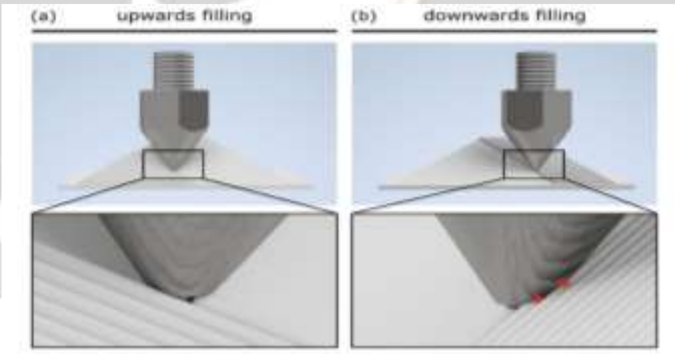

Figure 13 Surface texture parameters

Comparison of different study carried out in non-planner additive manufacturing based on FFF is illustrated in below table 1.

Sr no.	Author	Properties				
		Nozzle diameter	Print speed	Layer height	Material	Temperature
1	Daniel Ahlers [1]	0.4 mm	NA	0.3mm	PLA	NA
2	Mohammad S. Alsoufi [2]	0.3 mm	30 mm/s	0.4 mm	PLA/ABS+	220 °C
3	Abdullah T. Alsharhan [3]	0.4 mm	100 mm/s	0.4 mm	PLA/ABS	210 °C
4	John C.S. McCaw [6]	0.4 mm	NA	0.2 mm	PLA	216 °C
5	Mohammad S. Alsoufi [10]	0.5, 0.2, 0.3 mm	30 mm/s	0.1, 0.2, 0.3 mm	PLA +	220 °C
6	D Chaidas [11]	0.4mm	30-300 mm/s	NA	PLA	180-260 °C
7	Kovan V [12]	0.2 ,0.4 ,0.6 mm	60 mm/s	0.1, 0.2, 0.4 mm	PLA	190, 210, 230 °C
8	Ahmed Elkaseer [13]	0.4 mm	30 mm/s	0.2 mm	PLA/TPV	NA

Table 1 Properties of FDM Printing

3. CONCLUSION and FUTURE SCOPE

- Additive manufacturing is the core part of Industry 4.0 and FDM is widely used AM process in current industrial applications where surface roughness and Strength of the finished product are the key perquisite of the industries.
- As FDM is widely used AM process although there are few limitations which blocks the full penetration of this technology in current industrial revolution.
- Surface finish & strength of the final product are the main issues in FDM, many researchers are working on it to improve these parameters.
- Like other additive manufacturing processes, the stair stepping effect is the main reason of a low surface quality due to the layered nature of the process. Furthermore, the processing variables such as build direction, layer thickness and process parameters may significantly alter the obtained surface quality as a result of this effect.
- The stair stepping effect is a limitation for all layer manufacturing techniques particularly in the production of inclined or curved surfaces. When considering planar surfaces of the part, the stair stepping effect is expected to increase with increasing layer thickness and decreases with increasing inclination angle.
- Few researchers have started working on non-planner additive manufacturing which eliminates the stair stepping effect and improve surface finish and strength of 3d printed part.
- Further New Mechanism can be developed to eliminate all the surface finish error where the print nozzle is always perpendicular to printing direction in non-planner 3d printing.

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