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Significance of Fdm Printing Parameters on The Surface Roughness of 3d Printed Component

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Abstract

In the field of manufacturing, or 3D printing transformative potential. This innovative technology allows us to create three-dimensional objects that have complex designs at the production level. It is necessary to apply the best process parameters to gain the promised technical properties to the final printed product. This research paper explores the field of additive manufacturing and process parameter optimization, aiming to find optimal settings for 3D printing to get the desired results. By systematically experimenting with different printing parameters such as layer height, extruder temperature, feed, travel speed, raster angle, filament material, etc. we intend to pinpoint specific conditions that give the highest levels of performance at the output product. We majored in the surface roughness characteristic of the component with the help of surface roughness tester. Analysis of ANOVA is used to determine the 3D printing parameters and calculate the respective percentage contribution of control factors. The study shows that fill density highly influences the surface finish of the 3D printed component,where as printing speed has very less effect.

Keywords: 3D Printing, Printing Parameters, Surface roughness, ANOVA

Introduction

With the introduction of advanced technologies, the manufacturing industry has witnessed a revolutionary change, among which 3D printing stands as a formidable game changer. 3D printing has revolutionized the manufacturing industry through rapid prototyping, intricate customization, and reduced lead time, transforming traditional production methods. However, Optimizing process parameters is a critical prerequisite to achieving precise output products, enhancing time efficiency, ensuring feasibility, and fully unlocking the transformative potential of 3D printing technology. The strategic calibration of these parameters is the basis for realizing the technology's capabilities in delivering accurate, efficient, and impactful manufacturing outcomes.

This research paper seeks to discern the optimal 3D printing process parameters, encompassing factors like layer height, extruder temperature, feed rate, travel speed, raster angle, and printing material. The primary objective is to achieve superior surface finish at the output product, efficiency in terms of time, and the overall feasibility of the printing process. FDM process was used for experimenting along with PLA as printing material.

This paper is structured to guide readers through the introductory context, the research methodology employed, the presentation and analysis of findings, and a discussion that contextualizes the implications of the results within the broader landscape of additive manufacturing. Ultimately, this research paper aspires to contribute not only to the advancement of 3D printing technology but also to the broader understanding of how process parameters impact the final output characteristics.

Literature Review

The literature shows that the PLA+ is the most extensively used material and provide better mechanical properties when used for FDM. Tymark et al. [1] examine the mechanical properties of the PLA and ABS material and the results showed that PLA material has maximum tensile strength over ABS material. Polymers 2021[2] explored the FDM process and concluded that the FDM printed parts can sustain the stresses in similar way to the components manufactured by methods such as injection moulding. Radhwan et al. (2020) [3] focused on improving the surface roughness of 3D printed parts through the manipulation of outline speed, layer height, and extruder temperature. Their research illuminated the significance of layer height in influencing the surface quality and part accuracy. Notably, it was found that extruder temperature and outline speed have minimal effect on the surface roughness. The study conducted by Nagarjuna Maguluri et al. (2022) [4] examined the impact of printing settings on the shore hardness of 3D printed components through the use of the Taguchi L9 orthogonal array and S/N ratio analysis. In this instance, PLA was printed using the FDM method. C Burke et al 2020 [5] studied the effect of variation in parameters with the surface finish of the 3D printed component using 12 step Taguchi process, which concluded that infill percentage, orientation and nozzle diameter does not affect the surface rough.

Materials and Methodology

To the experiment FDM based 3d printing machine (Creality Ender-3) was used to print the testing specimen. The material used was eco friendly and biodegradable in nature. It requires the temperature of 205-225℃ while printing. The required CAD design was developed in the CATIA software and was exported in .STL format to feed it to the Ultimake Cura software. The designed component was a cuboid having dimensions as X= 30mm,Y= 30 mm and Z= 10 mm. Taguchi DOE was implemented, which helps determine the optimal printing parameters. The Taguchi L9 orthogonal array was used as a basis for conducting the research, as shown in Table 1.For the experiment three parameters were varied i.e. fill density, extrusion temperature and printing speed Table 1.The parameters were selected by refering previous research papers and through suggestions of experts from industry [ ].The levels of other printing parameters were kept constant as shown in Table 2. A test for surface roughness was conducted on the specimens using surface roughness tester (Mitutoyo SJ-201), as shown in Figure 1. Surface roughness tester is a device which calculates the roughness of the workpiece in terms of Ra value. The specimen has high surface finish if the Ra value is low and low surface finish if the Ra value is high. The following Equation (1) is used to determine the S/N ratios,

$$S/N = -10Log\left[\frac{1}{n}\Sigma_{i=1}^{n}\ \frac{1}{y_i^2}\right]$$

Table.1. Variable parameters with levels

Sr.No	Control Factors	Units	1	2	3
1	Fill Density	%	55	75	95

2	Extrusion Temp	℃	205	215	225
3	Print Speed	mm/sec	30	50	70

The most ideal level of input printing settings is the one with the smallest S/N ratio.
To determine the percentage contribution of each printing parameter ANOVA was carried out .

Table.2. Printing parameters

Sr.No	Parameters	Levels	Units
1	Nozzle Dia	0.4	mm
2	Layer Height	0.2	mm
3	Raster Angle	90	degrees
4	Infill Pattern (Top & Bottom)	Grid (Line)	-
5	Filament Dia	1.75	mm
6	Wall Thickness	0.4	mm
7	Build Orientation	Flat	-

To test the surface rough roughness the top surface of the cuboid was divided in to three section as a,b and c. The roughness test was carried out on each individual section as shown in Figure 1 and average Ra value was calculated as mentioned in Table 3.

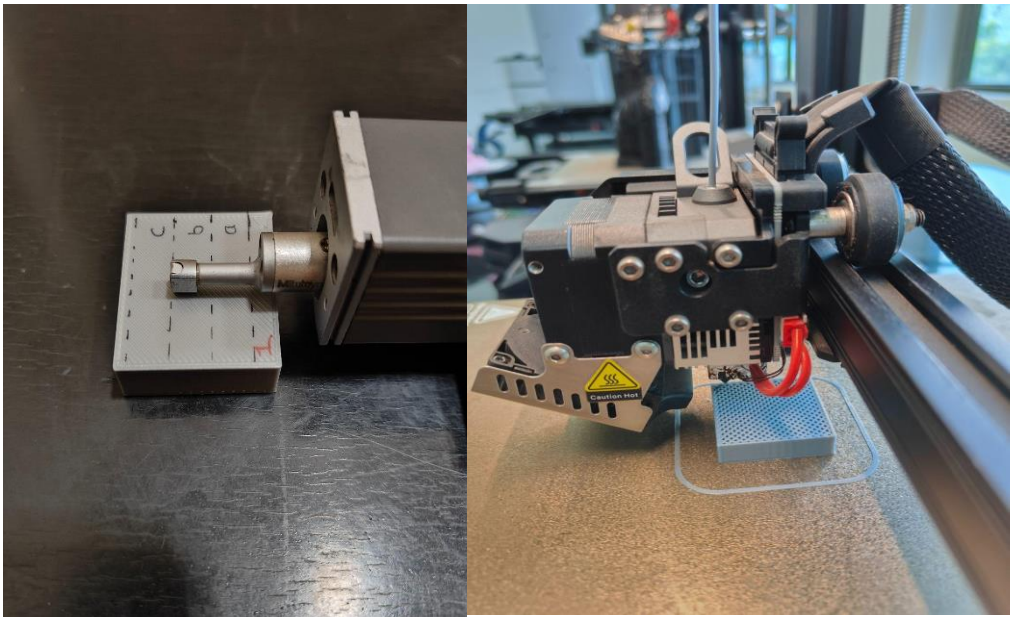


Figure.1. Printed specimen and Surface roughness testing

Results and discussions

Post experimental values were obtained as mentioned in the Table 3. In order to get the best possible combination of printing parameters, means and S/N ratios were determined. MATLAB software was used to evaluate the experimental data ,as shown in Table 4. On the basis the results shown in the Table 4 ,it could be stated that surface roughness of the specimen was affected by the fill density preceded by extrusion temperature and printing speed. Figure 2 shows the main effect plot for S/N ratios. As shown in Table 4 and Figure 2 ,a combination of A2B3C1,i.e. fill density (A) at 75%,extrusion temperature(B) at 225°C ,and printing speed(C) at 30mm/sec are the most optimal printing parameters to obtain better surface roughness in FDM process.

The ANOVA results are shown in Table 5, where it is discovered that fill density, printing speed and extrusion temperature have the greatest effects on the surface roughness of FDM manufactured components.Table 5 illustrates how fill density, extrusion temperature, and printing speed contributed in percentage terms to surface roughness: approximately 31.47%, 22.89%, and 3.64%, respectively.

Table.3. Post experimental results

Sr. No	**Fill Density,%**	**Extrusion Temperature, °C**	**Printing Speed, mm/s**	**Average Ra value**
1	55	205	30	3.09
2	55	215	50	4.31
3	55	225	70	5.27
4	75	205	50	4.27
5	75	215	70	4.32
6	75	225	30	2.84
7	95	205	70	4.83
8	95	215	30	7.38
9	95	225	50	4.11

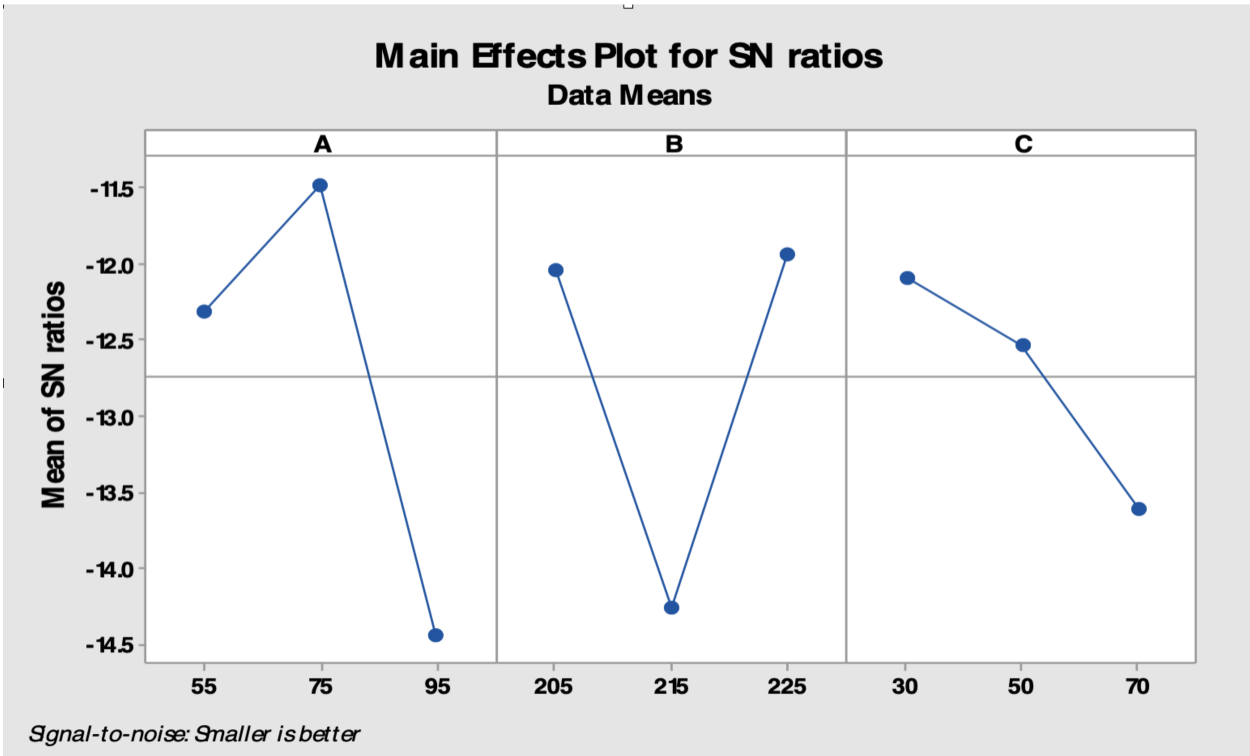
Table.4. Response table for S/N ratios (Smaller is better)

Sr.No	**Printing Parameters**	**Mean S/N ratio**				
		1	**2**	**3**	**Max-Min**	**Rank**
1	Fill density (%)	-12.32	**-11.47**	-14.45	2.98	1
2	Extrusion Temperature (°C)	-12.04	-14.26	**-11.94**	2.32	2
3	Printing Speed (mm/sec)	**-12.09**	-12.53	-13.61	1.53	3

Table.5. ANOVA results for Surface roughness

Parameters	DOF	Sum of squares	Mean squares	Contribution(%)
Fill density	2	3.3161	2.15	30.79
Extrusion Temperature	2	3.209	1.60	22.89
Printing Speed	2	0.509	0.25	3.64
Error	2	5.985	2.99	42.69
Total	8	14.019		100

Figure.2. S/N ratios for surface roughness,where A is fill density, B is extruder temperature and C is printing speed.



Conclusion

In this study, the three primary printing parameters—fill density, printing speed and extrusion temperature—were used to experimentally and analytically analyze the surface roughness of the 3D printed component. Using the Taguchi approach, nine experiments were conducted.

The following conclusions can be drawn from the data:

- The best printing settings for improved surface finish are 30 mm/s, 225°C for the printing speed and extrusion temperature, and 75% fill density.
- In terms of Ra value, the average surface finish at these settings is 2.84 µm.

- The study shows that, with a contribution of 31.79%, fill density has the largest significant impact on surface finish, while printing speed has the least significant impact, contributing only 3.64%.
  This study addressed the impact of three different characteristics on surface roughness: extrusion temperature, fill density, and printing speed. It is possible to research how these factors affect tensile strength, hardness, dimensional accuracy, and other factors.It is possible to research how different printing settings, including layer height, orientation, material, etc., affect the 3D printed object.

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