

# Surface Roughness of PLA, PETG, and Metal Copper Materials: Impact of Layer Thickness and Infill Design

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## ABSTRACT

The excessively rough surface of the printed parts is a disadvantage of the 3D printer for the production of fused filaments due to the fact that they are applied layer by layer. This study looked at how surface roughness affects layer thickness and infill design of 3D machine settings when using a 1 cm<sup>3</sup> block printed with PLA, PETG and metallic copper. The roughness of the block was evaluated using a non-contact profilometer and all materials had their layer thicknesses: 0.1, 0.2 and 0.3 mm, as well as their infill scheme changed to 30%, 40% and 50%. As the thickness of the layer increases, so does the surface roughness of all materials. Conversely, the surface roughness is not affected by the infill design parameter.

**Keyword:** Additive manufacturing; surface roughness; fused filament creation; 3D printer.

## INTRODUCTION

The approach, which generates geometric three-dimensional (3D) structures layer by layer through computer-aided design (CAD) data, is known as additive manufacturing, or more commonly, 3D printing. Due to the layer-by-layer deposition, one disadvantage of additive manufacturing (AM) is the very rough surface of the printed object, especially when using the fused filament fabrication (FFF) practice. This study investigates the effects of different build angles, layer heights, and print speeds on the perceived roughness of material samples produced using fused deposition modeling, or FDM, in three dimensions [1]. This study uses FDM 3D printing with different layer heights to investigate surface roughness and printing time on PLA material. The model was produced on a 3D printer known as Reality Ender 3. For a layer height of 0.15 mm and 0.2 mm, the surface roughness of the optimizer and the print time are 9.08  $\mu\text{m}$  and 158 min (Lh 0.15 mm) and 10.48  $\mu\text{m}$  and 120 min respectively for a layer height of 0.20 mm [2]. An experimental inquiry and report is used to assess the surface quality of Poly-Jet 3D printing technology (PJ-3DP). PJ-3DP's additive manufacturing technique uses photopolymer jet droplets that are instantly cured under UV light to create physical structures layer by layer. [3]. Therefore, relevant questions arise, such as whether the materials, environment and settings of the FFF machine affect the surface roughness. By examining the surface roughness of PLA, PETG, and metallic copper printed parts, the FFF machine layer thickness and infill design parameters were adjusted.

## METHODOLOGY

The project makes use of an open source, inexpensive to maintain fused filament fabrication Anet A8 (do-it-yourself kit) 3D printer *Figure 1*, illustrates the processes in the FFF process, from CAD model creation to post-processing to produce the finished output.

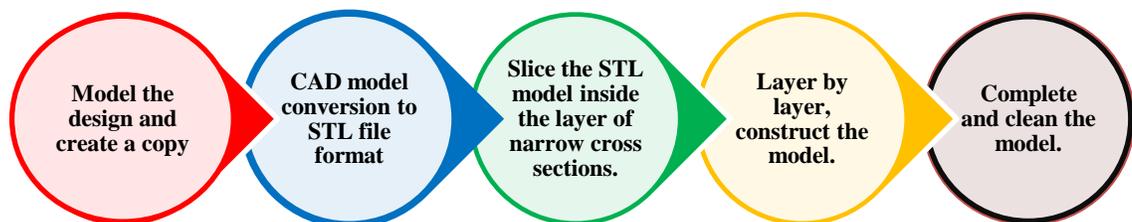
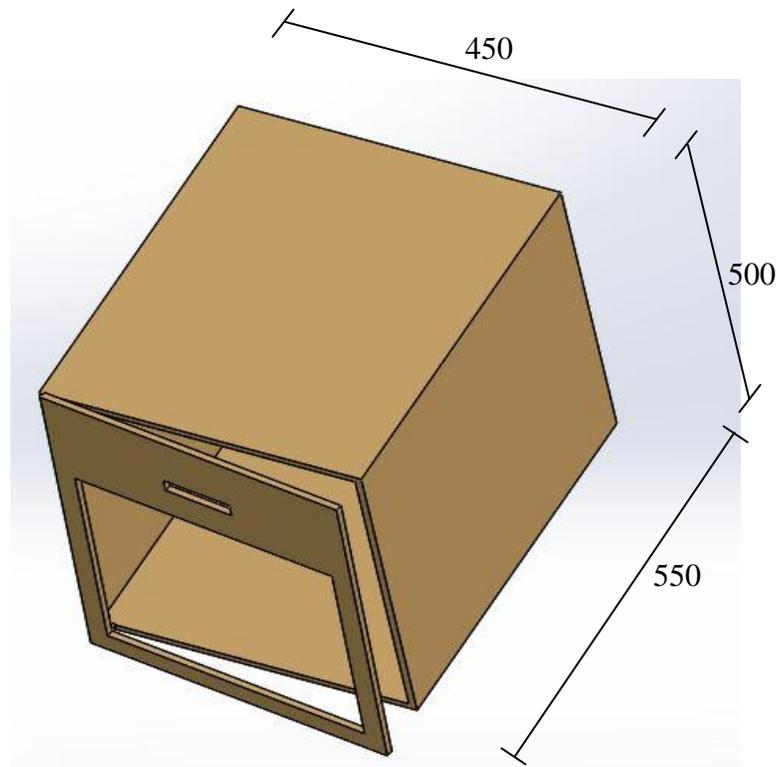


Fig 1: The FFF process's fundamental procedure

The 3D printer was housed in an enclosed chamber, like the one shown in *Figure 2*, to regulate the surrounding environment and achieve a good surface quality. Likewise, this could improve the 3D printer's performance by raising in an attempt to lessen warping and oxidation, the room temperature. [3]. A square measuring 10 mm (L), 10 mm (W), and 10 mm (H) basic geometry block was created in this study utilizing a 3D printer. In order to lower the total number and expense of the printed item, a specified size was chosen *Table 1* provided an overview of the experiment parameters. Both PLA and PETG, two types of plastic, were employed as materials in these research. Conversely, metal filament was studied using a copper substance. Instead, a metal filament was investigated via a copper material. The infill density was changed at 30%, 40%, and 50% during the layer's 0.1 mm to 0.3 mm thickness change. These machine parameters had been selected as an initial inquiry into how these factors affected surface roughness and because of the restrictions of the machine employed in the experiment.



**Figure 2: Three-dimensional printer enclosed room**

In order to examine the impact of layer thickness, for printed block samples, the surface roughness (Ra) was evaluated alongside the block using a 3D non-contact profilometer.

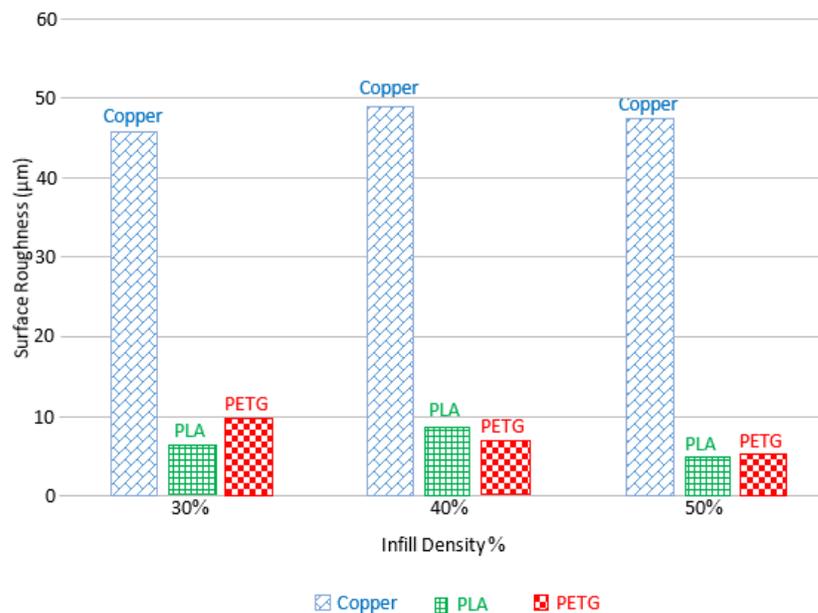
**Table 1: An overview of the working design of the 3D printer**

Parameter	Values
Filaments materials	PLA, MT-Copper, PETG
Shades of colour	Blue, Brown, and Black
AM process	FFF (fused filament fabrication)
Block of volume (mm <sup>3</sup> )	10 x 10 x 10
Layer Height (mm)	0.1, 0.2, 0.3
Density of Infill (%)	30, 40, 50
Nozzle temperature (°C)	195, 205, 220
Velocity of printing (mm/s)	30
Extrusion of Material (layer width) (mm)	0.48
Temperature of the Bed (°C)	30,60

**RESULT & DISCUSSION**

An illustration of the roughness comparison for infill density at 0.2 mm layer thickness for copper, PLA, and PETG is presented in *Figure 3*. This graphic demonstrates that the infill parameters essentially have no effect on roughness. This is seen by the bar chart for infill density at 30%, 40%, and 50%, which has the exact same pattern (type). This comes about due the surface roughness being measured on the block's side instead of the top. Layer thicknesses of 0.1 mm and 0.3 mm, this pattern is nearly the same. Furthermore, it is evident that metal has a much higher Ra value as a single of the thermoplastic polyesters. This indicates that, in contrast with PLA and PETG, the copper material brought in harsher surface quality for this open-source printer.

The surface roughness values for increasing layers of fill at 40% infill design are shown in *Figure 3*. The graph's pattern indicates that for all materials, grew layer thickness correlates to higher surface roughness values. This is a result of the block's surface grew softer owing to the lesser covering. For printed blocks with 30% and 50% infill density, the end result is very similar.

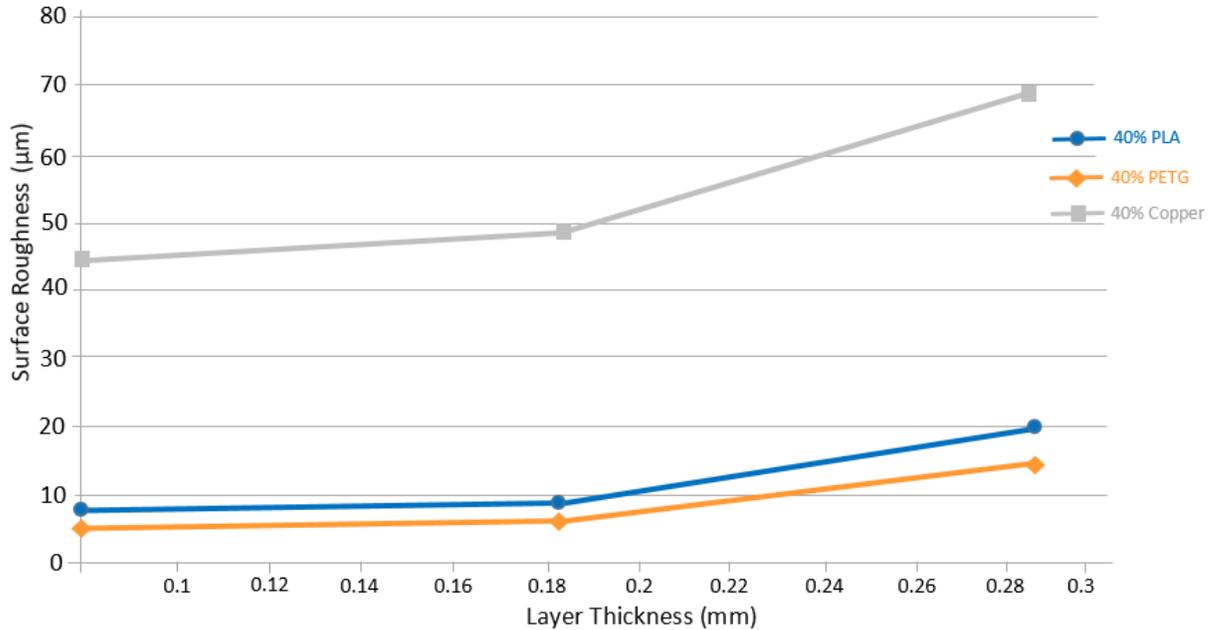


**Figure 3: Graph of surface roughness against infill design for 0.2 mm layer thickness**

**Table 2: Displays the roughness results from the trials for various materials and 3D printer settings.**

Parameters		copper	PLA	PETG
Layer Depth <i>t</i> (mm)	Infill (%)	Roughness, $R_a$ (µm)	Roughness, $R_a$ (µm)	Roughness, $R_a$ (µm)
0.1	30	52.5	5.5	8.0
	40	41.9	7.1	5.2
	50	39.9	3.9	4.1
0.2	30	44.6	5.8	9.5
	40	48.1	8.2	6.4
	50	46.7	5.0	5.1
0.3	30	69.9	5.4	26.9
	40	40.2	19.1	14.8
	50	48.2	11.4	17.0

The surface roughness values for increasing layers of fill at 40% infill design are shown in *Figure 4*. The graph's pattern indicates that for all materials, grew layer thickness correlates to higher surface roughness values. This is a result of the block's surface grew softer owing to the lesser covering. For printed blocks with 30% and 50% infill density, the end result is very similar.



**Figure 4: The correlation between layer thickness and surface roughness at 40% infill density.**

## CONCLUSION

An investigation into the layer thickness's effect on 3D printing block showed that while infill density has a minor effect, changes in surface roughness is greatly impacted by layer thickness. It also turns out that all of the materials produced via 3D printing in the investigation had a roughness range of 5 to 100 µm.

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