Society of Production Engineering

ICPES 2025

40th INTERNATIONAL CONFERENCE ON PRODUCTION ENGINEERING - SERBIA 2025

DOI: 10.46793/ICPES25.380DJ

University of Nis Faculty of Mechanical Engineering

Nis, Serbia, 18 - 19th September 2025

INFLUENCE OF LAYER HEIGHT ON THE SURFACE ROUGHNESS OF FDM PRINTED PETG PARTS

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Abstract: *This paper investigates the influence of layer height, one of the key parameters in Fused Deposition Modeling (FDM) 3D printing, on the surface roughness of parts manufactured using PETG (Polyethylene Terephthalate Glycol) material. Specimens were printed with different layer heights (0.1 mm, 0.2 mm, and 0.3 mm) under identical printing conditions to evaluate how this parameter affects surface quality. Surface roughness (Ra) was measured using a profilometer, and the results indicate that increased layer height leads to higher surface roughness values, resulting in a rougher surface finish. The findings highlight the importance of selecting an appropriate layer height to achieve the desired surface quality, particularly in applications where aesthetics or functional surface characteristics are critical. This study contributes to the optimization of PETG 3D printing processes in contexts where surface finish is of particular importance.*

Keywords: *3D printing, Fused Deposition Modeling, PETG, Surface Roughness.*

1. INTRODUCTION

Fused Deposition Modeling (FDM) is one of the most widely used additive manufacturing technologies due to its affordability, simplicity, and versatility in material selection [1]. Among the various thermoplastics used in FDM, Polyethylene Terephthalate Glycol (PETG) has gained significant attention for its excellent balance between mechanical properties and ease of printing. However, one of the main challenges in FDM is achieving a high-quality surface finish, which is critical for both functional and aesthetic applications.

Surface roughness is influenced by multiple process parameters, with layer height being one of the most critical. As the layer height determines the vertical resolution of a print, it directly affects the stair-stepping effect that contributes to surface irregularities. Lower layer heights typically result in smoother surfaces but also increase print time, while higher layer heights reduce production time at the cost of surface quality.

Many researchers have studied the effect of layer height on the surface roughness of PETG materials.

Taqdisillah et al. in their research examined the influence of layer height (0.1–0.3 mm), filling geometry and nozzle temperature on the surface roughness of PETG materials. Using the Taguchi method, it was determined that the height of the layer had a dominant effect on Ra, which ranged between 7.8 and 22.3 µm [2].

Christodoulou et al. studied the dimensional accuracy of parts printed with PETG as a function of layer height and print speed. It was found that layers with a thickness of 0.1 mm give the smallest deviations in dimensions and the least roughness, while 0.3 mm generates larger deviations and higher roughness [3].

Kadhum et al. investigated the effects of different printing parameters on the quality of PETG, PLA and PLA+ materials. PETG showed an average roughness of Ra = 6.4 µm, with the hexagon-shaped infill giving the best results [4].

Barrios and Romero specifically examined how printing parameters affect the surface quality of 3D-printed PETG. They investigated various parameters, including layer height, print temperature, print speed, print acceleration, and flow rate. Their results indicated that flow rate and print acceleration have the most significant impact on surface quality [5].

Akande et al. performed some experiments to optimize the parameters for two responses, dimensional accuracy and surface roughness. They assuemed layer height, fill density and speed of deposition as optimizing parameters. They observed that optimum factor level was different for dimensional accuracy and surface roughness. For good dimensional accuracy, layer height should be high but for low surface roughness, layer height should be low [6].

Anita et al. have analysed the effect of road width, layer height and printing speed on surface roughness of FDM build part using taguchi's technics. Objective of the experiment was to minimize the surface roughness (Ra value). They found out that the interaction between the layer height and speed of printing and, speed of deposition and road width have negligible contribution on surface roughness [7].

P. Vijay et al. conducted an investigation into the impact of orientation on surface roughness. Their findings revealed that as the orientation increases, there is an initial slight rise in surface roughness, followed by a gradual decrease. This nuanced relationship highlights the complexity of how orientation influences the texture of surfaces [8].

Che Mat et al. conducted a detailed study on the impact of layer height on surface roughness in additive manufacturing. Their findings revealed that the smoothest surface achieved a roughness measurement of Ra 4.2. This optimal surface quality was attained with a layer height of 0.1 mm and an infill density of 50%, highlighting the importance of these parameters in enhancing the finish of 3D-printed objects [9].

2. MATERIALS AND EQUIPMENTS

In this work, Solidworks 15x64 edition CAD software was used to model the test specimens. The 3D CAD model was saved as an STL file and imported into Ultimaker Cura 4.11.0 software (Figure 1), where layer heights were varied from 0.1 mm to 0.3 mm, while other parameters were standard.

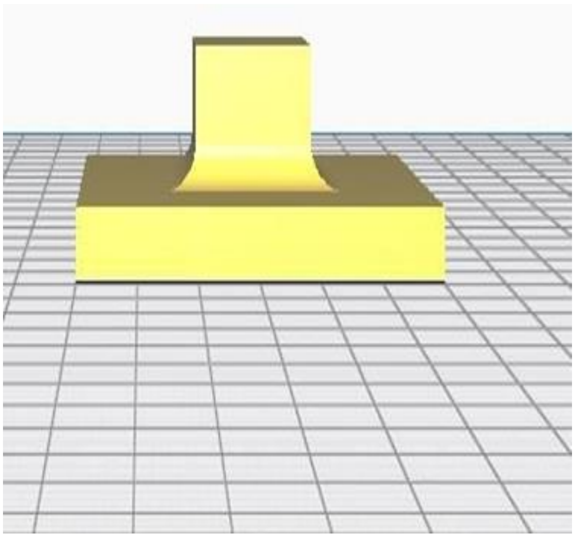

Figure 1. Model in UltimakerCura software

Specimens for surface roughness measurement were printed on low-cost Creality 10-s printer, which is located at Faculty of Tehnical Science in Kosovska Mitrovica (Figure 2). Characteristics of printer are: Build area of 300x300x400mm, nozzle diameter 0.4, print speed normal60mm/s - max 100mm/s, and with wide range of materials like PLA, PETG, TPU, ABS, But ABS, PETG and PLA are definitely the most represented.

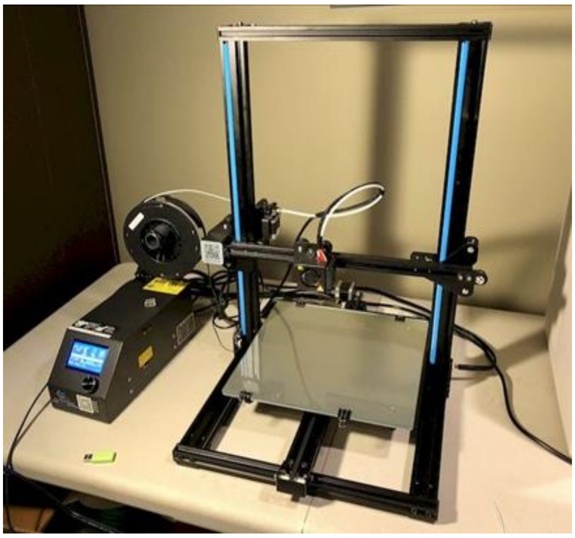

Figure 2. Creality CR 10-s 3D printer

Surface roughness was measured on a computerized measuring device Talysurf-6 (Figure 3) with an ISR-C002 INSIZE measuring device connected to a computer. Basic data about the device: device dimensions are 141x55x40 mm, measuring range 160 µm, measurement accuracy ±10 %, resolution 0.01 µm, movement speed 0.02 —/s, 0.04 —/s, measurement of 21 roughness parameters.

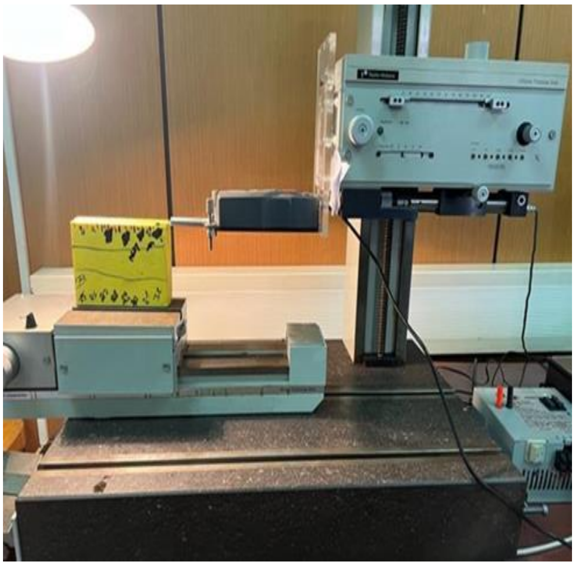

Figure 3. Talysurf-6 measuring system

3. EXPERIMENTAL RESULTS AND ANALYSIS

In Figure 4, we can see the effect of changing the layer height (from 0.1 mm to 0.3 mm), while the other parameters remained standard, on the surface roughness of the specimens made with PETG material.

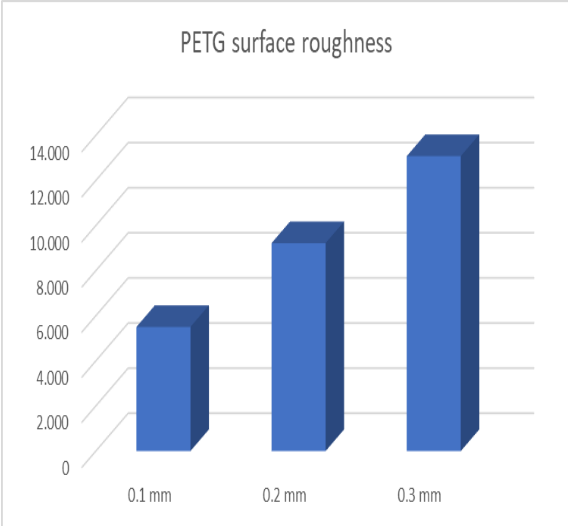

Figure 4. Surface roughness of PETG material

A layer height of 0.1 mm resulted in the lowest surface roughness (Ra=5,503 µm), which indicates a relatively good quality and smoother surface suitable for parts where aesthetic appearance is important.

A layer height of 0.2 mm resulted in a higher surface roughness (Ra=9.221 µm), which is in line with expectations, because higher layers create a step effect between the print layers.

The layer height of 0.3 mm resulted in the highest surface roughness (Ra=13,078 µm), which indicates an obvious decline in the quality of the final surface treatment. These values are characteristic for fast printing and printing with low resolution, where the aesthetic appearance and quality of the surface are sacrificed due to the manufacturing time of the parts.

The tendency for roughness to increase with increasing layer height is expected, and confirms previous research that dealt with these researches. In addition to layer height, surface quality can be affected by many other factors such as printing speed, extruder temperatures, filament quality, cooling conditions, print angle and orientation.

4. CONCLUSION

Based on the conducted analysis, it can be confirmed that the layer height has a significant influence on the surface roughness of the parts made with FDM technology and PETG material. With an increase in the of the layer height, there is a marked increase in the value of the surface roughness Ra, which is a consequence of the step effect that occurs when applying layers of a larger cross-section.

As expected, based on the insight into the literature, the lowest roughness was obtained at a layer height of 0.1 mm, while the highest roughness was obtained at a layer height of 0.3 mm.

In addition to layer height, additional factors such as printing speed, temperature, filament quality and others can have a great impact on the quality of the manufactured parts.

The obtained results can serve as a guideline for the selection of printing parameters, especially in cases where the aesthetic and functional requirements of the surface are critical.

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