

EXPERIMENTAL ROUGHNESS TESTING OF 3D PRINTED FDM PARTS

Goran Čubrić¹Petar Čurković²

Abstract: This study investigates the surface roughness of 3D printed FDM (Fused Deposition Modelling) parts produced with a Prusa i3 3D printer. The PCE-RT 2000 surface roughness tester was used to evaluate the surface quality, following ISO 3274 standards. The study focussed on the Ra parameter, which quantifies surface irregularities, to determine how printing conditions affect surface properties. The results indicate that print orientation and layer height significantly affect surface roughness, suggesting potential ways to improve the quality of 3D printed components.

Key words: 3D printing, surface roughness, FDM, Prusa i3

1. INTRODUCTION

Surface roughness is a critical quality feature of 3D-printed components, influencing both their functional performance and aesthetic appeal. In Fused Deposition Modeling (FDM), a widely used additive manufacturing technique, the surface finish is inherently affected by the layer-by-layer deposition process, leading to characteristic stair-stepping effects and surface irregularities. These imperfections can adversely impact mechanical properties, such as fatigue strength and wear resistance, and may require additional post-processing, thereby increasing production time and costs.

The Prusa i3, an open-source FDM 3D printer, is renowned for its reliability and versatility, making it a popular choice among hobbyists and professionals alike. Its widespread adoption underscores the importance of understanding and optimising the surface quality of parts produced using this platform. It is widely used for printing very complex geometries [1],[2] both hard and soft robotic components [3],[4].

Recent studies have analysed the optimisation of FDM process parameters to enhance surface finish. Research published in the International Journal of Advanced Manufacturing Technology employed Response Surface Methodology (RSM), Particle Swarm Optimization (PSO), and Symbiotic Organism Search (SOS) algorithms were used to minimise the surface roughness of FDM parts. The findings indicated that PSO and SOS improved surface roughness by approximately 8.5% and 8.8%, respectively, compared to conventional methods [5]. Another study used the Taguchi method to optimize FDM printing parameters for Thermoplastic Polyurethane (TPU) parts, identifying layer thickness as a significant factor influencing surface roughness [6].

Similarly, in [7] the impact of nozzle diameter and layer height on the surface quality of PLA parts is analyzed, concluding that these parameters play a major role in determining surface finish.

Based on these theoretical insight, the present study aims to experimentally evaluate the surface roughness of 3D printed FDM parts produced using a Prusa i3 printer. By systematically varying key process parameters and using precise measurement techniques, this research aims to provide actionable insights for practitioners aiming to optimize surface quality in FDM-manufactured components.

2. PRINTER

The 3D printer used in this study is the Prusa i3 (Figure 1), a model widely used in both academic and industrial environments. Known for its precision and reliability, the Prusa i3 supports a variety of materials and offers customisable printing parameters.

¹Assoc. Prof. Goran Čubrić, University of Zagreb Faculty of Textile Technology, Prilazbaruna Filipovića 28a, Zagreb, Croatia, goran.cubric@ttf.unizg.hr

²Assoc. Prof. Petar Čurković, University of Zagreb Faculty of Mechanical Engineering and Naval Architecture, Ivana Lučića 5, Zagreb, Croatia, petar.curkovic@fsb.unizg.hr



Figure 1 –The used 3D printer Prusa i3

Key specifications of the Prusa i3 include:

- Printing technology: Fused Deposition Modeling (FDM)
- Material compatibility: PLA, ABS, PETG, and more
- Layer height range: 0.05 mm to 0.35 mm
- Nozzle diameter: 0.4 mm
- Build volume: 250 x 210 x 210 mm

PLA (Polylactic Acid) was chosen as the printing material for this study because it is widely available and easy to process..The parts were printed with a layer height of 0.2 mm and a nozzle temperature of 210°C to maintain consistency.

3. EXPERIMENTAL

The surface roughness tester PCE-RT 2000 (PCE Instruments UK Ltd., United Kingdom) was used to determine the surface roughness (Figure 2.). The roughness tester works following the touch method in accordance with ISO 3274 [8]. The parameter Ra is selected for analysing the surface structure and interpreting the results. Ra represents the average "roughness" or "irregularity" of the material's surface within a specific segment. The higher the Ra value, the rougher the surface of the materials. The sampling length was set default to 0.80 mm.



Figure 2– The surface roughness tester PCE-RT 2000

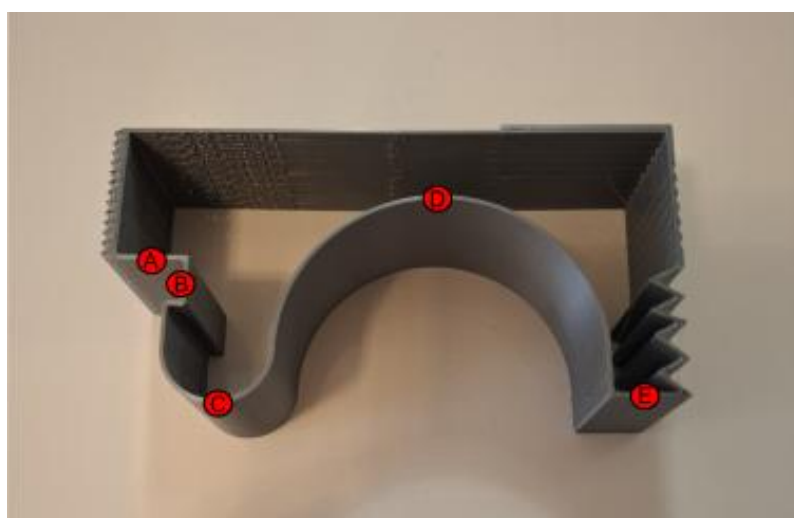


Figure 3– The 3D printed model with the marks on which the measurements were performed

Testing Procedure

1. Sample Preparation:

Test samples were designed as illustrated with Figure 3

2. Surface Roughness Measurement:

- The Ra parameter was chosen to represent average surface roughness.
- The sampling length was set to 0.80 mm, which aligns with standard practices for measuring small-scale roughness.
- Measurements were taken at five different points and mean roughness is calculated.

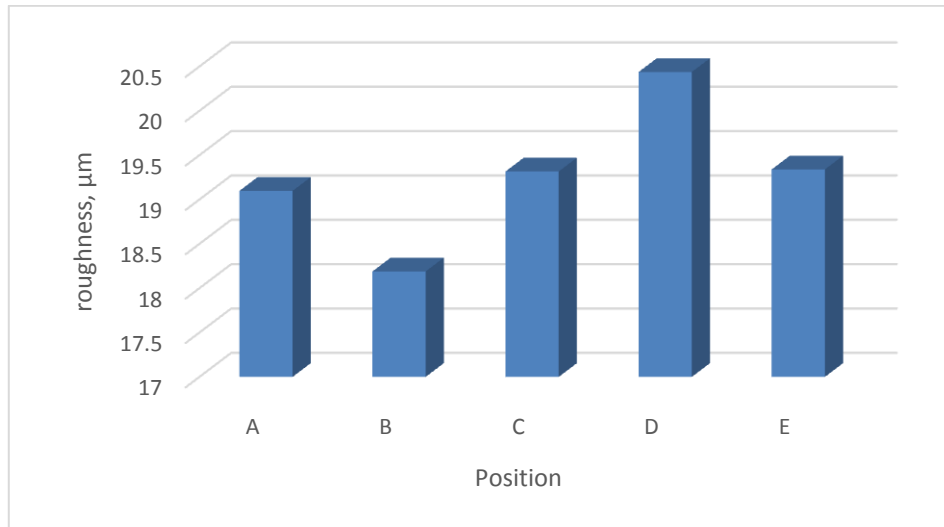


Figure 4– The mean roughness of 3D printed model at five positions

The data at Figure 4 presents mean roughness (in micrometers, μm) for five distinct positions (A, B, C, D, and E). The roughness values range from a minimum of 18.18884 μm (position B) to a maximum of 20.4377 μm (position D). The overall range is approximately 2.25 μm , showing a relatively small variation across all measured values. It is noticeable that the roughness in positions B and D deviate from the group. The observed differences may be because of instrument precision or environmental factors by sample preparation (e.g., vibrations, temperature). Also, printing orientation and layer height probably significantly influence surface roughness. All these parameters should be included in future research. Figure 5 shows the graphs generated by the surface roughness measuring device.

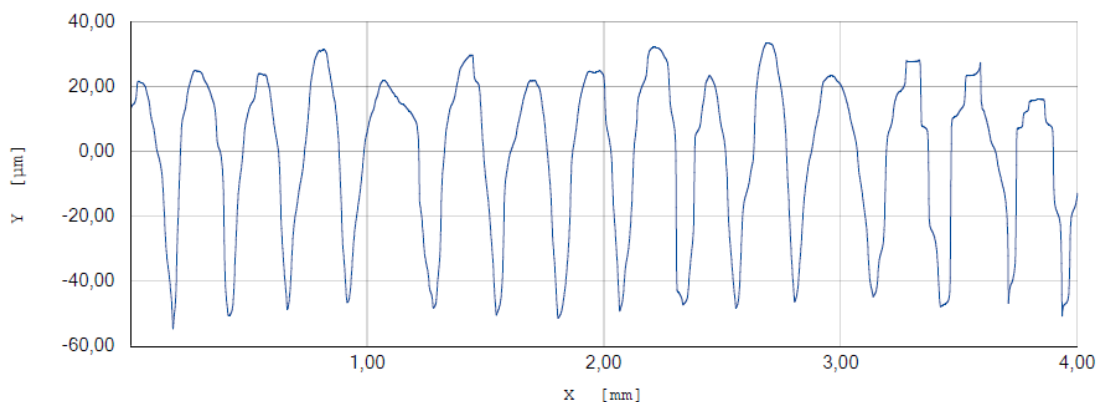


Figure 5–Characteristic illustration of Ra parameter results

4. CONCLUSION

This study conducted experimental testing of surface roughness on FDM (Fused Deposition Modeling) 3D printed parts using the Prusa i3 printer. Surface quality was analyzed with the PCE-RT 2000 surface roughness tester, adhering to ISO 3274 standards. The findings primarily focused on the Ra parameter, providing an average measure of surface irregularities.

The results indicate that surface roughness is influenced by factors such as printing orientation and layer height, as evidenced by variations in the Ra values measured across different sample positions. The roughness ranged from 18.18884 μm to 20.4377 μm , with minor deviations potentially arising from environmental conditions or sample preparation methods. These variations underline the complexity of maintaining consistent surface quality in 3D printing processes.

The study highlights the necessity of refining printing parameters and measurement methodologies to minimize surface irregularities and achieve uniform quality in FDM-printed parts. While this research provides initial insights into the relationship between process variables and surface roughness, further investigations are needed. Future work should incorporate a broader range of materials, printing orientations, and environmental conditions to comprehensively understand the parameters affecting surface quality.

In conclusion, this research serves as a foundational step in optimizing surface roughness in 3D printed FDM components. Its findings are instrumental for practitioners seeking to enhance the quality and functionality of 3D printed parts, ensuring better performance and reduced post-processing requirements.

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