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Tribological Behaviour and Surface Roughness Quality of 3D Printed ABS Material

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A B S T R A C T

Additive manufacturing or 3D printing is one of the newer methods of manufacturing. The basic difference to other types of production is that the material is added in the form of layers. There are many types of technologies in 3D printing, but the most common is fused deposition modeling. This technology uses different types of thermoplastic materials to build an object. This paper will present the tribological characteristics and surface roughness measurement of samples printed on a low-cost 3D printer using thermoplastic materials ABS.

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1. INTRODUCTION

3D printing or additive manufacturing is a technology that produces a functional and relatively complex working prototype directly from a digital representation of a spatial or three-dimensional (3D) model created in one of the CAD tools. 3D printing builds the model, unlike CAM technologies, which realize geometry by removing material. The construction of 3D models is based on digitally cut (sliced) model layers that are glued layer by layer in the physical space into the final shape. The advantage of building in layers is the creation of complex shapes that are almost impossible to create with classical methods. Using 3D technology, it is possible to build complicated structures within the model as well as thin layers [1].

Fused deposition modeling (FDM) is one of the most popular 3D printing technology. Most existing FDM machines use thermoplastic materials that are in the form of filaments for

extrusion and deposition. Polylactide (PLA) and Acrylonitrile butadiene styrene (ABS) thermoplastics are predominantly used in the process. Wire thickness of 1.75 - 3 mm is usually used. During 3D printing, the wire-shaped material is melted by passing a 0.4 mm diameter mold, and the production is done by axial movement. By stacking layers on top of each other, the object is created [2, 3].

One of the most important factors in the quality of parts is certainly the surface roughness, and it is most often expressed through the arithmetic roughness Ra [4]. We can describe tribology as a science and technology of surfaces that are in contact and relative motion, as well as supporting activities that should reduce costs resulting from friction and wear polymers can be picked as a solution in specific applications of machine construction because of their strength, chemical resistance, and self-lubricating ability [5,6].

Many researchers investigated surface roughness and tribological behavior of 3D printed parts.

Gurrala and Regalla [7] investigated the friction and wear behavior of ABS polymer parts made of FDM. They investigated the effect OF speed, LOAD, and orientation on the wear rate and friction coefficient of FFF parts. They concluded that speed has more effects on friction than orientation at a fixed load.

Norani et al., [8] used response surface methodology to determine the most optimal 3D printing parameters by analyzing the friction and wear coefficient of an ABS. The study found that layer height significantly affected the COF and wear rate. They discovered that a nozzle temperature of 234°C and layer height of 0.10 mm were the most optimal parameters to minimize wear rate and coefficient of friction.

Garg and Singh [9] used Nylon6-Fe composite material and investigated the friction and wear behavior of parts. They compared the friction and wear characteristics of the Nylon6-Fe composite WITH ABS filament. This experiment was carried out on the pin-on-disk setup by varying the load (5, 10, 15, and 20 N) and speed (200 and 300 r/min). They concluded that the newly developed composite has higher wear resistance than pure ABS material.

Hanon et al., [10] examined the tribological behavior of PLA and ABS polymers that had been 3D-printed with different colors at various printing temperatures. The results of the dynamic friction coefficient show that the PLA specimen is higher than the ABS specimen at all temperature ranges. The 3D-printed PLA specimen was tested with various settings; which found some inconsistencies; however, the use of different colors showed a clear dissimilarity.

Muammel *et al.* [11] examined the friction behavior of 3D printed PLA AND ABS with different colors and under alternative movements on cylindrical pairs of flat plastic plates. They found that dynamic and static friction factors were different.

Roy *et al.* [12] investigated the tribological behavior of 3D printed PLA and ABS polymers using a block-on-roller configuration. They analyzed the effects of the printing parameters on the tribological behavior of 3D printed ABS and PLA samples.

Nedić *et al.* [13]. used a tribometer with block-on-disc configuration and found a relatively lower coefficient of friction of 3D printed PLA samples than that from ABS samples.

Tahir et al [14] used Pin-on-disc dry sliding test, to investigate the interior structure of 3D-printed ABS specimens. They concluded the presence of internal structure can reduce both wear and friction.

Boparai et al. [15] prepared composite materials with more wear resistance and different proportions. The results show less friction force and friction coefficients than the commercially used ABS material for 3D printing.

This paper presents tribological characteristics and surface quality of 3D printed ABS specimens.

2. MATERIALS AND METHODOLOGY

In this work, specimens for surface roughness measurement and tribological behavior (Figure. 1) were printed on a low-cost Creality 10-s printer, which is located at the Faculty of

Technical Science in Kosovska Mitrovica. Characteristics of the printer are: Build area of 300x300x400mm, nozzle diameter 0.4, print speed normal60mm/s - max 100mm/s, and a wide range of materials like PLA, PETG, TPU, ABS, But ABS and PLA are the most represented.

Five specimens were sliced in Ultimaker Cura software (Figure 2) and then printed with ABS material.

Dimensions were 10x6.3x15, infill density 100%, printing speed 60mm/s, printing temperature 240°C, build plate temperature 80 °C and cooling was enabled.

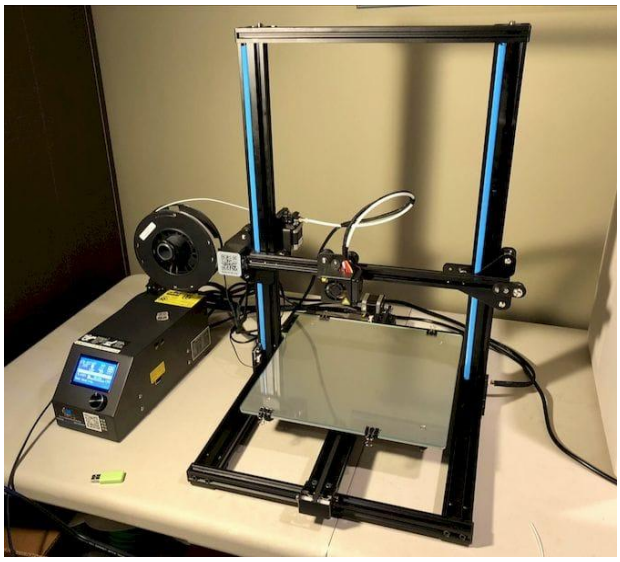


Fig. 1. Creality CR 10-s 3D printer.

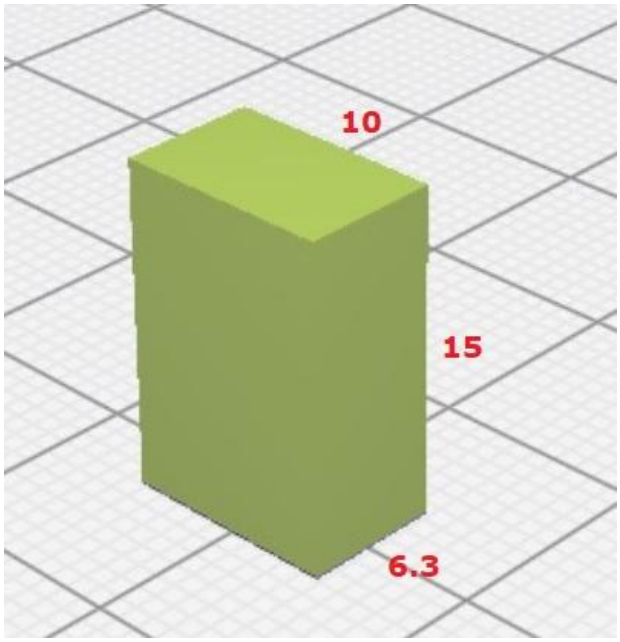


Fig. 2. Specimen in Ultimaker Cura software.

Mean arithmetic roughness (Ra) was taken as a surface roughness parameter and measured on all five specimens, which were previously subjected to certain types of processing, such as:

1. Milling,
2. Polishing,
3. Rubbing,
4. Acetone treatment,
5. Without processing.

Surface roughness was measured on Talysurf-6 computerized measuring device.

Tribological characteristics of ABS material were measured on a "Block-on-disc" tribometer TPD-93.

3. EXPERIMENTAL RESULTS

After the finishing of production specimens on the 3D printer, 4 models were exposed to a certain type of processing, while one specimen was measured without prior processing. The measurement was made in the middle of the surface of the specimens. The measured values of the surface roughness Ra are shown in table 1.

Table 1. Type of processing and measured values.

Type of processing	Ra (μm)
Milling	2.456
Polishing	0.498
Rubbing	6.715
Aceton treatment	0.443
Without processing	13.315

After analyzing the surface roughness results, we can conclude that it is additional processing because the highest roughness is precisely on the sample without processing. Treatment with acetone as well as polishing significantly improved the quality of the surface.

Tribological values, i.e. wear and friction, were measured on the TPD-93 tribometer Block On Disk. The normal load was 20, 50, and 80 N, and the sliding speed was 0.75 m/s. The total slip route was 150 m.

The width of the wear was measured on a UIM-21 microscope, and the results are given in Table 2, and table 3 shows the worn surfaces of tested specimens.

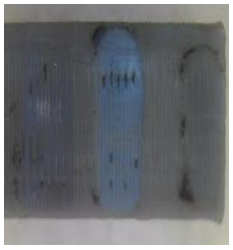
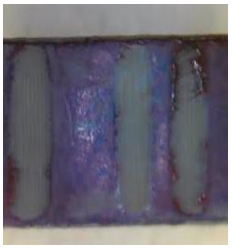
Table 2. Wear scar width, mm.

Fn, N	1	2	3	4	5
20 N	2.329	2.264	2.18	1.9	2.275
50 N	2.883	2.772	2.492	1.995	2.478
80 N	3.571	3.135	3.71	2.371	2.78

From Figure 3, we can see that with increasing load, the wear width of the specimens increases on every type of processed surface.

From Table 4, as well as from Figures 4 and 5, we can see that as the load increases, the friction coefficient decreases

Table 3. Wear specimens, v=0.75m/s.

				
1	2	3	4	5

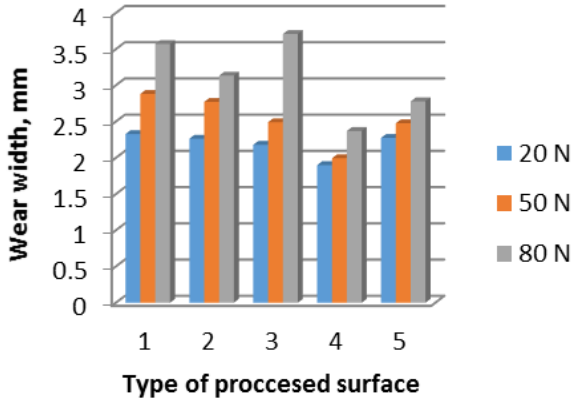


Fig. 3. Wear width with different load.

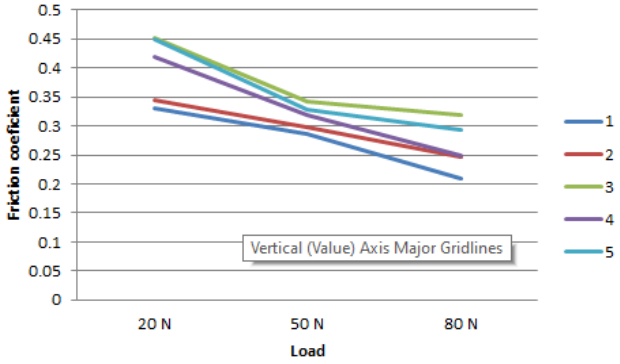


Fig. 5. Coefficient of friction with different load.

Table 4. Coefficient of friction depending on the load and type of processing

Fn	1	2	3	4	5
20 N	0.33	0.344	0.451	0.418	0.45
50 N	0.286	0.297	0.342	0.318	0.328
80 N	0.21	0.247	0.318	0.25	0.294

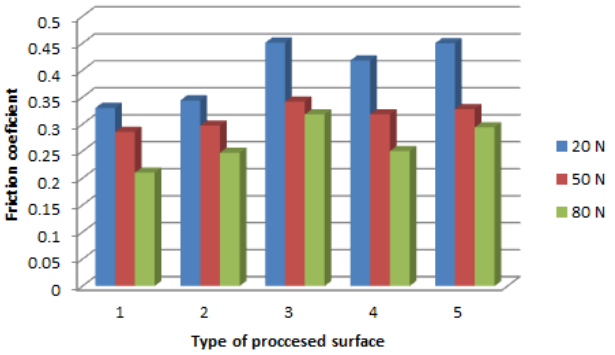


Fig. 4. Coefficient of friction for different types of processing.

4. CONCLUSION

Technologies and materials in the field of 3D printing have great potential for further research into tribological characteristics and surface quality. In this paper, the results of friction and wear as well as surface roughness were analyzed. We can conclude that different types of processing have a lot of influence on tribological characteristics and surface roughness.

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