**Internal structure part friction deviation between SLS and FFF 3D-printed methods**

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**ABSTRACT** – The aim of this study is to compare the friction deviation between two types of 3D-printed methods. Acrylonitrile butadiene styrene (ABS) polymer was used for fused filament fabrication (FFF), while nylon powder was used for Selective laser sintering (SLS) samples preparation to evaluate which material had the most significant impact on obtaining the lowest coefficient of friction (COF). The internal geometry compared include the solid, circular, square, rectangle, triangle, and triangle flip structure. The experiment was carried out using a pin-on-disc tribometer with fixed loads and sliding speeds in dry conditions. Results showed that SLS triangle nylon pins had a lower steady-state COF of 0.385 compared to the FFF circle ABS pins of 0.386 at 39.24 N loading and 400 rpm sliding speed. Early contact microstructure and changes in surface area composition in the SLS triangle pins and FFF circle ABS pins were expected to be the factors that led to low maximum stress yield, resulting in a lower COF.

1. **MECHANICAL PROPERTIES OF BIO-COMPOSITES FUSED DEPOSITION MODELING**

The 3D printing technology is rapidly evolving. Moreover, this additive technology enables a simpler one-of-a-kind and complex part [1]. Therefore, understanding the material properties of the emerging technology is critical for product design, which allows for better success without neglecting product safety and cost. For example, polymer is used for radiator grilles, panels, door trim, headlight housings, consoles, and interior trim.

It is imperative to reduce material construction costs and improve the geometric quality [2]. Hence, when designing bearing mechanisms, plastic rotary components, and other components, the ability to estimate expected coefficient of friction (COF) and wear performance in service for various design options and materials is an important aspect of the design process. The friction strength factor is the standard stress factor of COF. The generated friction force can be adjusted and calculated by adjusting the normal force level, so values for the material friction coefficient should be known for practical purposes. As the friction force lowers, the resulting coefficient of friction also reduces [3]. The wear rate and the COF values is relatively dependent to the normal loads, sliding speeds and internal geometries [4]. A 3D-printed ABS pin with an internal triangular flip structure is found to have the shortest run-in period and the lowest COF with high wear resistance [5].

Neglecting the tribological interactions due to lack of information may result in significant resource waste. In comparison to metals, sliding against metallic parts with polymer applications is extremely difficult to comprehend [6]. Thus, the aim of this study is to investigate the effects of different internal structures of the two 3D-printing methods (SLS and FFF) on the steady state COF at fixed sliding conditions.

2. **EXPERIMENTAL PROCEDURE**

The pin specimen, which was 20 mm long and 10mm in diameter was designed using a 3D CAD software. Figure 1 shows the 3D model saved in the STL format, which is a standard for stereolithography software.

![Figure 1 3D Models used for manufacturing different 3D-pin structures: (a) solid, (b) internal square, (c) rectangle, (d) circle, (e) triangle and (f) triangular flip structure. All dimensions are in mm.](image)

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The 3D model was printed using SLS 3D printer nylon powder according to normal setting (7.6 m/s laser beam velocity; 0.06 mm layer thickness; 0.3 hatch distance; 169.5°C chamber temperature; 50-watt laser power). The FFF FlashForge Creator Pro 3 (flashprint slicing software V 3.21) was used to control and fine-tune the printing characteristics (0.1mm layer height, 234°C nozzle temperature, triangle pattern). For printing the specimens, the build plate was set to 100% infill density in the software.

The pin-on-disc tribometer was used to conduct the dry sliding test in accordance with ASTM G99-05 (Standard Test Method for Wear Testing with a Pin-on-Disk Apparatus). The carbon chromium steel was used as a disc to slide the 3D-printed pin. Table 1 presents the disc material properties used in the study. Table 2 listed the testing parameters. The disc was cleaned using acetone before the test.

Table 1 Material properties used in the study before they were tested.

<table>
<thead>
<tr>
<th>Material Properties</th>
<th>Discs (carbon-chrome-steel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness [GPa]</td>
<td>7.45</td>
</tr>
<tr>
<td>Young’s modulus [GPa]</td>
<td>210</td>
</tr>
<tr>
<td>Density [g/cm³]</td>
<td>7.7</td>
</tr>
</tbody>
</table>

Table 2 Testing parameters for tribology test.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sliding speed [rpm]</td>
<td>400</td>
</tr>
<tr>
<td>Sliding distance [m]</td>
<td>1000</td>
</tr>
<tr>
<td>Applied load [N]</td>
<td>39.24</td>
</tr>
<tr>
<td>Temperature [°C]</td>
<td>27</td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSION

Figure 2 (a) shows the relationships between the COF and the 3D-printed internal structure along with (b) the percentage difference between the 3D-printed methods for the same internal structure. Based on Fig. 2 (a), the lowest COF recorded by SLS is by triangle structure and FFF is by circle structure with 0.385 and 0.386 respectively at sliding condition of 400rpm and 39.24N. The COF values for the SLS were sequence decrease when the SLS was applied to the internal structure of the triangle flip, square, solid, circle, rectangle, and triangle. As for the FFF method, lower values of COF were observed with the sequence of square, rectangle, triangle, solid, triangle flip and circle, respectively. Meanwhile, Figure 2(b) displays the percentage difference in the internal structure between the SLS and FFF methods. The results could be explained by the changes in the surface area composition and low maximum stress, resulting in lower COF.

Figure 2 (a) COF plotted against internal structure ABS pins respecting 3D-printed method and (b) Percentage difference between SLS and FFF method.

4. CONCLUSION

At 39.24N loading and 400rpm sliding speed, the SLS triangle nylon pins produced a lower steady-state COF with a value of 0.385 compared to the FFF circle ABS pins with the value of 0.386. These effects were observed in the SLS triangle pins, and FFF circle ABS pins may be due to early contact microstructure, changes in the surface area composition and low maximum stress, resulting in lower COF.

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