Tribological properties of 3D-printed pin with internal structure formation under dry sliding conditions

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ABSTRACT – 3D printer creates part layer by layer. It enables components with complex structure to be manufactured. This paper presents preliminary study of tribological analysis on internal structured 3D-printed pin fabricated by using 3D printing technique. Pin-on-disc dry sliding test was conducted on 3D-printed pin samples. The samples were fabricated into solid (unstructured) and internal structured (at different position) 3D-printed pins. Findings show that the presence of internal structure in 3D-printed pins reduce the coefficient of friction. Meanwhile, the wear rate results suggest that the 3D-printed pin with nearest internal structure to the contact surface yield lowest wear rate. Hence, the presence of internal structure can reduce friction and wear.

1. INTRODUCTION

Materials with small Young's modulus (E) can change its shape easily. Hence, release stress concentration at contact point. Meanwhile materials with high hardness (H) exhibit better wear resistance compared to soft materials. Thus, large H/E value can be considered as optimum condition in tribological aspect [1].

However, manufacturing complex shapes and structures using conventional techniques are costly and time consuming due to its difficult and long process chain [2]. Luckily, 3D printing technology presents the solution to this problem. 3D printer creates part by adding layer by layer from 3D computer aided design (CAD) files. 3D printer has been used in many fields such as automotive, aerospace, consumer goods, and casting [3].

Fused deposition modelling (FDM) is one of solid based 3D printing technique that uses lightweight thermoplastic filament as material. FDM was first invented in early 1990s and widely used due to its simple, low cost material and minimum waste that shows a great potential for fabricating plastic parts [3]. Thus, the use of FDM technique can reduce manufacturing cost of parts while still making reliable plastic parts [4].

It was reported by another researcher that the presence of internal structure can reduce coefficient of friction which they claimed that the internal structure releases the stress concentration [1].

Despite this promising finding, where the friction and wear are able to be reduced, there is still a lot of missing knowledge yet to be explored. Hence, this paper focuses on tribological effect on 3D-printed pins using opaque thermoplastic material; acrylonitrile butadiene styrene (ABS) in dry sliding test condition.

2. METHODOLOGY

2.1 Fabrication of sample

Four types of 3D-printed pin samples were prepared by using commercially available FDM 3D printer and labelled as; No Hole, Hole A, Hole B, and Hole C. All pin samples were made of ABS polymer thermoplastic material.

The drawing of the 3D-printed pin samples is as shown in Figure 1. Printing parameter combinations for all 3D-printed pins are as tabulated in Table 1. The description of the categories is as tabulated in Table 2 and the mechanical properties of the material (ABS) are as tabulated in Table 3.

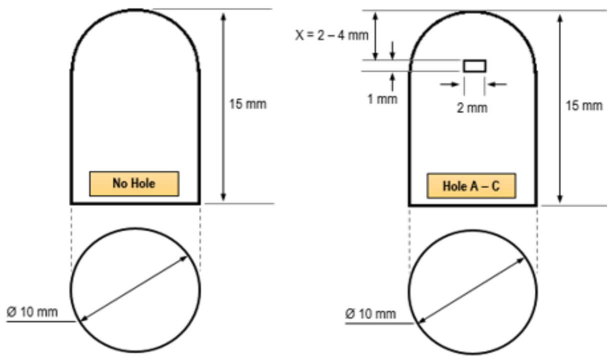

Figure 1 2D modelling of fabricated pins.

Table 1 3D-printed pin samples printing parameters.

Parameter	Selection
Layer resolution (μm)	70
Print strength	Solid
Print pattern	Cross

Table 2 Description of 3D-printed pin category.

Category	Condition
No hole	Unstructured pin
Hole A	Pin with hole 2 mm from contact surface
Hole B	Pin with hole 3 mm from contact surface
Hole C	Pin with hole 4 mm from contact surface

Table 3 Mechanical properties of ABS polymer.

Density, ρ [g/mm³]	Young modulus, E [GPa]	Poisson's ratio, μ
0.00105	1.2	0.35

2.2 Tribological test

The tribological tests were conducted by using pin-on-disc tribometer by following the ASTM G99 standard. The 3D-printed pins were attached on top of the rotating disc. The parameters for the test are as tabulated in Table 4 and the schematic diagram for pin-on-disc are as shown in Figure 2.

Table 4 Parameters used on pin-on-disc test.

Parameter	Condition
Pin material	ABS
Disc material	SKD-II
Sliding speed	100 rpm
Sliding distance	1000 m
Applied load	4.905 N
Temperature	27 °C

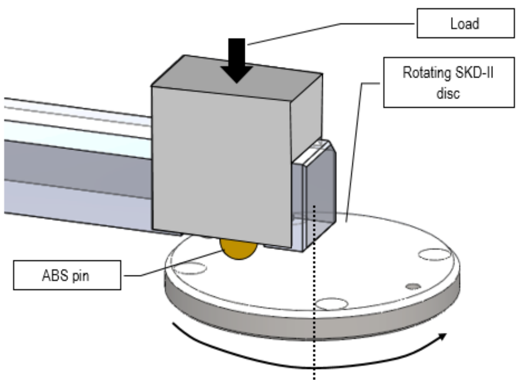

Figure 2 Schematic diagram of pin-on-disc test.

3. RESULTS AND DISCUSSION

The tribological results are plotted in Figure 3. Whereas the left axis is for Coefficient of Friction (COF) and wear rate, k is on the right. From the graph, it can be seen that the COF for unstructured (No Hole) 3D-printed pin is far higher than the others at 0.706. The COF for all internal structured 3D-printed pin are lower compared to the unstructured 3D-printed pin. These findings supported by [1] where they also found that the presence of internal structure can decrease the coefficient of friction. Between the internal structured 3D-printed pins, 3D-printed pin labelled 'Hole C' shows the lowest COF with 0.337.

In addition, [1] also explained that the presence of internal structure producing small apparent Young's modulus, and hence it increases the contact area. This mechanism reduces the coefficient of friction. However, the differences between the internal structured 3D-printed pins are very small and can be neglected. According to the guided line for the eye, the lowest COF with inner structures are around 0.34.

Meanwhile, for the wear rate, the wear rate data are a little bit scattered. However, based on the guided line for the eye, except for 'Hole A', the wear rate decreases with the presence of hole. The lowest wear rate with inner structures are around 6.5 x 10^{-4} mm^3/Nm.

Overall, based on the guided line for the eye plotted, the presence of inner structures reducing both COF and wear rate.

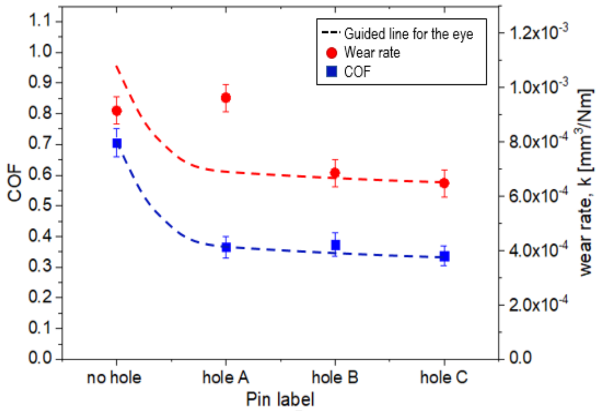

Figure 3 Friction and wear of 3D-printed pins.

4. CONCLUSIONS

In conclusion, the presence of internal structure can reduce the coefficient of friction by producing small apparent young modulus. On the other hand, the position of hole does not affect the coefficient of friction. From wear perspective, the wear rate seems to be reduced on certain structured 3D-printed pin.

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