

# Investigation of carbon fiber reinforced polymer (CFRP) composite behavior towards friction force and wear rate

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**ABSTRACT** – Tool wear formation during micro drilling process of Carbon Fiber Reinforced Polymer (CFRP) is influenced by the behavior of CFRP towards friction force with the drill bit. Hence, relationship between process parameter with the material behavior is important to improve the quality of drilling process. Ball-on-disk experiment have been carried out to investigate the impact of the applied load on the CFRP behavior towards friction force and wear rate over sliding distance. Results showed that as the applied load increase, the friction force and wear rate on the CFRP panel also increase. Therefore, lower value of applied load can prevent higher friction force and reduce wear rate.

## 1. INTRODUCTION

Carbon fibre reinforced polymer (CFRP) is the most commonly used material in modern airplanes, about 50% aircraft body are made of CFRP by weight [1]. However, machining of CFRP with high fibre content is troublesome due to the high abrasiveness of the carbon fibres and the heavy wear of the drilling tools [2]. For realistic modelling of CFRP machining processes the understanding of friction and determination of friction coefficients is required as the material has anisotropic and inhomogeneous properties along the structure [3]. The purpose of this study is to understand the behaviour of CFRP composite material towards friction force and wear rate to simulate with the actual practice in drilling process.

## 2. METHODOLOGY

Tribology behavior of the workpiece was measured using ball-on-disk (BOD) tester in dry sliding condition. BOD experiment has been carried out with variable applied load of 5 N, 10 N and 15 N The sliding velocity, duration of the test and ball bearing radius were constant at 5 mm/s, 30 min and 3 mm respectively. The tests were conducted in reciprocator mode with stroke 3 mm. The setup of the tribology tests is shown in Figure 1.

Before the test was conducted, the CFRP composites panel was cut to fit in the special fixture designed with the size of disc to ensure the specimen

will not moving or vibrate during the test. Table 1 presented the overall input parameter for the ball-on-disk experiment from the combination of applied load, sliding speed and sliding distance.

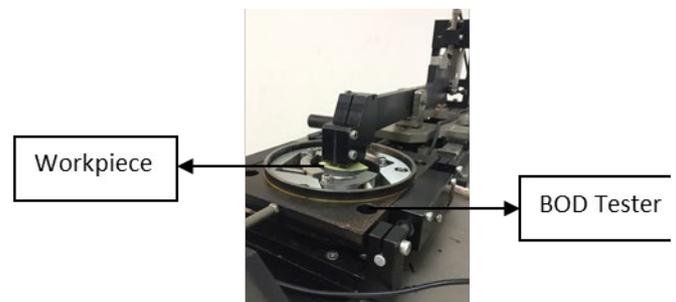


Figure 1 Ball-on-disk actual set up

Table 1 Ball-on-disk test parameter

Sample	Applied Load (N)	Sliding Speed (mm/s)	Sliding Distance (m)
1	5	5	11.305
2	10	5	11.303
3	15	5	11.302

Direct output parameter measured during the test were friction force and wear. The BOD tester was connected to the computer to analyze the real time data of friction force and wear. The Archard's Equation were used to measure the coefficient of friction (COF) as per Equation 1 [4].

$$COF = \frac{F}{N} \quad (1)$$

Where, F is the friction force and N is the applied load.

## 3. RESULTS AND DISCUSSION

### 3.1 Experimental Result of Friction Force

Table 2 illustrates the result of friction force and coefficient of friction for all the experiments. From the table, the average friction force increased as the applied

load increased. However, COF for Sample 3 is lower than Sample 2. The possible reason is due to the small different in applied load lead to small magnitudes of friction force [5]. Hence, the COF for the Sample 2 become slightly larger than the Sample 3. In addition, the lower sliding speed applied also contributed to the insignificant impact on the friction force.

Table 2 Friction Force

Sample	Average Friction Force (N)	COF
1	0.143	0.0286
2	3.788	0.3788
3	5.359	0.3572

Figure 2 described the comparison between the friction force result for Sample 2 and 3. The pattern of graph shows similar trend where the force starts to increase rapidly after sliding distance of 5 m. The results reveal that the experiment is carried out in stable condition with very minimum external noise.

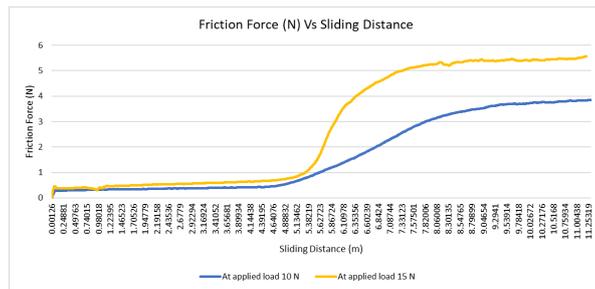


Figure 2 Friction force at applied load 10 N and 15 N

### 3.2 Experimental Result of Wear Rate

Table 3 shows the result of wear rate for all the experiments. From the table, the average wear rate increased as the applied load increased. The above finding is consistent with the study by Romoli and Dini (2008) [6]. The increased in thrust force directly proportional with the increasing of tool wear. Thus, that is why the wear rate also increased as the applied load increased.

Table 3 Wear Rate

Sample	Wear Rate (m <sup>3</sup> /Nm)
1	35.322
2	97.945
3	261.973

Figure 3 illustrates the trend of graph for wear rate in all experiments. The finding provides evidence that all the experiments is carried out in stable condition with no error coming from the machine or placement of workpiece. It can be proof by the similar pattern of graph shown in every experiments. At first, the wear

rate is increase rapidly then become stable before the sliding distance reaching 0.1m.

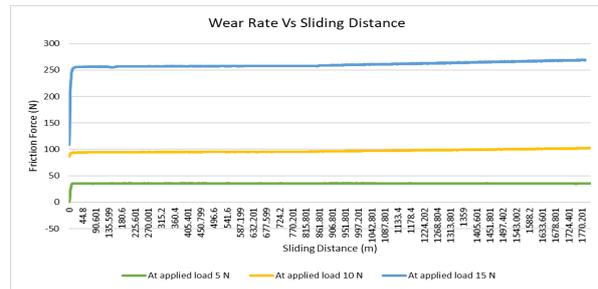


Figure 3 Wear rate at applied load 5 N, 10 N and 15 N

## 4. CONCLUSIONS

Results showed that as the applied load increase, the friction force and wear rate on the CFRP panel also increase. It can be concluded that, lower value of applied load or thrust force in actual term can prevent higher friction force and reduce wear rate. This measurement is relevance with the actual drilling process for thrust force and wear rate. However, the impact of sliding velocity also needs to be considered in future study.

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