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Friction in fiber-fiber contact: An experimental setup

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ABSTRACT – This study aims to develop a new experimental setup to measure friction between two interacting fibers. In the experiment, the frictional force is measured when two individual fibers are placed in perpendicular contact with applied normal load under several environmental conditions. It has been found that the dependence of the frictional coefficient on the normal load is substantial, as the coefficient was reduced by increasing the load. In addition, the moisture level also contributes to the friction factor force measured.

1. INTRODUCTION

Friction in fiber-fiber contact is a very important property at all phases in a composite industry in the alteration of fibers intend products. Many processes involved friction, such as during molding, drawing, spinning etc. During the process, there are interaction occur between fibers with machine parts as well as between fibers. Friction can be desirable or a nuisance depending on the type of application. Therefore it is vital to study the frictional behavior in details especially at microscopic level.

Although much research had been carried out to measure the frictional behavior using different types of instruments and techniques, still none of them could be considered as a standard [1-6]. Friction between single fibers is first explored Gralen and Olofsson [1] measuring the friction between natural fibers using a twisting method. Roselman and Tabor [2,3] have used cantilever and capstan apparatus in measuring the friction between the carbon fibers.

An overview by Yusekkaya [4] found that the effect of moisture level was dependent on the type of fiber being tested. It is also observed that friction proportional to relative humidity from dry to wet condition. However up to now, little has been published about especially the effect of moisture level on Aramid.

In this present paper, friction between fibers will be discussed. In particular, the effect of moisture also will be discussed.

2. EXPERIMENTAL SETUP

In this study, acantilever apparatus as illustrated in Figure 1 has been developed and tested. Before the experiment, the fiber is clamped on the fiber holder using UV hardening glue. The glued fiber are exposed to UV light and cured. During the experiment, the fiber is brought into contact with each other perpendicularly at a 90° skew angle. The first holder is mounted on the positioning stage. Using this stage, the normal load is being applied. The second holder is placed on the movable flat stage where its sliding motion can be controlled.

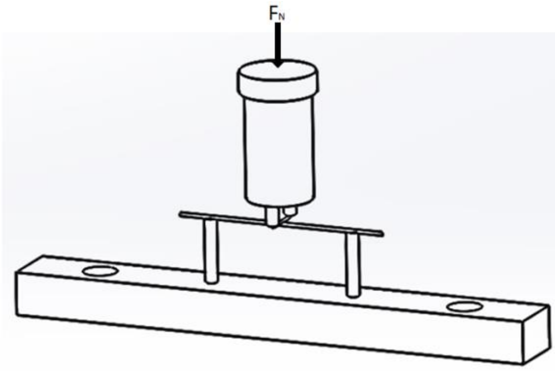

Figure 1 Schematic arrangement of crossed fibers.

In this experiment, the capacitive sensor is mounted on the force measuring mechanism (FMM) as shown in Figure 2. It is functioned to measure two perpendicular forces independently in two directions (the applied normal force and the friction force). This measurement setup is carried out in the vacuum chamber as shown in Figure 3. Here, this chamber is used to realize several humidity levels. The setup is described details in paper produced by M.A Yaqoob [7].

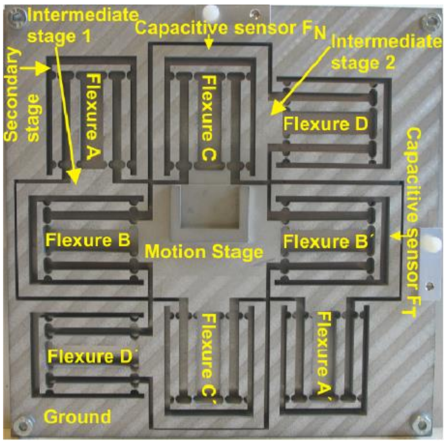

Figure 2 Details illustration of force measuring mechanism (FMM) [7].

Figure 3 Fiber holder mounted in a vacuum chamber.

In the friction experiment, single Aramid fibers with diameter of 10 µm and 2-10 mm long are used. Table 1 summarizes the relevant experimental parameters which had been controlled during friction experiments.

Table 1 Experimental parameters.

Description	Value
Load range	0.2 -10 mN
Speed	0.1 &1 um/sec
Relative humidity	1.8 – 96 %
Temperature	23 – 25 °C

3. PRELIMINARY RESULTS

The friction experiments have been carried out in wet and dry condition and the comparison between both is shown in Figure 4. The result shows that the coefficient of friction relies on the environmental conditions. An increment in friction on wet condition is expected as the contact may introduce adhesion and shear stress. However, further experimental studies are required to verify this theory.

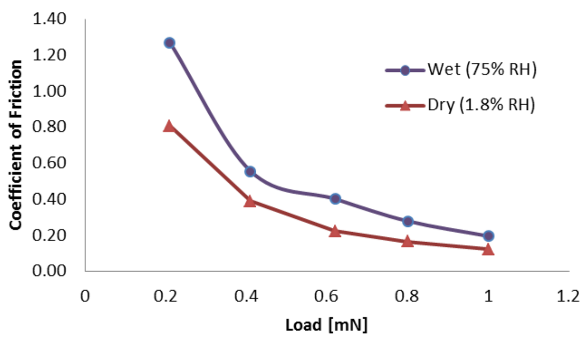

Figure 4 Coefficient of friction as s function of load for aramid fiber.

The load dependency of the friction force can be explained as follows:

$$\mu = \frac{F_w}{F_N} \propto \frac{\tau.A}{F_N} \propto \frac{\tau.{F_N}^{2/3}}{F_N} \quad (1)$$

$$\mu = \frac{1}{{F_N}^{1/3}} \quad (2)$$

where μ is coefficient of friction, F_w is frictional force, $F_N$is normal load, τ is shear stress and A is contact area.

From the results it is clear that the friction force is found to be higher under wet condition.

4. CONCLUSIONS

In summary, the experimental setup to measure friction between individual fibers has been developed and tested. It can be concluded that the frictional force is correlated to the applied normal load. Besides, result also show that there is significant effect of the moisture level on the friction behavior.

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