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EXPERIMENTAL INVESTIGATION OF FRICTION COEFFICIENT AND WEAR RATE OF COMPOSITE MATERIALS SLIDING AGAINST SMOOTH AND ROUGH MILD STEEL COUNTERFACES

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Abstract: *In the present study, friction coefficient and wear rate of gear fiber reinforced plastic (gear fiber) and glass fiber reinforced plastic (glass fiber) sliding against mild steel are investigated experimentally. In order to do so, a pin on disc apparatus is designed and fabricated. Experiments are carried out when smooth or rough mild steel pin slides on gear fiber and glass fiber disc. Experiments are conducted at normal load 10, 15 and 20 N, sliding velocity 1, 1.5 and 2 m/s and relative humidity 70%. Variations of friction coefficient with the duration of rubbing at different normal loads and sliding velocities are investigated. Results show that friction coefficient is influenced by duration of rubbing, normal load and sliding velocity. In general, friction coefficient increases for a certain duration of rubbing and after that it remains constant for the rest of the experimental time. The obtained results reveal that friction coefficient decreases with the increase in normal load for gear fiber and glass fiber mating with smooth or rough mild steel counterface. On the other hand, it is also found that friction coefficient increases with the increase in sliding velocity for both of the tested materials. Moreover, wear rate increases with the increase in normal load and sliding velocity. The magnitudes of friction coefficient and wear rate are different depending on sliding velocity and normal load for both smooth and rough counterface pin materials.*

Keywords: *Friction coefficient, wear rate, gear fiber, glass fiber, mild steel, normal load, sliding velocity.*

1. INTRODUCTION

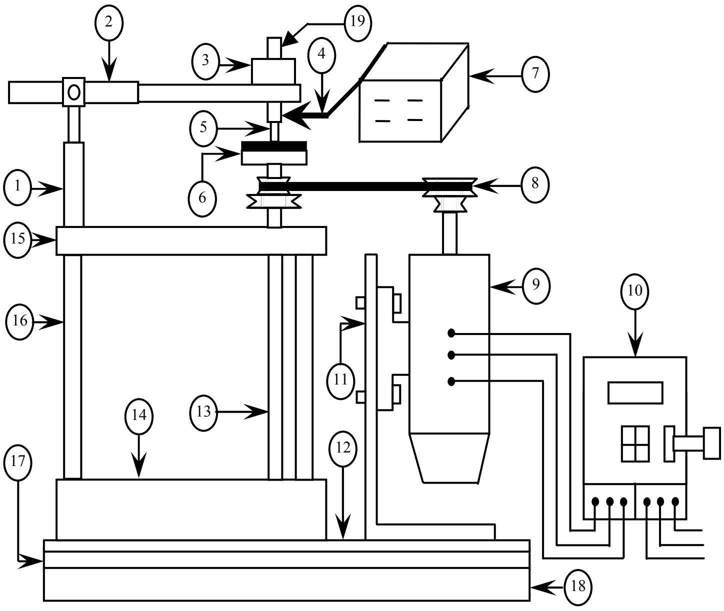
Numerous investigations have been carried out on friction and wear of different materials under different operating conditions. Several researchers [1-6] observed that the friction force and wear rate depend on roughness of the rubbing surfaces, relative motion, type of material, temperature, normal force, relative humidity, vibration, etc. The parameters that dictate the tribological performance of polymer and its composites include polymer molecular structure, processing and treatment, properties, viscoelastic behavior, surface texture, etc. [7-10]. There have been also a number of investigations exploring the influence of test conditions, contact geometry and environment on the friction and wear behavior of polymers and composites. [11-13] reported that the tribological behavior of polyamide, high density polyethylene and their composites is greatly affected by normal load, sliding speed and temperature. [14-15] showed that applied load and sliding speed play significant role on the wear behavior of polymer and composites. They also showed that applied load has more effect on the wear than the speed for composites. Experiments were carried out on friction and wear behavior of poly-ether-imide and its composites under different operating conditions [16-19]. Polymers and its composites are extensively used in sliding/rolling components such as gears, cams, bearings, rollers, transmission belts and grinding mills where their self-lubricating properties are exploited to avoid the need for oil or grease lubrication with its attendant problems of contamination [20,21]. However, when the contact between sliding pairs is present, there is the problem of friction and wear. [22-24] demonstrated that the friction coefficient can, generally, be reduced and the wear resistance increased by selecting the right material combinations.

It was reported [25-27] that the influence of sliding speed on friction and wear of polymer and its composite is greater than that of applied load though some other researchers have different views. Unal et al. [28,29]reported that the applied load exerts greater influence on the sliding wear of polymer and its composites than the sliding speed. Transfer film has important effects on the tribological behavior of polymer and its' composite. If the transfer film is thin, uniform and continuous, the wear loss and the friction coefficient are low [30]. The results by [31, 32] showed that tribological performance of polymer material can be improved significantly by fibre reinforcement or fillers. The reason was that the transfer films formed and adhered close on the surface of counterface material during friction which resulted in the increase in wear resistance of the composites [31,10]. It was showed [33] that reinforcement of fibre or filler significantly improves the tribological behavior of polymeric material but this is not necessarily true for all cases. Franklin [34] reported that wear behavior of polymers under dry reciprocating sliding conditions does not always follow the generally accepted engineering rule of 'higher sliding speed, the higher wear rate'. The influence of normal load on the friction coefficient and wear rate of different polymer and composite materials was investigated [35]and it was found that the values of friction coefficient and wear rate are different for different materials. Several researchers [36-39] reported that friction coefficient of polymers and its composites rubbing against metal increases or decreases depending on the range of sliding speed and sliding pairs. Researchers [40-43] have also observed that the friction coefficient of polymers and its composites rubbing against metals decreases with the increase in load though some other researchers have different views. It was showed [45-47] that value of friction coefficient increases with the increase in load. Friction coefficient and specific wear rate values for different combinations of polymer and its composite were obtained and compared [27]. For all material combinations, it was observed that the coefficient of friction decreases linearly with the increase in applied pressure values. Unal et al. [37,29] reported that the applied load exerts greater influence on the sliding wear of polymer and its composite than the sliding velocity. Friction and wear behavior of glass fiber-reinforced polyester composite were studied and results showed that in general, friction and wear are strongly influenced by all the test parameters such as applied load, sliding speed, sliding distance and fiber orientations [48]. Moreover, it was found that applied normal load, sliding speed and fiber orientations have more pronounced effect on wear rate than sliding distance. Wang and Li [26] observed that the sliding velocity has more significant effect on the sliding wear as compared to the applied load and variations of wear rate with operating time can be distinguished by three distinct periods. These periods are running-in period, steady state period and severe wear period, respectively. The friction and the wear behavior of the polymeric material depend on the nature, thickness and stability of the transfer film that is formed and on the properties of the metallic counter face material [49]. Yang [50] studied the transfer of polytetrafluoroethylene (PTFE) on to 316 stainless steel and silicon wafers using infrared spectrophotometry and founds that it was strongly time and temperature dependent and reached a steady state after a certain period of contact. Tsukizoe and Ohmae [33] showed that reinforcement of fiber or filler significantly improve the tribological behavior of polymeric material but this is not necessarily true for all cases. Suresha et al. [38] showed that there is a strong inter-dependence on the friction coefficient and wear loss with respect to the applied loads for steel composites contact. It was found that the coefficient of friction and wear loss increase with the increase in applied normal load for all the samples evaluated.

From the aforementioned research works, it can be concluded that friction coefficient of composite materials at different normal loads and sliding velocities differs significantly. Even now a day, the effect of normal load and sliding velocity on friction coefficient and wear rate of composite materials such as gear fiber and glass fiber sliding against different counterface surface conditions is less understood. This means that more research work is needed for a better understanding of friction coefficient and wear rate of these materials under different normal loads and sliding velocities for smooth and rough mild steel counterfaces. Therefore, in order to understand more clearly, in this study experiments are carried out to investigate the influence of normal loads and sliding velocities on friction coefficient and wear rate of gear fiber and glass fiber. The effects of duration of rubbing on friction coefficient of these materials are also examined in this study.

2. EXPERIMENTAL

A schematic diagram of the experimental set-up is shown in Fig. 1 i.e. a pin which can slide on a rotating horizontal surface (disc). In this set-up a circular test sample (disc) is to be fixed on a rotating plate (table) having a long vertical shaft clamped with screw from the bottom surface of the rotating plate. The shaft passes through two close-fit bush-bearings which are rigidly fixed with stainless steel plate and stainless steel base such that the shaft can move only axially and any radial movement of the rotating shaft is restrained by the bush. These stainless steel plate and stainless steel base are rigidly fixed with four vertical round bars to provide the rigidity to the main structure of this set-up. The main base of the set-up is constructed by 10 mm thick mild steel plate consisting of 3 mm thick rubber sheet at the upper side and 20 mm thick rubber block at the lower side. A compound V-pulley above the top stainless steel plate was fixed with the shaft to transmit rotation to the shaft from a motor. An electronic speed control unit is used to vary the speed of the motor as required. A 6 mm diameter cylindrical pin whose contacting foot is flat, made of mild steel, fitted on a holder is subsequently fitted with an arm. The arm is pivoted with a separate base in such a way that the arm with the pin holder can rotate vertically and horizontally about the pivot point with very low friction. Sliding speed can be varied by two ways (i) by changing the frictional radius and (ii) by changing the rotational speed of the shaft. In this research, sliding speed is varied by changing the rotational speed of the shaft while maintaining 25 mm constant frictional radius. To measure the frictional force acting on the pin during sliding on the rotating plate, a load cell (TML, Tokyo Sokki Kenkyujo Co. Ltd, CLS-10NA) along with its digital indicator (TML, Tokyo Sokki Kenkyujo Co. Ltd, Model no. TD-93A) was used. The coefficient of friction was obtained by dividing the frictional force by the applied normal force (load). Wear was measured by weighing the test sample with an electronic balance before and after the test, and then the difference in mass was converted to wear rate. To measure the surface roughness of the test samples, Taylor Hobson Precision Roughness Checker (Surtronic 25) was used. Each test was conducted for 30 minutes of rubbing time with new pin and test sample. Furthermore, to ensure the reliability of the test results, each test was repeated five times and the scatter in results was small, therefore the average values of these test results were taken into consideration. The detail experimental conditions are shown in Table 1.



1 Load arm holder
2. Load arm
3. Normal load (dead weight)
4. Horizontal load (Friction force)
5. Pin sample
6. Test disc with rotating table
7. Load cell indicator
8. Belt and pulley
9. Motor
10. Speed control unit
11. Vertical motor base
12. 3 mm Rubber pad
13. Main shaft
14. Stainless steel base
15. Stainless steel plate
16. Vertical square bar
17. Mild steel main base plate
18. Rubber block (20 mm thick)
19. Pin holder.

Fig. 1. Block diagram of the experimental set-up.

Table 1. Experimental Conditions.

Sl. No.	Parameters	Operating Conditions
1.	Normal Load	10, 15, 20 N
2.	Sliding Velocity	1, 1.5, 2 m/s
3.	Relative Humidity	70 (± 5)%
4.	Duration of Rubbing	30 minutes
5.	Surface Condition	Dry
6.	Disc material	(i) Gear fiber reinforced Plastic (ii) Glass fiber reinforced plastic
7.	Roughness of Gear and Glass fiber, R_a	0.70-0.80 μm
8.	Pin material	Mild steel
9.	Roughness of mild steel, R_a	(a) Smooth counterface: about 0.30 μm (b) Rough counterface: about 3.0 μm

3. RESULTS AND DISCUSSION

Figure 2 shows the variation of friction coefficient with the duration of rubbing at different normal loads for gear fiber sliding against smooth mild steel conterface. During experiment, the sliding velocity and relative humidity were 1 m/s and 70% respectively. Curves 1, 2 and 3 of this figure are drawn for normal laod 10, 15 and 20 N respectively. Curve 1 of this figure shows that during the starting, the value of friction coefficient is 0.104 and then increases very steadily up to 0.147 over a duration of 20 minutes of rubbing and after that it remains constant for the rest of the experimental time. These findings are in agreement with the findings of Chowdhury and Helali [4]. At starting of experiment, the friction force is low due to contact between superficial layer of pin and disc. As rubbing continues, the disc material becomes worn and reinforced material comes in contact with the pin, roughening of the disc surface causes the ploughing and hence friction coefficient increases with duration of rubbing. After certain duration of rubbing the increase of roughness and other parameters may reach to a certain steady value hence the values of friction coefficient remain constant for the rest of the time. Curves 2 and 3 show that for the high normal load, the friction coefficient is less and the trend in variation of friction coefficient is almost the same as for curve 1. From these curves, it is also observed that time to reach steady state values is different for different normal load. From the obtained results it is found that at normal load 10, 15 and 20 N, gear fibre takes 20, 17 and 15 minutes respectively to reach steady friction. It indicates that the higher the normal load, time to reach constant friction is less. This may be due to the fact that the higher the normal load, the surface roughness and other parameters take less time to stabilize.

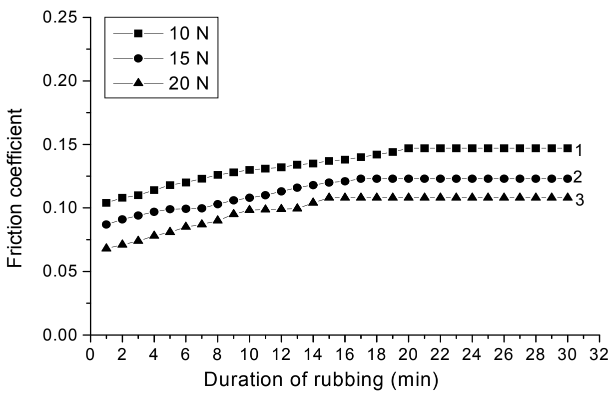


Fig. 2. Friction coefficient as a function of duration of rubbing at different normal loads (sliding velocity: 1 m/s, relative humidity: 70%, test sample: gear fiber, pin: mild steel, smooth).

Figure 3 shows the effect of the duration of rubbing on the value of friction coefficient at different normal loads for gear fiber sliding against rough mild steel counterface at sliding velocity 1 m/s and relative humidity 70%. Curve 1 of this figure drawn for normal load 10 N, shows that during starting of the experiment, the value of friction coefficient is 0.153 which rises for 22 minutes to a value of 0.195 and then it becomes steady for the rest of the experimental time. Almost similar trends of variation are observed in curves 2 and 3 which are drawn for load 15 and 20 N respectively. From these curves, it is found that time to reach steady friction is different for different normal loads. At normal load 10, 15 and 20 N, gear fiber-mild steel rough pair takes 22, 19 and 16 minutes respectively to reach steady friction That is, higher the normal load, gear fiber-mild steel rough pair takes less time to stabilize.

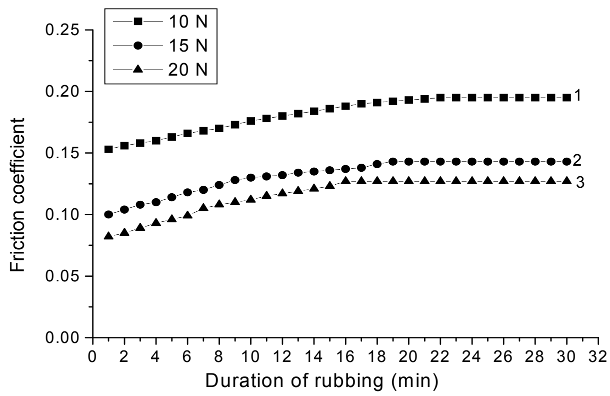


Fig. 3. Friction coefficient as a function of duration of rubbing at different normal loads (sliding velocity: 1 m/s, relative humidity: 70%, test sample: gear fiber, pin: mild steel, rough).

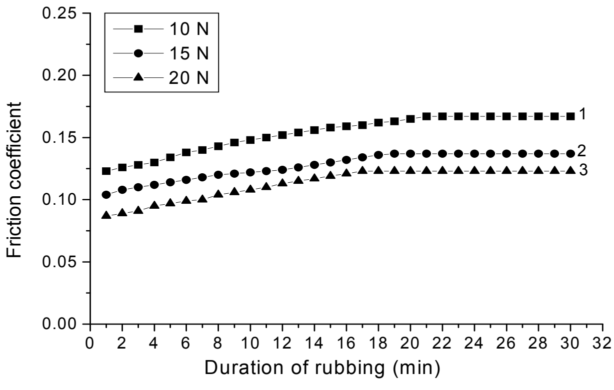


Fig. 4. Friction coefficient as a function of duration of rubbing at different normal loads (sliding velocity: 1 m/s, relative humidity: 70%, test sample: glass fiber, pin: mild steel, smooth).

Figure 4 shows the effect of the duration of rubbing on the value of friction coefficient at different normal load for glass fiber sliding against smooth mild steel counterface. Curve 1 of this figure drawn for normal load 10 N, shows that during starting of the experiment, the value of friction coefficient is 0.123 which rises for 21 minutes to a value of 0.167 and then it becomes steady for the rest of the experimental time. Almost similar trends of variation are observed in curves 2 and 3 which are drawn for load 15 and 20 N, respectively. From the obtained results, it can also be seen that time to reach constant friction is different for different normal load and higher the normal load, glass fiber takes less time to stabilize.

Several experiments are conducted to observe the effect of duration of rubbing on friction coefficient at different sliding speeds for glass fibre sliding against rough mild steel counterface and these results are presented in Figure 5. Curve 1 of this figure drawn for normal load 10 N, shows that during starting of the experiment, the value of friction coefficient is 0.175 which rises for 22 minutes to a value of 0.225 and then it becomes steady for the rest of the experimental time. Almost similar trends of variation are observed in curves 2 and 3 which are drawn for load 15 and 20 N respectively. From these curves, it is found that time to reach steady friction is different for different normal loads. At normal load 10, 15 and 20 N, glass fiber-mild steel rough pair takes 20, 18 and 15 minutes respectively to reach steady friction That is, higher the normal load, glass fiber-mild steel rough pair takes less time to stabilize.

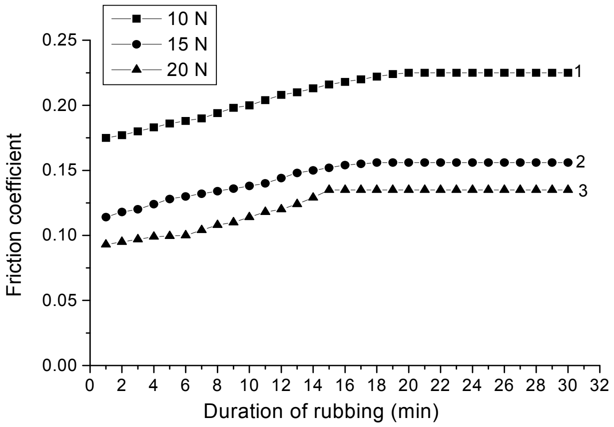


Fig. 5. Friction coefficient as a function of duration of rubbing at different normal loads (sliding velocity: 1 m/s, relative humidity: 70%, test sample: glass fiber, pin: mild steel, rough).

Figure 6 shows comparison of the variation of friction coefficient with normal load for gear fiber-mild steel smooth, gear fiber-mild steel rough, glass fiber-mild steel smooth and glass fiber-mild steel rough sliding pairs. Curves of this figure are drawn from steady values of friction coefficient shown in Figures 2-5 for gear fiber-mild steel smooth, gear fiber-mild steel rough, glass fiber-mild steel smooth and glass fiber-mild steel rough sliding pairs, respectively (to ensure the reliability of test results, each test was repeated five times and curves 1-3 of Figures 2-5 represent average value of five experiments). It is shown that the friction coefficient varies from 0.147 to 0.108, 0.195 to 0.127, 0.167 to 0.123 and 0.225 to 0.135 with the variation of normal load from 10 to 20 N for for gear fiber-mild steel smooth, gear fiber-mild steel rough, glass fiber-mild steel smooth and glass fiber-mild steel rough sliding pairs, respectively. From the obtained results, it can be seen that the coefficient of friction decreases with the increase in applied load. It is known that tribological behavior of polymers and polymer composites can be associated with their viscoelastic and temperature-related properties. Sliding contact of two materials results in heat generation at the asperities and hence increases in temperature at the frictional surfaces of the two materials which influences the viscoelastic property in the response of materials stress, adhesion and transferring behaviors [27]. From the obtained results, it can also be seen that the highest values of the friction coefficient are obtained for glass fiber-mild steel rough pair and the lowest values of friction coefficient are obtained for gear fiber-mild steel smooth pair. The values of friction coefficient of gear fiber-mild steel rough pair and glass fiber-mild steel smooth pair are found in between the highest and lowest values. It is noted that the friction coefficients of gear fiber-mild steel rough pair are higher than that of glass fiber-mild steel smooth pair. From this figure, it is also found that at identical conditions, the values of friction coefficient of gear fiber and glass fiber sliding against smooth mild steel counterface is lower than that of gear fiber and glass fiber sliding against rough mild steel counterface. It was found that after friction tests, the average roughness of gear fiber-mild steel smooth pair, glass fiber-mild steel smooth pair, gear fiber-mild steel rough pair and glass fiber-mild steel rough pair varied from 0.95-1.35, 1.25-1.65 and 1.55-1.75 and 1.67-1.91 μm respectively.

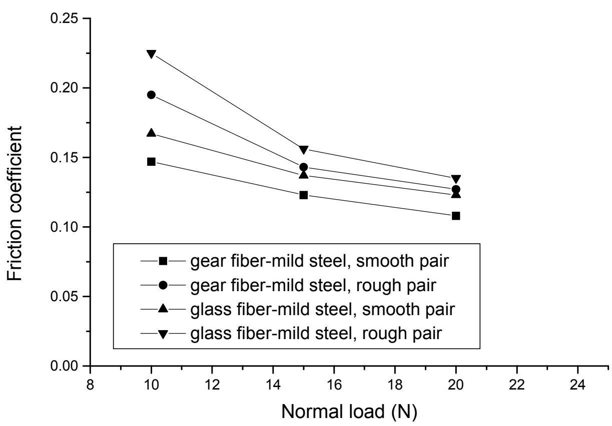


Fig. 6. Friction coefficient as a function of Normal load for gear and glass fiber for different counterface surface conditions (Sliding velocity: 1 m/s, relative humidity: 70%).

Figures 7, 8, 9 and 10 show the variation of friction coefficient with the duration of rubbing at different sliding velocities for gear fiber-mild steel smooth, gear fiber-mild steel rough, glass fiber-mild steel smooth and glass fiber-mild steel rough sliding pairs, respectively at normal load 15 N and relative humidity 70%. Curves 1, 2 and 3 of Fig. 7 are drawn for sliding velocity 1, 1.5 and 2 m/s respectively. Curve 1 of this figure shows that at initial stage of rubbing, the value of friction coefficient is 0.087 which increases almost linearly up to 0.123 over a duration of 17 minutes of rubbing and after that it remains constant for the rest of the experimental time. At starting of experiment, the friction force is low due to contact between superficial layer of pin and disc. As rubbing continues, the disc material becomes worn and reinforced material comes in contact with the pin, roughening of the disc surface causes the ploughing and hence friction coefficient increases with duration of rubbing. After certain duration of rubbing the increase of roughness and other parameters may reach to a certain steady value hence the values of friction coefficient remain constant for the rest of the time. Curves 2 and 3 show that for the higher sliding velocity, the friction coefficient is more and the trend in variation of friction coefficient is almost the same as for curve 1. From these curves, it is also observed that time to reach steady state value is different for different sliding velocity. From the results it is found that gear fiber-mild steel smooth pair at sliding velocity 1, 1.5 and 2 m/s takes to reach constant friction 17, 14 and 11 minutes respectively. It indicates that the higher the sliding velocity, time to reach constant friction is less. This may be due to the higher the sliding velocity, the surface roughness and other parameters take less time to stabilize. From Figs. 8, 9 and 10, it can be observed that the trends in variation of friction coefficient with the duration of rubbing are very similar to that of Fig. 7 but the values of friction coefficient are different for gear fiber-mild steel rough pair, glass fiber-mild steel smooth pair and glass fiber-mild steel rough pair.

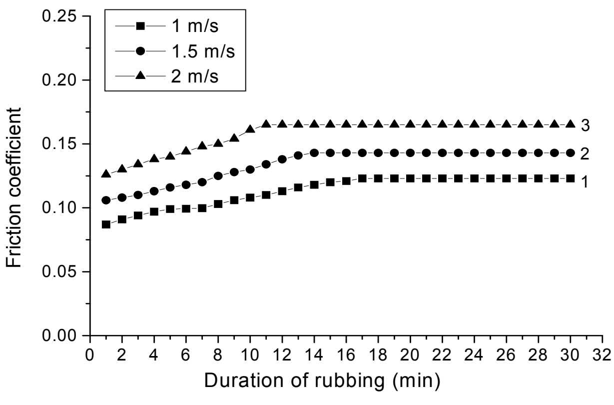


Fig. 7. Friction coefficient as a function of duration of rubbing at different sliding velocities (normal load: 15 N, relative humidity: 70%, test sample: gear fiber, pin: mild steel, smooth).

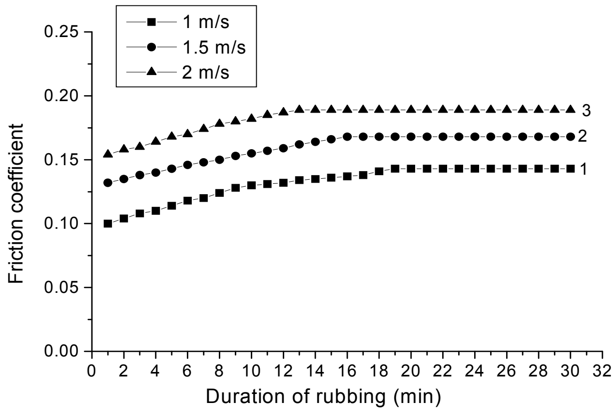


Fig. 8. Friction coefficient as a function of duration of rubbing at different sliding velocities (normal load: 15 N, relative humidity: 70%, test sample: gear fiber, pin: mild steel, rough).

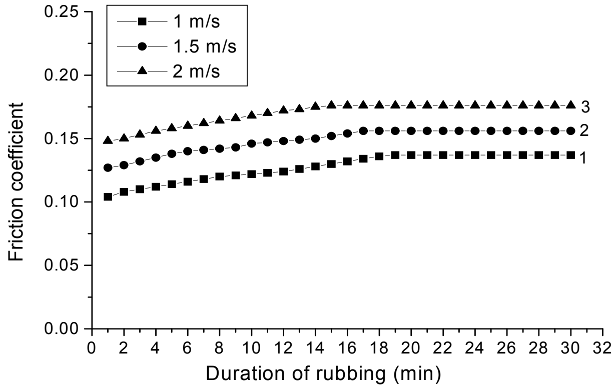


Fig. 9. Friction coefficient as a function of duration of rubbing at different sliding velocities (normal load: 15 N, relative humidity: 70%, test sample: glass fiber, pin: mild steel, smooth).

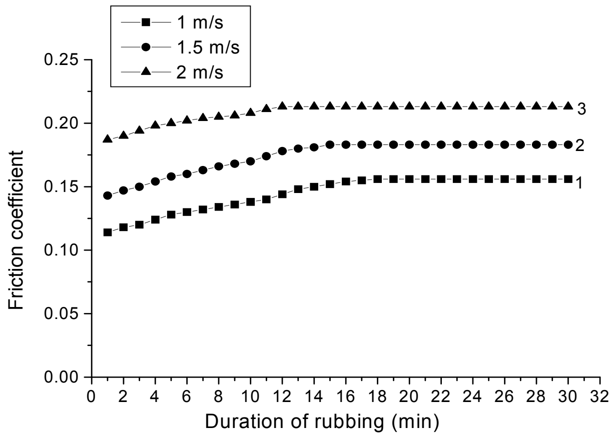


Fig. 10. Friction coefficient as a function of duration of rubbing at different sliding velocities (normal load: 15 N, relative humidity: 70%, test sample: glass fiber, pin: mild steel, rough).

Figure 11 shows the comparison of the variation of friction coefficient with sliding speed for gear fiber-mild steel smooth, gear fiber-mild steel rough, glass fiber-mild steel smooth and glass fiber-mild steel rough sliding pairs. Curves of this figure are drawn from steady values of friction coefficient shown in Figures 7–10 for gear fiber-mild steel smooth, gear fiber-mild steel rough, glass fiber-mild steel smooth and glass fiber-mild steel rough sliding pairs. It is shown that the friction coefficient varies from 0.123 to 0.165, 0.143 to 0.189, 0.137 to 0.176 and 0.156 to 0.213 with the variation of sliding speed from 1 to 2 m/s for gear fiber-mild steel smooth, gear fiber-mild steel rough, glass fiber-mild steel smooth and glass fiber-mild steel rough sliding pairs respectively. From these results it is seen that the values of friction coefficient increase almost linearly with sliding speed. These findings are in agreement with the findings of Mimaroglu et al. and Unal et al. [27,28]. With the increase in sliding speed, the frictional heat may decrease the strength of the materials and high temperature results in stronger or increased adhesion with pin [27,51]. The increase of friction coefficient with sliding speed can be explained by the more adhesion of counterface pin material on disc. From the obtained results, it can also be seen that the highest values of the friction coefficient are obtained for glass fiber-mild steel rough pair and the lowest values of friction coefficient are obtained for gear fiber-mild steel smooth pair. The values of friction coefficient of gear fiber-mild steel rough pair and glass fiber-mild steel smooth pair are found in between the highest and lowest values. It is noted that the friction coefficients of gear fiber-mild steel rough pair are higher than that of glass fiber-mild steel smooth pair. From this figure, it is also found that at identical conditions, the values of friction coefficient of gear fiber and glass fiber sliding against smooth mild steel counterface is lower than that of gear fiber and glass fiber sliding against rough mild steel counterface. It was found that after friction tests, the average roughness of gear fiber-mild steel smooth pair, glass fiber-mild steel smooth pair, gear fiber-mild steel rough pair and glass fiber-mild steel rough pair varied from 1.05-1.45, 1.35-1.78 and 1.67-1.88 and 1.76-1.98 μm respectively.

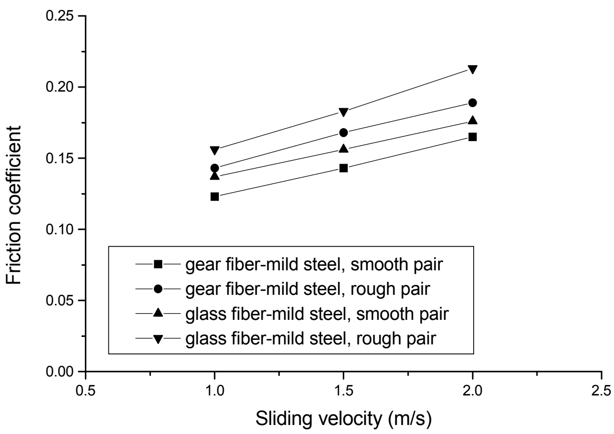


Fig. 11. Friction coefficient as a function of Normal load for gear and glass fiber for different counterface surface conditions (normal load: 15 N, relative humidity: 70%).

Variations of wear rate with normal load for gear fiber and glass fiber sliding against smooth or rough mild steel counterfaces are shown in Fig. 12. The experimental results indicate that the curves drawn showing the variation of wear rate from 0.815 to 1.453, 1.135 to 1.751, 0.929 to 1.553 and 1.638 to 2.35 mg/min with the variation of normal load from 10 to 20 N for gear fiber-mild steel smooth, gear fiber-mild steel rough, glass fiber-mild steel smooth and glass fiber-mild steel rough sliding pairs respectively. From these curves, it is observed that wear rate increases with the increase of normal load for all types of sliding pairs. When the load on the pin is increased, the actual area of contact would increase towards the nominal contact area, resulting in increased frictional force between two sliding surfaces. The increased frictional force and real surface area in contact causes higher wear. This means that the shear force and frictional thrust are increased with increase of applied load and these increased in values accelerate the wear rate. Similar trends of variation are also observed for mild steel–mild steel couples [52], i.e wear rate increases with the increase in normal load.

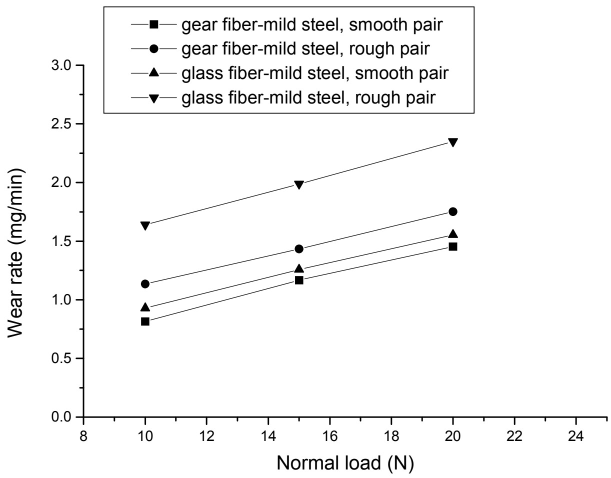


Fig. 12. Wear rate as a function of Normal load for gear and glass fiber for different counterface surface conditions (Sliding velocity: 1 m/s, relative humidity: 70%).

Figure 12 also shows the comparison of the variation of wear rate with normal load for gear fiber and glass fiber under different pin surface conditions. From the obtained results, it can also be seen that the highest values of the wear rate are obtained for glass fiber-mild steel rough pair and the lowest values of wear rate are obtained for gear fiber-mild steel smooth pair. The values of wear rate of gear fiber-mild steel rough pair and glass fiber-mild steel smooth pair are found in between the highest and lowest values. It is noted that the wear rates of gear fiber-mild steel rough pair are higher than that of glass fiber-mild steel smooth pair. From this figure, it is also found that at identical conditions, the values of wear rate of gear fiber and glass fiber sliding against smooth mild steel counterface is lower than that of gear fiber and glass fiber sliding against rough mild steel counterface.

Variations of wear rate with sliding velocity for gear fiber and glass fibre mating with smooth or rough mild steel counterfaces are presented in Fig. 13. Curves show the variation of wear rate from 1.167 to 1.778, 1.433 to 2.25, 1.258 to 1.95 and 1.987 to 2.78 mg/min with the variation in sliding speed from 1 to 3 m/s for gear fiber-mild steel smooth, gear fiber-mild steel rough, glass fiber-mild steel smooth and glass fiber-mild steel rough sliding pairs respectively. From these curves, it is observed that wear rate increases with the increase in sliding speed for all types of material combinations. These findings are in agreement with the findings of Mimaroglu et al and Suresha et al. [27,38]. This is due to the fact that duration of rubbing is same for all sliding velocities, while the length of rubbing is more for higher sliding velocity. The reduction of shear strength of the material and increased true area of contact between contacting surfaces may have some role on the higher wear rate at higher sliding velocity [51].

Figure 13 also shows the comparison of the variation of wear rate with sliding velocity for different sliding pairs. From the obtained results, it can also be seen that the highest values of the wear rate are obtained for glass fiber-mild steel rough pair and the lowest values of wear rate are obtained for gear fiber-mild steel smooth pair. The values of wear rate of gear fiber-mild steel rough pair and glass fiber-mild steel smooth pair are found in between the highest and lowest values. It is noted that the wear rates of gear fiber-mild steel rough pair are higher than that of glass fiber-mild steel smooth pair.

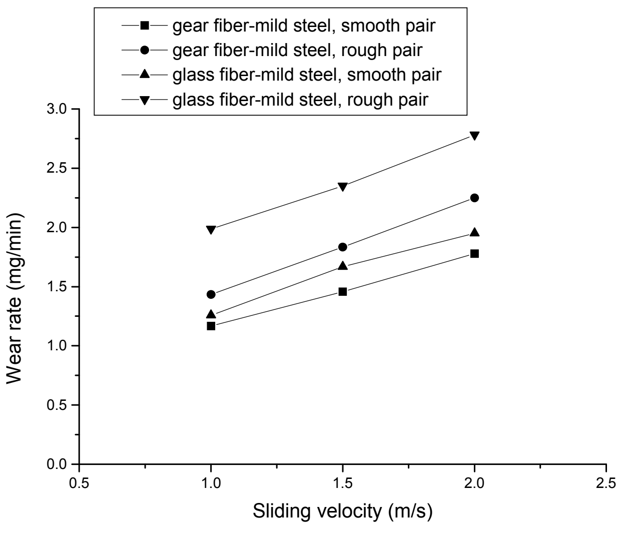


Fig. 13. Wear rate as a function of Normal load for gear and glass fiber for different counterface surface conditions (normal load: 15 N, relative humidity: 70%).

From this figure, it is also found that at identical conditions, the values of wear rate of gear fiber and glass fiber sliding against smooth mild steel counterface is lower than that of gear fiber and glass fiber sliding against rough mild steel counterface. It is due to the fact that rough surfaces generally wear more quickly and have higher friction coefficients than smooth surfaces.

4. CONCLUSION

The presence of normal load and sliding velocity indeed affects the friction force considerably. Within the observed range, the values of friction coefficient decrease with the increase in normal load while friction coefficients increase with the increase in sliding velocity for gear fiber and glass fiber sliding against smooth or rough mild steel pin. Friction coefficient varies with the duration of rubbing and after certain duration of rubbing, friction coefficient becomes steady for the observed range of normal load and sliding velocity. Wear rates of gear fiber and glass mating with smooth or rough mild steel counterface increase with the increase in normal load and sliding velocity. The highest values of the friction coefficient are obtained for glass fiber-mild steel rough pair and the lowest values of friction coefficient are obtained for gear fiber-mild steel smooth pair. The values of friction coefficient of gear fiber-mild steel rough pair and glass fiber-mild steel smooth pair are found in between the highest and lowest values. The friction coefficients of gear fiber-mild steel rough pair are higher than that of glass fiber-mild steel smooth pair. At identical conditions, the values of friction coefficient of gear fiber and glass fiber sliding against smooth mild steel counterface is lower than that of gear fiber and glass fiber sliding against rough mild steel counterface.

As (i) the friction coefficient decreases with the increase in normal load (ii) the values of friction coefficient increase with the increase in sliding velocity (iii) wear rate increases with the increase in normal load and sliding velocity and (iv) the magnitudes of friction coefficient and wear rate are different for smooth and rough counterface pins and type of materials, therefore maintaining an appropriate level of normal load, sliding velocity as well as appropriate choice of counterface surface condition and tested materials, friction and wear may be kept to some lower value to improve mechanical processes.

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