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Tribological behavior and vibration effect on the friction coefficient and temperature of glass fiber composite

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Abstract

The extents of contact coefficient are diverse for various material sets relying upon typical load and sliding speed. In the present research, grating coefficients and wear of glass fiber (GF) composite circles sliding against aluminum stick under vibration are explored and the outcomes were contrasted with a similar condition which is not in under vibration. So as to play out the tests, a stick on circle mechanical assembly is utilized. Tests are completed when aluminum stick slides on glass fiber (GF) plates of various organizations, for example, polyamide 6 (PA6), 20% GF and 15% GF. Examinations are led at ordinary load 2.5, 3.75 and 5N, sliding speed 0.5, 0.75 and 1 m/s. Varieties of erosion coefficient with the length of rubbing at diverse typical loads and sliding speeds are explored under vibration (vertical vibration). As a rule, contact coefficient expanded for a specific length of rubbing yet after that it stay steady for whatever remains of the test time. The trial result uncovers that contact coefficient diminished with the expansion in ordinary load for all the tried plates at steady speed and spring solidness. Then again, it is additionally found that grating coefficient diminished with the expansion in sliding speed however wear rate increments. Besides, both the friction coefficient and wear rate expanded with the expansion in spring firmness at consistent typical load and sliding speed for all sliding pairs. The contact coefficient is observed to be to some degree littler under vibration contrasted with that of vibration less condition.

Keywords: *Vibration, Friction coefficient, wear, PA6, GF and Temperature*

INTRODUCTION

Friction is the resisting force that opposes the motion during sliding or rolling that is experienced whenever one solid body moves tangentially over another with which it is in contact. The resistive tangential force which acts in a direction directly opposite to the direction of motion is called the friction force [1, 2].There are two main types of friction that are commonly encountered: dry friction and fluid friction [3, 4].If the solid bodies are in contact together and a tangential force (F)is applied, then the value of the tangential force that is required to initiate motion in one of the bodies is the static friction force F static or F_s. It may take a few milliseconds before relative motion is initiated at the interface [5]. The tangential force required to maintain relative motion is known as the kinetic(or dynamic)friction force, F kinetic or F_k. The static friction force is generally much greater than the kinetic friction force [6, 7].Surface contaminants or in films affect friction. Investigations showed that the well-lubricated surfaces generally have weak adhesion and friction. A small quantity of liquid present at the interface results in liquid mediated adhesion, which may result in high friction, especially between two smooth surfaces [8].In most other sliding and rotating components such as bearings and seals, friction is undesirable. Friction causes energy loss and wear of mating surfaces. In these cases, minimized [9, 10]. The basic laws of friction are generally obeyed with a little variation which is within a few percent in many cases. It has been observed that coefficient of friction (μ) is strictly constant only fo a given pair of sliding materials under a given set of operating conditions such as temperature ,humidity, normal pressure and sliding velocity etc. [11].The coefficients of static and kinetic friction in dry and lubricated contacts for many materials show dependence of normal load, sliding velocity and apparent area .Therefore ,Bhushan [2] stated that any reported values should be used with caution. We can be defined as the progressive loss of surface material due to normal load and relative emotion. This generally leads to degradation of the surface ,loss of component functionally, and in many situations, to catastrophic failure [12].The highly complex nature of the wear process made It difficult to develop generalized procedures for predicting it is occurred and intensity. Even wear test under seemingly controlled conditions, are now a days are producible. It is not unusual that repeated tests may give wear rates which differ by magnitude [13]. Wear, as friction, is not a material property, it is a system response. Operating conditions Such as roughness of rubbing surfaces, temperature, normal pressure and sliding velocity affect interface wear. Erroneously it is sometimes assumed that high-friction interfaces exhibit high wear rates. This is necessarily not true [14, 15].For example, interfaces with solid lubricants and polymers exhibit relatively low friction and relatively high wear, where as ceramics exhibit moderate friction but extremely low wear [16].Numerous investigations have been carried out on friction and wear of different materials under different operating conditions. Archard [1]an do the researchers[17-19]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 etc. Even now a day, the effects of normal load and sliding velocity on friction and wear for glass fiber are less understood [20, 21].This means that more work is needed to get better understanding of friction and wear under normal load, sliding velocity and other related parameters.

Therefore, in this study an attempt is made to investigate the effect of normal load and sliding velocity on the friction and wear of glass fiber. The relative frictional and wear behavior of these materials are also compared in this study. The aim in the present study are to determine the effect of sliding velocity and normal load on the frictional behavior of different disc materials such as polyamide 6, 20%GF and 15%GF with PA6, sliding against Aluminum Pin. The effects of vibration on friction and wear properties of glass fiber of different compositions at different normal loads and sliding velocities were also observed in this study and compared to the results with those which are obtained under no vibration. The variation of surface temperature for the test materials with the course of rubbing time was attained. The scope of this study is to find out a way of reducing friction force by applying known frequency of vibration at a particular direction so that mechanical process can be considerably improved.

Experimental and methodology

Experimental

A schematic outline of the test set-up is appeared in Fig. 1 i.e. a stick which can slide on a pivoting flat surface (circle). In this set-up a roundabout test (circle) is to be settled on a pivoting plate (table) having a long vertical shaft clasped with screw from the base surface of the turning plate. The pole goes through two close-fit shrub direction which is inflexibly settled with stainless steel plate and stainless steel base to such an extent that the pole can move just pivotally and any spiral development of the turning shaft is limited by the bramble. 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 aluminum, fitted on a holder is subsequently fitted with an arm. The arm is turned with a different base in a manner that the arm with the stock holder can pivot vertically and on a level plane about the rotate point with low erosion. Sliding rate can be differed by two courses (i) by changing the frictional range and (ii) by changing the rotational speed of the pole. In this exploration, sliding pace is differed by changing the rotational speed of the pole while keeping up 25 mm consistent frictional sweep. To quantify the frictional drive following up on the stick amid sliding on the turning plate, a heap cell (TML, Tokyo Sokki Kenkyujo Co. Ltd, CLS-10NA) alongside its computerized marker (TML, Tokyo Sokki Kenkyujo Co. Ltd, Model no. TD-93A) was utilized. The coefficient of grinding was acquired by isolating the frictional constrain by the connected ordinary drive (stack).

Wear was measured by measuring the test with an electronic adjust prior and then afterward the test, and afterward the distinction in mass was changed over to wear rate. To quantify the surface harshness of the test tests, Taylor Hobson Precision Roughness Checker (Surtronic 25) was utilized. Each test was directed for 30 minutes of rubbing time with new stick and test. Moreover, to guarantee the dependability of the test outcomes, each test was rehashed five circumstances and the disperse in results was little, in this way the normal estimations of these test outcomes were taken into consideration. All test conditions are appeared in Table 1.

Table 1: *Experimental Conditions*

Sl. No.	**Parameters**	**Operating Conditions**
1.	Normal Load	2.5, 3.75 and 5 N
2.	Sliding Velocity	0.5, 1 m/s
3.	Duration of Rubbing	10 minutes
4.	Surface Condition	Dry
5.	Material (Disc)	PA6 Glass fiber **(**15**%)** Glass fiber **(**20**%)**
6.	Pin material	Aluminum

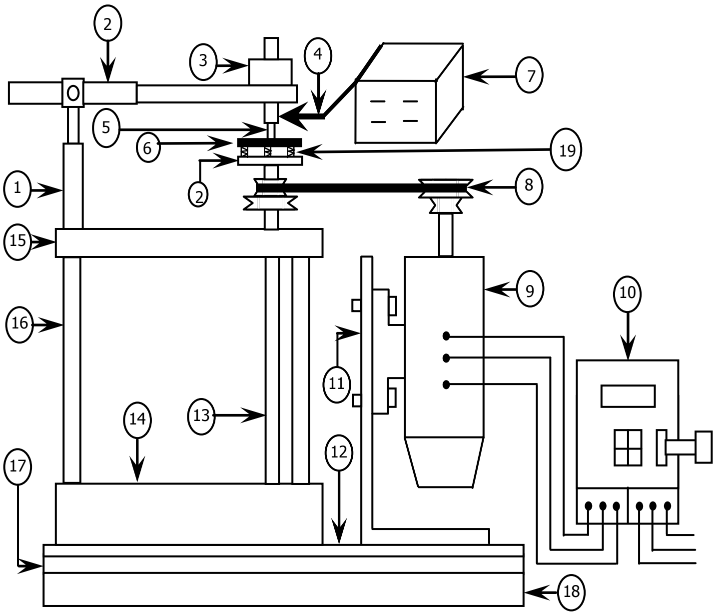

Fig. **1**:Block Diagram of the Experimental Set-up

1. Load arm holder
2. Load arm
3. Normal load (dead weight)
4. Horizontal load (Friction force)
5. Pin sample
6. Test disc
7. Load cell indicator
8. Belt and pulley
9. Motor
10. Speed control unit
11. Vertical motor base
12. Rubber pad (3 mm thick)
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. Spring
20. Rotating Table

Methodology

Test discs were prepared according to desired surface finish condition.The weights of the test sample discs were measured before the test by a precision digital weight balance equipment.Three springs of a particular stiffness were placed on the rotating table with the help of three screws to get the vibration and a test sample disc is clamped on the springs.A digital vibration analyzer was connected to the setup to know the amplitude, frequency, displacement and acceleration of the vibration.The sliding pin is clamped by a screw with the pin holder and placed on the upper surface of the test sample at a measured certain radius to maintain a constant sliding velocity.A measured weight is placed and fixed on the load arm in such a way that it can act directly at the tip of the sliding pin.A load cell was connected to the pin holder to measure the horizontal i.e. friction force.The rpm of the rotating disc is adjusted by using a compound V pulley speed control unit.After a certain duration (2 minutes) of rubbing of the pin against the test sample disc, the load cell was pulled in a given direction to measure the friction force and the disc was removed from the rotating table after a given period (10 minutes).After removal, the weight of the test disc was measured by the digital weight balance.Friction coefficient was measured as the ratio of horizontal force to vertical load created by the normal load.Wear rate was measured by taking the difference between the weights before and after abrasion loss of mass of the sample disc.Different known dead weights can be placed on pin holder (2.5, 3.75 and 5 N) so that required normal force will act on the test sample through the pin.Sliding velocity can be varied by two ways (i) changing the rotation of the shaft associated with the frequency change and

(ii) changing the radius of the point of contact of the sliding pin when frequency does not change. During experiment the radius of the point of contact of the sliding pin was kept constant at 25 mm because the change of curvature may affect resisting the measurement of force. Maximum allowable rpm of the shaft was 1500 with least count of 1 rpm.

RESULTS AND DISCUSSION

Experiments were carried out under different normal load, different spring stiffness and different sliding velocity conditions for different disc materials. In this study, the effects of normal load, duration of rubbing and sliding velocity under vibration on friction and wear behavior of different materials are discussed.

Effect of Normal Load on the Friction Coefficient

The effects of normal load for glass fiber disc of different compositions and different stiffness are discussed below. The variations of the friction coefficient with the changes in spring stiffness are also reported.

Fig. 2 shown the variation of friction coefficient at different normal load, constant spring stiffness and sliding velocity. During experiment, the sliding velocity was maintained to be 0.5 m/s and the spring stiffness was kept as 800.74 kg/m. **Fig. 2** is drawn for three normal loads of 2.5, 3.75 and 5 N at 0.5 m/s sliding velocity. From this curve, it is shown that the values of friction coefficient increase with the increase in normal load. For PA6 (Polyamide 6) disc, the changes are very significant but in the cases of 20% and 15% glass fiber discs, the curves are almost flat. From the curve, the variation of the friction coefficient with the increase of the percentage in glass fiber composition is not found to be clear to understand.**Fig. 3** shown the variation on friction coefficient due to the changes in normal load for different spring stiffness at constant sliding velocity for PA6 disc.The sliding velocity was kept to be 0.5 m/s. Two types of springs were used in this experiment whose spring stiffness was 800.74 and 100.74 kg/m respectively. The experiment was conducted only for polyamide (PA6) disc sliding against aluminum pin. From the graph, it is shown that the magnitude of the friction coefficient decreases with the increase in normal load for both types of spring. The graph shows that the friction coefficient of the spring having lower stiffness is greater than that of the spring having higher stiffness.

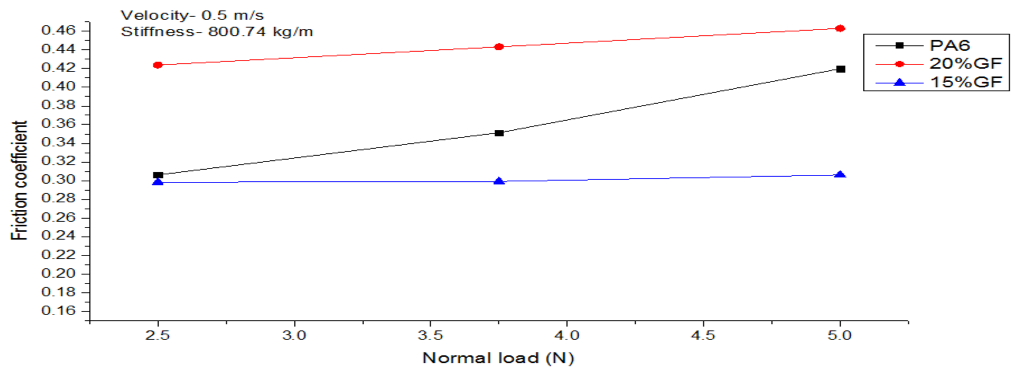

Fig. 2:*Effect of normal load on the friction coefficient for different disc materials at constant velocity and stiffness*

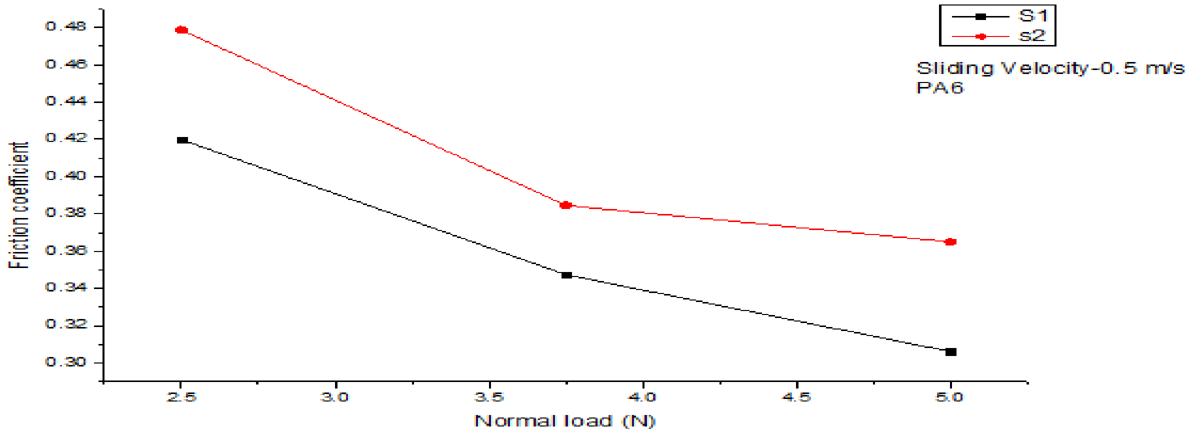

Fig. ***3***: *Effect of normal load on friction coefficient for different spring stiffness at constant sliding velocity for Polyamide 6 (PA6)disc*

Effect of Sliding Velocity on Friction Coefficient

Fig. 4 shown the variation on friction coefficient for different disc materials at constant spring stiffness and normal load. During the experiment, the normal load and spring stiffness were maintained as the constant values of 5N and 800.74 kg/m respectively. The curve was plotted for sliding velocities of 0.5, 0.75 and 1 m/s. From the curve, it is shown that the friction coefficient decreases with the increase in sliding velocity. The effect was observed for three different disc materials such as polyamide 6, 20% GF and 15% GF. In every case, **Fig. 4** showed the same effect. It may also be added that for 20% GF disc, the friction coefficient is largest among all the tested disc material.

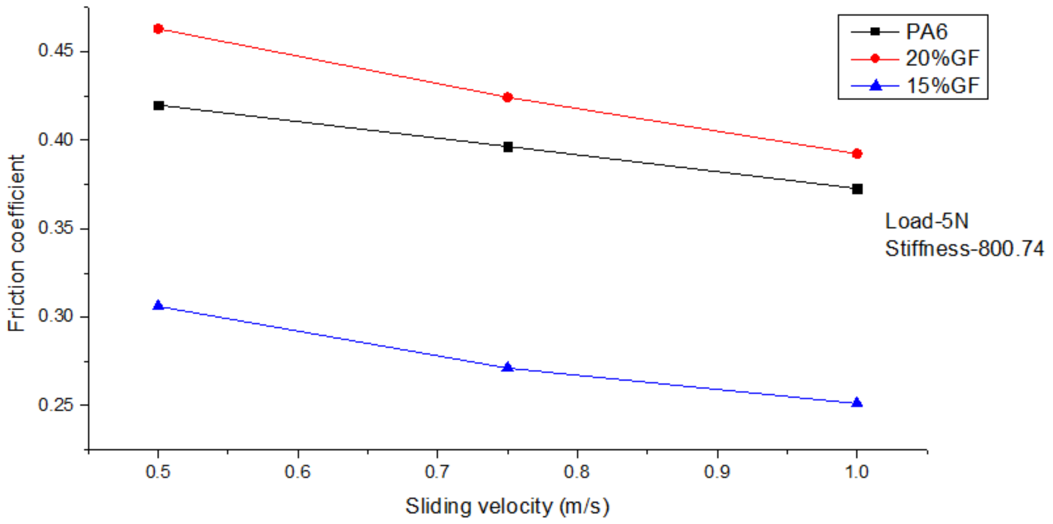

Fig. ***4***:*Effect of sliding velocity on the friction coefficient for different disc materials at constant load and stiffness*

Effect of Vibration on Friction Coefficient

Fig. 5 and**Fig.6** shown the variation on friction coefficient for different disc materials between under vibration and vibration less conditions.The effect was observed for two types of disc materials such as 20% and 15% GF. From the graphs, it is seen that the friction coefficient under vibration for 15% GF material is always larger than that of in vibration less condition. But in case of 20% GF material, initially the friction coefficient is almost same but after a certain period of rubbing, the friction coefficient increases significantly under vibration compared to vibration less condition.

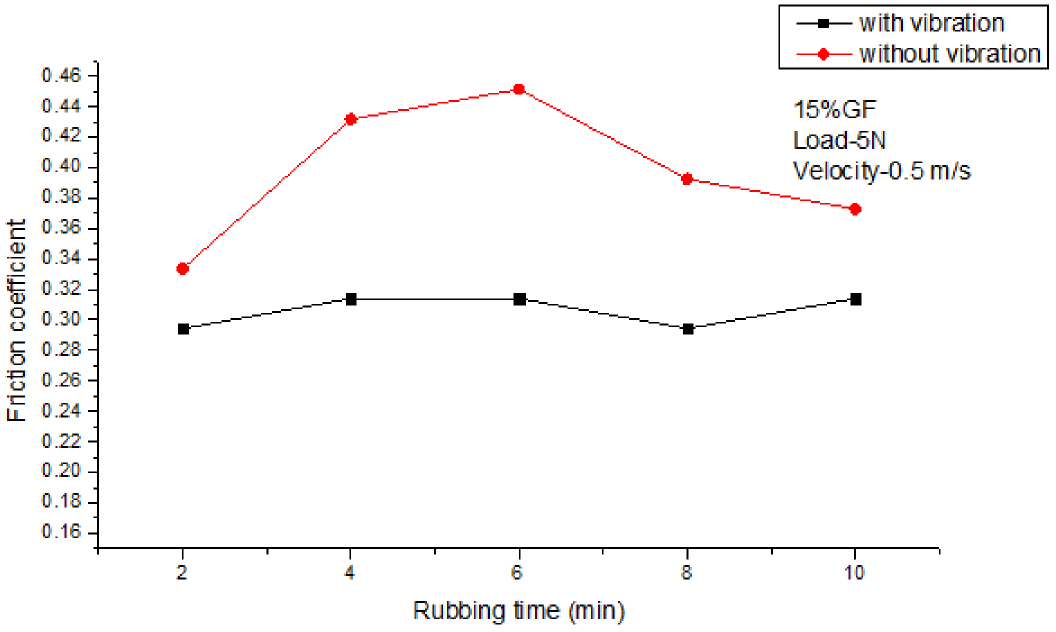

Fig. 5:*Variation of the friction coefficient with the course of rubbing time at constant normal load and sliding velocity (0.5m/s) between vibration and vibration less condition for 15%GF disc.*

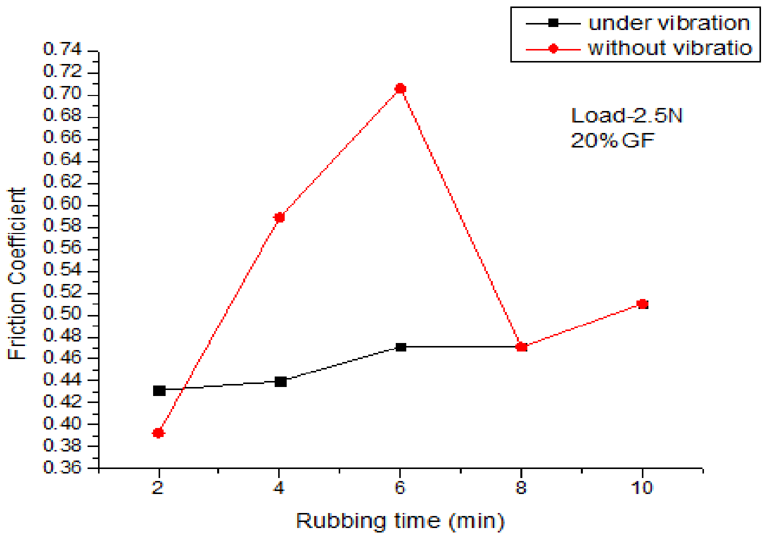

Fig. *6*:*Variation of the friction coefficient with the course of rubbing time at constant normal load and sliding velocity (0.5m/s) between vibration and vibration less condition for 20% GF disc.*

Effect of rubbing time on Friction Coefficient

Fig. 7and **Fig. 8**shown the effect of rubbing time on friction coefficient for different spring stiffness at constant normal load and sliding velocity with vibration.A constant normal load of 5N and sliding velocity of 1m/s were maintained in case of polyamide 6 material but in 20% GF materials, 2.5 N normal load and 0.5 m/s sliding velocity were kept constant. For PA6 material, the friction coefficient sometimes increases withthe rubbing time but the same effect is not found to be always constant. The friction coefficient slightly increases with the increase in rubbing time. Moreover, when the stiffness is increased, the friction coefficient also increases for each test disc material.

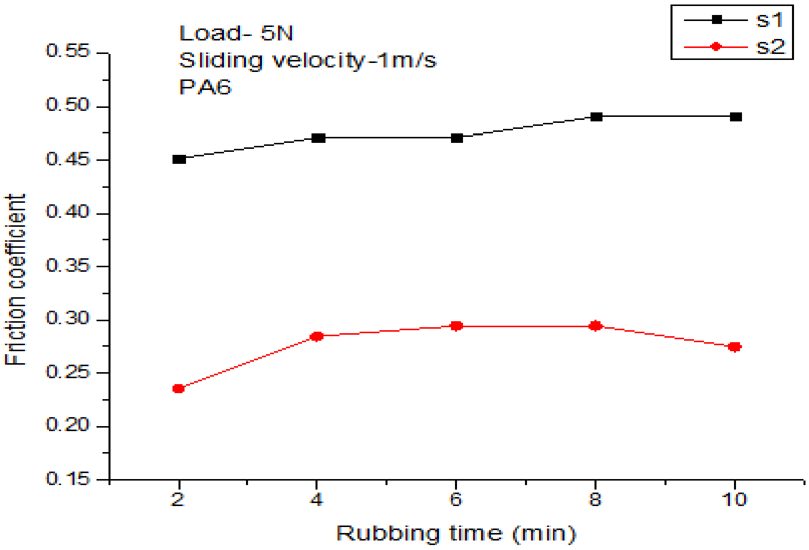

***Fig.** 7:Variation of friction coefficient with the duration of rubbing for different spring stiffness at constant normal load and sliding velocity for PA6 disc*

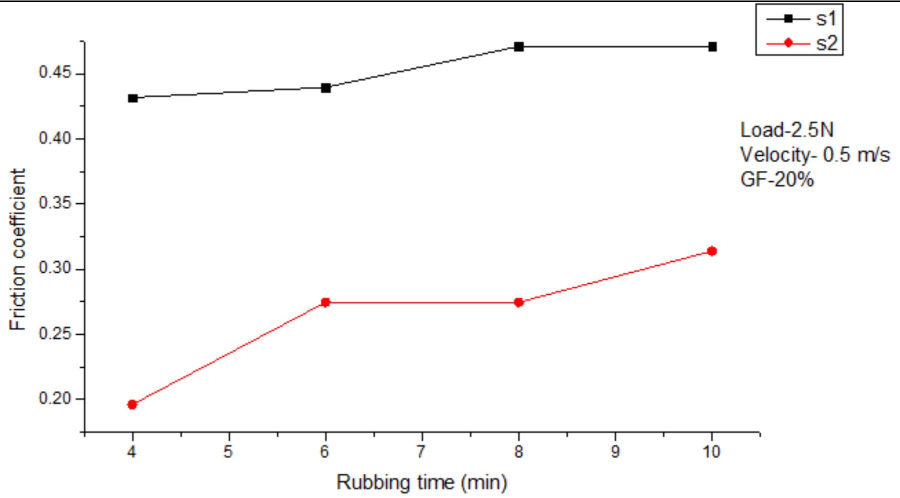

***Fig.** 8:Variation of friction coefficient with the duration of rubbing for different spring stiffness at constant normal load and sliding velocity for 20% GF*

Effect of Sliding Velocity on wear rate

Fig. 9 and **Fig. 10** showed the effect of sliding velocity on wear rate at constant normal load and spring stiffness for different disc materials such as polyamide 6, 20% GF and 15% GF. The curve is plotted for three different sliding velocities of 0.5, 0.75 and 1 m/s. The normal load and spring stiffness were kept constant as 5 N and 800.74 kg/m respectively. The wear rate increases with the increase in sliding velocity for each disc material.

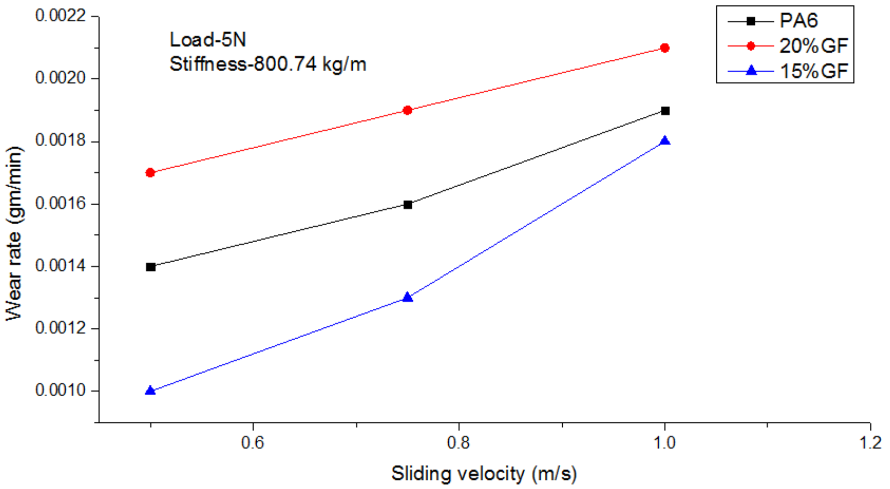

***Fig**. 9:Effect of sliding velocity on wear rate for different disc materials at constant normal load and stiffness*

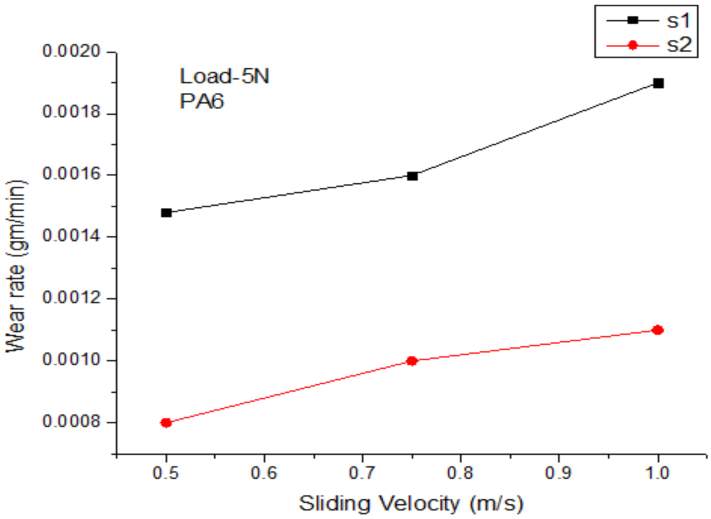

***Fig**. 10:Effect of sliding velocity on wear rate at constant normal load for PA6.*

Effect of Rubbing Time on the Surface Temperature of Disc Material

Fig. 11 showed the temperature variation of the disc surface with the rubbing time at constant normal load and sliding velocity. It also showed the comparison in surface temperature between under vibration and vibration less condition. In this experiment, the normal load and sliding velocity were maintained as the constant values of 2.5 N and 0.5 m/s respectively. The data was collected for 10 minutes of rubbing time. From the graph, it is shown that the surface temperature increases with the increase in rubbing period for both the conditions i.e., under vibration and vibration less condition.

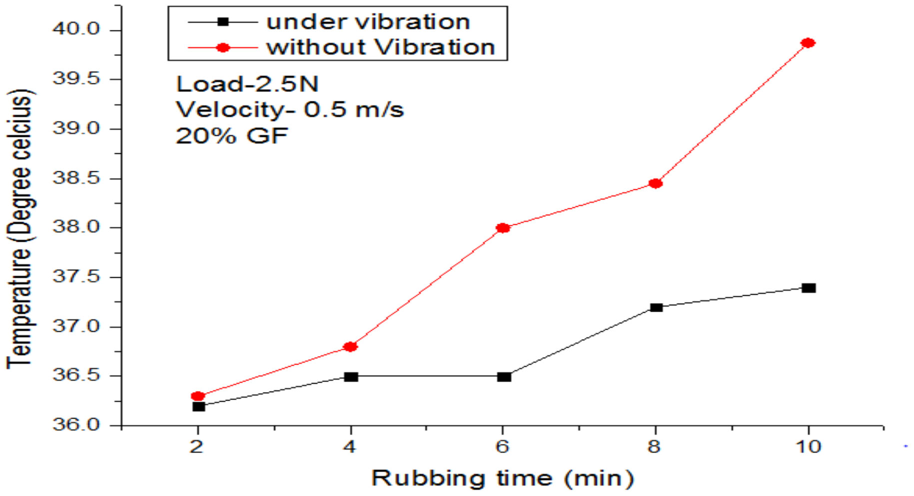

***Fig*. 11**:*Variation in temperature with the course of rubbing time at constant normal load and sliding velocity (0.5m/s) between vibration and vibration less condition for 20 % GF disc.*

CONCLUSION

The friction coefficient increases by 37.18%, 9.26% and 2.63% for PA6, 20% GF, and 15% GF materials respectively when the normal load is doubled at constant velocity and spring stiffness.The friction coefficient decreases by 12.63%, 18% and 21.87% for PA6, 20% GF, and 15% GF materials respectively when the sliding velocity is doubled remaining other conditions are to be constant.The friction coefficient ofPA6 material increases by 8.69% and 16.67% for the stiffness of 800.74 kg/m and 100.51 kg/m respectively at constant normal load and sliding velocity.The wear rate increments by 35.71%, 23.53% and 63.64% or PA6, 20% GF, and 15% GF materials individually while the sliding speed is multiplied staying different conditions are to be steady. The grating coefficient of 15% GF material increments by 11.76% under vibration when the rubbing time is expanded from 2 to 10 minutes at steady ordinary load and sliding velocity. The surface temperature of 20% GF material is observed to be 1.6 ◦C larger than its underlying temperature following 10 minutes of rubbing when the circle is pivoted under vibration.

REFERENCES

1. Sin, H., N. Saka, and N. Suh, *Abrasive wear mechanisms and the grit size effect*. Wear, 1979. **55**(1): p. 163-190.
2. Bhushan, B., *Handbook of micro/nano tribology*. 1998: CRC press.
3. Bhushan, B. and A.V. Kulkarni, *Effect of normal load on microscale friction measurements*. Thin Solid Films, 1996. **278**(1-2): p. 49-56.
4. Farahani, M.V., et al., *Effect of grain refinement on mechanical properties and sliding wear resistance of extruded Sc-free 7042 aluminum alloy*. Materials & Design, 2014. **54**: p. 361-367.
5. Nuruzzaman, D., et al., *Experimental Study on Friction Coefficient and Wear Rate of Gun Metal Sliding Against Different Counterface Materials*. Journal of the Balkan Tribological Association, 2014. **20**(2): p. 169-183.
6. Chowdhury, M.A., et al., *Experimental Investigation of Friction Coefficient and Wear Rate of Different Sliding Pairs*. World Applied Sciences Journal, 2013. **28**(5): p. 608-619.
7. Chowdhury, M.A. and M. Helali, *The effect of relative humidity and roughness on the friction coefficient under horizontal vibration*. Open

Mechanical Engineering Journal, 2008. **2**: p. 128-135.

8. Chowdhury, M.A., M.M. Helali, and A.T. Hasan, *The frictional behavior of mild steel under horizontal vibration.* Tribology International, 2009. **42**(6): p. 946-950.
9. Chowdhury, M., S.M.I. Karim, and M. Ali, *The influence of natural frequency of the experimental set-up on the friction coefficient of copper.* Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology, 2010. **224**(3): p. 293-298.
10. Chowdhury, M. and M. HELALI, *The Influence of Natural Frequency of the Experimental Set-up on the Friction Coefficient of Stainless Steel-304.* Tribology in Industry, 2010. **32**: p. 19-24.
11. Asaduzzaman Chowdhury, M., D. Muhammad Nuruzzaman, and M. Lutfar Rahaman, *Influence of external horizontal vibration on the coefficient of friction of aluminium sliding against stainless steel.* Industrial Lubrication and Tribology, 2011. **63**(3): p. 152-157.
12. Krousgrill, C. and F. Sadeghi, *Stability of sliding in a system excited by a rough moving surface.* 1997.
13. Kajio, T., et al., *Study on seismic behavior of special levees of rivers using centrifuge dynamic tests.* Japanese Geotechnical Society Special Publication, 2017. **5**(2): p. 141-146.
14. Saada, F.B. and K. Elleuch, *Tribological behavior of 304 L stainless steel used for olive oil extraction.* Mechanics & Industry, 2017. **18**(2): p. 207.
15. Sednaoui, T., et al., *Friction Reduction Through Ultrasonic Vibration Part 2: Experimental Evaluation of Intermittent Contact and Squeeze Film Levitation.* IEEE Transactions on Haptics, 2017.
16. Khodabakhshi, F., A. Simchi, and A. Kokabi, *Surface modifications of an aluminum-magnesium alloy through reactive stir friction processing with titanium oxide nanoparticles for enhanced sliding wear resistance.* Surface and Coatings Technology, 2017. **309**: p. 114-123.
17. Hekimoğlu, A.P. and T. Savaşkan, *Effects of Contact Pressure and Sliding Speed on the Unlubricated Friction and Wear Properties of Zn-15Al-3Cu-1Si Alloy.* Tribology Transactions, 2016. **59**(6): p. 1114-1121.
18. Maurya, R., et al., *Effect of carbonaceous reinforcements on the mechanical and tribological properties of friction stir processed Al6061 alloy.* Materials & Design, 2016. **98**: p. 155-166.
19. Bidmeshki, C., et al., *Effect of Mn addition on Fe-rich intermetallics morphology and dry sliding wear investigation of hypereutectic Al-17.5% Si alloys.* Journal of Materials Research and Technology, 2016. **5**(3): p. 250-258.
20. Vishwakarma, A., et al., *Effect of cenosphere size on the dry sliding wear behaviour LM13-cenosphere syntactic foam.* Tribology International, 2017. **110**: p. 8-22.
21. Tabandeh-Khorshid, M., et al., *Tribological performance of self-lubricating aluminum matrix nanocomposites: role of graphene nanoplatelets.* Engineering Science and Technology, an International Journal, 2016. **19**(1): p. 463-469.