Static/kinetic Friction behaviour of a Clutch Facing Material: Effects of Temperature and Pressure

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***Abstract*—**The feasibility of applying a simple and cost effective sliding friction testing apparatus to study the friction behaviour of a clutch facing material, effected by the variation of temperature and contact pressure, was investigated. It was found that the method used in this work was able to give a convenient and cost effective measurement of friction coefficients and their transitions of a clutch facing material. The obtained results will be useful for the development process of new facing materials.

***Keywords*—**Static/Kinetic friction, Sliding friction testing apparatus, Contact pressure and temperature dependent of friction coefficients

I. Introduction

A clutch is one of the most important components of a vehicle drive system. Its main task is to transmit torque and speed from engine to gear box via frictional engagement. During this engagement process, a transient sliding contact situation occurs between the pair of clutch facings mounted on the friction disk and the counter faces of the flywheel and the pressure plate. Clutch facing, which is a composite material consisting of binder resin, continuous glass fibrous yarn, friction modifiers and fillers, is considered to be the most essential part of a clutch disc. For an effective power transmission, it is desirable for clutch facing to possess high friction coefficient that is constant over wide range of pressure and temperature. It should also be resistant to wear and able to withstand high temperatures encountered in the service conditions. It is known that not only static and kinetic friction but also the transition from static to kinetic friction are very important for the performance of clutch facing [1]. In order to develop a more efficient and a better perform clutch, it is it is necessary to investigate both static and kinetic friction behavior of clutch facing materials as function of several parameters such as temperature, sliding velocity and contact pressure. Many standard laboratory tests are often employed by the manufacturers, for examples, JIS D-4311 [2] and SAE J661a [3] to study friction behavior of clutch facings. However, most of these tests are costly and time consuming.

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The results are usually useful for assessment of material specifications, but they are difficult to be used for research and development. Pin-on-disc method has shown to be one of the most effective test configurations which allow a reliable and quick determination of coefficient of friction and wear of friction materials [4][5][6]. However this method can only assess to the kinetic friction behavior of materials but not the static friction. A specially designed pellet-on-plate sliding tribometer was used to study static friction and transition from static to kinetic friction behavior of ceramic friction materials[7][8]. These studies were performed at room temperature to evaluate the effect of surface finish and contact pressure, thus the effect of temperature was not studied.

In this present paper, we investigated the feasibility to use a simple and cost effective sliding friction testing apparatus based on a standard testing method ISO 8285 [9], which is normally used for investigation of the static and dynamic frictional properties of film and sheet plastics, for the study of a clutch facing material's friction behavior effected by the variation of temperature and contact pressure. The results obtained can be used as a comparison with data obtained from other testing methods such as pin-on-disc and for development process of new facing materials.

II. Material, Experimental Methods

A. Clutch facing material

A commercially available clutch facing material from a supplier in Thailand was used in this study. A clutch facing investigated came in the form of an annular plate disk and was manufactured by the usual scatter wound process.

B. Experimental Methods

An apparatus was built and arranged for sliding friction testing. It was assembled onto the existing Instron 5567 universal testing machine. The arrangement of the apparatus, as shown in Fig 1, consisted of a horizontal test table, a sled, heating device and a pulling mechanism via a pulley and cable system attached to the universal testing machine's crosshead. On the top of the horizontal test table was a flat plate made from a single piece of cast iron with the same quality and roughness as used for flywheels. Underneath this flat plate were heating plates used for providing variance temperature conditions. The sled, which was to be pulled across the table, was made of a 12.5 thick square steel plate. Dead weights were placed on top of the sled for applying contact pressure. There were 3 specimen holders made from circular steel blocks attached underneath the steel plate using screws and fasteners. The clutch facing investigated was cut into small test pieces of the size approximately 20 mm. x 45 mm. One side of each test piece was adhered onto the specimen holder using a special adhesive. The arrangement of the specimen holders and test pieces described is shown in Fig.2.

Testing conditions performed was listed in Table I. The range of temperature used was 100 ^{o}C to 200 ^{o}C and the contact pressure was between 0.145 MPa and 0.385 MPa. Before each test, the flat cast iron top surface was cleaned by Acetone such that there was no dust or any contamination on the surface. The heating device was set to a selected temperature and the flat plate was heated until the desired temperature was achieved. Then the sled with the test pieces facing the flat plate and dead weight applied on the top was placed onto the test table. The variation of contact pressure was achieved by adding or removing the dead weights placed on sled. The sled was then pulled across the table at a constant speed of 500 mm/min for all tests. The pulling force was then recorded and the data was used to calculate for coefficient of friction at an instant using equation (1). The static coefficient of friction was determined as the maximum coefficient of friction obtained before sliding occurred (pulling force began to drop) and kinetic of friction coefficient as the average friction coefficient obtained during sliding.

$$\mu = \frac{F}{N} \tag{1}$$

Where μ is coefficient of friction, F is Tangential force (pulling force) and N is normal force or weight.

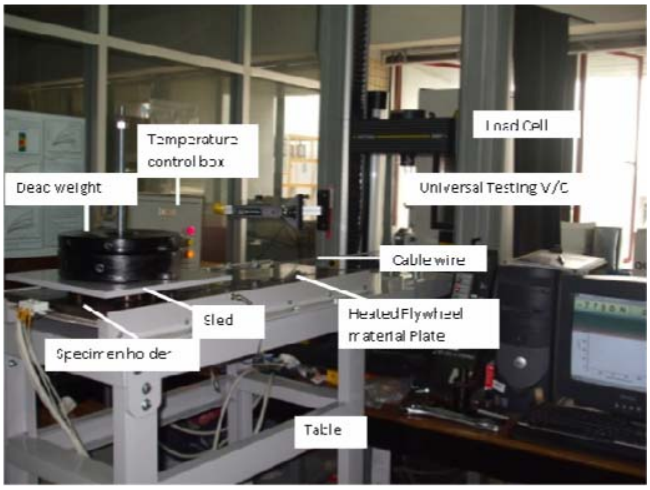

Fig. 1 The arrangement of the sliding friction testing apparatus

Fig. 2 The arrangement of the specimen holders and test pieces attached underneath the sled

TABLE I
TESTING CONDITIONS

Setting no.	Temperature (^{o}C)	Gross weight (N)	Gross Contact Presssure (MPa)
1	100	42.128	0.145
2	100	72.128	0.248
3	100	112.128	0.385
4	200	42.128	0.145
5	200	72.128	0.248
6	200	112.128	0.385

All tests were performed at speed 500 mm/min

III. RESULTS

The results obtained were plotted as apparent coefficient of friction vs. pulling distance (mm) as shown in Fig. 3 to Fig.7. The summary of results was presented in Table II and surface plot of the summary was shown in Fig 8.

TABLE II
SUMMARY OF RESULTS

Setting no.	Temperature (^{o}C)	Gross Contact Presssure (MPa)	Static Friction Coefficient, μ_s	Kinetic Friction Coefficient, μ_k
1	100	0.145	0.23	0.18
2	100	0.248	0.23	0.18
3	100	0.385	0.22	0.18
4	200	0.145	0.47	0.44
5	200	0.248	0.56	0.54
6	200	0.385	0.45	0.44

A. *Effect of Contact Pressure*

From the results shown in Fig. 3, it was found that at 100 ^{o}C there was no significant change in coefficient of frictions when contact pressure varied. However, at 200 ^{o}C, there was some change in coefficient of frictions with varying contact pressure as depicted in Fig. 4. There was an increase in friction coefficients when contact pressure increased from 0.147 MPa to 0.252 MPa, but when the pressure increased to 0.393 MPa the coefficients dropped down to almost the same level as with 0.147 MPa contact pressure. Thus, due to this fluctuation, the effect of contact pressure was not obvious.

B. *Effect of Temperature*

The effect of temperature on coefficients of friction at different levels of contact pressure was shown in Fig. 5 to Fig. 7. It can be seen that for all level of contact pressure, the friction coefficients increased greatly as temperature increased from 100 ^{o}C to 200 ^{o}C. It can also be noticed that the difference between static and kinetic friction coefficients was much lesser at 200 C which static and kinetic coefficients were almost the same.

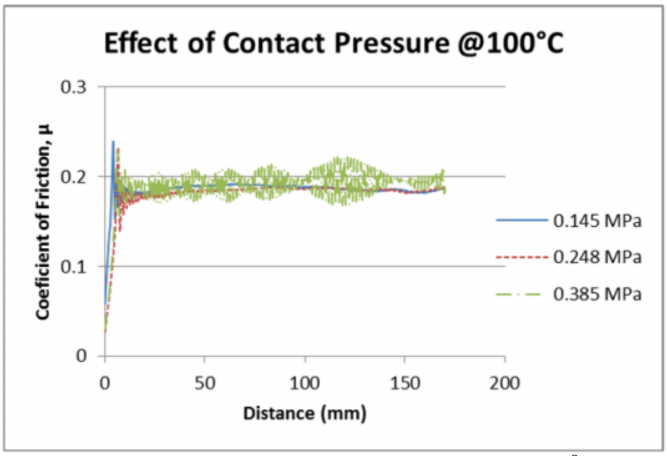

Fig. 3 Coefficient of friction versus sliding distance at 100 °C with variation of contact pressure

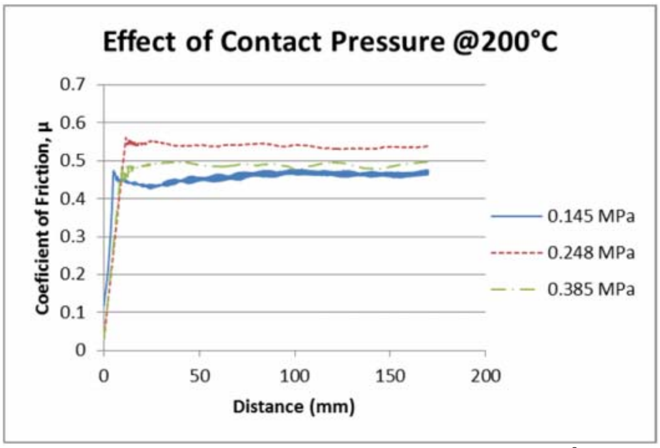

Fig. 4 Coefficient of friction versus sliding distance at 200 °C with variation of contact pressure

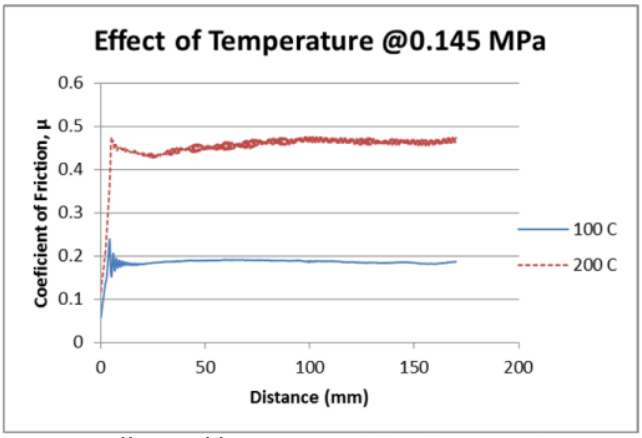

Fig. 5 Coefficient of friction versus sliding distance with contact pressure of 0.145 MPa, at 100°C and 200°C

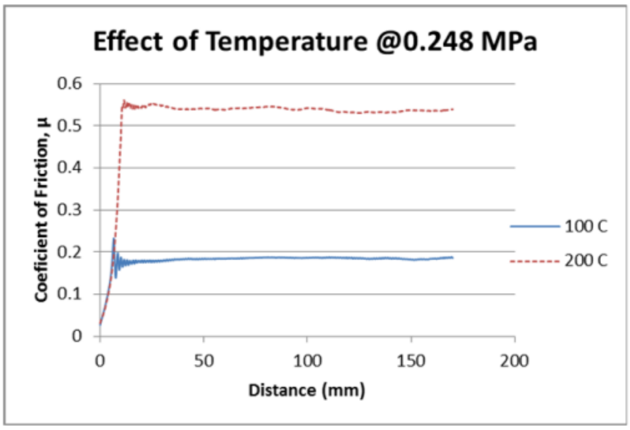

Fig. 6 Coefficient of friction versus sliding distance with contact pressure of 0.248 MPa, at 100°C and 200°C

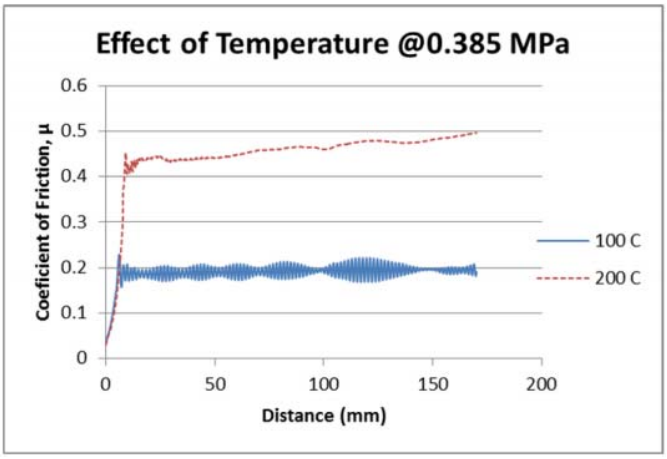

Fig. 7 Coefficient of friction versus sliding distance with contact pressure of 0.385 MPa, at 100°C and 200°C

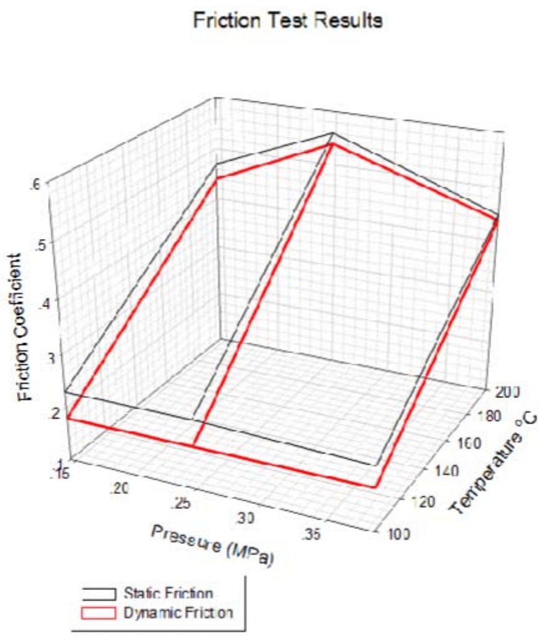

Fig. 8 Surface plot for static and kinetic friction Coefficients versus Temperature and Contact pressure

IV. Discussion and Conclusion

From the presented study, by using a simple sliding friction apparatus it was possible to obtain a preliminary investigation of the effect of temperature and contact pressure on static and kinetic friction coefficient of a clutch facing material. At the travelling speed of 500 mm/min, it was found that both static and kinetic friction coefficient were not affected by the variation of contact pressure used. However, temperature variation had a profound effect on static and kinetic friction coefficients as they increased approximately by two folds when temperature was raised from 100 ^{o}C to 200 ^{o}C. The values of static and kinetic friction coefficient obtained were almost the same at 200 ^{o}C. This was due to the change in the material's properties with temperature at the contacting surface as it softened and the friction mechanism at the transition from static to kinetic friction altered. It was also found that when the temperature was raised higher than 200 ^{o}C, clutch facing material began to melt at the contacting surface. The results obtained from this study will be compared with the results obtained from pin-on-disk method in the future. The method used had the limit of pulling speed of 500 mm/min and the application of contact pressure was limited by the amount of dead weight which can be placed on the sled. Thus, the range of speed and contact pressure studied may not be in the range of the real service conditions. Nevertheless, the method was able to give an easy and cost effective access to the friction coefficients and their transitions which can be useful for the development process of new facing materials.

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