PERFORMANCE OF ASBESTOS-FILLED RESIN COMPOSITES

PART II: TRIBOLOGICAL PROPERTIES

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ABSTRACT

Automotive brake linings used nowadays are a complex composite of organic resin binder, asbestos fiber reinforcement and friction modifying fillers. This paper investigate the dependency of the tribological properties, mainly, the coefficient of friction, the wear rate, and the fade temperature on the constituents used to formulate the linings. Seven formulations were produced with different asbestos/resin content ratio. The tribological properties were measured. The drag dynamometer results showed that the fade temperature and the wear rate increases as the asbestos content increases. The coefficient of friction of low asbestos content varies initially from 0.2 to 0.25 but it decreases rapidly to 0.1. For high asbestos contents, the coefficient of friction was appeared to be erratic.

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INTRODUCTION

A satisfactory brake friction-material must have moderate coefficient of friction and operate efficiently over a wide range of temperature. Significant decrease of coefficient of friction with rise of operating temperature is known as brake fade. Nelson [1] in his discussion on the effect of temperatire on friction materials put some temperature limitations for every type of friction materials. The friction heat generated may reach a point where the brake friction components may oxidize or melt, resulting in a rapid wear of the lining and sharp drop of the coefficient of friction (brake-fade). This phenomenon of brake-fade is the most important problem and originated mainly due to friction heating at the friction surface. Newcomb [2] studied theoretically and experimentally the temperature rise due to friction heating. A mechanism of brake fade was given by Kragelski [3] on the basis of decomposition of the resin in the friction lining at high temperature. Geogrioski [4] investigated the effect of various factors on the friction resin based friction materials. According to Geogrivski, decomposition of resin by heat produces liquid products above 300°C and gaseous products above 400°C. Tanaka et al. [5] verified Geogrivski finding by experimental investigation through their study of asbestos filled resin as friction materials.

Friction materials in brakes wear out by one or a combination of the following mechanisms [6, 7 and 8]:

1. Abrasive and microcutting wear.
2. Fatigue wear.
3. Macro shear wear.
4. Thermal wear.
5. Adhesion wear and tearing.

The influence of some of the opposing metal properties on wear of friction pads has been investigated by Rhee [8]. He used a drag dynamometer to investigate the effect of surface roughness, thermal conductivity and microstructure on wear of friction materials of brake pads. The author concluded that organic bonded friction composites wears by abrasive and possibly by adhesive wear mechanisms when the operating temperature of the brake is less than 280°C. When the operating temperature exceeds 280°C, thermal wear increases exponentially with the increasing temperature and is controlled by decomposition of the binder.

TEST PROCEDURE

Fig. 1 shows a sketch of test specimens used for friction and wear testing. Test specimens are prepared from different mixtures of chrysotile asbestos and phenalformaldehyde as binding resin. Asbestos is increased in steps of 10% (on expense of resin) over a range from 10% to 90% asbestos and the balance is resin. Test samples are prepared with the same procedure described in Part I.

Fig. 2 shows a schematic drawing of the SCHENCK brake drag dynamometer used for friction and wear testing. It employs a grey cast iron brake drum of an inside diameter of 300 mm, against which two test specimens are radially pressed. The brake drum is driven with variable speed motor and the temperature of the drum is controlled using cooling fan. Temperature of the drum surface is measured using contacting thermocouple. To obtain meaningful results, shoe pads must be conditioned (run-in) before testing is carried out. This ensures stable contact area on brake shoes. Running speed, operating pressure, friction torque and temperature rise may be readily measured. Wear is measured by weighing test specimens before and after a test is conducted.

TEST RESULTS AND DISCUSSION

It is well known that brake friction is generally dry friction in nature. The heat generated during braking plays an important role in brake friction behaviour. Other factors that affect the coefficient of friction are rubbing speed and brake pressure.

The coefficient of friction, when measured at constant temperature, decreases slightly with increase of sliding velocity. Nelson [1] explains that there is generally some decrease in the coefficient of friction with increase in rubbing speed, and this is a phenomenon of friction material and is known as "speed sensitivity". Tanaka et al. [5] described the friction behaviour of a friction material in an inertia brake dynamometer. The increase of initial speed causes, in general, slight decrease of the average coefficient of friction. When the bulk temperature was elevated to 300°C, the average coefficient of friction was found to increase with increase of speed. The coefficient of friction usually increases slightly as the flywheel is about to stop. Mathews [9] assumes that the increase of speed increases the rate at which asperities are employed. However, the increase of speed is also associated with higher interface temperature which weakens the mechanical forces and reduce friction.

Generally, the coefficient of friction of composite materials decreases slightly with the increase of pressure. Nelson [1] showed that most friction materials exhibit a decrease of the coefficient of friction with the increase of pressure. Tanaka et al. [5] had confirmed this general trend with their experiments on an inertia dynamometer. For all ranges of temperatures tested, they found that the average coefficient of friction decreased slightly with the increase of the unit pressure. Mathews [9] has suggested, however, that the increase of pressure may cause an pressure may cause deformation at the interface contracting points and brings more asperities to play part and to provide increased mechanical effects.

It may, therefore, be concluded that the friction temperature relationship is the most important relationship for a friction material.

Applying a load of 3 KN (1 M.Pa.) to each friction pad and at rubbing speed of 4 m/sec, the friction force and temperature of brake drum were measured against time and results are shown in Figs. 3 and 4. Fig. 3 shows results obtained for three types of composites with asbestos to resin ratios of 20%:80%, 40%:60% and 50%:60%, and Fig. 4 shows results for the other composites 60%:40%; 70%:30% and 80%:20%. As the temperature gradually increases, the coefficient of friction of composites with low asbestos content rapidly decreases. The time elapsed before friction attains its lowest value is the fade time. The friction coefficient after fade time is the fade friction coefficient. The temperature which causes fade to occur is the fade temperature.

Table 1

Composite (asbestos: resin)	Fade time min.	Fade friction coefficient	Fade Temperature °C
20% : 80%	3	0.075	135
40% : 60%	1	0.10	165
50% : 50%	9	0.11	175
60% : 40%	8	0.14	240
70% : 30%	24	0.1	330
80% : 20%	-	-	-
90% : 10%	-	-	-

It may be seen from Table 1 that the increase ofasbestos percent causes an increase of both fade time and fade temperature. For the composites of high asbestos content 80% and 90% no fade was detected. This observation demonstrates the heat resistant capability of asbestos in asbestos based friction composite. The low coefficient of friction at fade is because of the decomposed and oxidized resin. Products of resin oxidation or decomposition are hydrocarbons which may act as lubricants at the friction surface.

To obtain fade characteristics of different friction composites formulated from asbestos and resin, fade tests were carried out and results are shown in Fig. 5. It may be seen that composites with asbestos content equal to and less than 50% fades quite rapidly when the operating temperature approaches 120°C or 180°C. These composites can hardly be called friction materials, owing to their little resistance to temperature rise. As the asbestos content increases both the friction co-

Table 2

Composite Asbestos%/resin %	Friction-coefficient	Fade temperature °C
60/40	0.22	140
70/30	0.26	330
80/20	0.31	400
90/10	0.35	350

Table 2 is compiled from test results plotted in Fig. 5. Table 2 shows that the increase of asbestos content causes increase of both friction coefficient and fade temperature. A typical performance of a friction-composite is that of the 70% asbestos and 30% resin. The coefficient of friction tends to decrease slightly as the temperature approaches 200°C, whereafter the friction coefficient increases steadily till fade temperature is reached. At fade temperature the friction coefficient drops sharply. The coefficient of friction of cured resin decreases as the temperature increase above 100°C, owing to seggregation of liquid lubricant of light resin fraction. The liquid products of boundary or semi-fluid friction. As the temperature increases further, liquid products evaporate and conditions of dry contact are regained causing the steady increase of the coefficient of friction. As the temperature is further increased to 300°C or 400°C, thermal pyrolysis and oxidation of resin occurs resulting in brake fade. The composite with 60% asbestos does not show this characteristic since the temperature at which liquid products are produced is almost the composite fade temperature. For the composite with 90% asbestos, there is no indication of the friction coefficient being lowered on account of liberation of some liquid products. The coefficient of friction steadily increases as the fade temperature is approached. The increase of the coefficient of friction may be attributed to the accelerated wear rate of the friction composite. Wear debris are mainly asbestos particles which act as abrasives raising the coefficient of friction. The amount of resin present is so small that its contribution to friction is limited. As fade temperature is reached, the resin decomposes rapidly resulting in rapid wear of friction pad and sharp drop of the coefficient of friction.

Wear of different friction composites is shown in Fig. 6. The relationship between wear and asbestos percent is nearly logarithmic. Though asbestos in the friction composite enhances its friction, temperature resistance and mechanical strength [10], its percentage effect has some adverse effect on wear of friction pads. By examination of friction surface after friction test was carried out, it appears that thermal wear is the dominant wear mechanism of the friction material when the asbestos content is less than 60%. Thermal wear is the material loss caused by frictional heat interface of the friction surfaces. Thermal wear encompasses a group of physical and chemical reactions in the course of which inter-atomic bonds are continuously broken. These reactions include, pyrolysis (thermal decomposition), oxidation, melting, evaporation, sublimation and explosion. The rates at whibh these reactions occur increases exponentially with temperature. Pyrolysis occurs predominantly at the centre of the pad and to lower extent at corners and edges. Oxidation on the other hand, predominates at corners and edges and is less severe near the centre. Explosive reaction can occur under highly abusive braking conditions where the rate of heat input is so high that the solid resin is converted into gases beneath the surfaces. These gases, being of great volumes, rupture the lining in an explosive manner. Flash temperatures which may be caused by local weldments and subsequent ruptures at some asperity points cause rapid decomposition of the organic comp9nents used in the composite formulation.

Wear of composites with low percentage of asbestos is associated with a glazed surface layer. The glazed layer appears to be predominantly of carboneans nature. Therefore, the glazed layer has relatively low friction coefficient and low wear rate. With composites rich in asbestos with about 80% or 90%, the glazed layer does not appear after the friction test and results of the coefficient of friction shows that high coefficient of friction is usually mentioned. The small amount of resin present in the composite results in weak binding of constituents. Asbestos particles wears away easily and thus the friction surface becomes full of voids because of the departing asbestos particles. Stresses on the remaining area becomes so high that the surface layer wears out rapidly and fresh surface comes into action.

CONCLUSION

Friction materials cannot be formulated with composites of asbestos content less than 60% unless other friction and temperature resistant agents are added. Though, fading of brakes is a phenomenon that seems to be related to physical and chemical properties of the resin matrix, the value of the fade temperature depends on the ratio of resin to asbestos in the composite. Composites with low content of asbestos are more resistant to wear but they fade away at lower temperature than composites rich in asbestos. Composites rich in asbestos give higher coefficient of friction and higher resistance to fade but they wear out easily. A formula with 70% asbestos and 30% resin appears to provide a good compromise of friction coefficient, fade temperature and wear.

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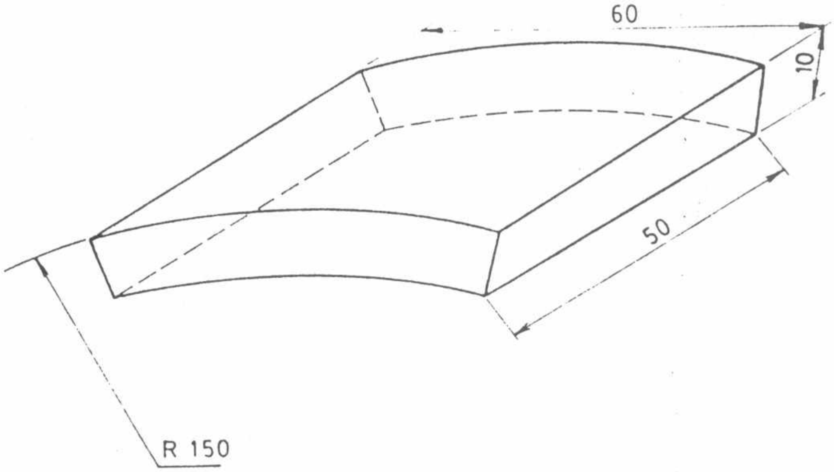

FIG.1 - FRICTION AND WEAR TEST SPECIMEN

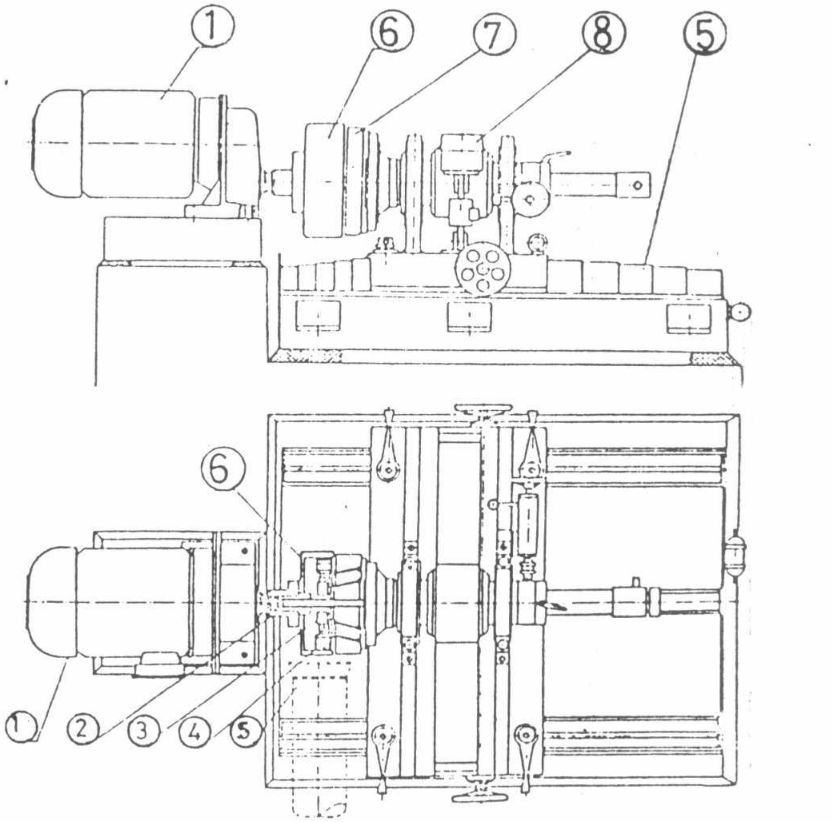

FIG. 2 _ SCHEMATIC LAYOUT OF DRAG DYNAMOMETER (SCHENCK)

1- MOTOR 2-DRIVE SOCKET 3-POWER CYLINDER

4-SPECIMEN 5-AIR DUCT 6 - DRUM

7-BRAKE ASSEMBLY 8-LOAD CELL 9 - BED

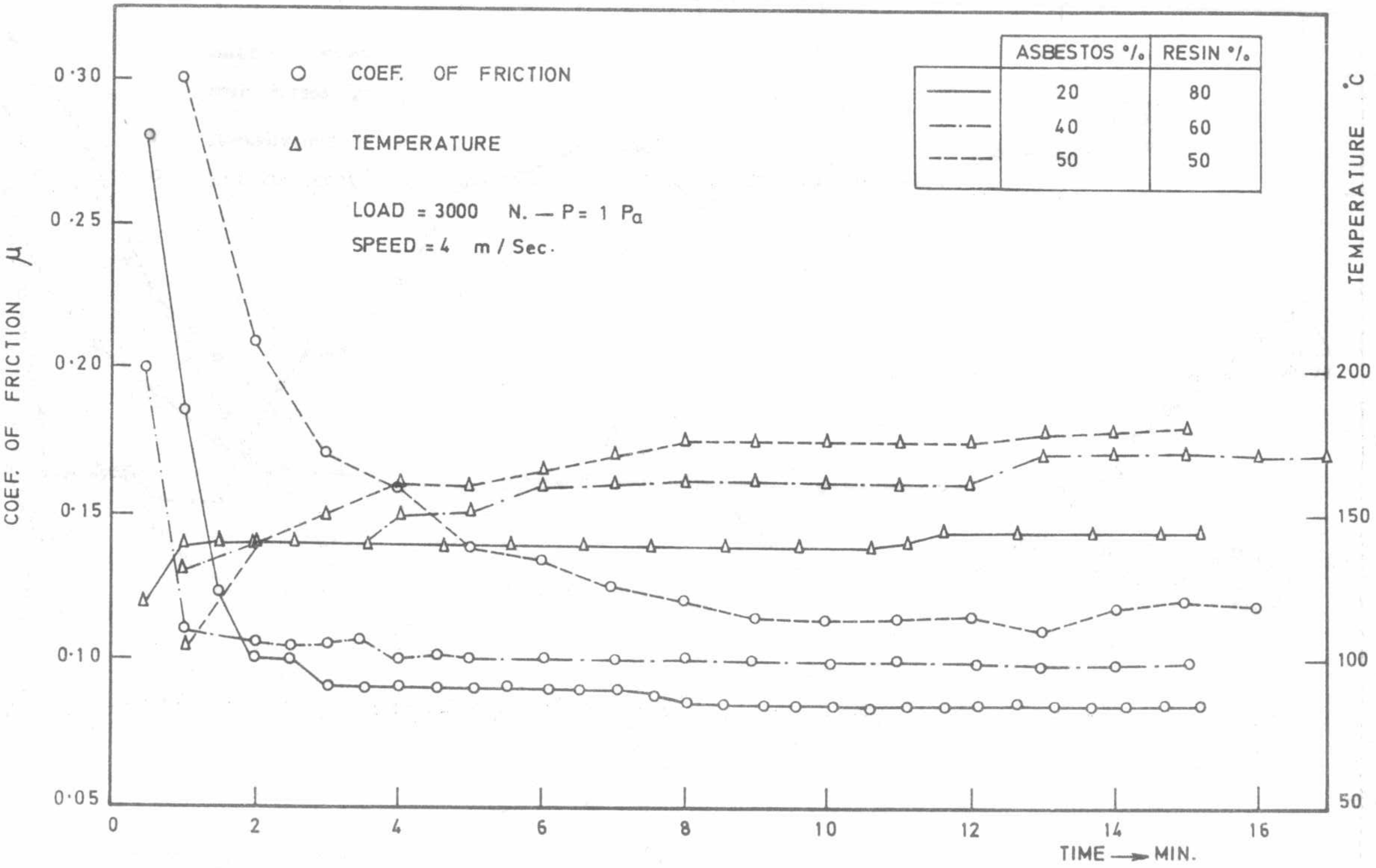

FIG. 3 – TIME TO FADE AND FADE TEMPERATURE FOR DIFFERENT FRICTION COMPOSITES

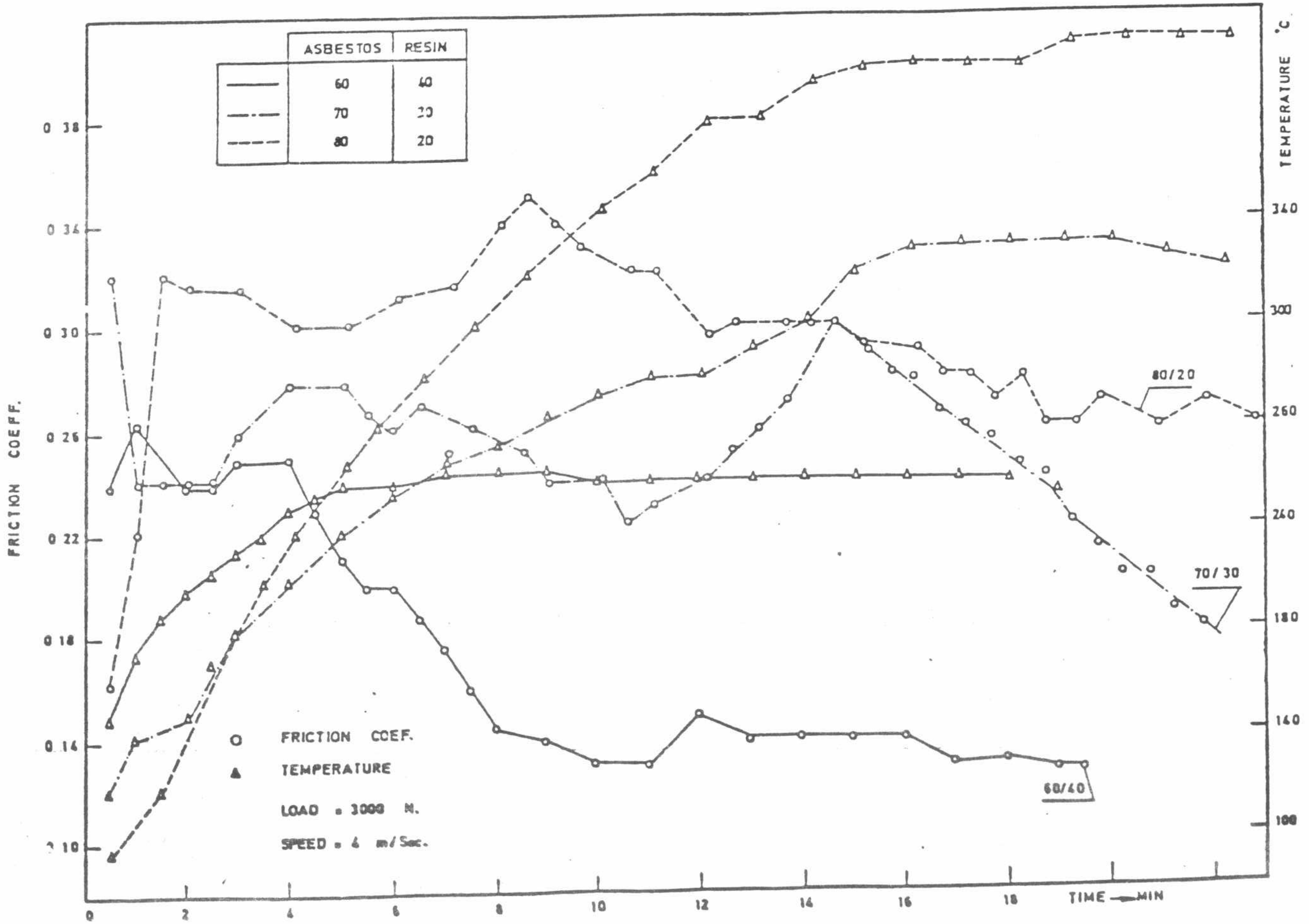

FIG.4 - TIME TO FADE AND FADE TEMPERATURE OF DIFFERENT FRICTION COMPOSITES

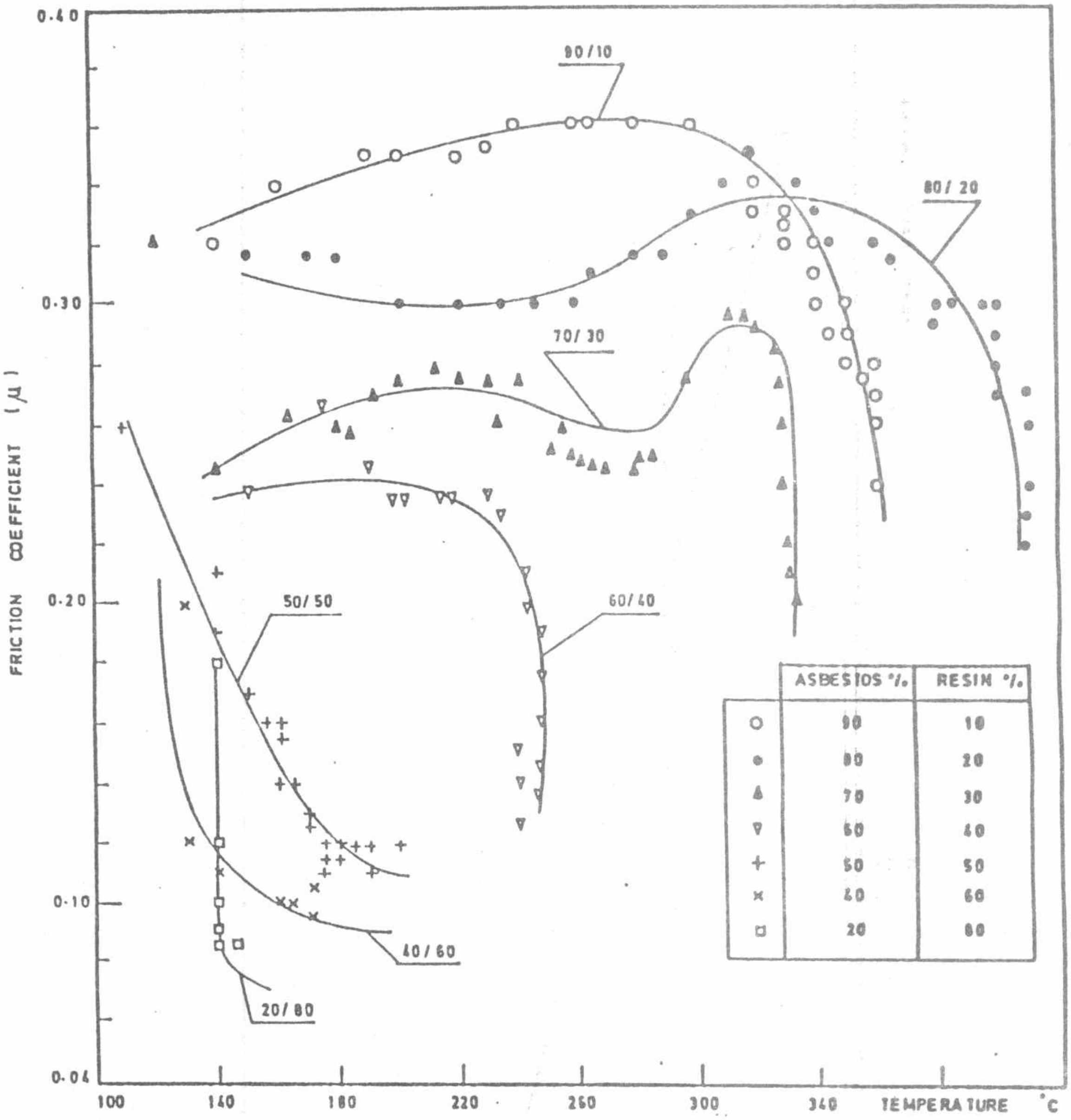

FIG. 9 - FADE CHARACTERESTICS OF DIFFERENT FRICTION - COMPOSITE

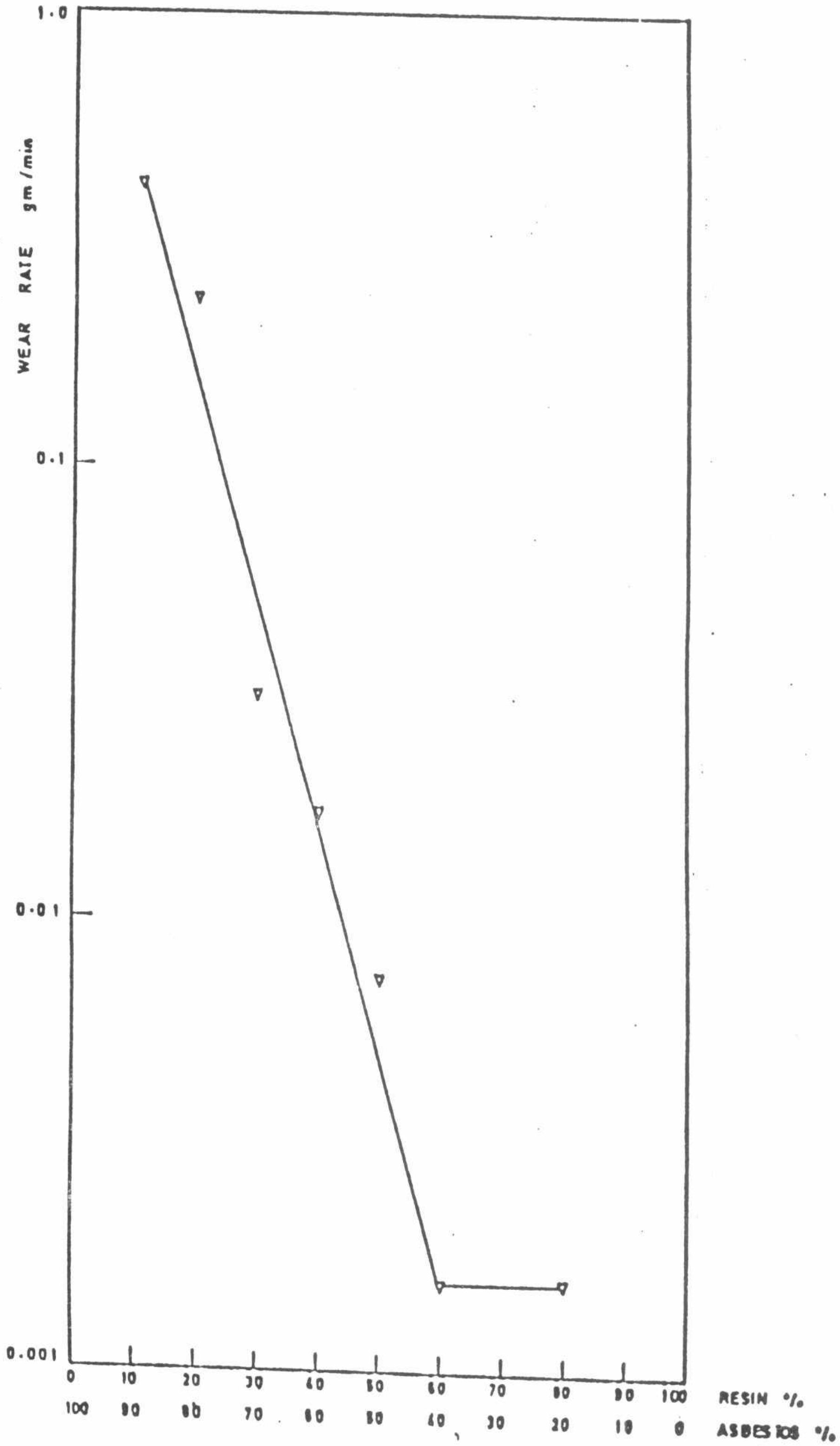

FIG. 6 - WEAR RATE FOR DIFFERENT FRICTION COMPOSITIONS