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EXPERIMENTAL STUDIES ON MECHANICAL, FRICTION AND WEAR OF NON ASBESTOS ORGANIC BRAKE LININGS FOR LIGHT MOTOR VEHICLE

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Abstract:- In this study, flyash based non asbestos organic brake lining composition of more than 14 ingredients was investigated to study the effect of ingredients on various behavior of friction properties. Two types of friction materials with different combinations were developed: i) fly ash range (10 %to 60%) and ii) without fly ash based friction materials were investigated to study the effect of ingredients on the friction characteristics and wear. The main focus on the average normal coefficient of friction, hot coefficient of friction (Fade and recovery), wear loss, mechanical, as the function of the relative amount of the ingredient. The results also showed that the friction coefficient of fly ash based friction material was better in the range of 0.35 to 0.48 when compared barites based brake linings in the range of 0.46 to 0.58. The materials such as potassium titanate(terraces), wollastonite, friction dust powder have strongly influence on friction coefficient. The wear résistance of the brake linings was strongly affected by the presence of rock wool calcium hydroxide and zircon silicate. The presence of glass fiber, twaron fiber, glass fiber has increased the strength of the friction material. All these samples were tested on chase type friction tester at automobile ancillary unit.

***Keywords** :-Flyash, braking lining material, Chase type friction tester, Mechanical, Friction, Wear.*

1.0 INTRODUCTION

Fly ash is a by-product of thermal power stations. Much of the fly ash is presently treated as a waste product for uses such as land fill although a small quantity is utilized as fillers in concrete, bricks and other materials[1-2]. Nowadays attempts has been made to utilize fly ash in manufacturing sectors where large volume usage of the same could be exploited will prove substantially beneficial in techno-commercial and environmental terms. Fly ash is composed of fine size particles (mean size 10–30 mm), with uniform physical and engineering characteristics. Fly ash possesses low specific gravity in the range of 2–3, as compared to ingredients used in contemporary brake linings[3]. Fly ash particles are typically generated at very high temperatures, i.e. 1000C upwards. Hence, they should provide a thermally stable bulk for high-temperature environments that a friction composite experiences. Also, majority of fly ashes contain substantial amounts of silica, alumina, calcium sulfate and unburnt carbon in them, which are already being used in many of current commercial brake linings. The specific heat of fly ash particles is also high (800 kJ/kg K). The successful incorporation of fly ash or fly ash derivatives into friction material formulations could greatly reduce the cost of the friction material i.e.50–60% assuming all the fillers are substituted Hence, incorporation of fly ash would possibly cater to various functional roles which otherwise are expected from a set of fillers as ingredients. The purpose of friction brakes is to decelerate a vehicle by transforming the kinetic energy of the vehicle to heat, via friction and dissipating that heat to the surroundings. The temperature sensitivity of friction materials has always been a critical aspect while ensuring their smooth and reliable functioning of the brakes. High friction materials have applications in automotive, aerospace and industrial brake systems. High friction compositions are a three-element composition consisting of a matrix of polymeric blends, reinforcing material, friction and anti-wear material [4-5]. Among the most well known polymeric systems known, the phenolic resins or modified phenolic resins are the well known thermo sets with good thermal stability. Friction materials for a brake system should be designed to maintain stable and reliable friction force at wide ranges of pressure, vehicle speed, drum temperature, humidity and others. No single material has met the performance related criteria such as safety, noise propensity, durability and comfort under various braking conditions. In general, more than 14 ingredients have been used for commercial brake friction material to accomplish above mentioned requirements. The friction materials have been formulated based on application such as light motor vehicle, light commercial vehicle and heavy duty vehicle and the ingredients comprise of fillers, binders, fibers, solid lubricants and friction modifiers and abrasive [6]. In this study an attempt has been made to incorporate fly ash in the brake liner for the effective brake application for the light motor vehicle.

2.0 EXPERIMENTS

2.1 Friction Materials

Friction materials investigated in this study were non-asbestos organic (NAO) type materials containing 14 different ingredients as shown in the table 1. The ingredients in the friction material comprise binder resin, reinforcing fibers, friction modifiers, solid lubricants as molybdenum disulphide. These ingredients were weighed in given proportions, blended well, molded in a steel die and then heat treatment process was carried out with the given parameters. Figure 1 shows conventional compression molding machine used for making friction material. The each quantity of ingredients was measured in the electronic scale and poured into the mixer for mixing. The mixing time was 15 min. After mixing, the mixture was taken out of the mixer and required quantity of.

Figure 1 shows conventional compression molding machine used for making friction material.

mixture of 220 gm was measured and kept in the die for pressing. The die was preheated to 145^0c and pressure of 160 kg/cm^2 was applied over a powder for a molding time of 6 min. The Friction material sample of size 105mm x 130mm x 30 mm was made.

Table 1 Material Composition for flyash based brake liner

Description (%) wt	Composition %
Fly ash	10-60
Filles	5-15
Friction Modifiers	15 -25
Fibers	5 -15
Binder	15
Lubricant –	3 – 9

Table 2 Process Parameters

Parameter / Level	Level1
Pressure (Kg/cm^2)	160
Temperature 0c	140
Time (min)	4 - 6

Figure 2. Frictional material used for testing purpose

2.2 Measurement of friction and wear characteristics

Friction and wear tests were conducted using a Chase-type friction tester with grey cast iron as the counterpart with a 280mm diameter and a hardness of 210 HB, according SAE J661test procedure. Figure 2 shows the fly ash based friction material used testing purpose.

2.3 Measurement of physical properties

Hardness, Porosity, tensile strength, was carried out in accordance with the ASTM D638. Rockwell hardness tester with a ball indenter was used for measuring the hardness of the brake pads machined out of the friction composites. Tensile specimen has a constant rectangular 115 mm x 25 mm x 14 mm.

3.0 RESULTS AND DISCUSSION

3.1 Effect of ingredients on physical properties

Physical properties hardness, porosity and tensile strength of the friction material specimens were measured from fly based composites and barites based composites. The mechanical property studies were carried out to find out the suitability of the composites for brake lining applications. The presence of fibers in the phenolic matrix improves the hardness and tensile, this is expected, since the hard fibers reinforce the soft resin matrix. The hardness, tensile strengths are the parameters that contribute significantly to the frictional behavior of the composites and these composites were found to exhibit good mechanical properties. Figure 3, 4, 5 and 6 exhibits correlation among the hardness of fly ash and barites based friction material under constant temperature and constant pressure for the molding of time 4 min and 6 min. The figure clearly indicates that the specimens with high hardness tend to exhibit low porosity. The low tensile strengths of the composites are attributed to the high filler content and the fibers being short in length. Though the fiber content in the case of glass composites is high (5–10 wt.%), the low tensile strength is due to the shortness of the fiber .The figure 7 and 8 shows the tensile strength of fly ash based composite were lower than fly ash based composite , due higher content of vermiculite, lime powder, mica and rubber which are added to samples. The figure 9 and 10 shows the tensile strength of barites based friction material were higher due to addition of twaron 1080 (aramid fiber), glass fiber which increases the strength of the composite.

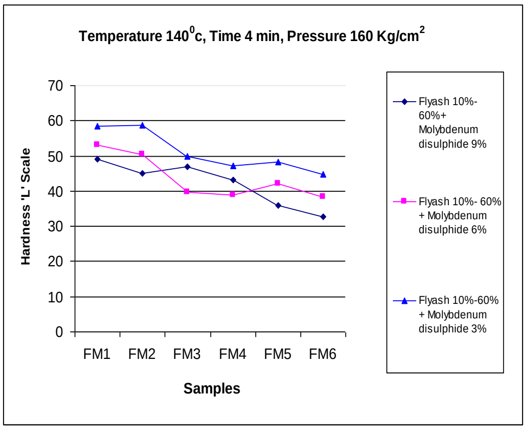


Figure 3 Samples Vs Hardness of fly ash with ifferent percentage of molybdenum disulphide based friction material molded at temperature 140^{0}c, time 4min, pressure 160 kg/cm^2

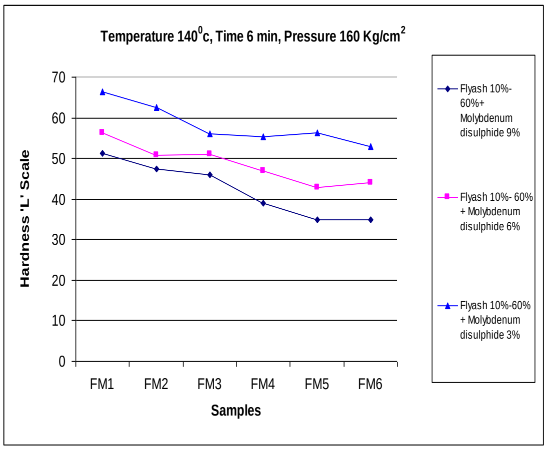


Figure 4 Samples Vs Hardness of flyash with different percentage of molybdenum disulphide based friction material molded at temperature 140^{0}c, time 6 min, pressure 160 kg/cm^2

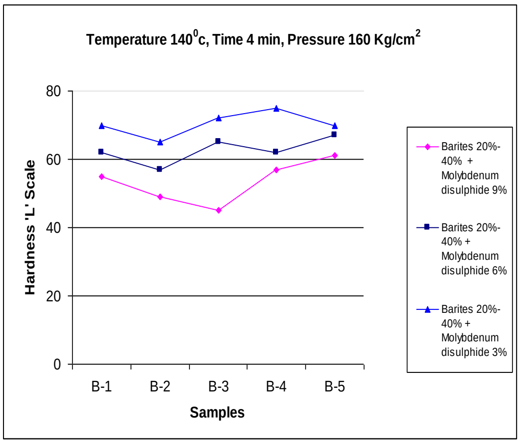


Figure 5 Samples Vs Hardness of barites (without flyash) with different percentage molybdenum disulphide based friction material moulded at temperature 140^{0}c, time 4min, pressure 160 kg/cm^2

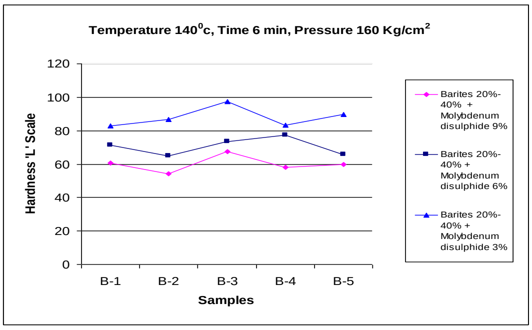


Figure 6 Samples Vs Hardness of barites (Without flyash) with different percentage of molybdenum disulphide based friction material molded at temperature 140^{0}c, time 6 min, pressure 160 kg/cm^2

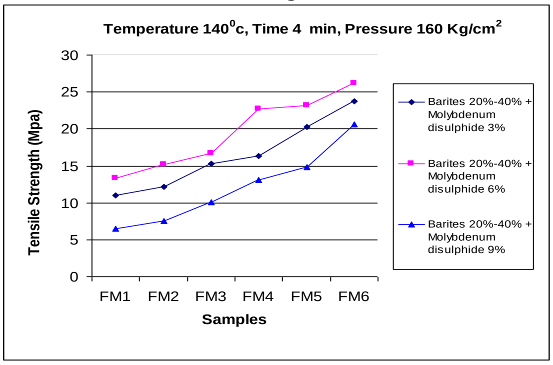


Figure 7 Samples Vs Tensile Strength of flyash with different percentage of molybdenum disulphide based friction material moulded at temperature 140^{0}c, time 4 min, pressure 160 kg/cm^2

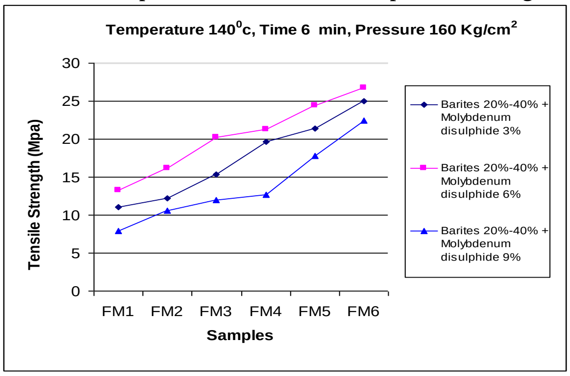


Figure 8 Samples Vs Tensile Strength of flyash with different precentage of molybdenum disulphide based friction material moulded at temperature 140^{0}c, time 6 min, pressure 160 kg/cm^2

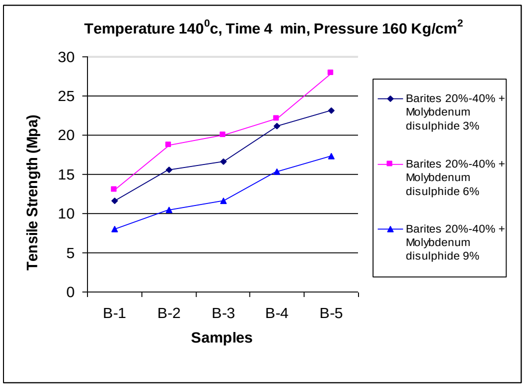


Figure 9 Samples Vs Tensile Strength of barites (without flyash) different percentage of molybdenum disulphide based friction material moulded at temperature 140^{0}c, time 4 min, pressure 160 kg/cm^2

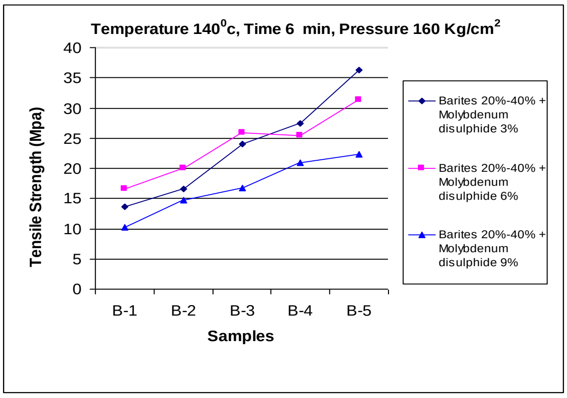


Figure 10 Samples Vs Tensile Strength of barites (without flyash) with 9 %, 6% and 3% molybdenum disulphide based friction material moulded at temperature 140^{0}c, time 6min, pressure 160 kg/cm^2

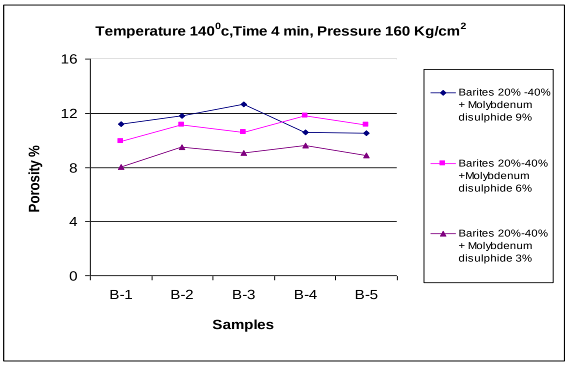
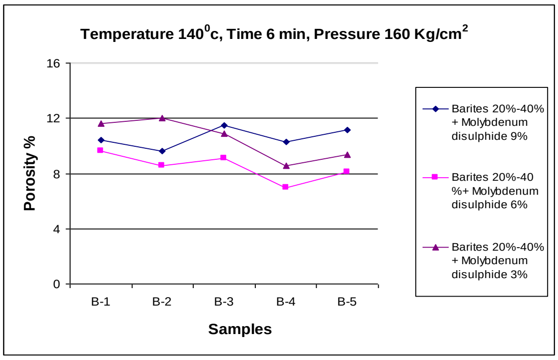


Figure 11 Samples Vs porosity of barites (without flyash) with different percentage of molybdenum disulphide based friction material moulded at temperature 140^{0}c, time 4min, pressure 160 kg/cm^2



Figre 12 Samples Vs Porosity of barites (without flyash) different percentage of molybdenum disulphide based friction material moulded at temperature 140^{0}c, time 6 min, pressure 160 kg/cm^2

The high hardness from the increase of phenolic resin is due to the fact that the binder resin is a thermosetting polymer showing high strength after curing. On the other hand, potassium titanate and cashew have contrary effects on hardness. This is because the potassium titanate is in the shape of fine particulate. However, the potassium titanate plays a crucial role in the formation of friction films. Cashew particles also reduced the hardness since this polymeric material does not play a particular role for the enhancement of strength of a composite [7,8]. The presence of potassium titanate particular powder, wollastonite, phenolic resin increases in hardness of composite decreases the porosity of the composite. Porosity was increased with E-glass fiber, ceramic wool, rock wool and cashew dust powder, suggesting that these ingredients did not flow during hot molding as shown in the figure 11and 12. Phenolic resin reduced porosity since the resin ran and filled the pores during hot molding. Figure 11 shows that friction material was molded with molding time 4 min, since molding time was insufficient for the resin to flow uniformly through out the friction material thereby increase in porosity of the friction material. Figure 12 shows that increase in molding from 4 min to 6 min had significant decrease in porosity and increase in tensile strength since fills the porous holes in the friction material.

3.2 Effect of ingredients on friction and wear characteristics

A study of the literature pertaining to wear/failure mechanisms of friction materials reveals that there are at least four or more different failure modes operating during braking: adhesive wear, abrasive wear, chemical wear, fatigue wear, thermoinstability, and microcracks [12–15]. The rate of wear and the coefficient of friction of friction materials are very important parameters for selection, since they decide the suitability of the materials for brake lining applications. It is the fibers that add to the wear resistance and the coefficient of friction. When the fibers are removed from the matrix by pull-out or abrasion. Even though many researchers have worked on the wear mechanisms in friction materials, still not much is known as to what happens exactly in the material process zone of the brake system. It is proposed that third body layers develop [10,11]. These layers have compositions different from those of the mating parts. Many researchers pointed out that the formation of a friction film by wear debris compaction plays an important role in stabilizing the coefficient of friction [15]. The barites based and fly ash based friction material were tested in the chase type friction test rig and the average of coefficient of friction of normal mu, Hot mu and wear of these composites were measured. The phenolic resin, wollastonoite and cashew increase the coefficient of friction and potassium titanate zircon, and rubber decrease the friction coefficient. The figure 13 and 14 shows the coefficient of friction of barites (without fly ash) molded at different time of 4 min and 6 min under uniform temperature and pressure. The figure 15 and 16 shows that the coefficient of friction of fly ash based friction materials were lower when compare to non fly ash based friction material due to higher amount of fillers and solid lubricants.

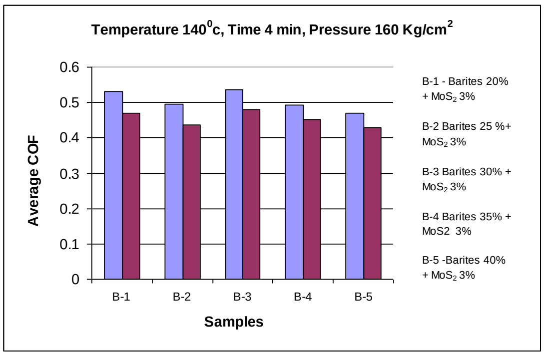


Figure 13a Samples Vs Average COF of barites (without flyash)

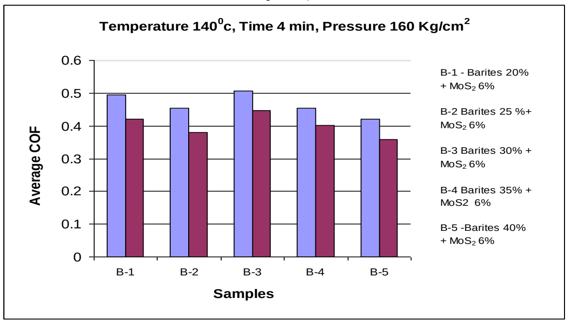


Figure 13 b Samples Vs Average COF of barites (without flyash)

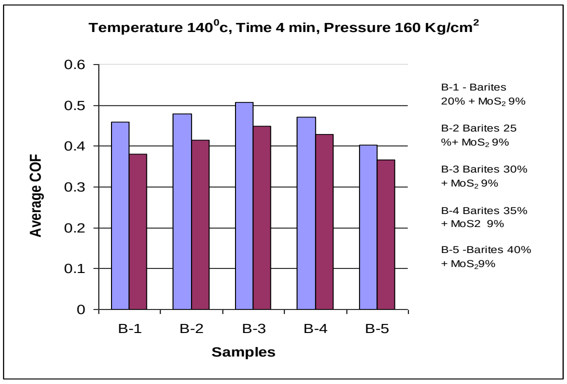


Figure 13 c Samples Vs Average COF of barites (without flyash)

Figure 13 Samples Vs Average COF of barites (without flyash) with different percentage of molybdenum disulphide based friction material moulded at temperature 140^{0}c, time 4 min, pressure 160 kg/cm^2 of friction is closely related to the hardness and morphological feature of each ingredient. Therefore, the ingredients with high hardness such as phenolic resin, and cashew increase the coefficient of friction due to abrasive action against the cast iron brake drum. The COF increases relative to the amount of cashew dust, wollastonite, barites added to the samples. From the figure 14 indicates that increase in molding time from 4 min to 6 min had significantly improved in friction coefficient. Wear of barites (without flyash) based friction material lower due to addition of potassium titanate, wollasnoite, to the samples.

Alternately, the increase in addition of other filler ingredients vermiculite, mica can result in low COF.

Figure 17 and 18 shows the wear of fly ash based friction material. The wear was higher amount due to increase in percentage of fillers such as fly ash , vermiculite, mica, hydrated lime powder in friction material FM-1, FM-2, FM-3, FM-4, FM-5 and FM 6 when compared to wear of the Barites based frictional material B-1, B-2, B-3, B-4

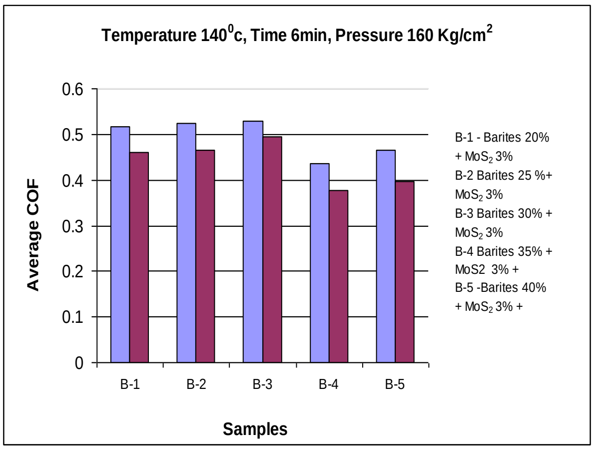


Figure14 a Samples Vs Average COF of barites

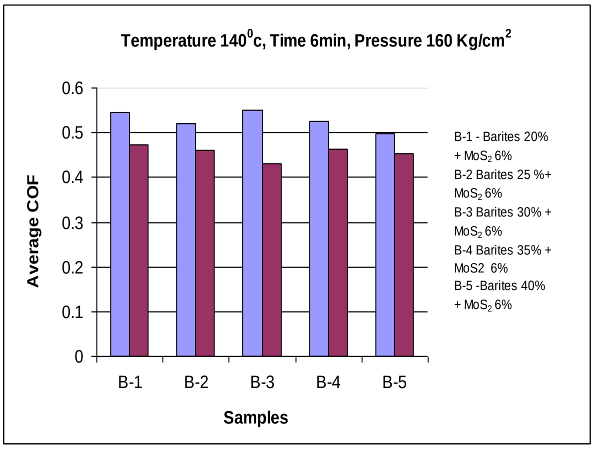


Figure 14 b Samples Vs Average COF of barites

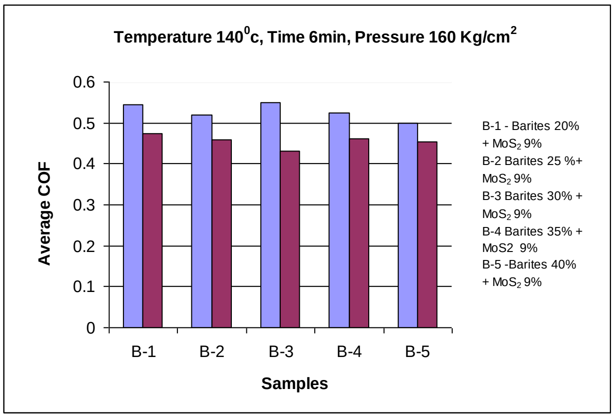


Figure 14 c Samples Vs Average COF of barites

Figure 14 Samples Vs Average COF of barites (without flyash) with different percentage of molybdenum disulphide based friction material molded at temperature 140^{0}c, time 6 min, pressure 160 kg/cm^2

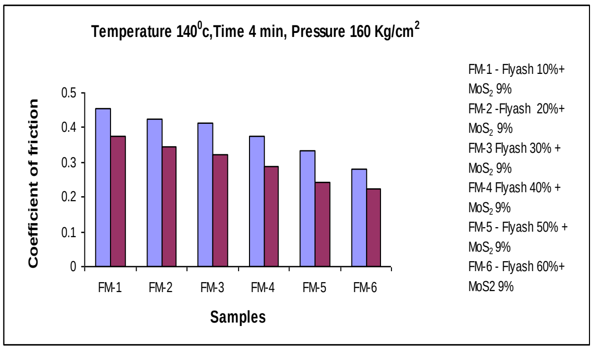


Figure 15 a Coefficient of friction Vs Samples of flyash based molybdenum disulphide friction material molded at temperature 140^{0}c, time 4 min, Pressure 160 Kg/cm^2

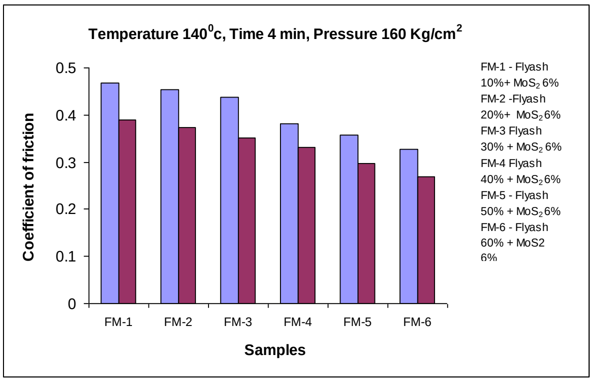


Figure 15 b Coefficient of friction Vs Samples

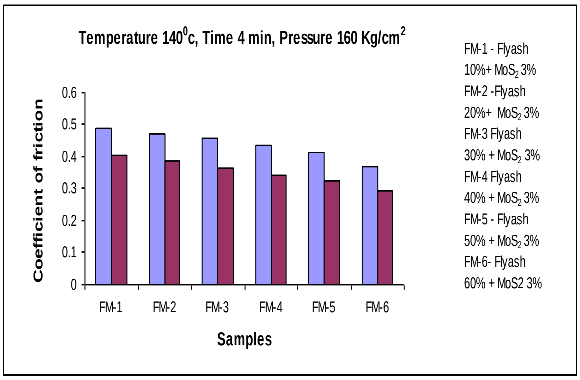


Figure 15 c Coefficient of friction Vs Samples

Fig 15 Coefficient of friction Vs Samples of flyash with different percentage of molybdenum disulphide based friction molded at temperature 140^{0}c, time 4 min, Pressure 160 Kg/cm^2

and B-5 as shown in figure 19 and 20. From the figure it can seen that lower amount of molybdenum disulphide shows better results when the higher amount of molybdenum disulphide. The increase in percentages of molybdenum disulphide from 3% to 9% reduces the hardness of friction material and increases wear of the friction material. The lowering of the friction level due to zircon is also attributed to the morphological effect. In general, zircon particles are used to either control the friction level or clean the pyrolized friction film. Coarse zircon particles are normally used to control the friction level and fine zircon flour is used to remove the friction film. However, zircon can improve negative wear rate caused by either gas release or thermal expansion of the nonmetallic friction materials [8,9]. The wear rate of barites(without flyash) friction materials with zircon is larger than that of without zircon as shown in the figure 19 and 20. The usage of potassium titanate (terraces), Twaron 1080 (Aramid Fiber) in the composite, increases the coefficient of friction and generally not in usage due to high cost. It may viable to be used in the heavy vehicle brake liner.

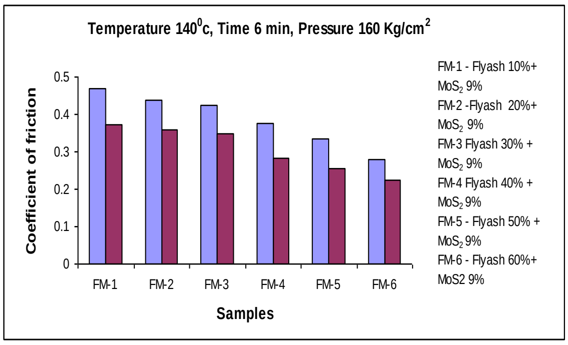


Figure 16 a Coefficient of friction Vs Samples

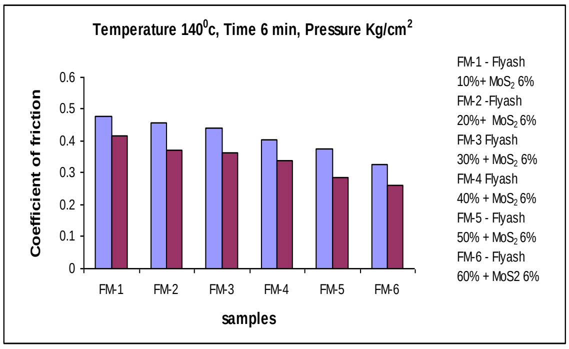


Figure 16b Coefficient of friction Vs Samples

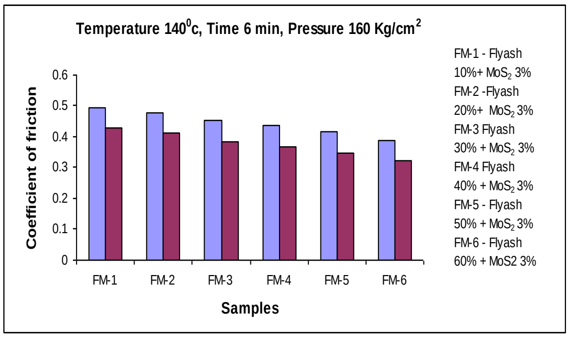


Figure 16c Coefficient of friction Vs Samples

Fig 16 Coefficient of friction Vs Samples of flyash with 9%, 6% and 3% molybdenum disulphide based friction molded at temperature 140^{0}c, time 6 min, Pressure 160 Kg/cm^2

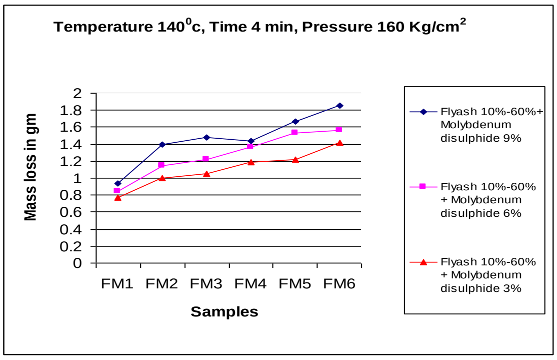


Figure 17 Samples Vs Wear of flyash with different percentage of molybdenum disulphide based friction material moulded at temperature 140^{0}c, time 4 min, pressure 160 kg/cm^2

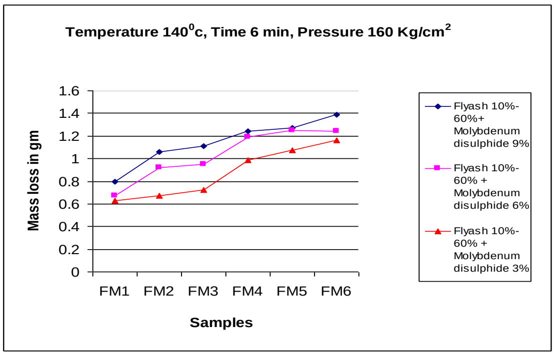


Figure 18 Samples Vs Wear of flyash with different percentage of molybdenum disulphide based friction material moulded at temperature 140^{0}c, time 6 min, pressure 160 kg/cm^2

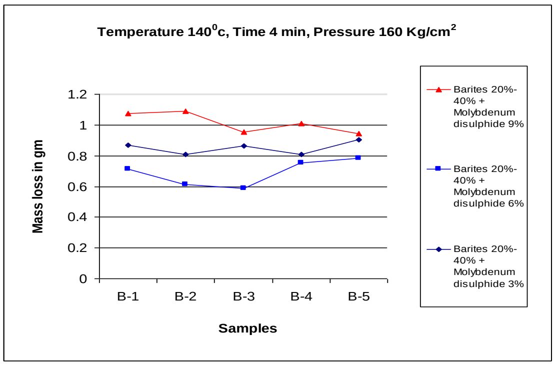


Figure 19 Samples Vs Wear of barites (without flyash) with different percentage of molybdenum disulphide based friction material molded at temperature 140^{0}c, time 4 min, pressure 160 kg/cm^2

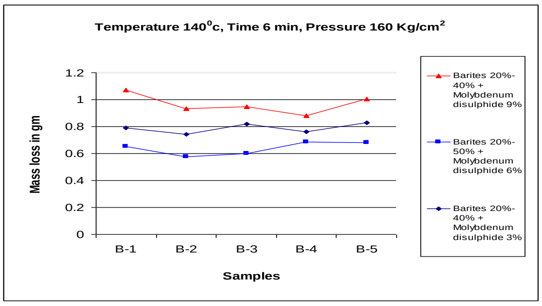


Figure 20 Samples Vs Wear of barites (without flyash) with different percentage of molybdenum disulphide based friction material molded at temperature 140^{0}c, time 6 min, pressure 160 kg/cm^2

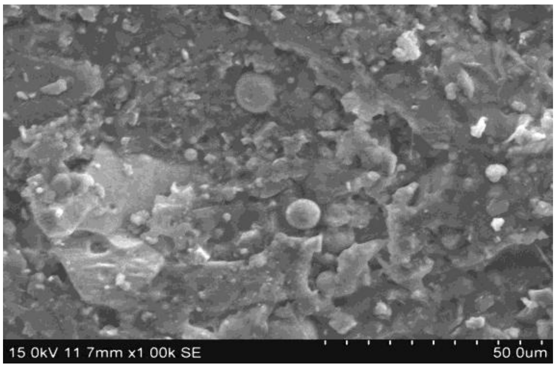


Figure 21 SEM image of FM-6

Figure 21 shows the composite mixture fly ash 60% with abrasive, fillers, fibers and friction modifiers such as cashew dust powders, potassium titanate (terraces) and wollastonite are shown in the SEM image

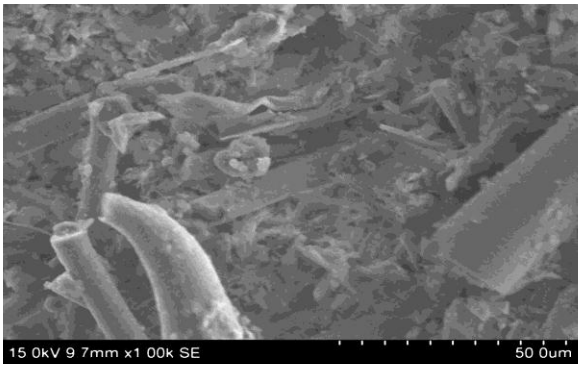


Figure 22 SEM image of B-1

Figure 22 shows the composite mixture containing abrasive, fillers, fibers and friction modifiers such as cashew dust powders, potassium titanate (terraces) and wollastonite are shown in the SEM image.

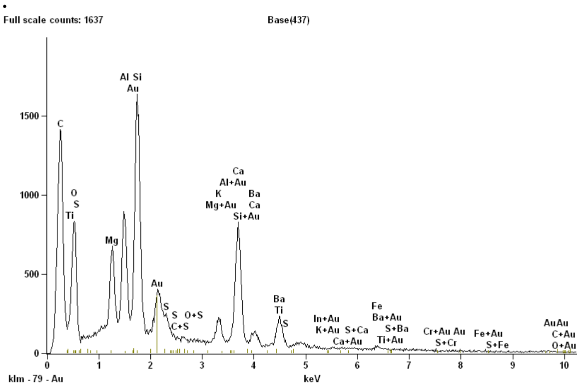


Figure 23 show EDX of B- 1

Figure 23 shows the EDX of B-1 sample with different material composition used for making friction material. The presence of silicon, potassium and Barium in the material composition that have been highly influenced to the increase the coefficient of friction and wear to decrease.

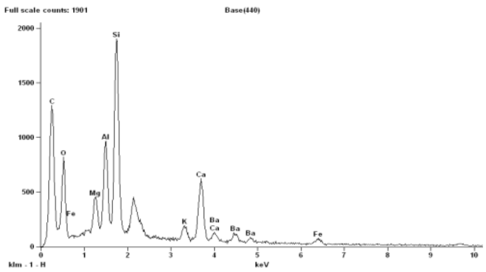


Fig 24 EDX of FM- 1

Figure 24 shows the EDX of FM-1 sample with different material composition used for making friction material. The presence of silicon, aluminum and smaller amount of barites and potassium that have been influenced to increase the coefficient of friction to some extend.

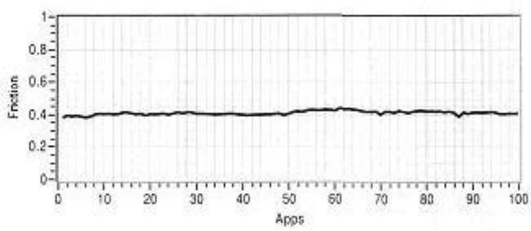


Figure 25 Number of brake application Vs Coefficient of Friction of FM1

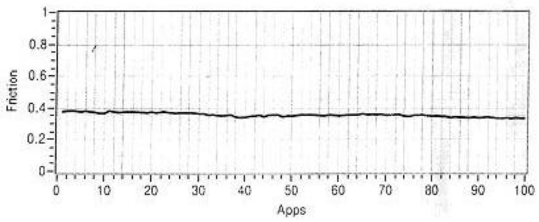


Figure 26 Number of brake application Vs Coefficient of Friction of FM 6

Figure 25 and 26 the coefficient of friction keeps on changing when the number of brake applications was increased, this is due to when drum temperature was increased beyond 250^0 c the morphological changes occurs in each ingredients and it was closely related to the hardness. Therefore, the ingredient with low melting point degraded and lose its bonding strength as a result the coefficient of friction decreases.

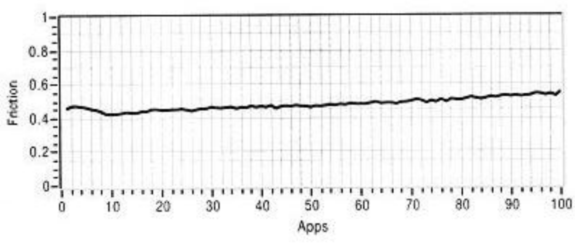


Fig 27 Number of brake application Vs Coefficient of Friction of B-1

Figure 27 the coefficient of friction changes when the number of brake applications was increased, this is due to morphological feature of each ingredients and closely related to the hardness. Therefore, the ingredients with high hardness such as modified phenolic resin, and cashew increase the coefficient of friction due to abrasive action against the cast iron brake drum.

A small percentage 3 % to 5 % of zircon and brown fused alumina were added to the brake liner samples as shown in the Table1. The decrease of the coefficient of friction due to zircon, therefore, appears due to the rolling action of the small particles in the sliding interface. Twaron 1080 (Aramid Fibers) are also widely used as reinforcing fibres, but they are a different class of fibers in that they are relatively soft fibers. They are very light and exhibit excellent thermal stability, with a very good stiffness weight ratio. Twaron fibers have been utilized in maintaining the uniformity of the friction material during the processing of a molded brake brake liner. The increase in percentage of twaron fibre1080 from 5 % to 10% improves the wear resistance of the samples. The addition of E- glass fiber and twaron 1080 (aramid fiber) maintains stability when the drum temperature increased beyond 250^0c.

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CONCLUSION

1. The increase in percentage of fly ash reduces coefficient of friction and also and the weight of brake liner and it is suitable for light motor vehicle.

2. In the fly ash based frictional material, the COF were moderate and wear losses were high. However in the case of non fly ash frictional material, it was observed that the COF were too high and the wear losses were minimum. The wear resistance and coefficient of friction was significantly improved by addition of Twaron 1080 Fiber, Wollastonite and ceramic wool.

3. The presence of potassium titanate particular powder, wollastonite, phenolic resin, and zircon increases in hardness of composite and decreases the porosity of the composite. The hardness has strong influence on porosity which reduces the wear of the friction material.

4. Increases in percentage of rubber powder, vermiculite and cashew friction dust powder

reduce the hardness of the sample and increases the porosity of the samples. Increase in molding time 4 min to 6 min has improved in performance of friction material.

5. It was observed that the tensile strength of fly ash friction material was lower than the barites friction material. The low tensile strengths of the composites are attributed to the high filler content and low fiber content in the friction material also due to short in length of fiber.

6. Addition of abrasive powder to the sample F2, F4 and F6 increase hardness of the friction material. The usage of potassium titanate (terraces), Twaron 1080 (Aramid Fiber) in the composite, increases the coefficient of friction and generally not in usage due to high cost. It may viable to be used in the heavy vehicle brake liner.

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