Tribological Investigation of Ferodo Lining Material Embedded with Copper and SiC particles For Clutch plate

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***Abstract*—**
Development of lightweight materials has provided the automotive industry with numerous possibilities for vehicle weight reduction. Presently several grades of Composites (such as ferodo linings) have been utilized in various high-tech functional applications such as aerospace, defense, automotive, and thermal management areas, as well as in sports and recreation. This trend has been credited to their superior specific strength and specific stiffness, high temperature capability, lower coefficient of thermal expansion, better wear resistance, improved dimensional stability, and responsiveness to conventional metal forming techniques. The surface characteristics and tribological behaviour of clutch plate materials strongly affect the lifetime of the clutch and influence the dynamic behaviour of the entire vehicle. In this study, the surface characteristics of clutch plate materials are investigated since it is closely related to friction. Samples of a commercial clutch facings of ferodo material is tested using a Pin on disk apparatus. The effect of the loading and the sliding speed on the friction coefficient is investigated. The correlation between the surface characteristics and the friction behaviour of clutch materials is explored. The samples of a commercial clutch facings of ferodo material are embedded with copper particles are analyzed to quantify the wear volume. The completed study provide a better understanding of the relationship between the material structure and the performance of clutch plates and it can be used as a reference for clutch material selection and transmission design.

***Keywords*— Ferodo friction lining, copper particles, Wear behaviour**

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I. Introduction

Now a day the Light weight composite materials are widely used in engineering field. The composite materials has good characteristic of resisting wear resistance, hardness and tensile strength. The term “composite” broadly refers to a material system which is composed of a discrete constituent (the reinforcement) distributed in a continuous phase (the matrix). Composite materials are classified on the basis of the physical or chemical nature of the matrix phase, e.g., polymer matrix, metal-matrix and ceramic composites. Due to less weight and good strength the composite materials plays a vital role in engineering field. Composites are of increasing interest because of their high specific stiffness and strength, high isotropic and excellent wear resistance as well as cost effective manufacturing. A moulded, asbestos free, friction material containing friction modifiers and randomly dispersed reinforcing fiber in a phenolic matrix composites (ferodo friction material) have been developed in the past two decades for various automobile, aerospace, electronic packaging and other structural applications. Composites have attracted more attention due to their combined properties such as high specific strength, high stiffness, low thermal expansion coefficient and superior dimensional stability at elevated temperatures as compared to the monolithic materials. A clutch is a device used to transmit the rotary motion of one shaft to another when desired.

The clutch plate should have good thermal conductivity, thermal resistance and withstand high contact pressures. Friction composites mainly consist of about ten classes of ingredients such as, binder, fibers, friction modifiers and fillers. Binder known as resin or matrix provides the mechanical integrity to the composite apart from contributing to the friction and wear. Fibers being multi-functional play a critical role in absorbing stresses generated at the mating interfaces, while simultaneously retaining the integrity of the composite at elevated temperatures and influencing wear also. Friction modifiers are added to moderate them and to minimize its fluctuations. The category of fillers is again subdivided as functional fillers (to enhance the specific function, such as resistance to fade, porosity, thermal conductivity, etc.) and space inert fillers (mainly to cut the cost).Among various fillers, metallic fillers are important in friction materials (FMs), since they control the conductivity of composites apart from additional functions, such as: wear resistance; strength, etc.

This review is concerned with development of composites and more specifically on the ferodo lining materials. The other constituent is embedded in this ferodo material and serves as reinforcement, which is usually metallic and ceramic such as Copper (Cu). The copper is also used to improve the solid lubrication of components.

II. LITERATURE SURVEY

Many studies have been performed on friction materials and cast iron disc applied in the clutch system. On the other hand few papers are available on the role of the friction film and its effects on the frictional behaviour of the clutch systems.

Aravind Vadiraj conducted Experimental studies on a commercially available sintered friction pad was coupled with a standard grey cast iron pressure plate (FG 250 grade) and tested in a clutch dynamometer for understanding the engagement characteristics and thereby predicting the useful life in number of engagements. Results shows that sintered friction pad have a very stable range of friction coefficient (0.43-0.51) even after 5000 engagement cycles. The torque transmitted ranges from 350 to 400 N during one engagement cycle. The energy dissipation and mass loss of friction materials linearly increasing sliding distance. The correlation was derived based on energy dissipation and mass loss in terms of total number of useful or available engagements before replacement or repair of friction pad or clutch pressure plate. Both the pressure plate and clutch disc with the sintered friction pad was tested in a 49 tons load capacity vehicle on a test track. Both sintered friction pad and pressure plate showed scoring marks along the sliding direction. Friction pad showed dense cracks along the top edge. Microscopic features of worn sintered friction pads show silica particle providing the required wear resistance for the pads. Pressure plate showed transfer layer of oxides and carbon with less scoring marks due to short duration vehicle level trials. [2]

G.P.Fernandes, W.HaertelJr, P.S.Zanotto, A.Sinatora proposed work on Influence of mild and severe wear condition in the formation and stability of friction film in clutch system In this work the same regime transition of standard clutch friction material was evaluated for varying loads and sliding velocity. For this purpose tribometric tests were carried out varying the normal load from 200 N to 450 N in two different sliding speeds: 750 rpm (2.05 m/s) and 1200 rpm (3.27 m/s). Each test was run continuously for 3 h at room temperature. The transitions from mild to severe wear have been observed only at 1200 rpm and loads ranging from 380 N to 450 N. Pin-on-disc tests frequently shows a transition from mild to severe wear when steel slides against steel in unlubricated condition.[6]

Guofeng Zhou, Xiaoyan Li, Yaowu Shi, Baohua Chang present a study on Wear mechanism of clutch separating ring in a heavy load vehicle worn separating ring was examined with scanning electron microscope, the metallographic structures were observed and the micro-hardness was measured. Results showed that the hardness of the slot surface was relatively low because the surface layer was mainly composed of austenite but not the preferred martensite; under the action of impact forces generated during the separation process of the ring, plastic furrows and pits were produced on the slot surface by particle abrasion. Based on these results, it was concluded that the wear failure of the separating ring was mainly caused by particle abrasion. [7]

I.M. Dagwa reported work on Development of Asbestos-Free Friction Lining Material from Palm Kernel Shell. For more than 80 years asbestos has been used as a friction material because of its good physical and chemical properties. However, due to the health hazard associated with its handling, it has lost favour and several alternative materials were being increasingly used. Thus, in that work, a non – asbestos friction material was developed using an agro-waste material base – palm kernel shell (PKS) - along with other constituents. The derived friction material was used to produce automobile friction linings. The results suggest that palm kernel shell could be a possible replacement for asbestos in friction lining materials. [9]

M. Bezzazi, A. Khamlichi, A. Jabbouri, P. Reis, J.P. Davim proposed work on performance of the friction coefficient experimentally. Samples of a commercial clutch facings material have been tested using a Pin-on-disk apparatus. When the previous three parameters were preset constant, this machine provides automatic acquisition of friction coefficient and wear measurements. The obtained results were compared with the classical SAE J661a standard test. It was found that the actual clutch facings material has good fading resistance and a rather stable coefficient of friction once running in phase was achieved. The tests carried out in the study have assessed that the most desired performances of clutch facings were confirmed for the actual material since a stable and sufficiently high coefficient of friction was obtained. [11]

Ost W, De Baets P, Degrieck J Studied that the wear was influenced by hardness, normal load, roughness, sliding velocity, temperature and time. The experimental conditions were sliding velocity of 2.05 m/s to 3.57m/s with pressure range of 1 MPa to 2.9 MPa. Pin-on-disc tests have been proved to be extremely useful to simulate simplified and accelerated operating conditions of clutch systems. [13]

S.C. Ho, J.H. Chern Lin proposed work on Effect of fiber addition on mechanical and tribological properties of a copper/phenolic-based friction material. The purpose of the work was to compare the effects of addition of different fibers on the mechanical and tribological properties of a copper/phenolic resin-based semi-metallic friction material using the same fiber contents and process conditions. Steel fiber-added material has the largest wear, while copper fiber-added material has the smallest wear. A loosely bonded layer of wear debris almost fully covers the worn surfaces of fiber-free as well as brass, cellulose and ceramic fiber-added materials. The debris layer partially covers the surfaces of copper and carbon fiber-added materials, and is substantially absent from the surface of that containing steel fiber. Among all fibers copper fiber appears to be the best candidate due to its relatively high and stable COF as well as low wear. [18]

III. PROBLEM STATEMENT

The clutch of passenger vehicles consist of clutch plate made up of non-asbestos organic lining material and pressure plate of grey cast iron. During action of clutch there is increase in axial force which leads to extreme wear of non-asbestos organic lining material and there is increase in temperature of clutch affecting clutch performance. Due to frequent engagement and disengagement there is formation of hot spots on clutch plate and formation of grooves on pressure plate and excessive wear leading to failure of clutch system. Due to this there is generation of high temperature at interface between clutch and pressure plate which leads to premature failure and fading. As the heat in clutch build up, the friction capability of the material and consequently its power transmitting capacity reduces. Also at high temperature there is generation of surface cracks and large amount of plastic deformation in plates. This problem gives out a way for development of composite and evaluation of its tribological characteristic.

For the evaluation of tribological characteristic of materials under study is to be carried out on pin on disc apparatus TR20PHM400.

A. Specimen preparation

Specimens are used are as follows,
Pin: Ferodo friction lining material, Ferodo with copper particles
Disc: Grey Cast Iron disc.

1) Ferodo friction lining material:
Ferodo material is rigid moulded friction material which is mottled state grey in appearance, having random organic fibre base and containing metallic inclusions in the form of brass chipping. It is a light weight material, it has superior specific strength, it has specific stiffness, it has high torque transmission capacity, it has high temperature capability, it has lower coefficient of thermal expansion.

2) Ferodo friction plate with copper:
Now a day's Ferodo is used as the friction lining material in clutch plate but due to needs of increasing the property of heat dissipation required in the friction lining material which plays an important role in the life reliability and performance of clutch so we mix copper in it which increase the following properties Excellent wear resistance, High torque transmission capacity, High specific stiffness, High thermal conductivity, Good heat dissipation property, Resistance to corrosion, Improves solid lubrication

3) Copper:
Properties of Copper are Good thermal conductivity, solid lubrication, good heat dissipation capacity, Ductile, Easy to alloy, Nonmagnetic, Tough and Corrosion resistant

4) Grey Cast Iron:
The Grey Cast Iron material consists of Iron as a major constituent and additives as Carbon, Manganese, Phosphor, Sulphur and Silicon.

B. Experimental Procedure

In this experimental work tribological characteristic of ferodo friction lining material and ferodo friction lining embedded with copper as pin are to be studied against disc which is having same chemical composition as that of actual clutch pressure plate used in vehicles i.e. Grey Cast Iron on pin on disc apparatus (TR20PHM400) at ambient & elevated temperature for duration of 10 minutes.
The ferodo friction lining material and ferodo friction lining embedded with copper as pins having circular cross section of diameter 8 mm & length 30 mm are selected.

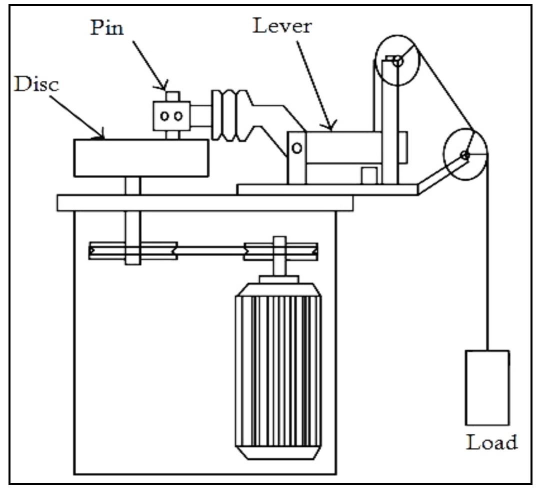

Fig. 1 Pin on disc apparatus

TABLE I
Technical Specification of TR20PHM400

Test Parameter	Values
Specimen pin size	3,6,8,10,12 mm dia. & 25–30 mm long
Wear Disc Size	Dia. 165 mm, 8 mm thick, 1.6 Ra surface roughness
Wear track diameter	Min: 50mm , Max: 100mm, In steps of 1mm
Disc rotation	Min: 200 rpm, Max: 2000 rpm, In steps of 1rpm
Sliding speed	0.5 to 10 m/s
Normal load	5N to 200N, In steps of 5N
Frictional force	0 to 200 N, L.C. of 0.1 N
Wear	Min:1 μm, Max: 2000 μm, L.C. of 1 μm
Temperature	Min: Ambient, Max:4000C, L.C. of 1OC

C. Calculations:

1) *Contact Pressure:* The nominal contact pressure acting between friction plate & pressure plate is,

$$P = F_N / A \quad \text{…………………………… (1)}$$

2) *Sliding Velocity:* For testing the sliding velocity is calculated,

$$V = (\pi * D * N) / 60 \quad \text{……………………….. (2)}$$

3) *Coefficient Of Friction:* The coefficient of friction is ratio of frictional force to normal load.

$$\mu = F / F_N \quad \text{... (3)}$$

4) *Wear Volume:* Wear volume is given as

$$W = \Delta H * A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

The contact pressure between friction plate & pressure plate varies from 1 MPa to 2.9 MPa [13], for test three average values are considered as 1.6 MPa, 2 MPa and 2.4 MPa. By calculations based on cross section of pin the normal loads acting on disc are 80 N, 100 N & 120 N. As the sliding velocity varies from 2.05 m/s to 3.57m/s [13], for test three average values are to be considered as 2.05 m/s, 2.77 m/s & 3.5 m/s.

TABLE II

Load Calculations

Sr. No.	Contact pressure (MPa)	Load due to c/s area (ϕ 8 mm) (N)	Load approx. (Kg)	New Load (N)
1	1.6	80	8	78.48
2	2	100	10	98.1
3	2.4	120	12	117.72

The temperature selected for elevated temperature condition is same as that of temperature attained by brake pad when brake pad & brake disc comes in contact during braking. The temperatures selected for testing are average temperatures and are 100^{O}C, 200^{O}C& 300 ^{O}C.

TABLE III

Wear Test Parameters

Load (N)	Sliding Speed (m/s)	Temperature (oC)
78.48	2.05	100
98.1	2.77	200
117.72	3.5	300

IV. Results and Discussion

The results from wear test carried out on ferodo friction lining and ferodo friction lining with copper are as follows,

TABLE IV

Result Table for varying normal load

Sr.No	material	Load (N)	Wear (µm)	Wear vol^m loss(mm^3)	F (N)	µ
1	Ferodo	78.48	210	1.05*10-8	17.5	0.22
2		98.1	211	1.1*10-8	20.5	0.21
3		117.7	237	1.24*10-8	20.7	0.17
4	Ferodo+ Copper	78.48	136	7.12*10-9	11.4	0.14
5		98.1	146	7.65*10-9	14.1	0.15
6		117.7	200	1.04*10-8	16.3	0.13
7	Ferodo+ Silicon carbide	78.48	152	0.76*10-8	22.3	0.284
8		98.1	205	1.02*10-8	23.4	0.236
9		117.7	266	1.33*10-8	24	0.220

TABLE IV

Result Table for varying velocity/speed

Sr.No	material	speed (m/s)	Wear (µm)	Wear vol^m loss(mm^3)	F (N)	µ
1	Ferodo	2.05	606	3.17*10-8	33	0.281
2		2.77	728	3.81*10-8	33.4	0.282
3		3.5	954	4.99*10-8	33.7	0.280
4	Ferodo+ Copper	2.05	428	2.24*10-8	32.2	0.275
5		2.77	577	3.02*10-8	32.7	0.277
6		3.5	583	3.05*10-8	33.1	0.282
7	Ferodo+ Silicon carbide	2.05	595	2.98*10-8	33.4	0.293
8		2.77	610	3.06*10-8	33.7	0.295
9		3.5	939	4.71*10-8	33.9	0.300

TABLE IV

Result Table for varying temperature

Sr.No	material	temp (oC)	Wear (µm)	Wear vol^m loss(mm^3)	F (N)	µ
1	Ferodo	100	381	1.99*10-8	25.3	0.21
2		200	395	2.06*10-8	26.1	0.22
3		300	444	2.36*10-8	26.1	0.22
4	Ferodo+ Copper	100	237	1.24*10-8	21.9	0.18
5		200	314	1.64*10-8	22.7	0.19
6		300	380	1.99*10-8	22.9	0.19
7	Ferodo+ Silicon carbide	100	380	1.90*10-8	29.9	0.255
8		200	383	1.92*10-8	30.4	0.259
9		300	414	2.07*10-8	31.1	0.265

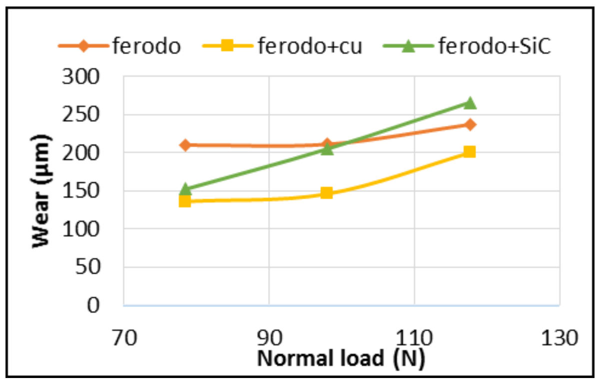

Fig. 2 Wear vs. Normal load

From above graph it is clear that as normal load increases wear of ferodo material is more than the wear of composite.

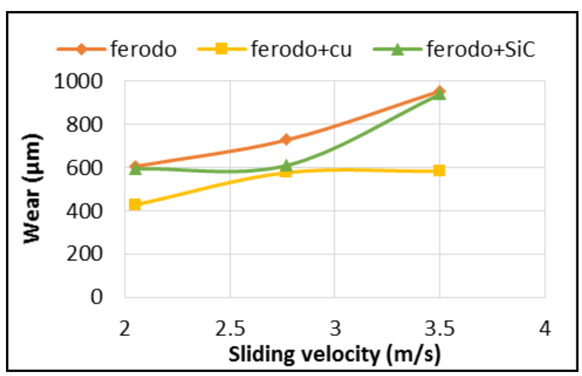

Fig. 3 Wear vs. sliding speed

As the sliding speed increases wear of ferodo material increases and wear of composite material nearly constant and less as compare to base material.

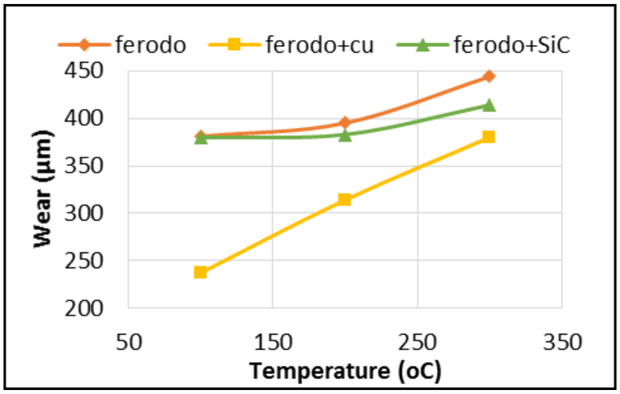

Fig. 4 Wear vs. Temperature

As the temperature goes on increasing wear of ferodo material is nearly constant. Though the wear of composite is less than base material but it is increases with temperature.

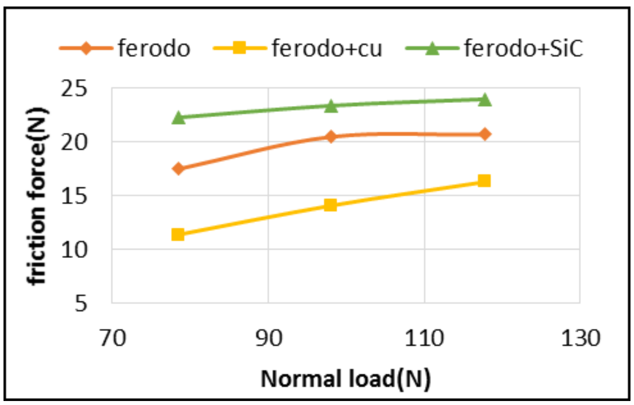

Fig. 5 frictional force vs. Normal load

Friction force of composite increases where friction force of base ferodo material is increases and afterwards nearly constant as normal load increases.

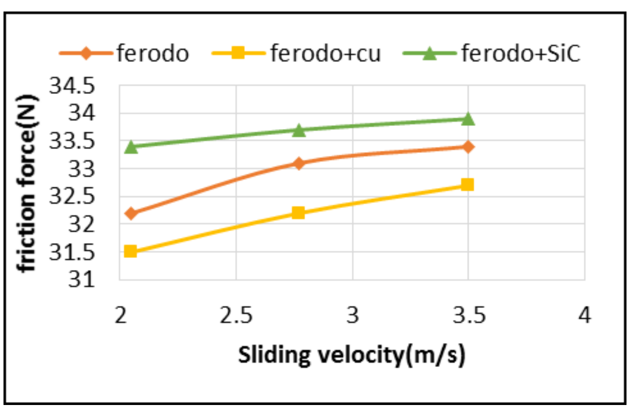

Fig. 6. Frictional force Vs. Sliding speed

As the sliding velocity increases friction force of composite is nearly constant and friction force of ferodo material is increases.

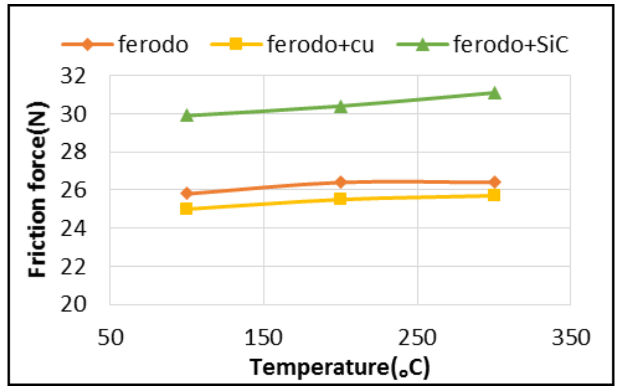

Fig. 7. Frictional force Vs. Temperature

As the temperature increases the friction force of both ferodo material and composite initially increases slightly and then remains constant.

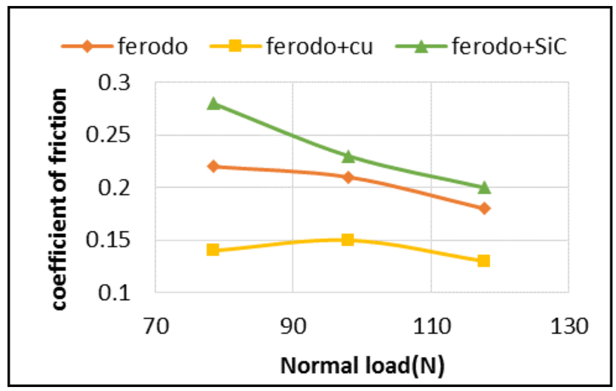

Fig. 8 Coefficient of friction Vs. Normal load

With increase in normal load coefficient of friction for both the material is reducing.

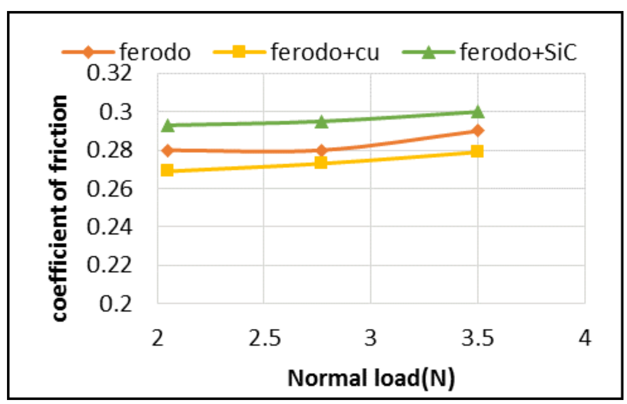

Fig. 9 Coefficient of friction Vs. Sliding speed

With increase in sliding speed coefficient of friction is nearly constant for ferodo material and coefficient of friction increases for composite but it is less than base material.

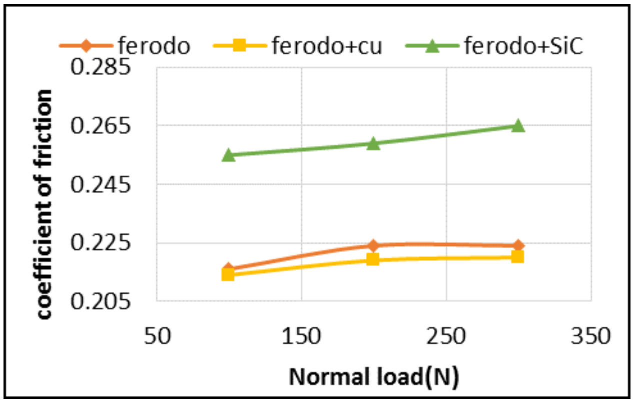

Fig. 10 Coefficient of friction Vs. Temperature

As the temperature increases the coefficient of friction for both the material is nearly constant.

CONCLUSION

The wear of newly developed composite is minimum at speed of 3.5 m/s and load of 100 N. while wear of ferodo material is maximum at load of 120N and at temperature of 300°C. the wear of ferodo material is increases continuously with increase in normal load. Though the wear of ferodo with cu composite is decreases with varying speed and load the coefficient of friction is also decreases as the friction force decreases. The coefficient of friction is nearly constant in the range of speed and range of temperature. Addition of copper helps to maintain stable coefficient of friction while addition of silicon carbide helps to improve coefficient of friction in some amount with less wear. The base ferodo material is having higher coefficient of friction than ferodo and cu composite material but lower coefficient of friction than ferodo and SiC composite it As the copper is added in ferodo material which improves the solid lubrication of material. The newly developed composite is light in weight and it retain its properties even at high temperature conditions. Friction force is increases with increase in normal load.

FUTURE SCOPE

As seen in this report the tribological investigation in the aspect of wear is done for ferodo friction lining material and ferodo friction lining with copper. Further the research can be done to improve coefficient of friction by adding different materials like paper based friction materials, fly-ash, and graphite in various % combination suitable to material.

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NOMENCLATURE

Quantity	Symbol
1. Change in length of pin (mm)	ΔH
2. Coefficient of friction	μ
3. Cross sectional area of pin (mm^2)	A
4. Frictional force (N)	F
5. Normal load applied on disc (N)	F_N
6. Pressure acting on disc (MPa)	P
7. Rotational Speed of disc (rpm)	N
8. Sliding Velocity (mm/s)	V
9. Wear Track Diameter (mm)	D
10. Wear volume (mm^3)	W

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