Experimental Evaluation of Clutch Plate Material by Tribological Properties Using Trobometer

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Abstract—**Automobile Clutch plates performance on contact conditions at the pad to disc interface. The aim of this study is to analyze the effect of different material composition on friction & wear of Clutch Plate material. The review of paper is to represent a general study on the alternative material for the clutch plate material. Instead of the conventional material if we used the composite material the cost, weight can be reduced and the life of that brake material can be increased in low cost. We can combine the two or more material and from that one material can manufactured and that material shows the superior properties of that combined material and eliminate the unrequited properties. The energy dissipation and mass loss of friction materials linearly increases with increasing sliding distance. The work of the composite materials are synthesized containing fibrous reinforcing constitutes ,friction imparting additives ,wear resistive additives ,fire regarding constituents and phenolic resins as binder. Apart from synthesise, the synthesized composite material characterization were performed with wear test to find generation of voids on the wear surface.**

Index Terms—**Clutch, Friction Materials, Composite Materials.**

I. INTRODUCTION

CLUTCH is a torque transmitting mechanical device in an automobile. This is designed according to the load carrying capacity of an automobile. There are two main types of clutches: Wet clutch and dry clutch. Dry clutches are commonly used for haulage and passenger vehicles. The main components of the clutch systems are: (i) pressure plate, (ii) clutch disc, (iii) flywheel (includes pilot bearing or bushing), (iv) release bearing and (v) release system (hydraulic, mechanical or cable). The clutch disc has friction facing buttons riveted radially around a central splined hub. The buttons are fitted both on front and back sides of the support plate facing. [1]

The cover assembly consists of pressure plate operated by coil or diaphragm springs from behind actuated by 3 or 4 finger arrangements through anti- rattle springs.

The release bearings operate the finger movement for engaging or disengaging through clutch operating lever connected to either mechanical actuation or hydraulic actuation ending with a clutch pedal. This entire assembly is fitted into the flywheel and clutch disc is placed between the pressure plate and flywheel. The engine power is transmitted through frictional engagement of clutch disc, pressure plate and flywheel.

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A. Composite Materials

Composite materials are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure.

Typical engineered composite materials include:

- Composite building materials such as cements, concrete
- Reinforced plastics such as fiber-reinforced polymer
- Metal Composites
- Ceramic composites

B. Friction materials

Friction material is material attached to the clutch plate that wears against the inside of the Pressure plate to slow and stop the vehicle. The friction between the brake pads and rotor is the key to stopping in a disc brake system. Eventually, however, the rubber shoes of a bicycle and the brake pads of a car will wear down and severely compromise the operator's safety. The use of asbestos was eventually banned, but some nonmetallic or organic pads are still sold. Only vehicles designed for organic brake pads can use them, however. The same material used in bullet proof vests, Kevlar, has replaced asbestos in non-metallic pads due to it good physical and mechanical properties.

Most of clutch plates sold today are considered semi-metallic. Manufacturers often guard their actual formulas, but in general semi-metallic Clutch plate use copper, brass and steel wool shavings held together in are sin .Because they are primarily metallic, these Clutch plate can last for thousands of miles. Their main drawback for drivers is a higher incidence of grinding noises. This is largely unavoidable since the metal shaving must rub against steel rotors every time the Clutches are applied. Some after-market Clutch plates are marketed as quieter than the standard semi-metallic brands. Good friction materials must fulfill these criteria which are:

a. The two materials in contact must have a high coefficient of friction.

b. The materials in contact must resist wear effects, such as scoring, galling, and ablation.

c. The friction value should be constant over a range of temperatures and pressures

d. The materials should be resistant to the environment (moisture, dust, pressure)

e. The materials should possess good thermal properties, high heat capacity, good thermal conductivity, with stand high temperatures

f. Able to withstand high contact pressures

C. Mechanical Properties of material

The scope of this work is to understand the engagement characteristics and failure analysis of a commercial vehicle clutch system.

II. NEED AND OBJECTIVES

A. Need

The value of coefficient of friction and wear of existing material has been noted by the literature view and hence to improve the coefficient of friction and wear experimental analysis on Pin on Disk Test rig has made also the analysis of composite material for selecting the clutch plate material was important. In this work attempt has been made to improve the mechanical properties of the selected composites.

B. Objectives

1. To design a heat resistant clutch material for optimum friction coefficient (μ) and internal shear strength (τs).
2. To design a perfect composite material which has low wear rate at different temperature, load and velocity conditions.
3. To carry out the Experimental verification of selected material at different temperatures & speed.
4. To compare composite material with commercial asbestos based clutch plate material.
5. To determine most significant parameter affecting coefficient of friction and wear.

C. Methodology of Study

1. Material selection
2. Preparation of composite material
3. Preparation of specimen
4. Perform the experimentation on tribometer
5. Analyses of results

III. MANUFACTURING OF TEST SPECIMEN

Methodology for the preparation of Asbestos based frictional material:

A. For material specimen no 1 (C1)

Asbestos based friction material is synthesized comprising of the following methodology. A die of 10 mm diameter and 40 mm length is used to prepare the specimens of friction material for wear test. 18% of phenol formaldehyde was blended with 25% of epoxy resin. To the uniformly blended mixture was added 9% of brass along with 5% of graphite and the resultant composition mixed well. 5% of Asbestos and 13% of iron fiber were blended into the mixture. Slowly, 6% of sulphur0.9% of silica flour and 6% of silicone resin were added. On obtaining a uniform blend, 8% of rubber solution and 5% of tris-phenol hardener were added.

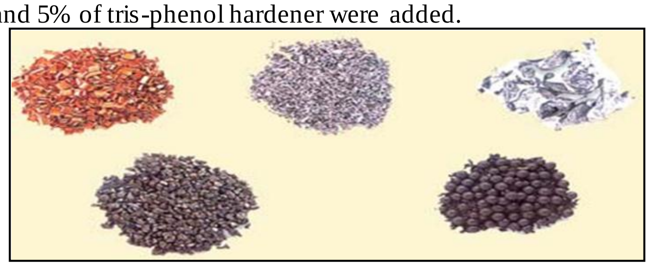

Fig.1 Metals used

The mixture was blended and transferred to a die for compaction. After allowing the mixture to harden partially, it was compacted in a press at a pressure of about 13.78 Bar to give the shape of the die. The samples are manufactured by dry-mixing, pre-forming, hot press molding, post curing and heat treatment.

B. For specimen no 2 (C2)

20% of phenol formaldehyde was blended with 23% of epoxy resin. To the uniformly blended mixture was added 7% of brass along with 5% of carbon black and the resultant composition mixed well. 5% of Asbestos and 13% of copper fiber were blended into the mixture. Slowly, 6% of sulphur and 6% of silicone resin were added. On obtaining a uniform blend, 8% of rubber solution and 7% of tris-phenol hardener were added.

TABLE 1. COMPOSITION OF THE SAMPLES

Sr. No.	Ingredients	C1 %	C2 %
1.	Epoxy resin	25	23
2.	Brass	9	7
3.	Phenol formaldehyde	18	20
4.	Graphite	5	--
5.	Asbestos	5	5
6.	Iron fiber	13	--
7.	Sulphur	6	6
8.	Silicone resin	6	6
9.	Tris-phenol hardener	5	7
10.	Rubber solution	8	8
11.	Carbon black	--	5
12.	Copper fiber	--	13
Total		**100**	**100**

IV. DIE WITH COMPOSITE MATERIAL

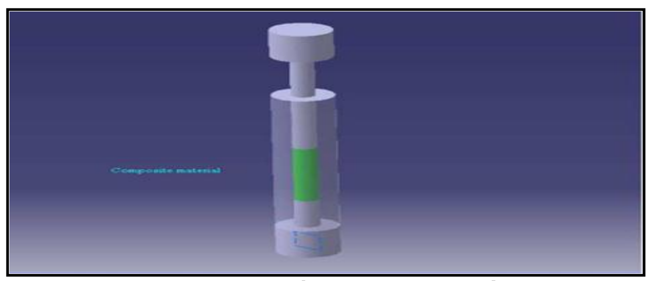

Fig. 2 Die with composite material.

The compacted sample was then subjected curing process which start from 600°C and end at 1800°C. The curing process started at 600°C is continued by the increment of temperature by 100°C upto 1800°C. The duration of curing process is one hour for every increment. After one increment the sample is allowed to cool and curing process is continued until the desired sample is obtained. The wear tests were done using a pin on disc wear test setup. The setup was connected to a computer to compute the results. Wear testing was done using samples of 8 mm diameter. Each sample was tested by sliding it against a steel disc and the friction and wear characteristics of the sample was then obtained from the test.

V. CURING FURNACE

Fig.3 Curing furnace

The curing process started at 600°C is continued by the increment of temperature by 100°C upto 1800°C . The duration of curing process is one hour for every increment. After one increment the sample is allowed to cool and curing process is continued until the desired sample is obtained.

All the clutch plate materials are cut into specimen size of 10 mm diameter and 40 mm length.

Ready sample of composite material:

As after the curing process the new composites are taken out from the die in the shape of pin. The new formed composite are now ready for friction test. The shape of the composite is made like this because the prescribed

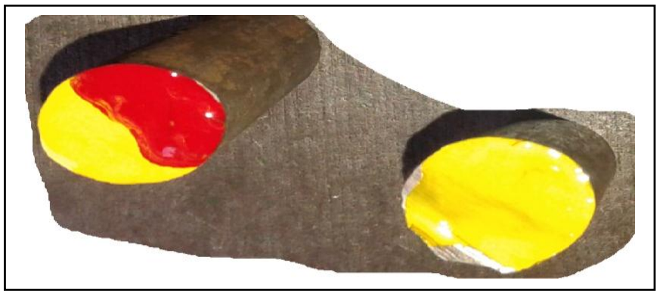

Fig.4 Ready Specimen for Testing (Sample C1 & C2)

specification of friction-wear test monitor. Now the new composite say C1 & C2 are having the chemical composition of Epoxy resin, brass, phenol formaldehyde, graphite, iron fiber, sulphur, silicon resin, tris-phenol hardener, rubber solution, carbon black, copper black and least percentage of asbestos.

VI. TESTING OF SPECIMAN

A. Pin on disc tribometer

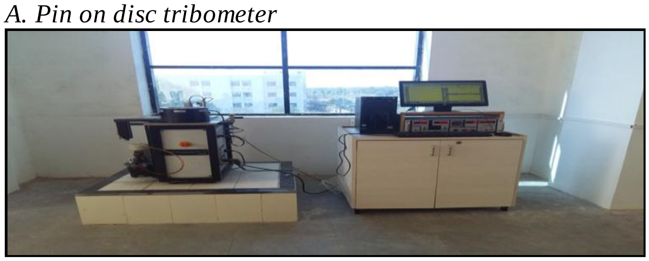

Fig.5 Set up of Pin on disc tribometer

Friction tests, on friction products under unlubricated conditions, were performed on a Pin-on-disk tribometer PLINT TE67HT, (Breaux et al., 2002) and (Davim and Cardoso, 2006). The objective was to evaluate the behavior of friction product/steel pair under the effect of sliding velocity, load and temperature. The normal load pressure was kept constant. The sliding distance was fixed at 1000 m.

Special DIN Ck45K steel pins (Flat-ended) with a diameter of 8 mm and a length of 67.8 mm were machined. All pins have the following chemical composition (wt.%) : 0.45% C, 0.25% Si, 0.65% Mn and present a hardness value of 230 HB. Before testing the pins were ultra- sonically cleaned in an acetone bath.

B. *Experimental Setup*

Friction tests, on friction products under unlubricated conditions, were performed on a Pin-on-disk tribometer PLINT TE67HT, (Breaux et al., 2002) and (Davim and Cardoso, 2006).

C. Numerical Analysis

Before specimen is set to pin on disc tribometer we have to set some parameter on machine they can be calculated as follows

Parameters to be set on pin on disc tribometer before testing are

1. Revolutions of specimen against disc
2. Time

For considering parameter of U215 Model, we are going to take readings against three sliding distances respectively and in varying velocity

$v1=1m/s$,$v2=2m/s$, $v3=3m/s$, $s1=1000mm$, $s2=2000mm$, $s3=3000mm$,

Where, s= sliding distance

v= velocity

N= revolutions

Radius of disc = 0.076m

TABLE 2. PARAMETERS TO BE FIXED ON PIN ON DISC TRIBOMETER

Sr. No.	Sliding Distance S (mm)	Temp. °c	Speed N(rpm)	Time T (sec)	Velocity V (m/s)	Load (kg)
1	1000	100	125.64	1000	1	1
			251.29	500	2	
			376.94	333.33	3	
2	2000	200	125.64	2000	1	2
			251.29	1000	2	
			376.94	666.66	3	
3	3000	300	125.64	3000	1	3
			251.29	1500	2	
			376.94	1000	3	

VII. TESTING RESULTS

Graphs give the friction coefficient as function of the sliding distance. In all cases a stable friction coefficient is obtained when bedding in phase has been achieved. This occurs approximately after running 100 m from the beginning of the test. It was show that there are some discrepancies between the friction coefficient results associated to direct side (a) of the tested samples and those associate to their rear side (b) From comparisons between results obtained for clutch facing materials C1, C2 it is shown that stability of the friction coefficient is only obtained in case of qualities C1 and C2. Comparing the friction coefficient values given in table 2, one could notice that there are only small variations between qualities C1 and C2. Both of these last qualities are found to fit the friction performance as to stability requirements with some advantage for material quality C1.

1. Coefficient Of Friction (μ)

The coefficient of friction is ratio of frictional force to normal load.

$\mu = F / FN$ (a)

Where,

μ = Coefficient of friction.

F = Frictional force (N).

FN = Normal load (N)

2. Wear Volume (W)

Archard's wear theory proposed wear volume as function of normal load, sliding distance & hardness of materials.

$W = K \times FN \times L / 3 \times H$ (b)

Where,

W = Wear volume (mm).

FN = Normal load (N).

L = Sliding distance (mm).

K = Wear coefficient.

H = Hardness of material (HRB).

(Wear) volume loss is given as $W = \Delta H \times A$

Where,

W = (Wear) volume loss in mm.

Δ H= Change in length of pin (μm).

A = Cross sectional area of pin (mm).

Following readings are recorded during the experimentation,

A. Testing Result of Composite C1 on Friction and Wear Test Rig

TABLE 3. EFFECT OF LOAD ON EACH SAMPLE (COF) AT TEMP.100°C & VELOCITY 1 M/S

Sr.No.	Load (N)	C1	C2
1.	10 N	0.3565	0.3637
2.	20 N	0.4302	0.4764
3.	30N	0.4211	0.4492

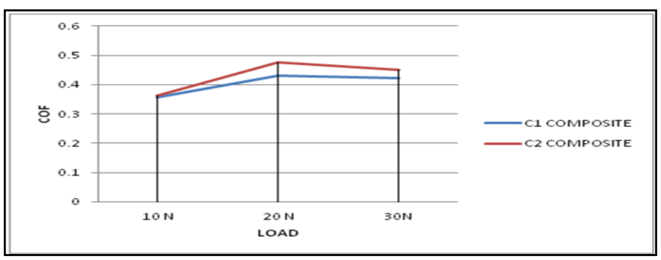

Fig. 6 Effect of load on each sample (COF) at temp.1000c & velocity 1 m/s

The coefficient of friction of C2 composites is found to be better than C1 material for all loads i.e. 10N, 20N, 30N

TABLE 4. EFFECT OF LOAD ON EACH SAMPLE (COF) AT TEMP.100°C & VELOCITY 2 M/S

Sr.No.	Load (N)	C1	C2
1.	10 N	0.3855	0.3712
2.	20 N	0.4678	0.4983
3.	30 N	0.4289	0.4814

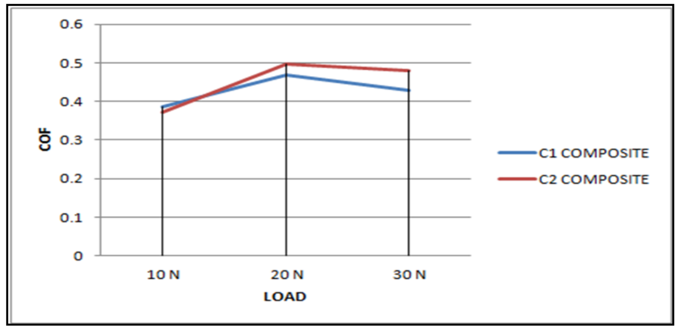

Fig. 7 Effect of Load on Each Sample (Cof) At Temp.100°C & Velocity 2 m/s

The fig.7 shows the C2 composite exhibits better coefficient of friction than C1 though the velocity increases.

TABLE 5. EFFECT OF LOAD ON EACH SAMPLE (COF) AT TEMP.100°C & VELOCITY 3 M/S

Sr.No.	Load (N)	C1	C2
1.	10 N	0.3945	0.4234
2.	20 N	0.4221	0.4992
3.	30 N	0.4903	0.5231

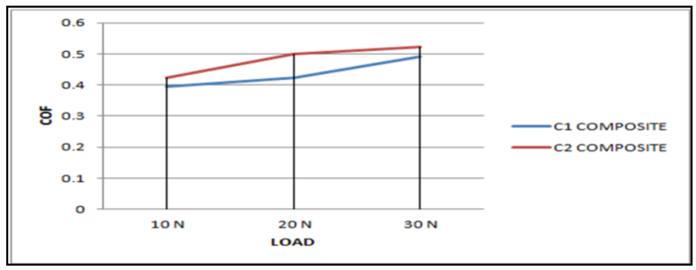

Fig. 8 Effect of Load on Each Sample (COF) At Temp.100°C & Velocity 3 m/s

The fig.8 shows the C2 composite exhibits better coefficient of friction than C1 though the velocity increases for all loads i.e. 10N, 20N, 30N.

TABLE 6. EFFECT OF LOAD ON EACH SAMPLE (COF) AT TEMP.200°C & VELOCITY 1 M/S

Sr.No.	Load (N)	C1	C2
1.	10 N	0.3514	0.3698
2.	20 N	0.4571	0.4321
3.	30 N	0.4932	0.5221

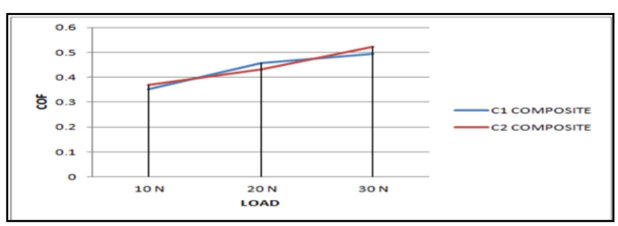

Fig. 9 Effect of Load on Each Sample (COF) At Temp.200°C & Velocity 1 m/s

The fig.9 shows that effect of increasing temperature on COF, as the temperature increases it affects the values of coefficient of friction still the composite C2 gives better values than composite C1.

TABLE 7. EFFECT OF LOAD ON EACH SAMPLE (COF) AT TEMP.200°C & VELOCITY 2 M/S

Sr.No.	Load (N)	C1	C2
1.	10 N	0.3603	0.3620
2.	20 N	0.3483	0.3898
3.	30 N	0.4098	0.4898

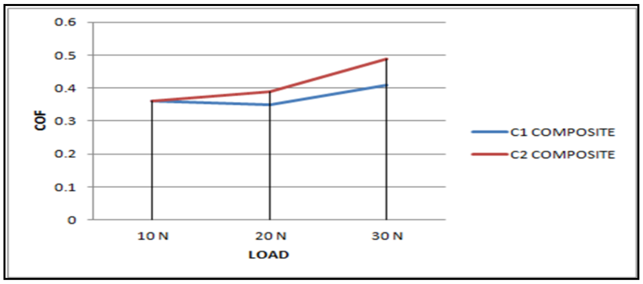

Fig. 10 Effect of Load on Each Sample (COF) At Temp.200°C & Velocity 2 m/s

The fig. 10 shows that effect of increasing temperature & velocity on COF, as the temperature & velocity increases it affects the values of coefficient of friction still the composite C2 gives better values than composite C1.

TABLE 8. EFFECT OF LOAD ON EACH SAMPLE (COF) AT TEMP.200°C & VELOCITY 3 M/S.

Sr.No.	Load (N)	C1	C2
1.	10N	0.3664	0.36
2.	20 N	0.3714	0.4487
3.	30 N	0.4888	0.5231

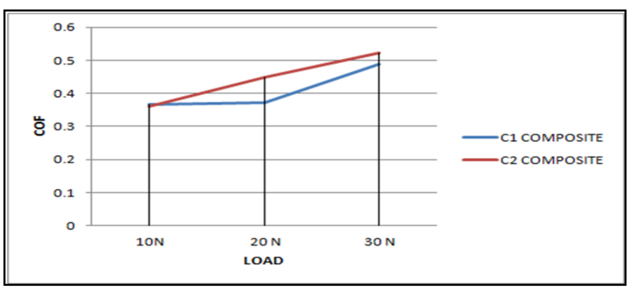

Fig.11 Effect of Load on Each Sample (COF) At Temp.200°C & Velocity 3 m/s.

TABLE 9. EFFECT OF LOAD ON EACH SAMPLE (COF) AT TEMP.300°C & VELOCITY 1 M/S

Sr.No.	Load (N)	C1	C2
1.	10N	0.3565	0.3573
2.	20 N	0.4302	0.3764
3.	30 N	0.4811	0.5392

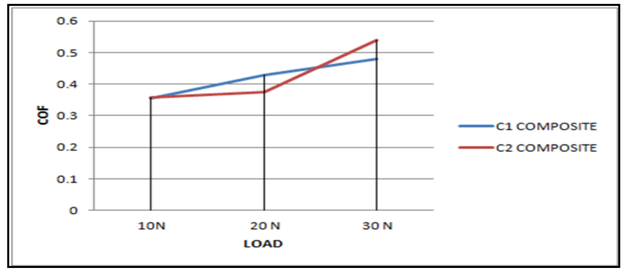

Fig.12 Effect of Load on Each Sample (COF) At Temp.300°C & Velocity 1m/S

The Fig.12. shows the change in coefficient of friction of composites C1 & C2 as the temperature increases the value of coefficient of friction slightly reduces, But for Load 30N the COF of C2 is better than C1.

TABLE 10. EFFECT OF LOAD ON EACH SAMPLE AT TEMP.300°C & VELOCITY 2 M/S

Sr.No.	Load (N)	C1	C2
1.	10N	0.3598	0.3602
2.	20 N	0.3841	0.4201
3.	30 N	0.4865	0.5148

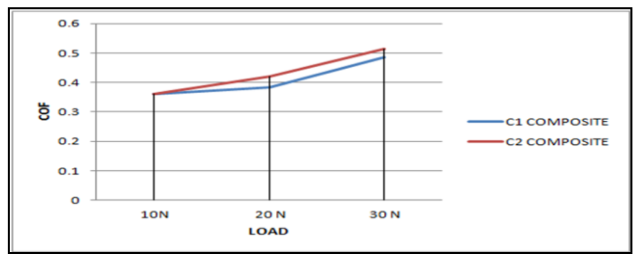

Fig.13 Effect of Load on Each Sample (COF) At Temp.300°C & Velocity 2 m/s

The Fig.13. shows the change in coefficient of friction of composites C1 & C2 as the temperature & velocity increases the value of coefficient of friction for C1 slightly reduces. But experimentally it can be noticed that values of C2 composite are better because iron fiber and Graphite contents are absent.

TABLE 11. EFFECT OF LOAD ON EACH SAMPLE (COF) AT TEMP.300°C & VELOCITY 3 M/S

Sr.No.	Load (N)	C1	C2
1.	10N	0.3514	0.3518
2.	20 N	0.4210	0.4728
3.	30 N	0.4697	0.4925

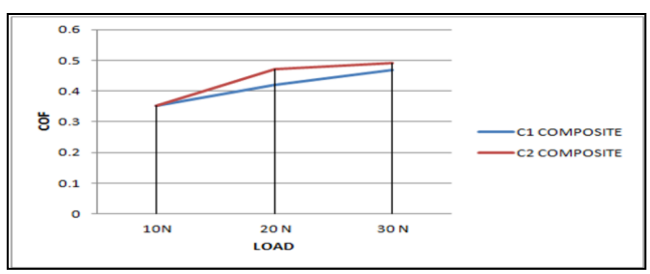

Fig. 14 Effect of Load on Each Sample (COF) At Temp.300°C & Velo. 3

m/s

In all the cases we can conclude that the COF of composite materials C1 & C2 gives the better frictional resistance than existing results whereas C2 greater than C1 in operation.

TABLE 12. EFFECT OF LOAD ON EACH SAMPLE (WEAR) AT TEMP.100°C & VELOCITY 1 M/S

Sr.No.	Load (N)	C1	C2
1.	10 N	11.46	5.73
2.	20 N	10.31	8.02
3.	30 N	10.31	9.17

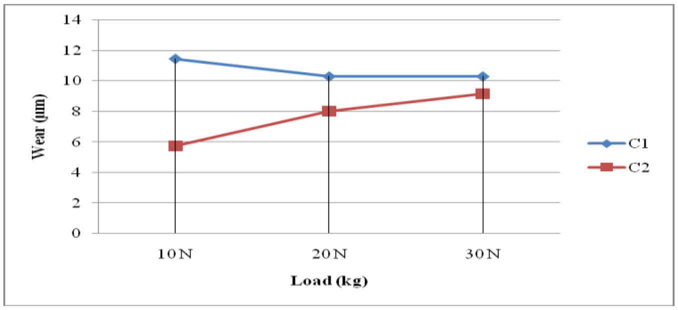

Fig. 15 Effect of Load on Each Sample (Wear) At Temp.100°C & Velocity 1 m/s

TABLE 13. EFFECT OF LOAD ON EACH SAMPLE (WEAR) AT TEMP.100°C & VELOCITY 2 M/S

Sr.No.	Load (N)	C1	C2
1.	10 N	35.81	25.78
2.	20 N	31.51	30.86
3.	30 N	34.09	31.51

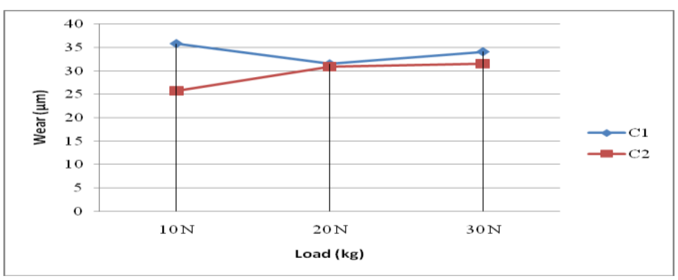

Fig. 16 Effect of Load on Each Sample (Wear) At Temp.100°C & Velo. 2 m/s

As itself the graph explains how the wear occurs in composite material when load, temperature and velocity increases wear occurs in the composite C1 & C2. Still the composite C2 exhibits the low wear rate compare with C1.

TABLE 14. EFFECT OF LOAD ON EACH SAMPLE (WEAR) AT TEMP.100°C & VELOCITY 3 M/S

Sr.No.	Load (N)	C1	C2
1.	10 N	85.94	79.07
2.	20 N	88.81	85.96
3.	30 N	73.34	72.48

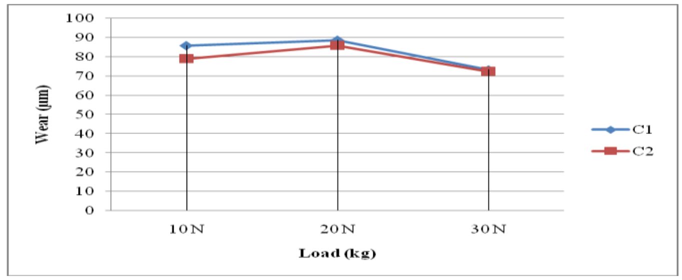

Fig.17 Effect of Load on Each Sample (Wear) At Temp.100°C & Velo. 3 m/s

The fig. 17 shows how the wear increases in the component when the sliding velocity increases the composites wears out with very high proportion when speed increases.

TABLE 15. EFFECT OF LOAD ON EACH SAMPLE (WEAR) AT TEMP.300°C & VELOCITY 1 M/S

Sr.No.	Load (N)	C1	C2
1.	10 N	19.71	19.21
2.	20 N	22.46	22.21
3.	30 N	28.85	26.17

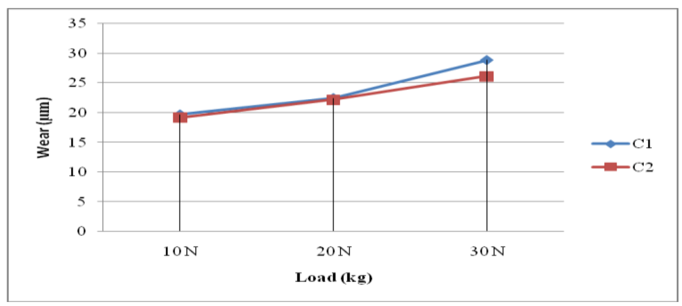

Fig.18 Effect Of Load On Each Sample (Wear) At Temp.300°C & Velo. 1 m/s

The Fig.18 shows as the load, temperature and speed increases the wear rate also increases in the material.

TABLE 16. EFFECT OF LOAD ON EACH SAMPLE (WEAR) AT TEMP.300°C & VELOCITY 2 M/S

Sr.No.	Load (N)	C1	C2
1.	10 N	58.86	52.47
2.	20 N	57.30	56.19
3.	30 N	77.35	75.05

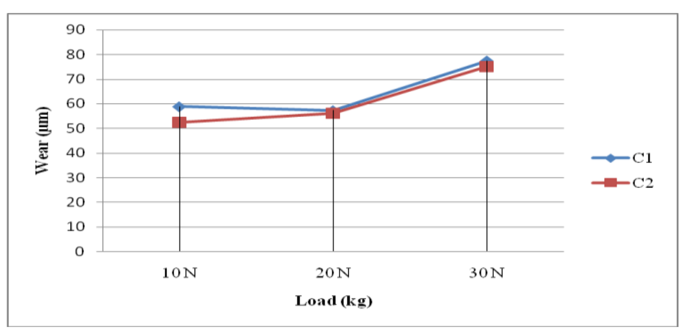

Fig.19 Effect of Load on Each Sample (Wear) At Temp.300°C & Velo. 2 m/s

The Fig.19 shows as the load, temperature and speed increases the wear rate also increases in the material.

TABLE 17. EFFECT OF LOAD ON EACH SAMPLE (WEAR) AT TEMP.300°C & VELOCITY 3 M/S

Sr.No.	Load (N)	C1	C2
1.	10 N	110.59	107.70
2.	20 N	140.37	88.56
3.	30 N	163.87	162.40

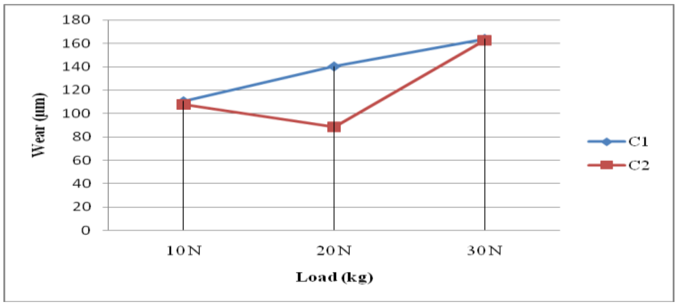

Fig.20 Effect of Load on Each Sample (Wear) At Temp.300°C & Velo. 3 m/s

We observe the reading of Wear Rate The C2 Composite has less wear compared with C1 material.

VIII. CONCLUSION

1) The friction coefficient (µ) and internal shear strength (τs). of composite C2 is better than composite C1.

2) The results shown that wear rate of C1 composite increases with increasing the sliding speed, load, temperatures as compare to C1 composite.

3) The C2 Composite material has less wear compared with C1 Composite material because of that we select C2 as a clutch plate material.

ACKNOWLEDGMENT

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