Influence on the Tribological Performance of the Pure Synthetic Hydrated Calcium Silicate With Cellulose Fiber

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Influence on the tribological performance of the pure synthetic hydrated calcium silicate with cellulose fiber

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ABSTRACT

The ultimate aim of this work is to examine the effect of pure synthetic hydrated calcium silicate with cellulose fibers on the Tribological performance by using chase testing machine test rig.In this particular Research work, the brake pad composites were manufactured by using the injection machine by carrying out the proper standards. The Mechanical/Physical/Chemical properties were developed and these properties were analysed as per norms prescribed by the industry . The experimental results that obtained signifies that the pure synthetic hydrated calcium silicate (SICACEL) based brake pads possess superior mechanical properties such as Mechanical/Physical/Chemical/Thermal properties .It has also been found that it has the better fade and recovery characteristics due to its unique flake morphology in structure and also it reduces sedimentation in dry mixtures and facilitates the pre-moulding stage

Keywords: pure synthetic hydrated calcium silicate, Cellulose Fibers, Friction composite, Brake pad

AIMS AND BACKGROUND

An automotive brake system is mainly used to stop and control the vehicle. Now a day's various types of braking systems are used in the vehicles. A summary of recent researches related to vehicle braking systems is presented in this section. Lee et al. [1] investigated the use of a rotary vane vacuum pump in a braking system. The results show the negative pressure formed inside the brake booster minimized the time required to produce the constant braking and also lower the torque required to drive the pump. Chung et al. [2] reported their estimation of brake judder characteristics in automotive hydraulic brake systems. The variation of the judder characteristics of disc brakes and change in the design parameters of hydraulic components were predicted using MATLAB. The coefficient friction between disc and pad and the convection coefficient on the disc surface were studied as functions of temperature. The simulation result's reliability was verified by comparison with dynamometer test results. Ping et al. [3] suggested auxiliary braking devices increase the brake power for reduction of the friction brake torque. An innovative brake guidance system for vehicles with friction brake and engine brake guided the driver to reduce the use of the friction brake on the downhill and keeping the friction brake temperature in a safe range. Lee et al. [4] reported that the design of a vacuum pump is highly critical to creating enough negative pressure for immediate application of the brakes. For vacuum brake booster optimal dimension design values were proposed to minimize the driving torque using the Taguchi method. The research in brake pads is generated by stricter regulations especially that are related to the environment and security (Chan & Stachowiak, 2004). Therefore, strong efforts are made for the improvement of braking performance of friction materials, based especially on the choice of nature, shape and weight percentage of ingredients in the friction formulation (Lee et.al.,2018).

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Generally, there are four classifications of ingredients binder, filler (inert and functional), fibers and friction modifiers (lubricants and abrasives). Fibers consist of a fundamental ingredient in the brake pads, which replaces asbestos, with metallic, ceramic and glass fibers (Ozturk et.al.,2013; Manoharan et.al.,2017). The most frequently used metallic ingredients are iron and steel according to their major role in contributing to the friction level, wear resistance and thermomechanical performance (Thiyagarajan et.al.,2016; Jaafar et.al.,2017). Though copper was used effectively previously, due to its debris and harmfulness to aquatic life has led to the reduction of its usage leading to a ban in friction composites in the developed nations (Lenin Singaravelu et.al.,2015). So steel fibers and other metallic ingredients usage have raised. However, steel fibers suffer from corrosion, particularly when the vehicle is operated near-coastal environment and induces several problems to both mating as well as composite (Chau et.al.,2016). Oxide coated steel (Stilox) are considered a new generation of metallic ingredient that can present a possible challenge to resolve steel fibers problems, justified particularly by its composition which changes in function because of the temperature (Keerthana et.al.,2016; Chau et.al.,2016). However, there is no research investigating Sicacell braking performance in the literature. Thus the current study deals on the tribological performance of Sicacell based friction composites using a comparative approach with cellulose fibers based one with the same weight%.

Table 1 Manufacturing steps involved in development of brake pads

Procedure	Conditions
Sequential mixing in plough shear (lodigee) mixer	Total duration 20 minutes, shovel and chopper speed: 140 and 2800 rpm. 3 kg mix was prepared. Mixing sequence is fibers (10 minutes), frictional modifiers & fillers (6 minutes), binders (4 minutes) .
Curing in hydraulic cure press	Compression Moulding machine with eight mould cavities was used, Die temperature was set to 145ºC; Compression Pressure 13 MPa; Each cavity was filled with 75 grams of mixture, Curing Time: 8 minutes Five intermittent breathings for removing volatile gases evolved during curing
Post curing	5.5 hours at 160 °C in a hot air oven
Finishing	Grinding of the baked pad in belt grinder

2. Materials and Methods

2.1 Ingredients, Formulation and Manufacturing

Figures 1(a&b) shows SEM micrographs of the Sicacell and cellulose fibers that elaborate unique morphology and its anti-segregating properties, it improves the homogeneity of the mix in composite materials. SICACELL Consists of hydrated synthetic calcium silicate, silica free having a size and thickness of 0.2-0.5 mm, 0.01 mm respectively it possess a density of with a density 5.2 g/cc. It is known commercially as SICACELL 990 Grade Whereas, Cellulose fibers with the median size of 1.2-2.0 mm as a length and 0.4 mm as a diameter is shown in Figure 1(b). It mainly consists of cellulose and lignin in different proportions.This chemical constituents details of Sicacell and Cellulose Fibers were provided by the suppliers.

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The friction composites were developed in the form of standard brake pads on the basis of a dry mix formulation containing 15 parental ingredients namely, fibers with additives(18 weight%): acrylic fiber, Wolostonaite fiber, calcium sulphate whiskers, hydrated lime; binders with additives (16 weight%): straight phenolic resin, NBR, crumb rubber, calcium oxide; Friction modifiers (14 weight%): synthetic graphite, MoS_2; fillers (inert and functional) (47 weight%): cashew friction dust, vermiculite, barites, tin powder, mica and remaining 5 weight% as varying ingredient. In the formulation of brakepads Two brake pads were developed and they are designated as per the formulation developed SICCACEL was used in this and it is termed as S1 and. While in the other Cellulose fiber was used and it is termed as S2. The methodology involved is given in Table 1. The developed friction composites in the form of standard brake pads are shown in Figure 2.

Table 2 Experimental procedure of the Chase test as per IS2742-Part-4 Standards

Stages	Speed (rpm)	Temp (°C)		Load (N)	On time		Off time	No. of Applications	Heater
		min	max		min	sec	sec		
Burnish	308	-	93	440	20	-	-	1	Off
Baseline-I	411	82	104	660	-	10	-	20	Off
Fade-I	411	82	289	660	10	-	-	1	On
Recovery-I	411	261	93	660	-	10	-	1	Off
Wear	411	193	204	660	-	20	10	100	Off
Fade-II	411	82	345	660	10	-	-	1	On
Recovery-II	411	317	93	660	-	10	-	1	Off
Baseline-II	411	82	104	660	-	10	20	20	Off

Table 3 Various characteristics of the developed friction composites S1 and S2

S.No.	Property	Unit	Test Method/ Condition	Observed value	
				C 1	C 2
1	Density	g/cc	IS -2742-Part 3	1.89	1.93
2	Hardness	No Unit		93	97
3	Acetone Extraction	%		1.71	1.69
4	Heat Swell at 200°C	mm		0.06	0.07
5	Cold Shear Strength	kg/m^2	ISO-6312	42	40
6	Porosity	%	JIS-D-4418	4.9	4.5

2.2. Characterization of developed friction composites

The Archimedes Principle was used to measure the density of the developed composites. The percentage of uncured resins was found out using acetone extraction test. Hardness was measured using the K scale having a steel ball indenter of 3.125 mm diameter by applying a load of 1500 N in a Rockwell hardness tester. Heat swell was measured by considering a sample of size 10

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mm*10 mm*4 mm. The sample was maintained at 200±3°C for about 40 minutes in a hot air oven. The difference in the thickness was noted. The above-said tests were measured as per the IS2742-Part-3. Porosity was measured as per JIS-D-4418 in which sample size of 25 mm*25 mm was considered. The cold shear strength of the developed pads was measured as per ISO-6312 measured at room temperature conditions.

The tribological characterizations of the developed friction composites were analysed using Chase testing machine following IS2742-Part-4. The test Procedure for chase test consists of seven cycle's namely initial baseline, fade-1, recovery-1, wear, fade-2, recovery-2 and final baseline. The sample of size 25 mm*25 mm with 28 mm cast iron drum were considered for testing. The test procedure is given in Table 2. The desired properties of various friction coefficient as shown in Figure 3(a&b) are calculated based on The wear loss% of the Chase tested samples were found in terms of weight loss% and thickness loss% using the digital weighing machine and digital micrometer respectively.Corrosion study was done for the developed pads by cutting a sample and keeping it immersed in

3. Results and discussions

3.1. Physical, chemical, thermal and mechanical characteristics of the developed friction composites

The test results of the developed friction composites are given in Table 3. The density of S1 is considerable high when compared to S2 compared .It is mainly because of the unique morphology and its anti-segregating properties, it improves the homogeneity of the mix in composite materials.This property also helps to improve the porosity. While the acetone extraction was also good for C2, which is due to the proper curing of resin and it can be authenticated with the literature that the (Thiyagarajan et.al.,2016) when the curing of resin is good the acetone extraction can be improved considerably. This sequentially causes heat swell. Though the values do not show a drastic difference, it is quite common that usage of harder calcum silicate C2 increases hardness and the same is inferred here. The same can be witnessed by the literature(Jaafar et.al.,2012). that if the density is high, Hardness will also be in the trend of increasing and there will a drop in the porosity, and there is not a much deviation in the values and the same trend is assertained in this also.The shear strength of the friction composites is high in the case of C1, which is due to its flake morphology enabling good bonding. There is not a specific trend followed in the literature the trend values tends to change. Specific trend not followed.

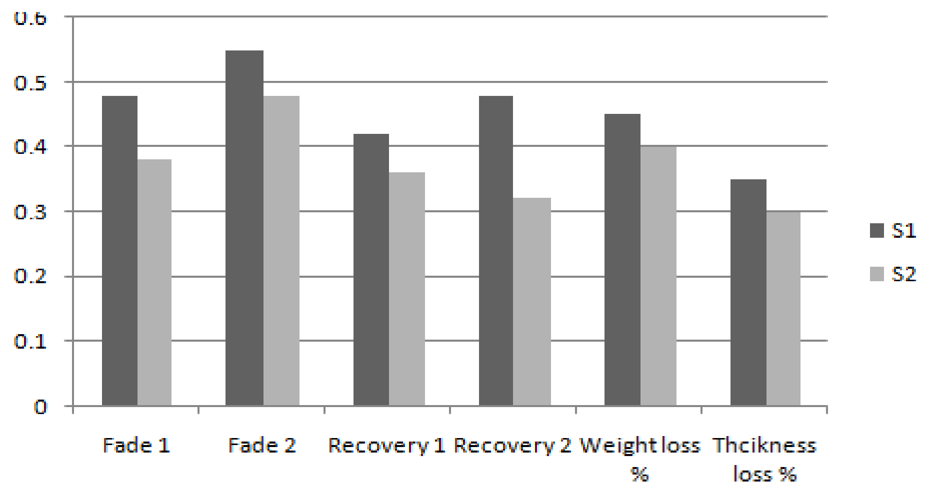

Figure 3 (a) µ performance, µ fade (1&2), µ recovery (1&2), % weight loss and % thickness loss

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3.2. Tribological characteristics of the developed friction composites

The fade μ and the recovery μ evolutions in function of the drum temperature rising, and the performance μ was registered during 100 cycle braking run for both the composites developed .It is observed that for the first fade the friction coefficient is still 0.42 until a temperature of 220°C for the composite S1 reinforced with SICACELL respectively but for the second composite C2 the loss of efficiency of the material in terms of friction coefficient is detected after only 180°C as 0.38 which is given in the figure 4(a &b).The first Recovery is examined based on the quick recovery with respect to the quick recovery of baseline friction characteristics.The recovery values of the composites are given in the range between 0.42 to 0.36.The Recovery characteristics for S1 is 0.42 and for S2 is 0.36.The brake pad temperature is increased because of the friction generated in the brake pad In general friction can be generated only by the accumulative heating,This heating is attributed only in the concentrated rubbed surface of the composites.Owing to this the brake pad temperature got increased. The maximum μ fade for the developed composites was observed only in the second fade. It is seen only after the second fade after the cold cycle It was observed as 0.55 for the first composite S1 and for the second one S2 it is observed as 0.48 .The decrease in the μ Fade was observed in both the composites but it was more for the composites than S1.The values of the composites S2 started reducing sooner than the S1.The second recovery run is calculated, the friction slopes in the way of the first recovery run but for S1 the friction level attempts higher value (0.48).But for the composites S2 it got reduced from 0.48 to 0.32.When comparing average μ for different braking situations (Figures 3(a),4(a&b)),by observing all the values it is noticed that the composites S1 is more stable than the composites S2 in the performance indicators in braking particularly a stable μ evolution which continues until a temperature of 280°C of the disc. Besides the composite S1 is characterized by a more coherent and synchronized frictional fluctuation, suggesting a better tendency to develop a steady-state friction plateau zone across, particularly the 30^{th} braking cycles (Figures 4(a&b)).

It can be noticed that the performance μ of the S1 is higher than the S2 as inferred from Figure 3(a). In fact, the SICACEL assures a higher μ than the cellulose fibers because of the more established unique flake morphology and homogeneity of the mix in the pad surface for the S1 than the S2 material, i.e. because of its increased contact area due to its flake morphology rather than fiber shape in case of cellulose fibers. This increase in friction of S1was mainly due to its unique flake morphology which enables the material to perform well by enabling good porosity leading to good recovery it can be witnessed by the literatue.

In case of wear loss, the S2 produced lesser weight loss as well as thickness loss which are mainly due to the presence the of harder cellulose fibrs and its composition which make the composites hard as inferred from Table 3, causes the resistance to penetration (i.e. higher the hardness, higher the wear resistance) and also it is a postulate that higher the friction higher will be the wear rate as inferred from literature, is also seen in this study Thus, wear loss followed the trend of S1>S2. This wear resistance and friction behaviour may vary upon the real-time conditions, and that study is the near future scope of this work.

4. Conclusions

In this study, the brake performance of the friction composite incorporated with pure synthetic hydrated calcium silicate (SICACELL) was compared with the same weight percentage (75weight %) for its possible substitution. Based on the test results following conclusions were drawn:

- SICACELL which is made of pure form of calcium silicate based friction composite exhibits a Stable and higher coefficient of friction and maintains the frictional values uniformly particularly at elevated temperatures, from 0.38 to 0.50It possess good recovery characteristics and good resistance when compared with the cellulose fibers composites.The μ performance, μ fade, and μ

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recovery values were significantly influenced by the type of elements used as a key ingredient in the composites .Therefore, the Sicacell based friction composite showed higher resistances to friction-fade but less wear resistance than cellulose fibers composites.Such performances make the Sicacell brake pads an important alternative material to other fibers that could be used for brake operating at both cold, hot as well as corrosive environments

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