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CHARACTERIZATION OF COMPOSITE MATERIALS REINFORCED WITH COCONUT FIBERS USED FOR AUTOMOTIVE BRAKE PADS

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Abstract: *The aim of this paper is to develop new organic composite for automotive brake pads without any harmful effect. Different laboratory formulations were prepared with varying coconut fiber, friction modifiers, abrasive material and solid lubrificant using powder mettallurgy techique. The properties examined are density, porosity, hardness, mechanical properties, loss of weight based on termo-gravimetric analysis and SEM morfology. The new composites tested in the laboratory, modeling appropriate percentage between matrix and reinforcement volume and can be obtained with low density material, high hardness properties, good thermal stability, higher ability to hold the compressive force and without any harmful effect. The results obtained make them useful for brake pads of light and medium weight vehicles.*
Keywords: *brake, coconut, fiber, material, pad*

1. INTRODUCTION

The braking system constitutes an integral part of an automotive, [1]. The purpose of the braking system is to decelerate a vehicle by transforming the kinetic energy to heat, via friction, and dissipating that heat to the surroundings, [2]. Failure of the automotive brake system at the time of emergency can lead to accidents, property damage or even death of an individual. This is the reason why special attention is paid to the design and manufacture of braking systems components. The brake system is composed of many different parts including brake pads, a master cylinder, wheel cylinders and a hydraulic control system. The brake pads are an important component in the braking system of automotive. These are of different types, suitable for different types of automotive and engines. Brake pads are designed for friction stability, durability, minimization of noise and vibration. The typology of the brake pads depends on the material which they are made. Materials used for brake pads should have stable and reliable frictional and wear properties under varying conditions of load, velocity, temperature and environment, and high durability, [3]. Nowadays, factors such as economics of operation, increased power to weight ratio, road development, and road traffic demand more efficient braking system which requires improved brake pad materials [4]. It is difficult to select effective brake pad material, because of the large number of competing parameters which often must be satisfied simultaneously, [5]. Current trend in the research field of brake pads materials is to utilization of industrial or agricultural wastes as a source of raw materials for composite development. This will provide more economical benefit and also environmental preservation by utilize the waste of natural fiber, [3]. In recent years, automotive engineers use a variety of materials to maximize performance in this areas, often combining five to twenty different material ingredients to form complex composite friction materials, [6]. Recently, more research has been focused on the non-asbestos organic fiber reinforced metallic friction composites which are increasingly being used in automotive brake discs pads, shoes, linings, blocks, clutch facings, and so forth, primarily because of awareness of health hazards of asbestos, [7]. These organic composites are essentially multi ingredient systems in order to achieve the desired amalgam of performance properties [8-10]. They are generally a compound of a number of different materials broken down into four different categories: binder, structural materials, fillers and frictional modifiers, [3]. The influence of these ingredients on performance properties is so complex that formulation of friction materials is still referred as an art rather than science [2].
The aim of this paper is to develop new organic composite for automotive brake pads without any harmful effect. In this sense, four different laboratory formulations were prepared with varying coconut fiber, friction

modifiers, abrasive material and solid lubrificant using powder mettallurgy techique. The properties examined are density, porosity, hardness, mechanical properties, loss of weight and microstructural analysis. The new composites tested in the laboratory, modeling appropriate percentage ratio between matrix and reinforcement volume and can be obtained with low density, high hardness properties, good thermal stability, higher ability to hold the compressive force and without any harmful effect. These characteristics make them useful in automotive industry.

2. TECHNICAL REQUIREMENTS

2.1. Experimental procedures for formulation the samples

The new composite brake pads material was developed through the process beginning with the selection of raw materials, weighing, mixing, compacting and sintering. There are four formulations with different composition of coconut fiber content. The fabrication of composites containing seven ingredients was based on keeping parent composition of five ingredients (around 75%) constant and varying two ingredients, namely aluminium and coconut fiber (around 25 %) in complementary manner as shown in Table 1, [11]. In establish of this recipes it was considered the study realized in paper [2] referring to automotive brake pad formulations. Similar recipes were used by authors in paper [3]. In this paper the difference consist of various proportions of components and in replacement of aluminum oxide with titanium oxide. We considered this approach because a small change of the composites recipe and of manufacturing technology can improve the characteristics of the final product.

Table 1: The recipes used in the product of composite brake pads material

Samples	Aluminium [%]	Graphite [%]	Zirconia oxide [%]	Silicon carbide [%]	Titanium oxide [%]	Phenolic resin [%]	Coconut fiber [%]
C 1	25	10	2	10	13	40	0
C 2	20	10	2	10	13	40	5
C 3	15	10	2	10	13	40	10
C 4	10	10	2	10	13	40	15

All materials were prepared in powder form. Graphite was added to minimize fracture in the mixing process. The coconut fiber was used as a filler material in this investigation. Fillers, such as mica, vermiculite, and barium sulphate are used mainly to reduce cost of pads, [2]. The method for fabrication of brake pad material was powder metallurgy technique. The prime reason for using the powder metallurgy process is the possibility of obtaining uniform parts and reducing tedious and expensive machining processes, [3]. The ingredients were mixed in a drum mixing machine, type PM 100, to ensure the macroscopic homogeneity, using a chopper speed of 1500 rpm. First, aluminium and titanium oxide were churned together for 6 minutes. Zirconiu oxide and silicon carbide both were switched on at 120 rpm. After this, graphite and coconut fiber were added and mixed for 16 minutes. Then straight phenolic resin was added and the mixer was run for 5 minutes. The mixing sequence and time of mixing of each ingredients led to proper uniformity in the mixture. If mixing time is low, proper homogeneity cannot be achieved. If it is too high, it does not improve the homogeneity further. Then, the materials were introduce in a mold presented in Figure 1.

Figure 1: The mold for making samples

The compaction was performed using a hydraulic press machine under a force of 0,5 KN. After removing from compaction, the material was sintered in an oven at a temperature of 200°C for an hours, after which cooling was carried out in air for 12 hours. Good consistency of the sample is due by heating-cooling regime.

Extracting the samples from the mold was done without sticking problems, which is solved by using aluminum foil layer grafit. All samples are appropriate in appearance, shape and consistency. The surfaces of the samples were then polished with a grinding wheel to attain the desired thickness and smooth surface. The finished composite samples with variable addition of coconut fiber is shown in Figure 2.

Figure 2: Finished composite samples with variable addition of coconut fiber

In order to characterize the new composite material for brake pads, they were achieved tests to determine density, porosity, hardness, thermo-gravimetric analysis, mechanical testing, and microstructure. The samples for each test were carried out by cutting in concordance with actual standards.

2.2. Characterization of the brake pad material

A density measurement test has been carried out on a laboratory scale to examine the density of the new material obtained. The true density was determined by weighing each sample on a digital weighing machine and measuring their volume by liquid displacement method. The specific gravity formula is:

$$\circ = \frac{m}{V} \qquad (1)$$

The results shown in Table 2 and represents the average density of five readings for each formulation.

Table 2: Density, porosity and hardness for new developed brake pad materials

Samples	C1 (0% coconut fiber)	C2 (5 % coconut fiber)	C3 (10% coconut fiber)	C 4 (15% coconut fiber)
Density [g/cm^3]	2,59	2,42	2,38	2,29
Porosity [%]	21,23	15,63	16,6	23,43
Hardness HRS	55,7	69,3	62,6	41,7

Composite C4 with 15 % coconut fiber content shows lower density compared with other three formulations. The density of this composite which have more coconut fiber shows lower density than formulation of C1 without coconut fiber. The high density of C1 is explained by the greater amount of aluminum in the recipe. Comparing the densities of the materials obtained in this paper with the paper [3] is observed higher densities. This is explained by the fact that the chosen recipe consists of titanium oxid which is more denser than aluminum oxide. On the other hand, the densities obtained are much lower than in the case of metallic and semi-metalic pads.

The function of porosity is to absorb energy and heat. Theoretically, lower porosity will result in higher friction coefficient and wear rate, [3]. The paper [12] presented that increasing porosity by more than 10% could reduce the brake noise. On the other side, brake pad should have a certain amount of porosity to minimize the effect of water and oil on the friction coefficient, [3]. Porosity test was performed in accordance with Japanese Standard JIS D 4418: 1996, [3]. The specimen was cut to dimensions: 25 mm x 25 mm x 7 mm, then left in a desiccator for 24 hours at room temperature and cooled to room temperature in desiccator, Figure 3. The sample was weighed to the nearest 1 mg before test sample placed in the test oil in the container and keeps at 90 ± 10 °C for 8 hours. The test sample was left in the oil container for 12 hours until the oil cools to the room temperature and then withdrawn from the oil container, Figure 4. Finally, the sample was rolled on a piece of cloth for 4 to 5 times to remove oil from the test sample. The sample was weighed again to the nearest 1 mg. This certain amount of porosity could minimize the effect of water and oil on the friction coefficient. Table 2 shows the porosity test results for all formulations of brake pad materials. From the porosity results it can be seen that two break disc formulations such as 5 and 10 % coconut fiber content shown lower percentage of porosity compared to other two formulations. Same conclusions were obtained in the paper [3] the difference consisting on values obtained for porosity. In this paper were obtained higher values of porosity which is explained by the different manufacturing technology of composite materials.

Figure 3 :The test samples left in a desiccator

Figure 4: The test samples immersed in the oil container

The hardness test was conducted on a Rockwell unit PH-C-01 /02 in accordance with EN ISO 6508-1 standard: 2002. The hardness measurements were conducted under test load of 980,6 N, the stell ball diameter is 1,58 mm, using scale B as stipulated in the standard. The measurements were performed at a distance of 13 mm. Drive speed of the load is 0.8 m/s and the holding time is 10 s. The hardness of the sample is the arithmetic mean of the readings five indentations. Table 2 shown the hardness values of the four formulations brake pads material. It can be seen that the hardness value of C2 with 5 % coconut fiber is the highest of all and the hardness value of 15 % coconut fiber show lower hardness value. This is because of too ductile nature of the material as more coconut fiber content in the composition. The lowest hardness has C4 because of too ductile nature of the material as more coconut fiber content in the composition. Formulation C2 composite with 5 % coconut fiber content has the highest hardness value of 69,3 HRS because of having more aluminium content used as a matrix. Varying content of aluminium and coconut fibre will exhibit different hardness value of the material.
The compressive strength was done using a universal testing machine type Zwick/Roll Z005 with a corresponding software name TestXpert II, that retrieves data from experimental testing machine and process them statistically. The dimensions of thesamples are: 25mm x 25mm x 7 mm. Figure 5 shows a complete set of samples to achieve compression test. The samples was subjected to compressive force, loaded continuously until failure occurred. The load at which failure occurred was then recorded, Figure 6.

Figure 5: A complete set of samples for compression test

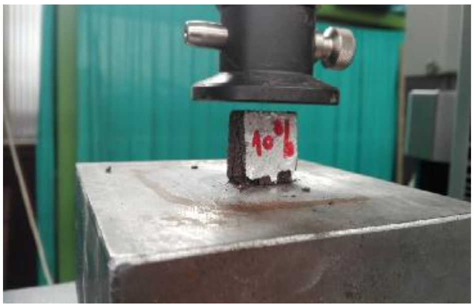


Figure 6: Sample with 10 % coconut fiber during compression tests

Table 3 shows the compressive strength for new composite materials developed.

Table 3: Compressive strength for new composite materials developed

Mechanical strength	Brake pad formulation			
	C1	C2	C3	C4
Compresive load at tensile strength [N]	2260	3719	3910	4440
Compresive strength [MPa]	21,45	41,56	39,72	47,67

The compressive strength showed the formulation of C4 (with 5 % coconut fibre) exhibited higher strength to withstand the load application and higher ability to hold the compressive force. The ultimate strength of the formulation C4 is corresponds to the stress of 47,67 MPa. The sample starts to break at stress of 45,21 MPa.
Thermo-gravimetric analysis results of new developed composites which reveals the weight loss when exposed to 50–300∘ C, [7]. Thermo-gravimetric analysis of the developed composites is carried out in a TLB 180 series type machine at a heating rate of 15^0 C/min. The sample is weighed accurately with a balance of fouth decimal place in a previously ignited, cooled, and weighed silica crucible. Figure 7 present the procedure of weighing of the samples utilized in thermo-gravimetric analysis.

Figure 7: The procedure of weighing with a balance of fouth decimal

The crucible containing the sample is introduced into the muffle furnace maintained at 250 to 300^0 C and soaked for two hours. Then the crucible shall be removed from the furnace, cooled in a desicator and weighed. The weight loss % of new natural material for brake pad during exposure was calculated with relation:

$$\Delta M = \frac{M_2 - M_3}{M_2 - M_1} \cdot 100 \quad (2)$$

In relation (2) M_1 represent$_s$ the weight of empty crucible, [g]; M_2 is the weight of crucible + sample, [g]; and M_3 is weight of crucible + sample (after ignition), [g].

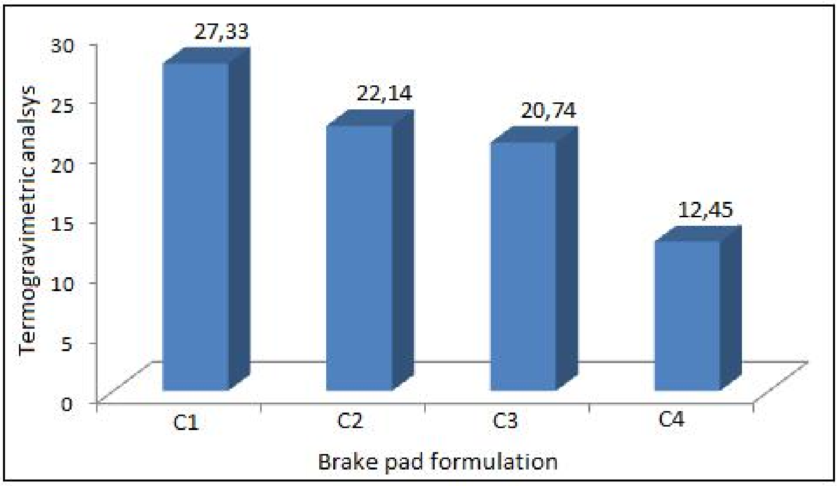
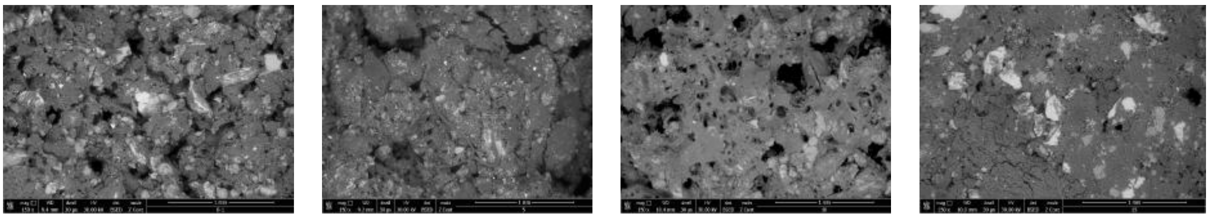


Figure 8: Termogravimetric analsys results

Figure 8 shows thermo-gravimetric analysis results of the developed composites which reveals the weight loss % when exposed to 50–300∘ C. The weight loss % of C1 during exposure was 27,33%, for C2 it was 22,14%, for C3 it was 20,74%, and for C4 the loss was 12,45%. Hence C4 has better thermal stability than the other composites. We can observe that the higher of coconut fiber content offer to composite materials higher thermal stability. Loss by weight % is as follows: C4 < C3 < C2 < C1.

For morphology study scanning electron microscopy SEM was used in order to observe and investigate the distribution of microstructural features along with elemental constituents of new composite reinforced with various content of coconut fiber for automotive brake pads. Figures 9 showed the SEM micrographs for new composites materials with variable addition of coconut fiber.



C1-0 % coconut fiber C2- 5 % coconut fiber C3 -10 % coconut fiber C4 -15 % coconut fiber

Figure 9: SEM microstructure for composite samples with variable addition of coconut fiber

The resin binder in dark region along with aluminium distribution in white region can be saw in microstructure for composite with 0 % coconut fiber. The graphite element in gray regions also can be visualized in Figure 12.
The microstructures of 5 % coconut fiber composites showed the homogeneous distribution of abrasive, solid lubricant, binder and friction modifier in the aluminium matrix. Higher amount of aluminium is present in C4 due to more coconut fiber in the formulation. The other three structures showed the heterogeneously distribution of elements which explain by different weight of elements. Also the sintering process of materials at different temperatures contribute to the change of the structure

3. CONCLUSION

Based on the results obtained in this paper the following conclusions can be made**:**

- Composite C4 with 15 % coconut fiber has lower density, but higher porosity compared to other formulations.
- C2 and C3 composites even have a greater density than C4 they have less of porosity.
- Formulation C2 with 5 % coconut fiber content has the highest hardness value of 69,3 HRS.
- Composite C4 with 10 % coconut fiber exhibited higher strength to withstand the load application and higher ability to hold the compressive force.
- Composite C4 is more efficient than other compositions since it has good thermal stability. A good thermal stability have composites C2 and C3.
- From the SEM study it can be see that microstructures of C2 composite showed the homogeneous distribution and this composite modeling appropriate percentage between matrix and reinforcement volume.

It can be concluded that Composite 2 and Composite 3 showed almost similar properties from the four formulations and it could be utilize in the manufacturinhg of brake pads .
The study led that natural coconut fiber is a potential candidate filler material for the light and medium weight vehicles brake pads.

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