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Research paper

Development of Drum Brake Pad Material Motorcycle Based Composite Hazelnut Shells, Aluminum and Pineapple Leaf Fibers with Polyurethane Matrix

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Abstract

This study aims to determine the mechanical properties of composite materials which consist of hazelnut, aluminum and pineapple leaf fibers with polyurethane matrix. Therefore, the properties of flexural strength, hardness, wear rate, heat resistance and microstructure of drum brake pad materials motorcycle should be investigated. The process used for brake pad specimen preparation was casting method, and is compressed by 19 tons. The variation of the material composition divide into 50, 60, 70 and 80 % of filler weight consist of hazelnut shell, aluminum and pineapple leaf fiber with the polyurethane matrix. The size of the hazelnut shell is 100 mesh, aluminum is less than 230 mesh and pineapple leaf fiber around 5 to 10 mm. By the experimental test compared with the microstructure observation, the best composition in consonance with requirement of brake pad composite material is 70 % filler. The composition of 70 % of fillers obtained by density of 1.677 $g.cm^{-3}$, flexural strength of 11.331 $N.mm^{-2}$, hardness of 86.8 Rockwell, wear rate of 0.084 $mm^3.s^{-1}$ and heat resistance up to about 260 ^0C.

Keywords: *Drum brake pad; hazelnut shell; pineapple leaf fiber; polyurethane; composite*

1. Introduction

The development of automotive technology from time to time is something that must be faced. Materials needed for such technology must also continue in innovation from hard-to-find materials in nature to be easy to come by, such as composite materials. So it creates a technology that is cheap and environmentally friendly. The composite materials are progressing very rapidly due to the renewable or renewable properties features as well as the high strength to weight ratio of stiffness, corrosion resistance and others, thus reducing the consumption of chemicals as well as environmental disturbances [1]. Motorcycles are the result of technological developments that require many components and types of materials. Motorcycle components are most often replaced and also important to note in order to maintain safety both by vehicle technology designers and drivers who use the vehicle is the brake system. Brake pad is one of the most important parts of the braking system [2]. The strength of the brake pad recording depends heavily on the brake pad material. Materials for brake pad sold in the market are asbestos, steel fiber, cellulose, rock wool, graphite and kevlar. From the material of the brake pad in circulation raises concerns about its dangerous particles [3]. Uses such as asbestos can cause cancer disease [4]. While the increased use of other materials are leading to scarcity in nature, so there is a need to find another alternative as a friction material for brake pad. To overcome this, various types of brake pad materials are developed.

The strength of the brake particle composite material is greatly influenced by the particle, its matrix material and the manufacturing process. The particle composite strength is obtained maximally in sizes from 0.01 to 0.1 mm and the strength of surface bonding, diffusion, and sintering [5].

Currently, there are three universally accepted friction material formulations for brake pad [6] (1) semi metallic, Semi metallic brake pad is made of steel fiber as fiber reinforcement. Most semi-metallic friction materials contain at least 60% steel fiber. Steel fiber acts as a frame work to bind the friction material simultaneously. (2) Organic non-asbestos (NAO), an organic Non-asbestos brake pad (NAO) consists of organic fibers used to strengthen the friction materials and provide strength to the brake pad. The NAO friction materials contains less than 20% heavy steel fibers, the NAO brake pads are designed to replace the dangerous asbestos brake pad and are popular in pre-FWD vehicles. (3) Ceramic, ceramic brake lining does not contain steel fiber. Instead, this formulation uses ceramic and copper fibers to manage heat dissipation.

The technical requirements of brake pad are in accordance with SAE J661 standard [1] (1) Hardness value according to security standard 68-105 (Rockwell) (2) Heat resistance 360 ^0C, for continuous use up to 250 ^0C (3) Value brake pad wear is $5x10^{-4}$ - $5x10^{-3}$ $mm^2.kg^{-1}$ (4) Brake pad mass is 1.5-2.4 $gr.cm^{-3}$ and fracture strength 480-1500 $N.cm^{-2}$.

In this research the researchers tried to examine the material of motorcycle brake pad made of hazelnut shell, aluminum and pineapple leaf fiber with polyurethane as a matrix.

Hazelnut shells are used with size 100 mesh. Because the principle of brake work is to change the kinetic energy into heat energy so needed a good material in absorbing heat like aluminum. In general, with addition of 10% to 20% metal, characteristics such as water absorption, porosity and hardness are increasing [7]. The size of aluminum used is smaller than 230 mesh. In this research, pineapple leaf fibers will be tried as fiber replacement which is commonly used by manufacturers in making brake pad, and is expected to increase the flexural strength of the brake pad. Pineapple leaf fibers pieces are cut in sizes between 10 and 15 mm.

2. Material and method

2.1. Material/equipment

Materials and equipment used in this research are hazelnut shells, aluminum, pineapple leaf fiber, polyurethane polyisocianate and polyol), NaOH, scissors, blender, stone mill, screen mesh 100, digital scales, vernier calliper, brake pad moulds, press machines, metallographic pre grinder, cutting machine, optical microscope, measuring cup, hardness testing machine, flexural strength testing machine, pin on disc machine, differential scanning calorie meter machine (DSC), scanning electron microscope (SEM).

2.2. Method

Processing of hazelnut shell is done with several stages. Initially, hazelnut shell that has been purchased from the farmer must be cleaned thoroughly with water in order to remove dirt like sand, soil etc. After cleansing, the hazelnut shell is soaked in 1M1% NaOH for 2 hours.

Fig. 1: Hazelnut shell

Fig. 2: Hazelnut shell sieve 100 mesh

After the pecan shell is soaked for two hours, it is cleansed with clean water and dried at temperature 35^0C to 70^0C for 8 hours. To get a fine hazelnut shell, it is first milled manually, then in blender until it gets smooth and later in sieve using sieve 100 mesh.

The process of making pineapple leaf fiber is done manually. Pineapple leaves that are being cut from the stem are washed initially, to remove dirt like sand, soil and other dust particles. Once the washing process is done, it is dredged using iron plate of about 3 mm thickness. Pineapple leaf fibers are cleaned and are soaked in water that has been mixed with NaOH 1M1% for 2 hours [8]. Once the soaking process is done for 2 hours, they are washed with clean water and then dried at temperature between 35^0C and 70^0C for eight hours. After drying the pineapple leaf fiber is cut to a length of approximately 10-15 mm [9].

Fig. 3: Pineapple leaf

Fig. 4: Pineapple leaf fiber

The process of making the drum brake pad motorcycle materials starts by weighing the mass of the mixture material according to the composition and size of the specimen. Fillers are composed of hazelnut shells, aluminum and pineapple leaf fiber, while the matrix is polyurethane (polyisocianate and polyol). The specimens consisted of four comparison compositions of weight (wt.) composition 50% filler compared 50% matrix, composition 60% filler compared 40% matrix, composition 70% filler compared 30% matrix and composition 80% filler compared 20% matrix. Table 1 shows the composition of the material specimen of the brake pad material.

Table 1: Composition of filler and matrix (wt%)

Composition Specimen	Hazelnut shells	Aluminum	Pineapple leaf fiber	Polyurethane	
wt% filler : wt% matrix	%	%	%	polyisocianate	polyol
50 : 50	89	10	1	66,67	33,33
60 : 40	89	10	1	66,67	33,33
70 : 30	89	10	1	66,67	33,33
80 : 20	89	10	1	66,67	33,33

Mixing of the first material is done between the hazelnut shells and aluminum until homogeneous mixture is obtained. Then add the pineapple leaf fiber, mix until homogeneously for about 3 minutes. Combine the polyisocianate and stir again until homogeneous for 3 minutes. Once they are mixed homogeneously, add polyol and mix again for 3 minutes, then pour it into a mold and press with 19 ton compact for 10 minutes. Later the specimen shall be placed in a room at room temperature for 3 days.
The above method applies to all specimen forms. As for the specimens would make are specimens of type density, flexural strength test specimen, hardness test specimen, and wear rate test specimen. For heat resistance test using differential scanning calorimeters (DSC), specimen is cut with mass 11.40 mg, while for micro structure test using scanning electron microscopy (SEM) specimen is cut in cube shape with size 0.5 mm.
To know the density of the specimen, weighing using digital scales is done. Specimens casted in the form of a cube with a size of 20 mm, is weighed and calculated volume of that. Formula used to calculate the density of the material is as follows.

$$\text{Density } (\text{gram/mm}^3) = w/v \quad (1)$$

Definition 1: w = Mass, v = Volume
Flexural strength is tested using three point bending using tensile testing machine. Specimens are casted in size using ASTM D790 standard. Test specimen is mounted right in the middle of the two supports i.e between the support and the indenter.
Hardness testing was performed by rockwell scale B hardness tester method (rockwell hardness tester, model Matsuzawa Seiki Co. LTD) with 1.588 mm indenter. Specimen size refers to ASTM E18 standard. Before testing, the surface of the specimen is smoothed with a metallographic pre-grinder with a particle size of 120 mesh.
Wear rate test is done by pin on disk method which refers to ASTM G99-04 standard. Specimens of 10 mm thickness and diameter of 50 mm are tested in a dry state. Before performing the specimen test, the surface of the specimen is first smoothed with a metallographic pre-grinder with a particle size of 120 mesh. The test is done with a load of 1 kgf, a rotational speed of 180 rev / min with a time of 600 seconds. All testing is done at room temperature. The formula used to calculate the wear rate is [10]:

$$Wear\ Rate\ (mm^3/s) = \frac{(A_2 - A_1) x \bar{b}}{t} \quad (2)$$

Definition 2: = Inside the track area, A_2 = Outside the track area, $\bar{b}$ = The average depth of the wear path , t = Wear time

$$Track\ radius\ (mm) = \frac{d + (\bar{a} x 10^{-3})}{2} \quad (3)$$

Definition 3: $\bar{a}$ = Average width of the wear track (µm), d = Test track diameter
Differential scanning calorimeters (DSC) are used to determine the heat resistance of brake pad materials. Differential Scanning calorimeters used DSC-60 model with heating specimens carried out to a temperature of 500 ^{0}C. Flow rate testing 30 ml / min, temperature rate 10 ^{0}C / min and gas used is nitrogen. Scanning electron microscope (SEM), the EVO MA10 model is used to view the sample microstructure at 20 kV. The goal is to look at the homogeneous level of the mixture of each composition.

3. Material and method

Density testing is done by making a cube-shaped specimen with a size of 20 mm. Figure 5 shows the density test results for each weight percent of the brake pad material.

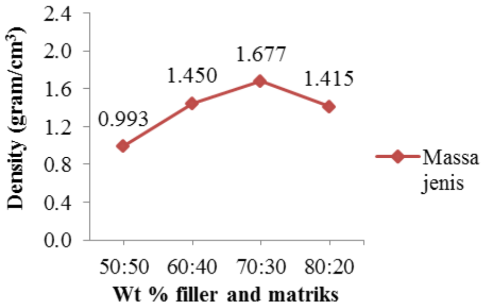

Fig. 5: Variation density with wt % filler and matrix

Looking at the composition ratio of 50:50 to 70:30, there was an increase in the density ratio. At 80:20 composition there is a decrease and this is probably caused by, too few binding elements so that there is no significant resistance reaction when in compacting with a pressure of 19 tons. From the result of testing the recommended density values for the brake pad materials according to the reference [10] is the weight percent composition 60:40 and 70:30.

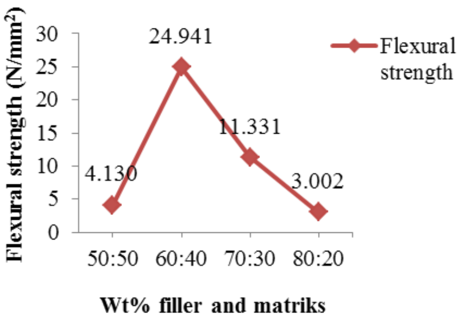

Fig. 6: Variation flexural strength with wt. % filler and matrix.

Figure 6 shows the result of testing the bending stress of the brake pad material. In a 60:40 weight percent composition specimen, the bending stress value occurring is considerable and does not fall into the category of motorcycle brake pad material, the value included in the range is at 70 percent weight percent composition [1].
Figure 7 variation of hardness with wt. % filler and matrix weight. Testing of drum brake pad material on motorcycle using Rockwell scale B test. Each composition consists of three samples and each sample will be tested with five experiments or five points. The test load given is 100 kgf and each specimen is tested with five points. Figure 7 indicated the results of the specimen test of each composition ratio with weight of the filler and the matrix.

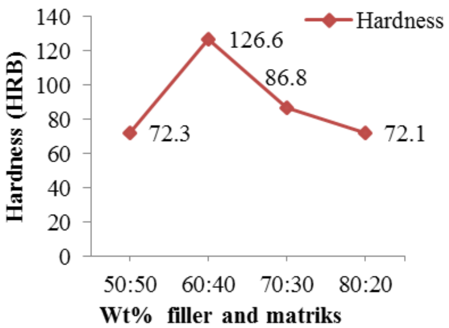

Fig. 7: Variation of hardness wt. % filler and matrix

For comparisons the weight percent composition of 60:40 hardness exceeds that of 68-105 (Rockwell) brake hardness material [1], while for weight percent composition 50:50, 70:30 and 80:20 are still eligible for the brake pad materials.
Wear rate testing tool used in wear test is a Pin-on-Disk Apparatus as per standard ASTM G99-04. Figure 8 is shown specimen before to the test.

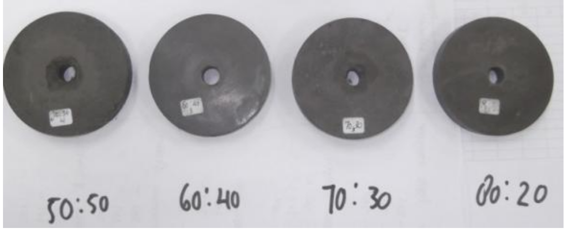

Fig. 8: Specimens of drum brake pad materials before wear test

After the test, specimen shown in Figure 9 to 12.

Fig. 9: Specimens composition 50 wt. % filler and 50 wt. % matrix**.**

Fig. 10: Specimens composition 60 wt.% filler and 40 wt. % matrix.

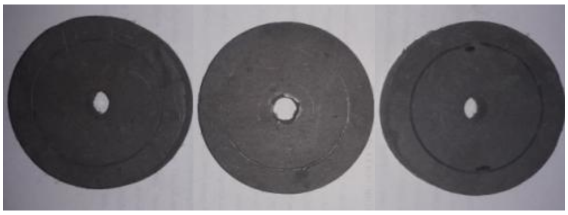

Fig. 11: Specimens composition 70 wt. % filler and 40 wt. % matrix.

Fig. 12: Specimens composition 80 wt. % filler and 20 wt. % matrix.

From Figure 9 to 12 there is a track on the test specimen. The track cause by capacity pin load during the test so that the pin rubs against the specific surface. The track width and depth track could be measured using Reflected Metallurgical Microscope with type Rax Vision No.545491, MM10A, 230V-50Hz. Figure 13 to 16 is the track width from testing materials of brake pad of hazelnut shells, aluminum and pineapple leaf fiber with polyurethane.

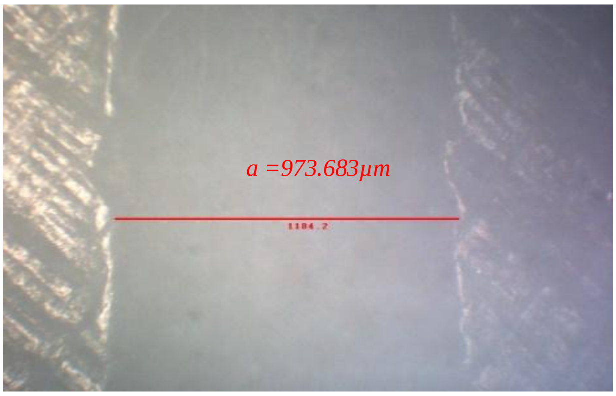

Fig. 13: Wear track width composition 50 wt. % filler and 50 wt. % matrix (zoom 50 X)**.**

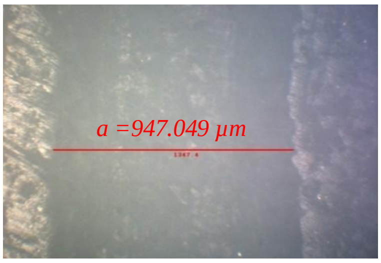

Fig. 14: Wear track width composition 60 wt. % filler and 40 wt. % matrix (zoom 50 X).

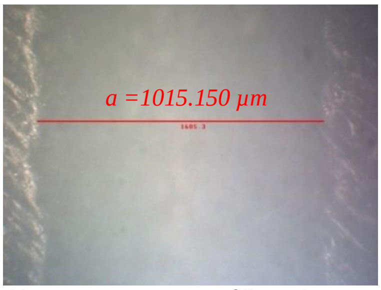

Fig. 15: Wear track width composition 70 wt. % filler and 30 wt. % matrix (zoom 50 X).

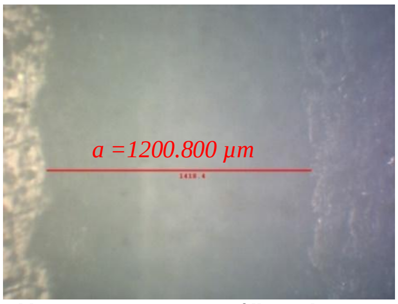

Fig. 16: Wear track width composition 50 wt. % filler and 50 wt. % matrix (zoom 50 X).

From Figure 13 to 16 the alphabet *a(µm)* denotes track width. visible differences in surface width of the track of each specimen.

Fig. 17: Wear track depth composition 50 wt. % filler and 50 wt. % matrix (zoom 50 X).

Fig. 18: Wear track depth composition 60 wt. % filler and 40 wt. % matrix (zoom 50 X)

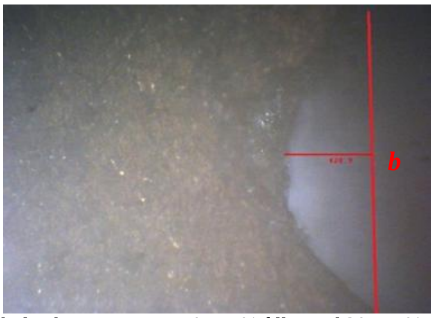

Fig. 19: Wear track depth composition 70 wt. % filler and 30 wt. % matrix (zoom 50 X)

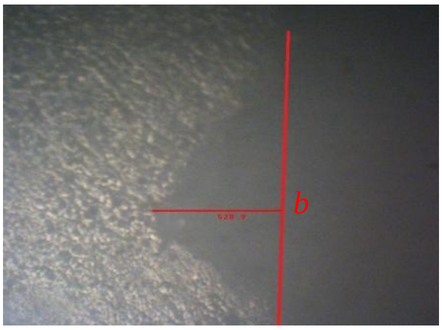

Fig. 20: Wear track depth composition 80 wt. % filler and 20 wt. % matrix (zoom 50 X)

Figure 17 to 20 are shown the wear track depth. The alphabet b (μm) denotes track depth.
After calculation, the wear rate is obtained as shown in Figure 21**.**

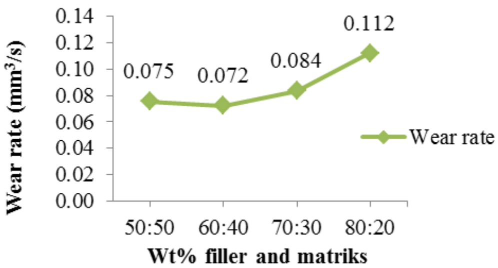

Fig. 21: Variation of wear rate with% filler and matrix weight

The wear rate is increasing with the reduction of the matrix. This is understandable because strong bonds are hard to obtain by the addition of fillers. From weight percent composition ratio performed heat resistance testing using differential scanning calorimeters obtained results shown in the Figure 22.

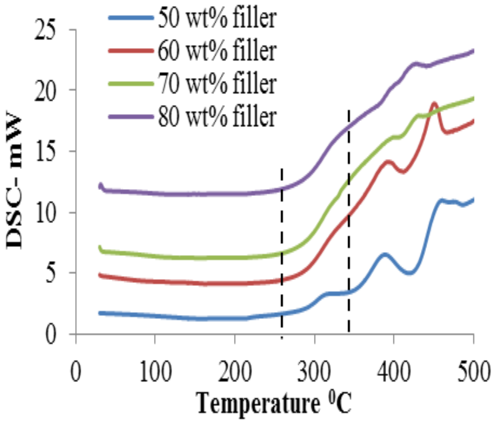

Fig. 22: Transformation of specimen because heating

The straight horizontally positioned line indicates that the use of the material, which is around 260^0C, is indicated by a vertical dashed line. The rising line indicates the material is starting deprecated and burned with marked the emergence of the pick which is about temperature 340^0C that is on vertical dashed line. Testing is done with two runs, and figure 22 shows the second run.
In order to see the homogeneity of the mixture of each composition comparison, the figure 22-25 shows a microstructure photograph with magnification of 1.00 K X.

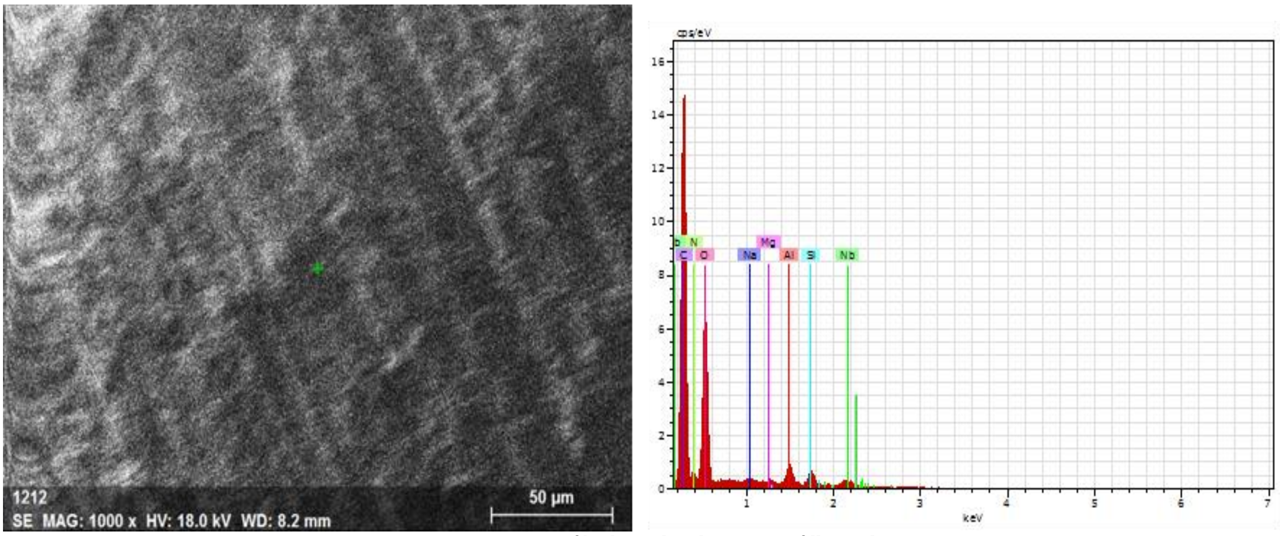

Fig. 23: SEM/EDS Microstructure of brake pad with 50 wt. % filler and 50 wt. % matrix.

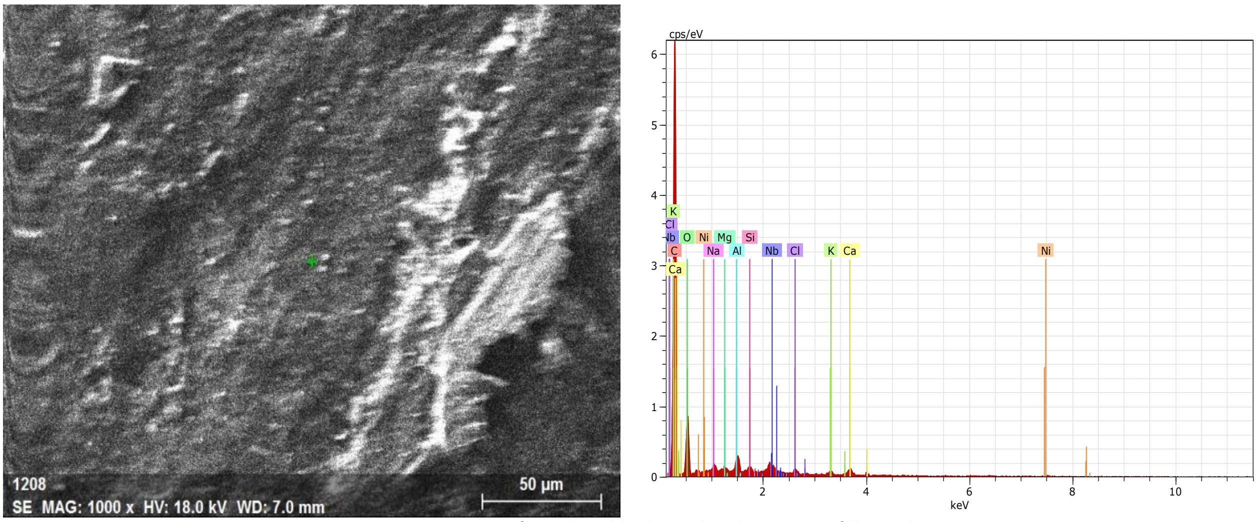

Fig. 24: SEM/EDS Microstructure of developed brake pad with 60 wt. % filler and 40 wt. % matrix.

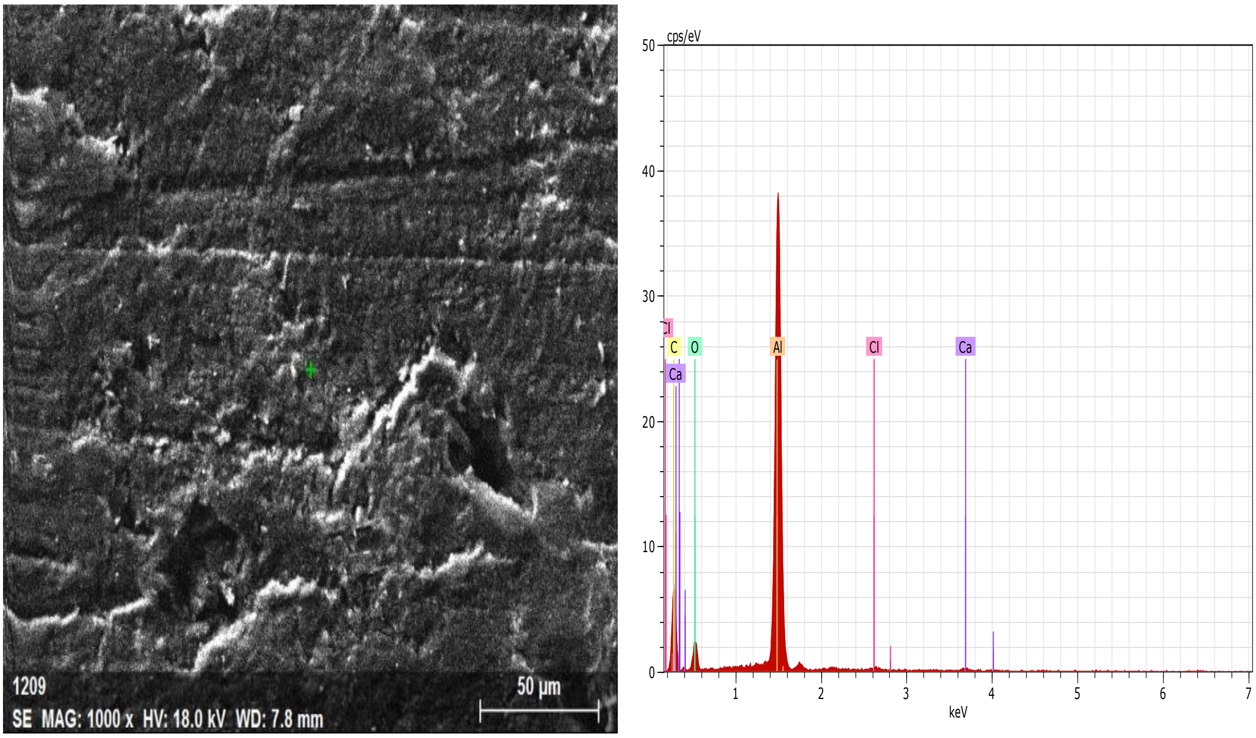

Fig. 25: SEM/EDS Microstructure of developed brake pad with 70 wt. % filler and 30 wt. % matrix

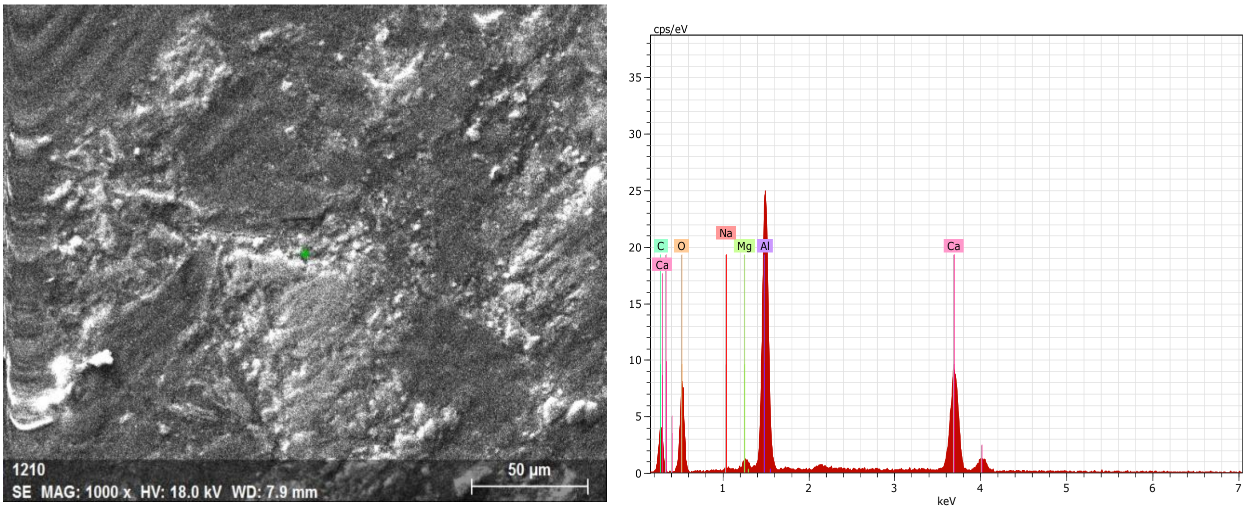

Fig. 26: SEM/EDS Microstructure of developed brake pad with 80 wt. % filler and 20 wt. % matrix

Figure 23 to 25 we can see the structure difference. In a specimen with 50 wt. % filler mixture there was no noticeable difference in the element. This may occur because the material is too aqueous, whereas in the sample with 60 and 70 wt. % filler looks different micro-structural. A rather white color indicates the fiber while the hazelnuts shells, aluminum and polyurethane as well as the dark-colored. Specimen with 80 wt. % of the fiber visible fillers in clumped state or mixtures are very less homogeneous, this may be due to the lack of polyurethane and thus unable to bind fillers.

4. Conclusion

The mixing composition of the fillers between the hazelnut shells, aluminum, pineapple leaf fiber with matrix of polyurethane in this study were 50%, 60%, 70% and 80% by weight of the filler. After testing and looking at the microstructure we can recomended feasible to use as requirement of motorcycle brake pad made of composite material is 70% by weight of filler. 70% weight composition of filler obtained by mass of type 1,677 $gr.cm^{-3}$, flexural strength 11,331 $N.mm^{-2}$, Hardness 86,8 HRB, The wear rate is 0.084 $mm^3.s^{-1}$ and the heat resistance is up to about 260 ^{0}C. Drum brake pad materials full in requirement of brake pad materials refers to SAE J661.

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