Effect of pressure to rice plant fibre reinforced composite on coefficient of friction of brake lining

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Abstract. Brake lining of motor cycle made from asbestos can produce powder when friction occurs. The resulting powder can enter the human body and cause disease. For this reason it is necessary to find alternative materials that can replace asbestos. One material that has the potential to replace asbestos as brake lining is a rice plant fibre reinforced composite. This study aims to determine the effect of pressure on the coefficient of friction of a rice plant fibre reinforced composite. The rice plant fibre reinforced composite are made from fibre rice plant, aluminium powder and fibreglass as a dispersed phase and polyester resin as a matrix. Pressure varies from 10 kg/cm² to 30 kg/cm², with a speed of 2000 rpm. Micro photographs were also taken to investigate the phase and bond failure on the composite. The results showed an insignificant increase in the coefficient of friction by 1.74% in dry conditions and 6.23% in wet conditions. In addition, the results also show the coefficient of friction in dry conditions is higher than in wet conditions.

1. Introduction
Both motorcycle and car brakes are usually equipped with brake lining components, and are placed near the wheels. This brake lining has very vital functions, including helping to control braking, making it easier to cross the downhill and uphill roads, and providing easy braking facilities. Nowadays, brake lining of motor cycle made from natural resources and waste can replace classic materials that are difficult to process and help protect the environment [1, 2]. Brake lining material is designed to meet various performance requirements, including high and stable coefficient of friction, wear, strength, high recovery, low fade, noise and vibration in various work environments [3]. One of them is natural fiber ingredients [4]

Natural materials combined with metals, polymers and ceramics form a composite material. Composite materials can be defined as a combination or a mixture of two phases in a macroscopic and microscopic manner in order to obtain the desired combination of properties. To achieve the desired properties, various combinations of metals, ceramics and polymers are made and produce various types of composite materials. In general, composite materials are made to improve the predominance of mechanical properties such as strength, toughness, stiffness at room temperature and at high temperatures [5-7].
Composite materials are widely used in industry. Its uses include the fields of aircraft and military [8, 9], aerospace applications [10, 11], the automotive industry [12, 13], packaging materials [14] and sports equipment [15].

Composites in the current context are multi-phase materials that are made and not formed naturally. The forming phases are chemically different. This is different from metal alloys which, although also a multi-phase material (e.g. carbon steel with ferrite and cementite phases), are formed by natural phenomena. Most composite materials consist of only two phases: Matrix and Dispersed Phase. The matrix is the phase that binds to the dispersed phase. The properties of a composite material are a function of the properties of its constituent materials, their relative quantities, and the geometrical shape of the dispersed phase (including its distribution and orientation) [16, 17].

The use of composites as a motor cycle brake lining material will cause the composite to experience friction. This friction is affected by pressure as well as speed and operating conditions. Therefore, this study aims to investigate the effect of pressure on the coefficient of friction of a fiber reinforced composite rice plant. Rice plant fiber reinforced composite are selected because it has hardness and wear resistance suitable for use as brake lining of the motor cycle.

2. Materials and Methods
The materials used in this study are rice plant fiber reinforced composite containing 40% fiber rice plant, 40% polyester resin, 10% fiberglass and 10% Aluminum powder. The mesh size of aluminum is 60.

The first step of the study was to weigh the material using a digital scale according to the composition and then manually mixed until the material was evenly mixed. Brake lining molds are installed and brake lining plates are installed on the mold.

The next step is the brake lining plate is given polyester resin which is useful for attaching the material to the surface of the canvas. Then the composite material that has been mixed was put into the mold.

After that the mold is pressed using a press machine. Pressing is done by giving heat to a temperature of 90 °C. Then the composite is sintered at temperature of 180 °C with duration of 15 minutes. After it cools the brake lining is released from the mold.

After the specimen is obtained into a brake pad, then a micro photograph is taken. Micro photographs are carried out using optical microscope. The next test is testing the coefficient of friction. The friction tests were conducted in dry condition and wet condition. The coefficient of friction testing is carried out at 2000 rpm. In this test, the effect of pressure variations is examined by applying pressure variations of 10 kg/cm², 15 kg/cm², 20 kg/cm², 25 kg/cm² and 30 kg/cm². Failures that occur with the bond in the composite are also examined using optical microscopy.

3. Results and Discussions
Brake linings made of the composites are shown in figure 1. The composite is composed by 40% fiber rice plant, 40% polyester resin, 10% fiberglass and 10% Aluminum powder. Figure 2 shows a photo micro of a rice plant fiber reinforced composite. Rice plant fiber, aluminum powder and fiberglass play the role of transferring the load inside the polyester resin matrix.
The relationship between the coefficient of friction and pressure is shown in figure 3. The higher pressures in the brake lining the greater the coefficient of friction will be exist. However, the increasing coefficient of friction was not significant. This trend is shown both in dry conditions and wet conditions.

The wet conditions show a smaller coefficient of friction than dry conditions. Dry conditions produce a coefficient of friction of 0.632, 0.635, 0.634, 0.64 and 0.643 for pressures of 10 kg/cm$^2$, 15 kg/cm$^2$, 20 kg/cm$^2$, 25 kg/cm$^2$ and 30 kg/cm$^2$, respectively. While wet conditions produce a coefficient of friction of 0.594, 0.597, 0.598, 0.628 and 0.631 for pressures of 10 kg/cm$^2$, 15 kg/cm$^2$, 20 kg/cm$^2$, 25 kg/cm$^2$ and 30 kg/cm$^2$, respectively.
Figure 3. Relationship between coefficient of friction and pressure.

Figure 4 shows the bond failures that occur in composites when experiencing friction. Failures that occur in the form of adhesive bond failure. In the rice plant fiber reinforced composite, adhesive failure was an interfacial bond failure between the adhesive and the adherent.

4. Conclusions
An increase in pressure will result in an increase in the coefficient of friction, although not significantly. Operating conditions affect brake lining. Wet operating conditions will result in a lower coefficient of friction than dry conditions. In dry conditions, an increase in pressure from 10 kg/cm$^2$ to 30 kg/cm$^2$ will result in an increase in the coefficient of friction from 0.632 to 0.643. While in a wet condition an increase in pressure from 10 kg/cm$^2$ to 30 kg/cm$^2$ will result in an increase in the coefficient of friction from 0.594 to 0.631.

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References

[1] Yun R, Filip P and Lu Y 2010 Performance and evaluation of eco-friendly brake friction materials, Tribology International 43(11) 2010–2019

[2] Darmawan A S, Purboputro P I and Febriantoko B W 2020 The aluminum powder size’ effect on rice plant fiber reinforced composite to hardness, wear and coefficient of friction of brake lining, IOP Conference Series: Materials Science and Engineering 722 012002.

[3] Singh T, Kumar N J A R, Grewal J S, Patnaik A and Fekete G 2019 Natural fiber reinforced non-asbestos brake friction composites: Influence of ramie fiber on physico-mechanical and tribological properties, Materials Research Express 6 115701.

[4] Cavalcanti D K K, Banea M D, Neto J S S, Lima R A A and Carbas R J C 2019 Mechanical characterization of intralaminar natural fibre-reinforced hybrid composites, Composites Part B: Engineering 175 107149.

[5] Sarikaya E, Çallioğlu H and Demirel H 2019 Production of epoxy composites reinforced by different natural fibers and their mechanical properties, Composites Part B: Engineering 167 461-466.

[6] Salernitano E and Migliaresi C 2003 Composite Materials for Biomedical Applications: A Review, Journal of applied biomaterials & biomechanics 1(1) 3-18.

[7] Verma D, Gope P C, Shandilya A, Gupta A and Maheshwari M K 2013 Coir Fibre Reinforcement and Application in Polymer Composites: A Review, J. Mater. Environ. Sci. 4(2) 263-276.

[8] Ren Y, Qiu L, Yuan S and Fang F 2020 Gaussian mixture model and delay-and-sum based 4D imaging of damage in aircraft composite structures under time-varying conditions, Mechanical Systems and Signal Processing 135 106390.

[9] Turczyn R, Krukiewicz K, Katunin A, Sroka J and Sul P 2020 Fabrication and application of electrically conducting composites for electromagnetic interference shielding of remotely piloted aircraft systems, Composite Structures 232 111498.

[10] Zhou J, Li Y, Cheng L and Zhang L 2019 Indirect Microwave Curing Process Design for Manufacturing Thick Multidirectional Carbon Fiber Reinforced Thermoset Composite Materials, Applied Composite Materials 26(2) 533–552.

[11] Kappel E. 2019 Distortions of composite aerospace frames due to processing, thermal loads and trimming operations and an assessment from an assembly perspective, Composite Structures 220 338-346.

[12] Pietroluongo M, Padovano E, Frache A and Badini C 2020 Mechanical recycling of an end-of-life automotive composite component, Sustainable Materials and Technologies 23 e00143.

[13] Khatkar V, Behera B K and Manjunath R N 2019 Textile structural composites for automotive leaf spring application, Composites Part B: Engineering 182 107662.

[14] Mohamed S A A, El-Sakhawy M, Nashy E H A and Othman A M 2019 Novel natural composite films as packaging materials with enhanced properties, International Journal of Biological Macromolecules 136 774-784.

[15] Wang J L 2012 Application of Composite Materials on Sports Equipments, Applied Mechanics and Materials 155-156 903-905.

[16] Ding Z, Li Y, Lu C and Liu J 2018 An Investigation of Fiber Reinforced Chemically Bonded Phosphate Ceramic Composites at Room Temperature, Materials 11 858.

[17] Williams G I and Wool R P 2000 Composites from Natural Fibers and Soy Oil Resins, Applied Composite Materials 7 421-432.