ISSN 2347 - 3983
Volume 8. No. 9, September 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter124892020.pdf
https://doi.org/10.30534/ijeter/2020/124892020

The effect of speed on wear rate and coefficient of friction of rice plant fiber reinforced composite as a brake lining material

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ABSTRACT

A rice plant fiber reinforced composite is composed from a matrix in the form of polyester resin and a dispersed phase in the form of aluminum powder, fiberglass and rice plant fiber. This composite has the potential to replace asbestos as a brake lining material, because asbestos powder is harmful to human health. In use, the brake lining will move and rub against another component. The purpose of this research was to determine the effect of speed on wear rate and the coefficient of friction. The composite material mixture that has been in accordance with the composition is put into the brake lining mold and then pressed and sintered. Furthermore, tests for wear and friction resistance are carried out to obtain the wear rate and coefficient of friction. The results showed that the higher the speed the higher the wear rate. In dry operating conditions, increasing the speed from 1000 rpm to 3000 rpm will provide an increase in wear rate of 11.67%. Meanwhile, in wet operating conditions, the increase in speed from 1000 rpm to 3000 rpm increases the wear rate by 11.35%. At the same speed, the wear rate under dry operating conditions is higher than the wear rate under wet operating conditions. In the friction test under dry operating conditions, there was an increase in the coefficient of friction of 10.46% when the speed was increased from 1000 rpm to 3000 rpm. The coefficient of friction also increased by 6.86% when the test was carried out under wet operating conditions. The coefficient of friction under wet operating conditions is lower than the coefficient of friction under dry operating conditions at the same speed. Metallographic observations of the friction surface show a cohesive failure due to friction.

Key words: Aluminum, Brake lining, Cohesive failure, Composite, Wear resistance.

1. INTRODUCTION

Component that play an important role in braking process of vehicle is braking lining. Brake is a safety tool to ensure the driver remains safe. Nevertheless, many problems arose in transportation due to failures in the braking system. Brake system in automotive engineering is a system that functions to reduce vehicle speed, stop the vehicle that is running, keep the vehicle stopped [1]. In the braking process, the kinetic energy will be converted into thermal energy [2].

Brake shoes and brake lining are components of the brake system, the brake shoe is commonly made of steel while the brake lining is usually made of asbestos. Brake lining is mounted on the brake shoe by riveting (large vehicle) or glued (small vehicle) and will rub against the drum. Because brake linings are components that rub against other components, brake linings must have high wear resistance properties [3], [4].

Friction on the brake lining made of asbestos will produce a powder that is harmful to human health [5]. Therefore, other materials are sought which besides having high wear resistance are also not harmful to human health. One of the materials that meet these requirements is a composite [6], [7].

Structural composite materials are a combination of composites and homogeneous materials. Composites are engineering materials made more than one material to obtain properties according to the requirements. However, the physical and chemical properties of the constituent materials in the composite remain separate in the final result of the material [8], [9]. Composites have many advantages, including lower assembly costs, higher strength, lighter weight, and higher corrosion resistance. Even, the tensile strength of carbon fiber composites is higher than the tensile strength of all metal alloys. The advantages result in lighter aircraft weight, greater carrying capacity, fuel savings and longer mileage [10]-[14].

In today's context, composites are materials made by humans and not naturally occurring materials. The constituent phases of the composite are chemically different. Although composites are also multiphase materials such as steel having ferrite and pearlite phases, the phenomenon of human-made composite forming is different from multiphase forming in steel which is a natural phenomenon. Composites have properties that are influenced by the properties, size, geometric shape, distribution and orientation of the dispersed matrix and phase. Composites usually have two forming phases called dispersed phases and matrix [15].

In composites, matrix plays an important role to transmit the load throughout the composite reinforcing material. In this case, the composite reinforcing material is the dispersed phases. The dispersed phases are bound by a matrix[16].The dispersed phase of the composite material is the equivalent particles. The fiber reinforced composite phase is a fiber having a large length to diameter ratio. The reinforcing material plays the important role to bear the load applied to the composite. The properties of the dispersed phases are usually high strength, high toughness and rigidity. dispersed phases usually used in industry are glass, carbon, aramid and ceramic [17], [18].

Composite are widely used in various fields. Composites are mostly implemented in the packaging materials [19], industrial equipment [20], the sports equipment [21], the automotive industry [22], [23], the aircraft and military [24], [25] and the aerospace applications [26], [27].

Natural fibers have the potential to be used as the dispersed phase in composites with polymer matrix. This natural fiber has beneficial properties. Natural fibers which have a combination of high strength, high toughness and light weight can be an alternative material for fiberglass as reinforcement in composites with polymer matrix [28], [29].

Pujari and Srikiran [30] investigated hardness, wear resistance and corrosion resistance properties of palm kernel reinforced composite. This composite was used as brake component material. The research showed the higher the volume fraction of palm kernelsthe higher the hardness and wear resistance of the composite. High corrosion resistance will be achieved at the palm kernel volume fraction of 30%. This research showed that that palm kernel composite can be applicated as a substitute of asbestos as a friction component material.

Liu et al. [31] comprehensively considered the composition and manufacturing techniques in investigating the morphological and tribological properties of the corn stalk fiber reinforced composite. The composite with phenolic resin matrix reinforced with corn stalk fiber is applicated as a brake component. The wet granulation technology method was applied to make composites with a phenolic resin composition of 5 wt.% -13 wt.%. Furthermore, the influence of the phenolic resin composition on the morphological and tribological properties of the composites was observed systematically. The morphological and tribological properties of composite materials can be significantly improved by using wet granulation technology. This research also showed that the phenolic resin composition can be reduced by up to 7 wt.% while the coefficient of friction is still stable and wear resistance is still high.

Composites that are used as brake lining will experience friction on their services. This friction will cause wear on the material so that the brakes will experience a decrease in performance. In addition, if friction produces a powder in the form of poison it can endanger human health. Therefore, it is necessary to look for other materials as substitutes. It is considered that the rice plant fiber reinforced composite can be applicated as a replacement brake lining material of motor cycle. The composite was chosen because they are non-toxic and have a hardness and wear resistance that conforms to the requirements of brake lining components [32]. Speed affects the friction experienced by the brake lining material. Furthermore, based on these considerations, the work aims to determine the effect of speed on the wear rate and the coefficient of friction of brake lining made of rice plant fiber reinforced composite.

2. MATERIALS AND METHODS

The research material was a rice plant fiber reinforced composite. The matrix of the composite was polyester resin of 40%. Meanwhile, the dispersed phase consists of 10% aluminum powder, 10% fiberglass and 40% rice plant fiber. Aluminum powder used in this research has a mesh size of 60. The use of this composite is for brake lining which are an important component in the braking process.

Composite material that has matched the composition are mixed. Then the mixture of composite materials is put into the mold (Figure 1). Furthermore, the composite is pressed with a compression force of 4.5 tons at temperature of 80 °C. Further, the brake lining was removed from the mold. After that, brake lining was put into the oven. In the oven, sintering process was conducted at temperature of 180 °C for 10 minutes so that the bond between the brake lining is strong.

Figure 1: Dies for manufacturing of brake lining

After the brake lining was completed (Figure 2), the tests were carried out, namely micro-photo testing, wear and friction testing under dry and wet conditions. The media used for testing in wet conditions is water. The friction test itself is performed to obtain coefficient of friction.

Testing to obtain wear and coefficient of friction data was conducted with variations in speed of 1000, 1500, 2000, 2500 and 3000 rpm. The constant pressure applied in the test was 20 kg/cm^2.

Figure 2: Brake lining made of composite

3. RESULTS AND DISCUSSIONS

A micro photograph of the composite is provided in Figure 3. The size of the aluminum powder was about 2.5 μm. The content of this aluminum powder in the material was 10%. The other content consists of 40% polyester, 40% rice plant fiber, and 10% fiberglass.

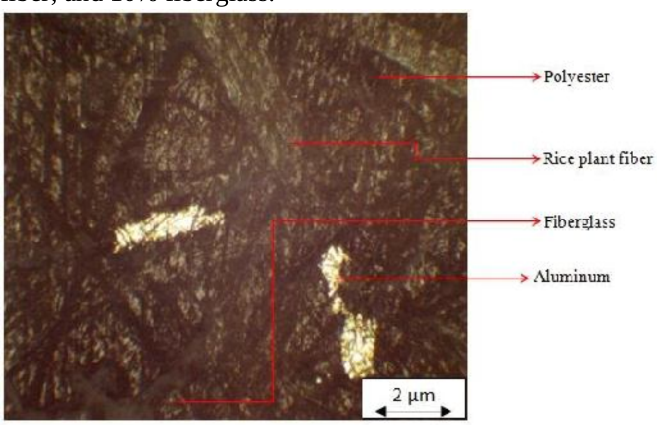

Figure 3: The micro photograph of composite

The wear rates were shown in Figure 4. The tests were carried out at speeds of 1000, 1500, 2000, 2500 and 3000 rpm under dry operating conditions resulted wear rates of 74.52, 75.81, 77.84, 81.49 and 83.22 mm^3/hour, respectively. Increased speed from 1000 to 3000 rpm resulted an increase in the wear rate of 11.67%. Furthermore, wear resistance testing carried out in wet operating conditions with speeds of 1000, 1500, 2000, 2500 and 3000 rpm produced wear rate of 70.73, 72.88, 75.32, 77.45 and 78.76 mm^3/hour, respectively. These results indicated an increased wear rate by 11.35% when the speed was increased from 1000 to 3000 rpm. Figure 4 also shows the decreased wear rate when the brake linings were applicated in wet operating conditions compared to when applicated in dry operating conditions. The highest reduction in wear rate of 5.36% occurred at speeds of 3000 rpm.

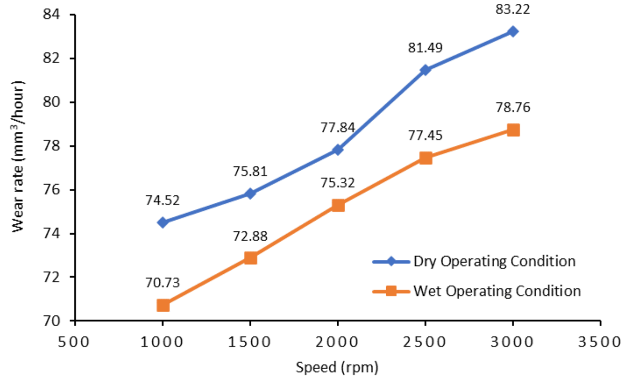

Figure 4: Increased wear rate due to increased speed

The trend that increasing the speed will increase the coefficient of friction can be seen in Figure 5. There was an increased coefficient of friction by 10.46% in the dry operating condition. At a speed of 1000 to 3000 rpm, the coefficient of friction increased from 0.593 to 0.655. While a similar trend was shown in wet operating conditions, the higher the speed the higher the coefficient of friction. Figure 5 also shows that there was an increased coefficient of friction of 6.86% when the speed increased from 1000 to 3000 rpm. Speed of 1000 rpm produced a coefficient of friction of 0.583 and a speed of 3000 rpm produces a coefficient of friction of 0.623. At the same speed, the coefficient of friction due to the wet operating condition is smaller than it due to the dry operating condition. The highest decreased coefficient of friction of 5.68% occurred at a speed of 2000 rpm. This showed that the water media used in the wet operating condition functions as a lubricant.

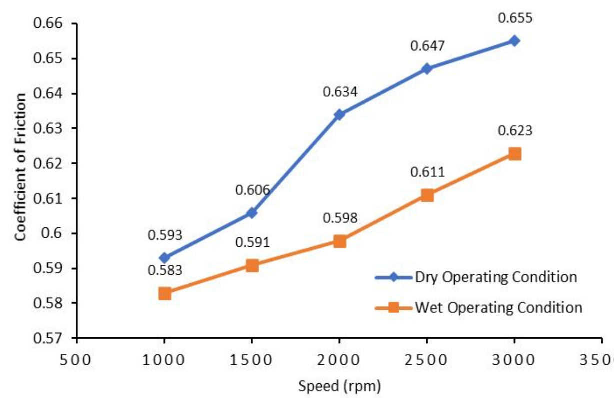

Figure 5: Increased coefficient of friction due to increased speed

In friction testing, cohesive failure is seen occurring on the friction surface of the composite material (Figure 6). Cohesive failure occurs when a failure occurs in an adhesive material so that the adhesive material remains on both fractured surfaces.

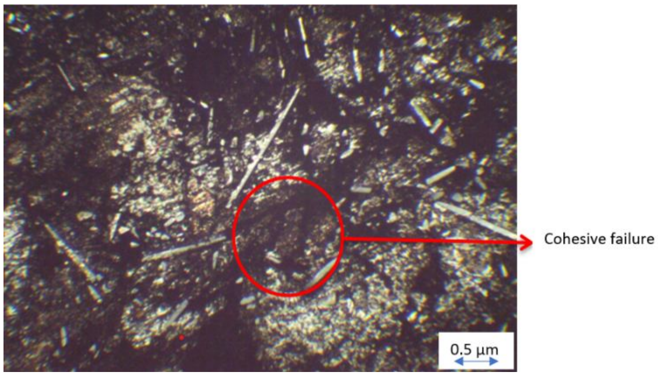

Figure 6: Cohesive failure shown in fracture surface.

5. CONCLUSION

From the results of the research that has been done, it can be concluded as follows:

1. Increased speed will increase the wear rate in both dry and wet operating conditions. The increase in speed from 1000 to 3000 rpm in dry operating conditions resulted in an increase in the wear rate of 11.67%, while an increase in speed from 1000 to 3000 rpm in wet operating conditions increased the wear rate of 11.35%. At the same speed the wear rate due to dry operating conditions is higher than the wear rate due to wet operating conditions.
2. Increasing the speed will increase the level of coefficient of friction in both dry and wet operating conditions. Increasing the speed from 1000 to 3000 rpm due to dry operating conditions causes increasing the coefficient of friction by 10.46%, while increasing the speed from 1000 to 3000 rpm due to wet operating conditions increased the coefficient of friction by 6.86%. At the same speed, the coefficient of friction due to wet operating conditions is lower than the coefficient of friction due to dry operating conditions.
3. Observations on the friction surface show the phenomenon of cohesive failure on the composite friction surface.

ACKNOWLEDGEMENT

The research was funded by Project Number = 133.13/A.3-III/LPPM/IV/2020 of The Directorate of Research and Community Service, The Ministry of Research, Technology and Higher Education of the Republic of Indonesia. Other than that, for material preparation and testing, the authors also acknowledge Material Laboratory of Universitas Muhammadiyah Surakarta.

REFERENCES

1. M. Günay, M. E. Korkmaz, and R. Özmen.**An investigation on braking systems used in railway vehicles**, *Engineering Science and Technology, an International Journal*,vol.23, pp. 421-431, February 2020.
2. P. D. Milenkovic, S. J. Jovanovic, A. S. Jankovic, M. D. Milovanovic, N. D. Vitosevic, M. V. Djordjevic, and M. Raicevic.**The influence of brake pads thermal conductivity on passenger car brake system efficiency**, *Therm Sci.*,vol. 14, suppl.,pp. S221-S230, 2010.
3. A. S. Darmawan, P. I. Purboputro, and B. W. Febriantoko. **The aluminum powder size' effect on rice plant fiber reinforced composite to hardness, wear and coefficient of friction of brake lining**, *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 722, 012002, January 2020.
4. A. S. Darmawan, W. A. Siswanto, and T. Sujitno. **Surface Modification of Commercially Pure Titanium by Plasma Nitrocarburizing at Different Temperatures and Duration Process**, *Research Journal of Applied Sciences, Engineering and Technology*, vol. 5, no. 4,pp. 1351-1357, February 2013.
5. S. P.Jadhav and S. H. Sawant.**A review paper: Development of novel friction material for vehicle brake pad application to minimize environmental and health issues**, *Materials Today: Proceedings*.vol. 19, part 2, pp. 209-212, 2019.
6. M. Baklouti, A. L. Cristol, Y. Desplanques, and R. Elleuch. **Impact of the glass fibers addition on tribological behavior and braking performances of organic matrix composites for brake lining**, *Wear*,vol. 330-331, pp. 507-514, May-June 2015.
7. V. Matějka, Y. Lu, L. Jiao, L. Huang, G. S. Martynková, and V. Tomášek. **Effects of silicon carbide particle sizes on friction-wear properties of friction composites designed for car brake lining applications**, *Tribology International*, vol. 43, no. 1-2, pp. 144-151, May 2009.
8. E. Salernitano and C. Migliaresi. **Composite Materials for Biomedical Applications: A Review**, *Journal of applied biomaterials & biomechanics*, vol. 1, no. 1, pp. 3-18, January 2003.
9. D. Verma, P. C.Gope, A.Shandilya, A.Gupta, and M. K.Maheshwari. **Coir Fibre Reinforcement and Application in Polymer Composites: A Review**, *J. Mater. Environ. Sci.*, vol. 4, no. 2, pp. 263-276, 2013.
10. K. I. Alzebdeh, M. A. Nassar, and R.Arunachalam. **Effect of fabrication parameters on strength of natural fiber polypropylene composites: Statistical assessment**, *Measurement*, vol. 146, pp. 195-207, November 2019.
11. S. Goutianos, T. Peijs, B. Nystrom, and M. Skrifvars. **Development of Flax Fibre based Textile Reinforcements for Composite Applications**,*Applied Composite Materials*, vol. 13, no. 4, pp. 199-215, June 2006.
12. M. Ramesh, K. Palanikumar, and K. H. Reddy.**Plant fibre based bio-composites: Sustainable and renewable green materials**, *Renewable and Sustainable Energy Reviews*, vol. 79, pp. 558-584, November 2017.
13. R.Sivagurunathan, S. L. T.Way, L.Sivagurunathan, and M. Y.Yaakob. **The Effects of Triggering Mechanisms on the Energy Absorption Capability of Circular Jute/Epoxy Composite Tubes under Quasi-Static Axial Loading**, *Applied Composite Materials*, vol. 25, no. 6, pp. 1401-1417, January 2018.

14. Y.Zhou, M.Fan, and L Chen. **Interface and bonding mechanisms of plant fibre composites: An overview**, *Composites Part B: Engineering*, vol. 101, pp. 31-45, September 2016.
15. A. S. Darmawan, P. I. Purboputro, and B. W. Febriantoko. **The effect of composition on hardness and wear resistance of rice plant fiber reinforced composite as a material of brake lining**, *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 771,012069, March 2020.
16. M. K.Surappa. **Aluminium matrix composites: Challenges and opportunities**, *Sadhana*, vol. 28, no. 1, pp. 319-334, February 2003.
17. Z.Ding, Y.Li, C.Lu, and J.Liu. **An Investigation of Fiber Reinforced Chemically Bonded Phosphate Ceramic Composites at Room Temperature**, *Materials*, vol. 11, no. 5, 858, May 2018.
18. G. I.Williams and R. P.Wool. **Composites from Natural Fibers and Soy Oil Resins**,*Applied Composite Materials*,vol. 7, no. 5-6, pp. 421-432, November 2000.
19. S. A.A. Mohamed, M. El-Sakhawy, E. H.A. Nashy, and A. M. Othman.**Novel natural composite films as packaging materials with enhanced properties**, *International Journal of Biological Macromolecules*, vol. 136, pp. 774-784, September 2019.
20. V. A. Ivanov. **Wear Resistance of Repair Composite Materials with Ceramic Fillers**, *International Journal of Emerging Trends in Engineering Research*, vol. 8, no. 4, pp. 1192-1195, April 2020.
21. J. L.Wang. **Application of Composite Materials on Sports Equipments**, *Applied Mechanics and Materials*, vol. 155-156, pp. 903-906, February 2012.
22. M.Pietroluongo, E.Padovano, A.Frache, and C.Badini. **Mechanical recycling of an end-of-life automotive composite component**, *Sustainable Materials and Technologies*, vol. 23,art. e00143, April 2020.
23. V.Khatkar, B. K.Behera, and R. N.Manjunath. **Textile structural composites for automotive leaf spring application**, *Composites Part B: Engineering*, vol. 182, art. 107662, February 2020.
24. Y.Ren, L.Qiu, S.Yuan, and F.Fang. **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*, vol. 135, art. 106390, January 2020.
25. R.Turczyn, K.Krukiewicz, A.Katunin, J.Sroka, and P.Sul. **Fabrication and application of electrically conducting composites for electromagnetic interference shielding of remotely piloted aircraft systems**,*Composite Structures*, vol. 232, art. 111498, January 2020.
26. J.Zhou, Y.Li, L.Cheng, and L.Zhang. **Indirect Microwave Curing Process Design for Manufacturing Thick Multidirectional Carbon Fiber Reinforced Thermoset Composite Materials**, *Applied Composite Materials*, vol. 26, no. 2, pp. 533-552, July 2019.
27. E.Kappel. **Distortions of composite aerospace frames due to processing, thermal loads and trimming operations and an assessment from an assembly perspective**, *Composite Structures*, vol. 220, pp. 338-346, July 2019.
28. S. Thalib, N. Ali, Husni and F. Imanuddin. Fracture Surface of Polyester/Areca Nut Fiber Composite Under Impact and Tensile Loading, International Journal of Emerging Trends in Engineering Research, vol. 8, no. 6, pp. 2523-2528, June 2020.
29. J.Gassan and A. K.Bledzk. **Possibilities to Improve the Properties of Natural Fiber Reinforced Plastics by Fiber Modification – Jute Polypropylene Composites –**, *Applied Composite Materials*, vol. 7, no. 5-6, pp. 373-385, November 2000.
30. S.Pujari and S.Srikiran. **Experimental investigations on wear properties of Palm kernel reinforced composites for brake pad applications**, *Defence Technology*, vol. 15, no. 3, pp. 295-299, June 2019.
31. Y.Liu, L.Wang, D.Liu, Y.Ma, Y.Tian, J.Tong, P.Senthamaraikannan, and S.Saravanakumar.**Evaluation of wear resistance of corn stalk fiber reinforced brake friction materials prepared by wet granulation**,*Wear*,vol. 432-433, art. 102918, August 2019.
32. A. S. Darmawan, P. I. Purboputro, B. W. Febriantoko, and A. Hamid. **Effect of pressure to rice plant fibre reinforced composite on coefficient of friction of brake lining**, *IOP Conf. Ser.: Mater. Sci. Eng.*, vol.851,12020, May 2020.