The effect of composition on hardness and wear resistance of rice plant fiber reinforced composite as a material of brake lining

Agung Setyo Darmawan\textsuperscript{1,}\textsuperscript{*}, Pramuko Ilmu Purboputro\textsuperscript{1} and Bambang Waluyo Febriantoko\textsuperscript{1}

\textsuperscript{1}Department of Mechanical Engineering, Faculty of Engineering, Universitas Muhammadiyah Surakarta, Surakarta, Central Java, Indonesia

\textsuperscript{*}Corresponding author: Agung.Darmawan@ums.ac.id

Abstract. Asbestos type brake lining is widely circulating at a cheap price and guarantees the durability of brake shoes, but the result of friction powder in the form of small particles is very dangerous for human health. The study is based on the investigation of hardness and wear resistance in rice plant fiber reinforced composite which is fabricated with polyester resin, fiberglass, and addition of aluminum powder. The composite is hardness tested by using durometer shore D hardness tester. The composite is also wearing resistance tested. The result showed that the mechanical properties were improved due to the increasing of the rice plant fiber composition. The more composition of the rice plant fiber, the harder and the higher wear resistance of the composite. An increase in the composition of the rice plant fiber from 20\% to 40\% resulted in an increase in hardness of 23\% and a decrease in wear by 9\%.

1. Introduction
Composite is a material that is composed of a mixture of two or more materials with different chemical, physical properties and mechanical, and produces a new material that has different properties from the constituent materials. Composite materials are composed of two types of materials namely matrix and fiber (reinforcement). Both have different functions, fiber functions as the frame material that composes composites, while the matrix functions to glue the fiber and keep it from changing positions. A mixture of the two will produce a hard, high strength, but lightweight material [1, 2].

Fiber has properties that are easy to change its shape by cutting or also forming according to the needs of the design. In addition, differences in the arrangement of fiber structures will also change the properties of the resulting composite. This can be used to obtain composite properties according to the parameters needed. The reinforcing material in the composite has the role of holding the load received by the composite material. The nature of the reinforcing material is usually rigid and tough. Strengthening materials commonly used so far are carbon fiber, glass fiber and ceramics [3, 4].

The matrix is generally made of resin. It functions as an adhesive of fiber material so that the stack of fibers can adhere strongly. The resin will bind to the fiber material so that the burden imposed on the composite will spread evenly. In addition, the resin also serves to protect fiber from chemical attack or also extreme weather conditions that can damage it. Matrix materials can also generally be in the form of metals, polymers, ceramics, and carbons. The nature of the matrix is usually ductile. The matrix in the composite serves to distribute the load into all composite reinforcing materials [5].
In addition to the ease of designing composites in any form, one of the main reasons for using composite materials is that high strength materials are obtained with a much lighter weight than conventional materials.

Composite materials are widely used. Its uses include the fields of aircraft and military, aerospace applications [6, 7], the automotive industry [8], sports equipment [9], packaging materials [10] and others.

Reinforcement material to be able to produce composite materials that are lightweight, high strength, environmentally friendly and economical [11-15]. One of them is natural fiber ingredients. Natural fiber as a type of fiber that has advantages began to be applied as a reinforcing material in polymer composites. Natural fiber composites combine good mechanical properties with a low specific mass and seem to be an alternative material to glass-fibre-reinforced plastics in some technical applications [16].

Elastic, high strength, abundant, environmentally friendly and lower production costs are advantages possessed by natural fibers [17]. In addition, there are also disadvantages of this type of fiber, especially strength that is not always evenly distributed. Types of natural fibers such as jute, coconut, sisal, hemp and flax began to be used as reinforcing materials for polymer composites [18].

This composite material is mainly used as a car exterior material [19]. Based on the results of their development can be obtained polymeric composite materials - natural fibers with a strength of 40% stronger and lighter than glass-fiber polymer composites. Lighter means it can reduce the total weight of the vehicle, which in turn can contribute to fuel savings. The process of making natural fiber based composites is relatively cheaper and more environmentally friendly. Its manufacture consumes about 70% less energy than glass-fiber polymer composites. From an ecological point of view, this natural fiber based polymer composite material can be recycled for reuse, although in terms of performance it has dropped considerably [20-22].

So far, several educational and research institutions have begun to conduct research on the use of natural fiber as a reinforcing material for composites. Starting from coconut fiber, water hyacinth fiber and palm fiber. Besides that, rice plant fiber is a material that has the potential to be used as reinforcement in natural composite.

When materials are used as components that rub against each other, hardness and wear resistance play an important role [23]. Therefore, this study investigates the effect of fiber composition on the hardness and wear resistance of composites. The composite is used for brake lining as a component of automotive.

2. Materials and Methods

The research was carried out in five stages. The first stage is preparing tools and materials that will be used in the research process. The material was weighed using a digital weighing according to the composition shown in table 1.

| Rice Plant Fiber (%) | Polyester Resin (%) | Fiberglass (%) | Al Powder (%) |
|----------------------|---------------------|----------------|--------------|
| 20                   | 60                  | 10             | 10           |
| 30                   | 50                  | 10             | 10           |
| 40                   | 40                  | 10             | 10           |

The second stage is the process of mixing dry materials, mixed using a blander machine so that the results of mixing the material can be mixed evenly.

Then in the third stage, the brake lining molds are prepared and put the brake lining plates into the mold. Furthermore, the brake lining plate was given an epoxy resin that is useful for materials attached to the surface of the brake lining. After that, the material that has been mixed is put into the mold. The next step is to press the mold using a press machine. Pressing is done by giving heat with a temperature of 90 °C. Then the sintered canvas with a temperature of 180 °C with duration of 15
minutes. The fourth stage is to do microphotographs, hardness test using shore D durometer hardness
test equipment, and wear test. The final stage is analyzing data obtained from testing and making
conclusions.

3. Results and Discussions
Microphotographs of composites are shown in Figure 1. Composites were made with variations in rice
plant fiber’s composition of 20%, 30% and 40%.

Figure 1. Microphotograph of composite, (a) composition of rice plant fiber is 20% (b) composition
of rice plant fiber is 30% (c) composition of rice plant fiber is 40%.

Figure 2 and figure 3 show the results of hardness and wear testing of the composite. Hardness testing
is performed with a durometer shore D hardness tester while wear testing is carried out using a
friction-testing machine.
Figure 2. The effect of rice plant composition on the composite’s hardness.

From the results of this hardness test (figure 2), the hardness value with 20% composition of rice plant fiber was 64.8 HD, the value of hardness with 30% composition of rice plant fiber was 73.1 HD, and the hardness value with 40% composition of rice plant fiber was 79.5 HD. Figure 2 shows that the highest hardness value was 79.5 HD when the composition of the rice plant fiber was 40%. This result shows that the more the composition of rice fiber plants, the hardness will increase if the composition of fiberglass and aluminum powder remains unchanged.

Figure 3. The effect of rice plant composition on wear.

Figure 3 shows the results of wear testing with dry conditions, wear results obtained on composites with 20% fiber composition was 122.1 $\text{mm}^3$/hour, wear on composites with 30% fiber composition was 119.7 $\text{mm}^3$/hour, and wear on composites with 40% fiber composition was 112.5 $\text{mm}^3$/hour.

The results of this test show a tendency to increase composite wear resistance when fiber composition increases. This is due to surface hardness that also increases when fiber composition increases.
4. Conclusion

From the results and discussions, it is concluded that the more composition of rice plant fiber, the harder and the higher wear resistance to the composite. An increase in the composition of rice plant fiber from 20% to 40% results in an increase in hardness from 64.8 HD to 79.5 HD and a decrease in wear from 122.1 mm³/hour to 112.5 mm³/hour.

Acknowledgement

The authors would like to acknowledge the Directorate of Research and Community Service, The Ministry of Research, Technology and Higher Education of the Republic of Indonesia [Project Number = 199.24/A.3-III/LPPM/V/2019]. The author would also like to thank the Mechanical Engineering Laboratory of Universitas Muhammadiyah Surakarta for mechanical test facilitations.

References

[1] E. Salernitano and C. Migliaresi, Composite Materials for Biomedical Applications: A Review, Journal of applied biomaterials & biomechanics 1(1), 3-18 (2003).
[2] 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. 4(2), 263-276 (2013).
[3] Z. Ding, Y. Li, C. Lu and J. Liu, An Investigation of Fiber Reinforced Chemically Bonded Phosphate Ceramic Composites at Room Temperature, Materials 11, 858 (2018).
[4] G.L. Williams and R.P. Wool, Composites from Natural Fibers and Soy Oil Resins, Applied Composite Materials 7, 421–432 (2000).
[5] M. Surappa, Aluminium Matrix Composites: Challenges and Opportunities, Sadhana 28(1), 319-334 (2003).
[6] D.K.K. Cavalcanti, M.D. Banca, J.S.S. Neto, R.A.A. Lima and R.J.C. Carbas, Mechanical characterization of intralaminar natural fibre-reinforced hybrid composites, Composites Part B: Engineering 175, 107149 (2019).
[7] 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 26(2), 533–552 (2019).
[8] E. Sarikaya, H. Çallioğlu and H. Demirel, Production of epoxy composites reinforced by different natural fibers and their mechanical properties, Composites Part B: Engineering 167, 461-466 (2019).
[9] J. L. Wang, Application of Composite Materials on Sports Equipments, Applied Mechanics and Materials 155-156, 903-906 (2012).
[10] 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 136, 774-784 (2019).
[11] K.I. Alzebdeh, M.M.A. Nassar and R. Arunachalam, Effect of fabrication parameters on strength of natural fiber polypropylene composites: Statistical assessment, Measurement 146, 195-207 (2019).
[12] S. Goutianos, T. Peijs, B. Nystrom and M. Skrifvars, Development of Flax Fibre based Textile Reinforcements for Composite Applications, Applied Composite Materials 13(4), 199–215 (2006).
[13] M. Ramesh, K. Palanikumar, and K. H. Reddy, Plant fibre based bio-composites: Sustainable and renewable green materials, Renewable and Sustainable Energy Reviews 79, 558-584 (2017).
[14] 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 25(6), 1401–1417 (2018).
[15] Y. Zhou, M. Fan, and Li. Chen, Interface and bonding mechanisms of plant fibre composites: An overview, Composites Part B: Engineering 101, 31-45 (2016).
[16] J. Gassan and A. K. Bledzk, Possibilities to Improve the Properties of Natural Fiber Reinforced Plastics by Fiber Modification – Jute Polypropylene Composites –, Applied Composite
[17] K. Oksman, Mechanical Properties of Natural Fibre Mat Reinforced Thermoplastic, *Applied Composite Materials* 7(5–6), 403–414 (2000).

[18] F. Tian and Z. Zhong, Modeling of load responses for natural fiber reinforced composites under water absorption, *Composites Part A: Applied Science and Manufacturing* 125, 105564 (2019).

[19] M.M. Davoodi, S.M. Sapuan, A. Aidy, N.A. Abu Osman, A.A. Oshkour and W.A.B. Wan Abas, Development process of new bumper beam for passenger car: A review, *Materials and Design* 40, 304–313 (2012).

[20] E. Asmatulu, J. Twomey and M. Overcash, Recycling of fiber-reinforced composites and direct structural composite recycling concept, *Journal of Composite Materials* 48(5), 593–608 (2014).

[21] T.Q. Truong Hoang, F. Lagattu and J. Brillaud, Natural Fiber-Reinforced Recycled Polypropylene: Microstructural and Mechanical Properties, *Journal of Reinforced Plastics and Composites* 29(2), 209-217 (2010).

[22] V. Srebrenkoska, G. Bogoeva-Gaceva and D. Dimeski, Biocomposites based on polylactic acid and their thermal behavior after recycling, *Macedonian Journal of Chemistry and Chemical Engineering* 33(2), 277–285 (2014).

[23] A.S. Darmawan, W.A. Siswanto and T. Sujitno, Comparison of Commercially Pure Titanium Surface Hardness Improvement by Plasma Nitrocarburizing and Ion Implantation, *Advanced Materials Research* 789, 347-351 (2013).