Environmental effects on hardness and wear resistance of composites reinforced by rice plant fiber as a material of brake lining

Pramuko Ilmu Purboputro1,*, Agung Setyo Darmawan1 and Bambang Waluyo Febriantoko1
1Department of Mechanical Engineering, Faculty of Engineering, Universitas Muhammadiyah Surakarta, Pabelan, Surakarta 57162, Indonesia
*e-mail: pip272@ums.ac.id

Abstract. The environment has an important role in determining the mechanical properties of composites. This study aims to investigate the effect of in-service environment on composite wear resistance in its use as a brake lining. Composites made from a mixture of rice plant fiber, fiberglass, aluminum powder and polyester resin are produced into brake linings. The brake lining is then tested for wear resistance using a friction machine. The test environment is dry, water, salt-water and brake oil. The highest wear is shown by the brake lining in the salt-water environment, while the lowest wear is shown when the brake lining is working in the brake oil environment.

1. Introduction
In the field of material technology, natural fiber materials are candidates as reinforcement materials to be able to produce composite materials that are lightweight, strong, environmentally friendly and economical. Nature has provided many human needs ranging from food to shelter. One of them is natural fiber ingredients [1-6].

Composite is a material that is formed from a combination of two or more materials to produce a composite material that has different mechanical properties and characteristics from the forming material. Composite consists of two main parts, namely: Matrix, serves as an adhesive or binder and protective filler (fillers) from external damage. Commonly used matrices such as carbon, glass and Kevlar [7]. Composite materials are widely used, such as in the fields of automotive industry [8], aerospace [9], aircraft and military [10], the sports equipment [11] and packaging materials [12].

In general, composite materials consist of two kinds, namely particulate composite materials and fiber composite materials. Particle composite material consists of particles that are bound by a matrix. The shape of these particles can vary as round, cubic, tetragonal or even irregularly shaped randomly. While the fiber composite material consists of fibers that are bound by a matrix. There are two kinds of forms, namely long fiber and short fiber [13].

In a composite structure, particle composite materials are composed of particles called particulate composite by definition; these particles are of various shapes such as round, cubic, tetragonal or even randomly shaped, but on average of the same dimension. Particle composite materials are generally used as fillers and reinforcement of ceramic composite materials (ceramic matrix composites). Particle size affects the strength of the composite. Particle composite materials are generally weaker than fiber composite materials. Particle composite materials have advantages, such as resistance to wear, do not small crack and have a binding force with a good matrix [14].

The main element of the composite is fiber that has many advantages; therefore, fiber composite materials are the most widely used. Fiber composite materials consist of fibers - as well as those bound
by interconnected matrices. This fiber composite material consists of two types, namely long fiber (continuous fiber) and short fiber (short fiber and whisker). The use of fiber composite materials is very efficient in accepting loads and forces. Because of that, the fiber composite material is very strong and stiff when loaded in the direction of the fiber; on the contrary, it is very weak when burdened in the perpendicular direction of the fiber [15, 16].

Fiber composites in the industrial world began to be developed rather than using particle material. Fiber composite materials have the main advantages that are strong (strong), stiff (tough), and more resistant to heat when inside the matrix. In the development of fiber processing technology, making fiber is now more favored than the materials used. The method used to combine high tensile strength fiber and high elastic modulus with lightweight mass, lace tensile strength, and low elastic modulus is increasingly being developed in order to obtain maximum results. Composites generally use plastic material which is the material most often used as a fiber-binding material besides that the plastic is easy to obtain and easier to treat, rather than metal materials that require their own material [17,18].

Along with innovations made in the material field, natural fibers are re-examined to be used as composite reinforcing materials. Natural fibers have elastic, strong, abundant and environmentally friendly properties [19-22]. In addition, there are also disadvantages of this type of fiber, especially strength that is not always evenly distributed. The types of natural fibers that began to be used as reinforcement for polymers include Hemp, sisal, Coconut, Flex, and Jute [23].

Furthermore, because the in-service environment also has an important role in determining the mechanical properties of composites, an investigation is carried out to determine the effect of the environment on composite wear.

2. Materials and Methodology
Composite material is made of a mixture of rice plant fiber, fibreglass, aluminum powder and polyester resin. The composition of this composite can be seen in table 1.

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

To achieve the research objectives, this research was conducted in three stages. The first step is to make the brake lining from the composite. At this stage, the composite material that has been mixed then pressed with a compacting load of 4500 kg with a heated temperature of 80 °C and held for 15 minutes. After reaching the desired holding time, the brake lining is removed from the mold then put into the oven and the sintering process is carried out at a temperature of 180 °C for 15 minutes.

The second stage is the wear test. In this stage, the wear test is carried out on the brake lining using a friction machine based on the China National Standard (CNS) GB 5763 standard. The test is carried out in a dry, air, saltwater and brake oil, respectively.

The final stage of this research is to analyze the data obtained from the test and draw conclusions of the research.

3. Results and Discussion
Photograph of brake lining made of rice fiber reinforced composites shown in figure 1. Meanwhile, figure 2 shows microphotographs of rice plant fiber reinforced composites. Figure 2a, figure 2b and figure 2c show the rice plant fiber reinforced composites with the composition of the rice plant fiber are 20%, 30% and 40%, respectively.
Figure 1. Brake lining.

Figure 2. The microphotographs of rice plant fiber reinforced composites (a) the rice plant fiber is 20%, (b) the rice plant fiber are 30% (c) the rice plant fiber are 40%

Figure 3 shows the results of wear testing in different environments. Wear is seen reaching the highest levels of 126.4 mm³/hour in the salt-water environment with a composition of 20% rice plant fiber. This is because the 20% rice plant fiber is the smallest composition of the variation of fiber composition tested, while the presence of Na⁺ ions and Cl⁻ ions in salt solution will make the Al⁺ ions escape into the environment. Meanwhile, the lowest wear of 110 mm³/hour experienced by composites in the brake oil environment with 40% composition of rice plant fiber. This is because in addition to the fiber composition is the highest composition; the friction that occurs in the specimen is also reduced by the lubrication by brake oil.
4. Conclusion
After testing for wear on several types of environments, it can be concluded that the environment has an effect on composite wear resistance. The highest wear experienced by composites in the salt-water environment and the lowest wear experienced by composites in the brake oil environment.

Acknowledgement
This research is funded by 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 authors would also like to acknowledge the Mechanical Engineering Laboratory of Universitas Muhammadiyah Surakarta for material preparations and mechanical test facilitations.

References
[1] Elanchezhian C, Ramnath B V, Ramakrishnan G, Rajendrakumar M, Naveenkumar V and Saravanakumar M K 2018 Review on mechanical properties of natural fiber composites Materials Today: Proceedings 5 1785–1790.
[2] Salernitano E and Migliaresi C 2003 Composite Materials for Biomedical Applications: A Review Journal of applied biomaterials & biomechanics 1(1) 3–18.
[3] Chegdani F and Mansori M E 2018 Friction scale effect in drilling natural fiber composites Tribology International 119 622–630.
[4] dos Reis J M L 2012 Effect of temperature on the mechanical properties of polymer mortars Materials Research 15(4) 645–649.
[5] Dittenber D B and Rao H V S G 2012 Critical review of recent publications on use of natural composites in infrastructure Composites: Part A 43 1419–1429.
[6] 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.
[7] Hassan M L, Rowell R M, Fadl N A, Yacoub S F and Christainsen A W 2000 Thermoplasticization of Bagasse. II. Dimensional Stability and Mechanical Properties of Esterified Bagasse Composite Journal of Applied Polymer Science 76 575–586.
[8] 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.
[9] 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.

[10] 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.

[11] Wang J L 2012 Application of Composite Materials on Sports Equipments Applied Mechanics and Materials 155-156 903-906.

[12] 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.

[13] Zhang C, Li F, Li J, Wang L, Xie Q, Xu J and Chen S 2017 A new biodegradable composite with open cell by combining modified starch and plant fibers Materials & Design 120 222-229.

[14] Ahmed S and Jones F R 1990 A review of particulate reinforcement theories for polymer composites Journal of Materials Science 25 4933-4942.

[15] 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.

[16] Williams G I and Wool RP Composites from Natural Fibers and Soy Oil Resins Applied Composite Materials 7 421–432.

[17] Oksman K 2000 Mechanical Properties of Natural Fibre Mat Reinforced Thermoplastic Applied Composite Materials 7(5–6) 403–414.

[18] Gassan J and Bledzk A K Possibilities to Improve the Properties of Natural Fiber Reinforced Plastics by Fiber Modification – Jute Polypropylene Composites – Applied Composite Materials 7(5–6) 373–385.

[19] Ramesh M, Palanikumar K and Reddy K H 2017 Plant fibre based bio-composites: Sustainable and renewable green materials Renewable and Sustainable Energy Reviews 79 558-584.

[20] Alzebdeh K I, Nassar M M A and Arunachalam R 2019 Effect of fabrication parameters on strength of natural fiber polypropylene composites: Statistical assessment Measurement 146 195-207.

[21] Goutianos S, Peijs T, Nystrom B and Skrifvars M 2006 Development of Flax Fibre based Textile Reinforcements for Composite Applications Applied Composite Materials 13(4) 199–215.

[22] Zhou Y, Fan M, and Chen L 2016 Interface and bonding mechanisms of plant fibre composites: An overview, Composites Part B: Engineering 101 31-45.

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