Moroccan Journal of Chemistry
ISSN: 2351-812X
http://revues.imist.ma/?journal=morjchem&page=login
Nandiyanto & al. / Mor. J. Chem. 10 N°4 (2020) 663-677
DOI: https://doi.org/10.48317/IMIST.PRSM/morjchem-v10i4.34291

Effect of palm fronds and rice husk composition ratio on the mechanical properties of composite-based brake pad

Asep Bayu Dani Nandiyanto*, Risti Ragadhita, Gabriela Chelvina Santiuly Girsang, Sri Anggraeni, Silmi Ridwan Putri, Fitriani Halimatus Sadiyyah, Miussa Rio Hibatulloh, Valensia, Dwi Putra Setiadi

Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam, Universitas Pendidikan Indonesia, Jl. Setiabudi No. 229, Bandung 40154, Indonesia

**Corresponding author.*
E-mail: nandiyanto@upi.edu

Received 03 Apr 2021,
Revised 21 May 2021,
Accepted 25 Aug 2021

Abstract

The purpose of this study was to determine the effect of biomass composition (i.e. palm frond (PF) and rice husk (RH)) on the mechanical properties of composite-based brake pad (CBP). CBP was made by mixing polyester resin matrix with PF and RH (as the reinforcing agent) using a step-growth mechanism reaction with additional methyl ethyl ketone peroxide (MEKP) as a catalyst. CBP was made by mixing polyester resin and catalyst with a ratio of 10:1 with PF and RH. The PF and RH were added with a ratio of 10/90; 30/70; 50/50; 70/30; and 90/10. To support the analysis, mechanical tests such as compressive and friction tests were carried out. The experimental results showed that the RH composition allowed the obtainment of a strong composite-based brake pad and a low wear value since RH has a high component of lignocellulose. Although PF also strengthened the brake pad, the mechanical impact is not higher than RH. The high lignocellulose content in the RH made the optimal quality of composite-based brake pad-based. This study demonstrates the effectiveness of the use of biomass as an alternative reinforcing agent in the composite-based brake pad material.

Keywords: *Composite polymer-based brake pad, palm fronds, rice husk, mechanical properties, lignocellulose.*

1. Introduction

A brake pad is a part of vehicle components that serves to slow or stop land vehicles [1, 2]. Generally, the brake pad is made from blends of 40-60% of asbestos, metal, and ceramic embedded in a polymer matrix. Asbestos as the main constituent in brake pads provides high friction properties thus it functions well as a motion stopper [3]. The asbestos-based brake pad is widely available in commercials at low prices and guarantees durability of the brake pad, but the result of friction powder in the form of small particles is very dangerous for human health due to asbestos content. The use of asbestos is avoided because of its carcinogenic properties. Therefore, a brake pad supported by asbestos-free materials is inevitable [4]. Currently, natural composite materials have the potential to be used in various fields such as automotive [4,5] [5-10], aerospace [11], building and construction [11, 12], and the furniture industry[13] because of their excellent performance (such as abundance, low cost [14], biodegradable [15-17], non-toxic [18], and having good mechanical properties [6]). Therefore, biomass is a natural source of composite materials that are considered a potential raw material [B, C, D] for the production of lignocellulosic functional composites[19]. Lignocellulose from biomass has been utilized for the development of a non-asbestos-based brake pad. Apart from being environmentally friendly, this composite-based brake pad shows good performance, which is not only in mechanical behavior but also in physical and thermal properties compared to asbestos-based brake pads [20-22]. Asbestos-based brake pad survives only at 200°C, while brake pad supported by composites can withstand temperatures up to 360°C[23]. Table 1 shows some reports[5, 7, 24-32] on the development and utilization of alternative materials using biomass as natural reinforcing agents for strong substitutes for asbestos-based friction materials.

Table 1. ***Various types of biomass materials (as a reinforcing component) in the production of composite-based brake pad***

Type of agricultural waste	Supporting components	Results	Reference
Bamboo	•Aluminum oxide •MgO •Epoxy resin	The composition of bamboo greatly affects the mechanical properties of the brake pad. Bamboo fiber-based brake pads have the potential to replace the asbestos-based brake pad. The best brake pad specimens had a wear rate of 0.9612x10^{-8}g/mm^2, hardness of 91.8 HRR, and heat resistance at 280°C with a duration of 810 days.	[5]
Coconut and Bamboo	•MgO •Al_2O_3 •Epoxy Resin	•Composite made from bamboo with a composition of 29% of coconut, 40% of epoxy, 6% of MgO, 25% of $Al_2 O_3$ has a temperature resistance of 251.53°C, a hardness of 37.14 HRB, a wear rate of 0.323 mm^3 / N.mm, and a friction coefficient of 0.454. •The coconut fiber-reinforced composite (consisting of 20% of natural fiber, 46% of epoxy, 6% of MgO, 28% of $Al_2 O_3$) has a temperature resistance of 250.56°C, a hardness of 44.10 HRB, a wear rate of 0.242 mm^3/N.mm, and a coefficient of friction of 0.46 •The hardness values of the two composite brake pads are lower than that of the commercial brake pad, but they have almost the same values for the wear rates and the coefficient of friction.	[27]
Coconut Fiber	•Aluminum •Graphite •Zirconium Oxide •Silicon Carbide •Titanium Oxide •Aluminum Oxide	The brake pad has superior physical and mechanical characteristics due to the proper homogenization of the composition, the particle size of the material, the distribution of the fill material through the matrix, and the optimal proportion of the amount of metal and other components. The greater the amount of coconut husk, the higher the density and strength of the composite-based	[25]

	•Phenolic resin	brake pad.	

Table 1 (continue). ***Various types of biomass materials (as a reinforcing component) in the production of composite-based brake pad***

Type of agricultural waste	Supporting components	Results	Reference
Banana Peel	Phenolic Resin	•The brake pad has a lower wear rate as the added binder composition increases due to the strong bond between the peels and the resin due to the high microstructure of the packaging. •Increases in the resin composition in banana peel particles also increase the strength, hardness, and friction coefficient of the brake pad.	[26]
Palm Kernel Fiber (PKF)	Epoxy Resin	The presence of PKF and a small amount of binder (epoxy resin) increases the wear rate of the sample. This means that the brake pad has a low wear rate. However, the addition of the reinforcing material composition (PKF) increases the compressive strength of the brake pad.	[32]
Maize Husk	Epoxy Resin	The addition of maize husk as a filler can increase the wear rate, hardness, compressive strength, thermal conductivity, and tensile strength.	[24]
Rice Husk	Epoxy Resin	•Decreasing the CBS composition increases the compressive strength and hardness of the brake pad •The presence of epoxy resin increases compressive strength. •CBS has the potential to be used as a reinforcing material to replace asbestos in brake pad material friction.	[7]
Cocoa Beans Shells (CBS)	Epoxy Resin	•Decreasing the CBS composition increases the compressive strength and hardness of the brake pad •The presence of epoxy resin increases compressive strength •CBS has the potential to be used as a reinforcing material to replace asbestos in brake pad material friction	[29]
Saw-Dust	Epoxy Resin	•Improved sawdust composition reduces brake pad density, compressive strength, and hardness. •Saw-dust particles with sizes of 100 μm have the potential to be used as a substitute for asbestos-based brake pads.	[28]
Groundnut Shells	Phenolic Resin	•Increases in the phenolic resin composition increase the compressive strength of the brake pad •Decreasing the composition of groundnut shells increases the compressive strength density of the brake pad.	[31]

This study aims to determine the effect of additional rice husk (RH) and palm frond (PF) as the reinforcing agents on the brake pad. The mechanical characteristics of the prepared brake pad were analyzed using the wear rate test, mass loss, friction coefficient, heat resistance, compressive strength, and puncture strength[33, 34]. The composite-based brake pad fabrication method was carried out at room temperature without the influence of pressure and involved polymerization reactions. This study provides information on how the utilization and potential of biomass, especially RH and PF as the main reinforcing material in the fabrication of brake pads that are more environmentally friendly. Although there are reports on the use of RH [35, 36] and PF, the weakness of the current research is that the main ingredient of biomass waste such as RH and PF has not been widely used as the main component for the production of the environmentally friendly non-asbestos brake pad. In fact, RH and PF are plenty and largely available in agricultural countries such as Indonesia, providing their prospects for being utilized. RH and PF are potential since

they contain lignocellulose that can improve performance[37]. The chemical composition of RH and PF is summarized in Table 2.

Table 2. ***Chemical composition of RH and PF***

Type of biomass	Chemical content (%)				Reference
	Cellulose	**Hemicellulose**	**Lignin**	Silica	
RH	43.2	32.5	15.0	22.0	[38]
PF	31.5	19.2	14.0	12.3	[39]

2. Materials and Methods

2.1. Materials

The main materials used in the fabrication of the composite-based brake pad are polyester resin, methyl ethyl ketone peroxide (MEKP) catalyst, as well as RH and PF. The polyester resin was used as a matrix-forming material, while RH (Bandung, Indonesia) and PF (Bangka Belitung, Indonesia) were used as matrix reinforcing materials.

2.1. Brake Pad Production Process

RH and PF were used as the main reinforcement for the brake pad. Both materials were cut into small pieces and dried in the sun for 3 days. To get the specific particle size of RH and PF, the sieving process was conducted thus particle size in the range of 250-500 µm was obtained, in which the sieving process is explained in our previous studies[40]. The brake pad was made with variations in the composition of the reinforcing ratio for PF/RH as follows: 10/90; 30/70; 50/50; 70/30. Then, 100 mL of polyester resin as a matrix and 10 mL of catalyst were added to the PF/RH mixture. The prepared brake pad mixture was then poured into a silicone mold (2 x 2 x 2 cm) and cooled at room temperature which was not exposed to sunlight for one day. After the brake pad dried, the brake pad was sanded to remove the resin effect on its surface. The flow chart of the experimental method is shown in Figure 1.

2.3. Mechanical Properties Tests

The compressive strength and puncture strength tests were carried out to determine the mechanical properties of the composite-based brake pad that has been prepared. For the compressive test, the Screw Mount Test Instrument (Model I ALX-J, China) equipped with a digital force measuring instrument was used (Model HP-500, Serial, No H5001909262). The test was carried out by applying a constant displacement rate of 2.6 mm/minute to the brake pad. The compressive forces were recorded simultaneously resulting in a curve that shows the texture profile. The compressive strength was then obtained from the maximum point of the compressive stress-strain curve. Detailed information about mechanical properties is done in our previous studies[7, 15-17, 40-46].

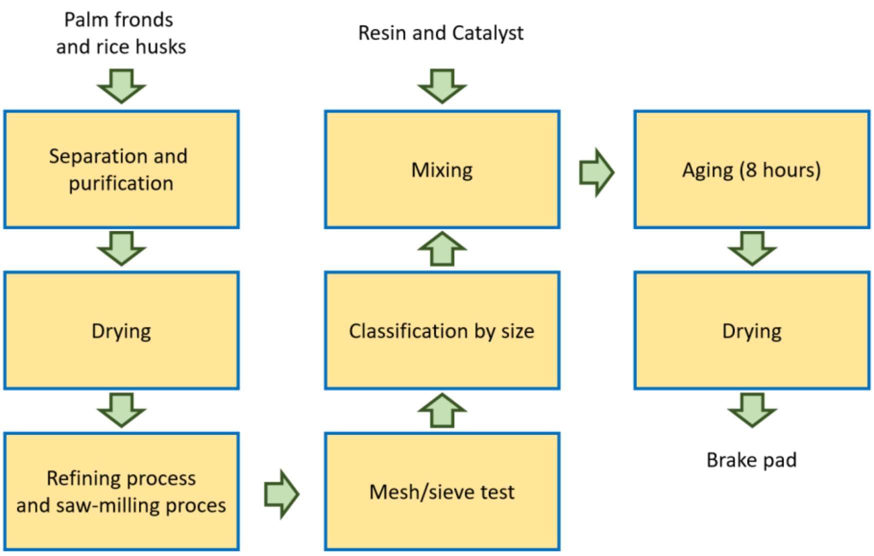

Figure 1. The Flow chart of the experimental method

Furthermore, the maximum force (in N units) was applied to assess the hardness of the sample. The Shore Durometer instrument (Shore A Hardness, In size, China) was used to test the puncture strength. During the test, a needle or probe was used to perforate the brake pad. Hardness was measured on a scale from 0 to 100. Then, the density (g/cm^3) of the brake pad was calculated by dividing the mass of the brake pad (g) by the volume of the brake pad (cm^3). The friction test was carried out by rubbing the brake pad against the sandpaper (80 grit) for 20 min at a speed of 25 cm/s. Every two minutes, the mass of the brake pad was recorded. The wear rate (M) was calculated by dividing different masses (the initial mass (M_a; g) and the final mass (M_b; g)) with the testing time (t) and the friction cross-sectional area (A; mm^2)[5]. The coefficient of friction (μ) is the ratio of the friction force (f; Newton) to the normal force applied (N; Newton).

3. Results and Discussion

3.1. Reaction Mechanism Proposal of Formation Composite-Brake Pad

Polyester is made through a step-growth process involving an acid with two carboxylic and alcohol with two hydroxyl groups. The synthesis process of polyester as a matrix brake pad is carried out under room conditions. Figure 2 shows the synthesis of polyester using maleic acid anhydride, isophthalic acid, and 2-alkyl-1,3-propanediol as precursor material.

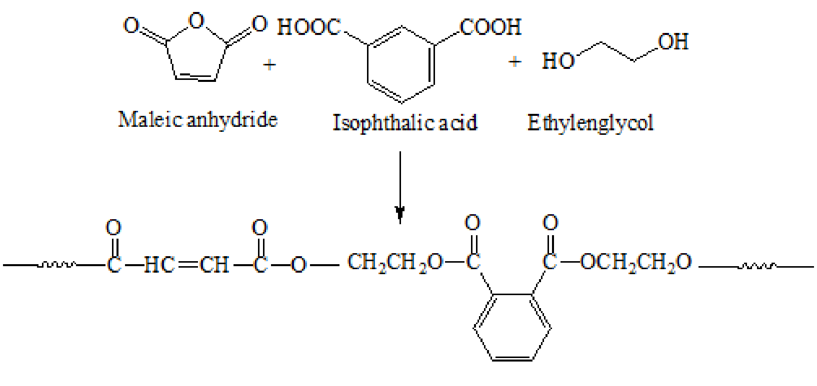

Figure 2. Synthesis of Polyester (adopted from reference[47])

Polymerization through a step-growth mechanism involves a catalyst (usually MEKP), initiating the formation of free radicals. These free radicals scatter the double bonds from the polyester chain. The reaction mechanism of the polyester chain formation is shown in Figures 3-6. To confirm the mechanism, further chemical analysis and instrument must be done[47-49]. In short, the reaction stages are as follows:

a.The peroxide catalyst breaks down into tert-butyldioxy-O* free radicals. After that, tert-butyldioxy-O* free radicals initiate a polymerization reaction.

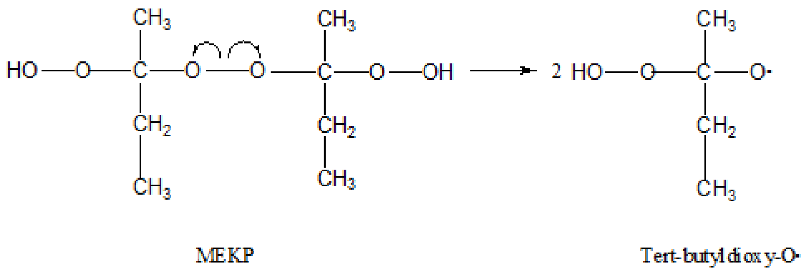

Figure 3. Free radical formation from MEKP catalyst (adopted from reference[47])

b. Tert-butyldioxy-O* free radicals attack the double bonds of the polyester chain thus polyester chain radical is formed.

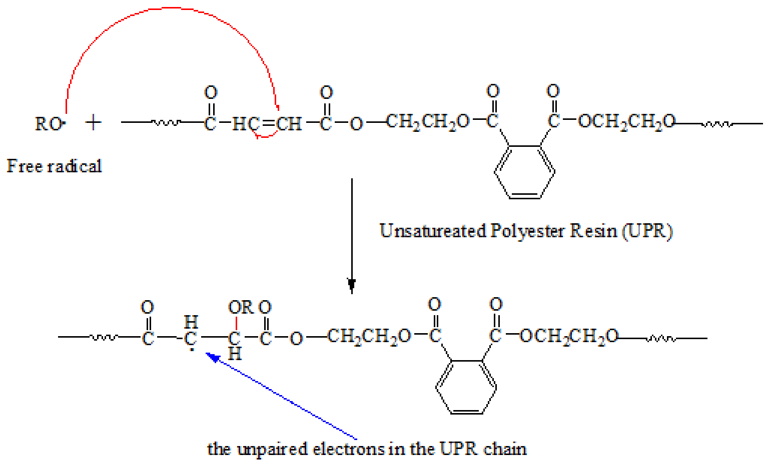

Figure 4. Tert-butyldioxy-O* free radicals attack the double bonds of the polyester chain (adopted from reference[47])

c. Polyester chain radical attacks the double bond in styrene and forms a crosslinking bond between polyester and styrene. Furthermore, since there is a crosslinking bond, styrene radical is formed.

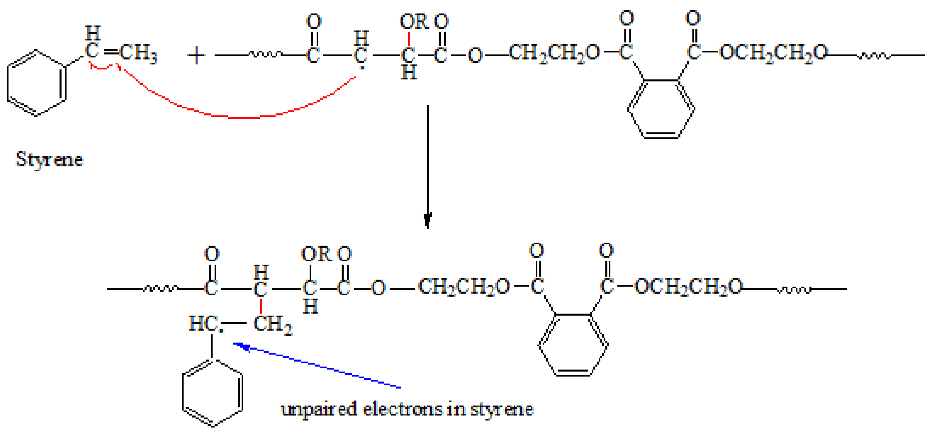

Figure 5. Formation of crosslinking bond between polyester and styrene (adopted from reference[47])

d. Furthermore, styrene radical attacks other polyester molecules over and over again and forms a long chain that traps the fibers in the brake pads. This reaction continues until the polyester that binds the fibers becomes hardened (cured), as shown in Figure 6.

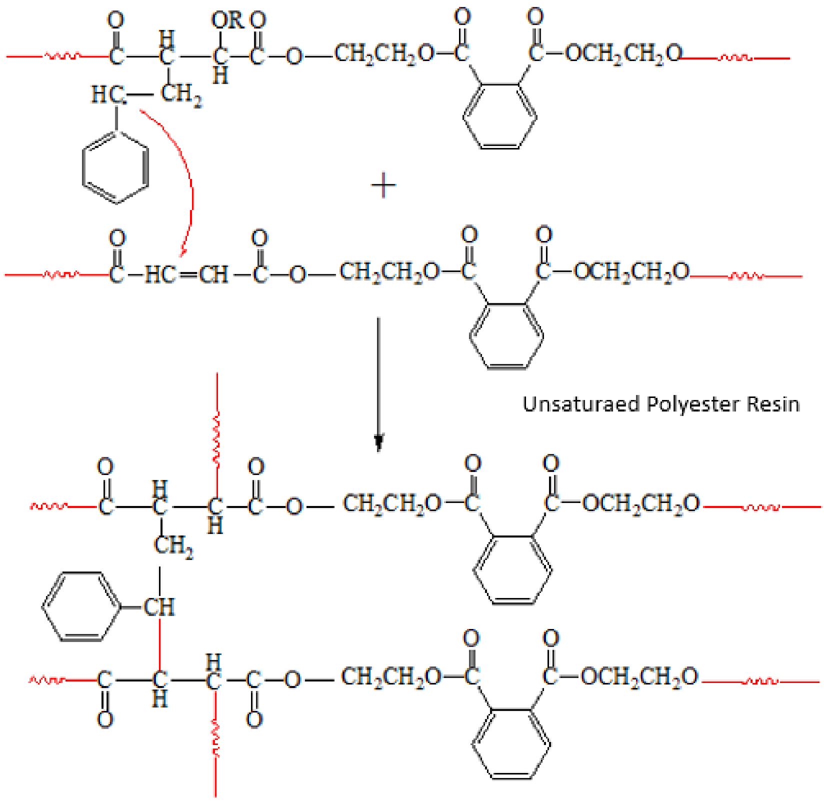

Figure 6. A hardening process in which the polyester binds the fibers (adopted from reference[47])

3.2. Physical Properties of Composite-Based Brake Pad

Figure 7 shows a photograph of the composite-based brake pads that were prepared. Based on Figure 7 physically, the composite-based brake pads that were prepared seemed similar but there is a color difference starting from lightest brown to darkest brown. The existence of this color difference is mainly due to the difference in the ratio of the composition of PF and RH. In the composition ratio of PF/RH at 10/90, the lightest brown composite-based brake pad was formed. Meanwhile, the darkest color was produced by the PF/RH with a composition ratio of 90/10. All composite-based brake pads had a rough and tough texture.

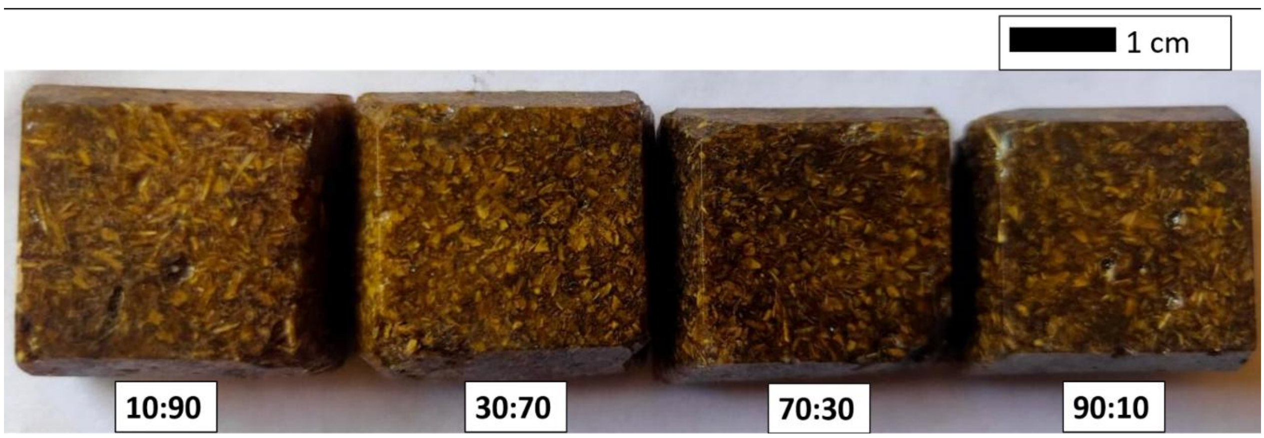

Figure 7. The photograph of prepared composite-based brake pads

Figure 8 shows microscope images of the surface of the composite-based brake pads. All composite-based brake pads surface show similar surface textures. Figure 8 shows a photograph of the composite brake pad surface. All composite-based brake pad surfaces exhibited a similar surface. All composite-based brake pads had a relatively large size of PF and RH reinforcement material.

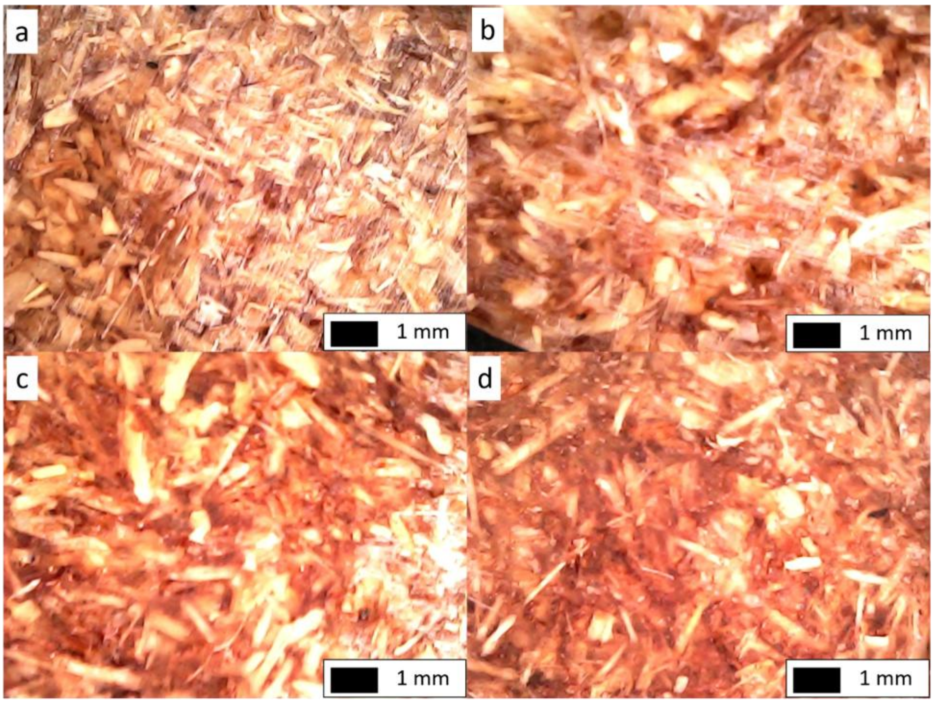

Figure 8. Composite-based brake pads surface for 10/90 (a), 30/70 (b), 70/30 (c), and 90/10 (d) composition ratio of PF/RH

3.3. Mechanical Properties of Composite-Based Brake Pads

Figure 9 shows the compression test of composite-based brake pads. This compression test aims to see the ability of a material to withstand the pressure exerted by another hard object. In a compression test, a force is applied. The amount of force applied is proportional to the hardness of the composite-based brake pads. A higher compression test value indicates that the sample is getting harder. Based on Figure 9, the composite-based brake pad with a composition ratio of PF/RH at 10/90 showed excellent performance because it had a high compression test result value compared to other specimens. Meanwhile, the composite-based brake pad with a composition ratio of PF/RH at 90/10 shows the lowest compression endurance value. Table 3 shows the results of the composite-based brake pad puncture test. Table 3 shows that the composite-based brake pad with a ratio composition of PF and RH at 10/90 shows better hardness properties than other specimens. Composite-based brake pad specimens with a composition ratio of PF and RH at 90/10 have the lowest hardness characteristics. This puncture test confirms the compression test results where there is a match between the puncture test and the compression test. Based on these two tests (compression and puncture tests), the order of the best composite-based brake pad specimens in terms of best mechanical properties are 10/90; 30/70; 70/30; and 90/10. Figure 10 and Table 4 show the results of the friction test. This friction test includes the level of mass loss, wear rate, and friction coefficient of composite-based brake pads. The level of mass loss occurs due to surface contact or friction between the brake pad specimens with the sandpaper which occurs repeatedly. When friction occurs, there is a change in kinetic energy into heat energy. The rate of mass loss has a positive correlation with wear rate[50, 51]. Based on the mass loss values, the hardness level of the composite-based brake pads can be

determined. The less mass loss indicates a high level of hardness [52]. Based on Figure 10 and Table 4, the mass loss and wear rate of the composition ratio of PF/RH at 10/90 is relatively higher than other specimens which shows that a large amount of PF content is not too significant in the improvement of the mechanical characteristics of the composite-based brake pads. At a composition ratio of PF/RH at 90/10, composite-based brake pads have the most fragile mechanical characteristics and are not durable or it can be said that the specimens with a PF/RH ratio of 90/10 have the lowest strength properties than other specimens. Meanwhile, the composite-based brake pad with a PF/RH composition ratio of 10/90 shows the best mechanical characteristics because it has the smallest mass loss and wear-rate value. RH component plays a major role in improving the hardness properties of the brake pad. The order of the brake pad specimens starting from the hardest is in the composition ratio PF/RH at 10/90; 30/70; 70/30; and 90/10 sequentially.

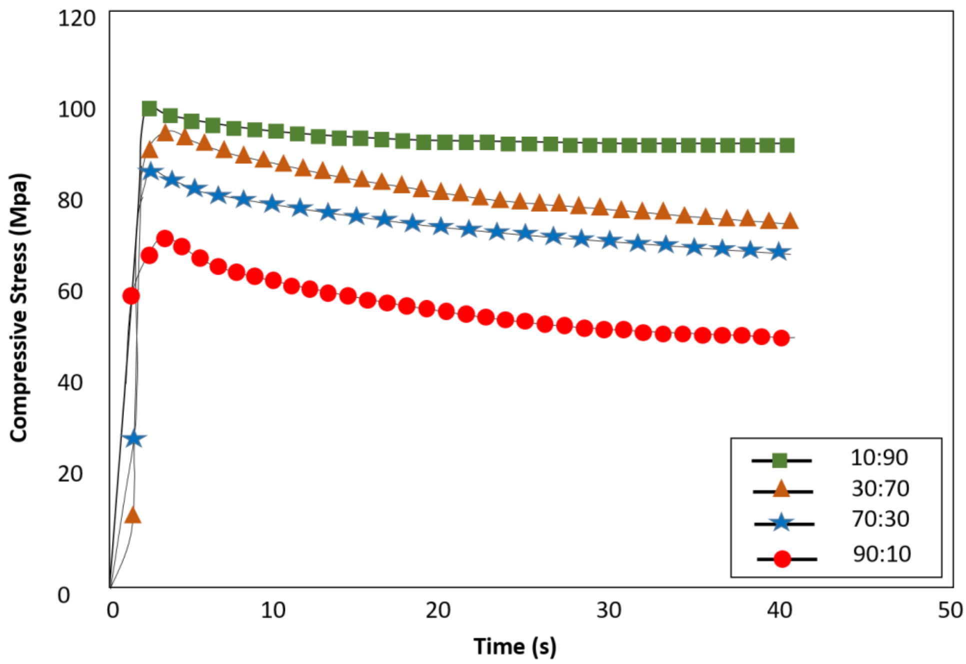

Figure 9. The compressive test curve of composite-based brake pads

Table 3. ***The puncture test of composite-based brake pads***

Ratio composition of PF/RHs	10:90	30:70	70:30	90:10
Bulk density (g/cm^3)	0.7089	1.0418	0.6957	0.7492
Durometer Shore Hardness Scale	94.1111	93.555	91.7778	87.1111

Table 4 confirms the mass loss test results in Figure 5. Based on Table 4, the composition of the PF/RH ratio at 90/10 shows the highest friction coefficient than other specimens. Meanwhile, the composition of the PF/RH ratio at 10/90 showed the smallest friction coefficient compared to other specimens. The values of mass loss and wear rate are inversely related to the friction coefficient (see Table 2). The higher mass loss and the higher wear-rate value resulted in a lower friction coefficient. The lower friction coefficient, thus, allowed the lower material to resist friction. The order of the composite-based brake pad specimens that have the highest level of friction is in the composition ratio of PF/RH at 10/90; 30/70; 70/30; and 10/90. Again, the specimens with the highest RH content had the best mechanical characteristics among other specimens. The study results indicated that composite-based brake pads have good mechanical characteristics if they contain high RH content. There are variations in the composition of cellulose and hemicellulose and lignin in RH and PF that affect the mechanical properties of composite-based brake pads. The

content of cellulose, hemicellulose, and lignin which is the highest in the reinforcing agent contributes most to the improvement of the mechanical properties of composite-based brake pads.

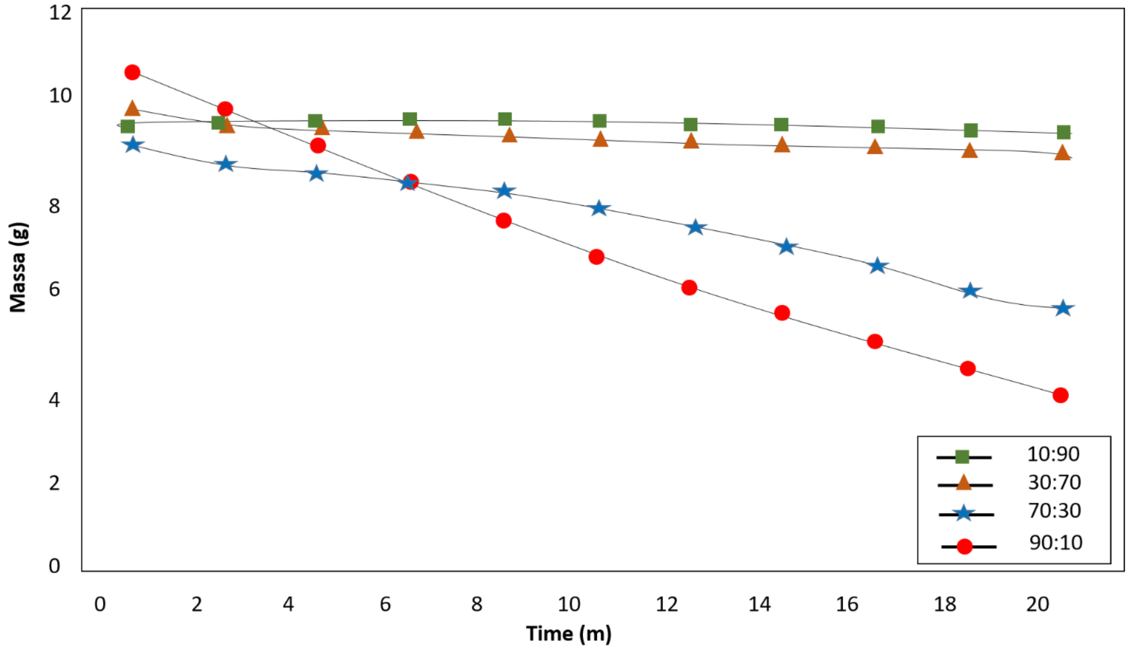

Figure 10. Mass loss of composite-based brake pad as a function of time

Table 4. ***Mass loss, wear rate, and friction coefficient of prepared composite-based brake pads. M_a is the initial weight of the brake lining (g), M_b is the final weight of the brake lining (g), t is the testing time (s), A is the friction cross-sectional area (mm^2), and M is the wear rate ($g/s.mm^2$)***

Composition of PF/RH	M_a (g)	M_b (g)	Mass loss rate (g/min)	t (s)	*A* (mm^2)	*M* ($g/s.mm^2$)	Friction coefficient
10/90	9.75	9.26	0.0245	1200	0.0230	$9.39x10^{-6}$	0.558974
30/70	9.92	9.09	0.0415	1200	0.0414	$2.86x10^{-5}$	0.314516
70/30	9.20	5.80	0.17	1200	0.0575	$1.62x10^{-4}$	0.163043
90/10	10.77	4.01	0.338	1200	0.0200	$1.12x10^{-4}$	0.285051

Apart from the different contents of cellulose, hemicellulose, and lignin, the contribution of other components in RH and PF also affects the mechanical properties of the material. Based on Table 2, RH and PF contain other components, namely silica[19]. RH contains an extraordinary amount of silica than PF. A high percentage of silica in a material is more blended with cellulose, hemicellulose, and lignin; therefore, RH becomes resistant to biodegradation, pressure, and friction[47]. This study informs the possibility for the alternative problem solver in the usage of organic waste material. Indeed, this can help creating problem solving for current issues in the waste management and waste treatment[53-65].

4. Conclusion

The effect of RH and PF amount on the quality of composite-based brake pads has been carried out. Composite-based brake pads with more RH contents have the best strength, which is durable, having the lowest wear value. This is because of the high content of cellulose, hemicellulose, lignin, and silica which is the major influence on the mechanical characteristics of composite-based brake pads.

Acknowledgements- This study acknowledged RISTEK DIKTI for Grant-in-aid Penelitian Terapan Unggulan Perguruan Tinggi (PTUPT).

References

[1] I. K. A. Atmika, I. D. G. A. Subagia, I. W. Surata, I. N. Sutantra, "Hardness and wear rate of basalt/alumina/shellfish powder reinforced phenolic resin matrix hybrid composite brake lining pads", *IOP Conference Series: Materials Science and Engineering*, 539(1) (2019, June) 012012.

[2] R. Ragadhita, D. F. Al Husaeni, A. B. D. Nandiyanto, "Techno- economic evaluation of the production of resin-based brake pads using agricultural wastes: Comparison of eggshells/banana peels brake pads and commercial asbestos brake pads", *ASEAN Journal of Science and Engineering*, 3(3) (2023) 243-250.

[3] A. B. D. Nandiyanto, D. F. Al Husaeni, R. Ragadhita, T. Kurniawan, "Resin-based brake pad from rice husk particles: From literature review of brake pad from agricultural waste to the techno-economic analysis", *Automotive Experiences*, 4(3) (2021) 131-149.

[4] S. Y. Aku, D. S. Yawas, P. B. Madakson, "Characterization of periwinkle shell as asbestos-free brake pad materials", *Pacific J Sci Technol.*, 13(2) (2012) 57-63.

[5] Y. Sukrawan, A. Hamdani, S. A. Mardani, "Effect of bamboo weight faction on mechanical properties in non-asbestos composite of motorcycle brake pad", *Material Physics and Mechanics*, 42(3) (2019) 367-372.

[6] A. B. D. Nandiyanto, S. N. Hofifah, G. C. S. Girsang, S. R. Putri, B. A. Budiman, F. Triawan, A. S. M. Al-Obaidi, "The effects of rice husk particles size as a reinforcement component on resin-based brake pad performance: From literature review on the use of agricultural waste as a reinforcement material, chemical polymerization reaction of epoxy resin, to experiments", *Automotive Experiences*, 4(2) (2021) 68-82.

[7] E. M. Ezeh, "Comparative cone calorimetric analysis of the fire retardant properties of natural and synthetic additives in banana peduncle fibre reinforced polyester composites", *Moroccan Journal of Chemistry*, 9(3) (2021) 3-9.

[8] A. Kasim, M. Abdulwahab, A. O. Babatunde, "Degradation behaviour of polyester/nano-locust bean pods ash (LBPA) composite", *Moroccan Journal of Chemistry*, 3(4) (2015) 3-4.

[9] B. Sefati, M. Masrournia, H. Beheshti, J. Feizy, "Solid-phase extraction of Lead in saline matrix using by GF-AAS with multivariate optimization", *Moroccan Journal of Chemistry*, 9(4) (2021) 4-9.

[10] M. Karbeka, S. Nuryono, "Synthesis of silica coated on iron sand magnetic materials modified with 2-mercaptobenzimidazole through sol-gel", *Moroccan Journal of Chemistry*, 8(1) (2020) 1-8.

[11] V. K. Abitha, A. V. Rane, "Studie in mechanical, thermal and morphological analusis of epdm/polypropylene conconut pith composites", *Moroccan Journal of Chemistry,* 3(2) (2015) 298-305.

[12] C. Zannagui, H. Amhamdi, S. El Barkany, I. Jilal, O. Sundman, A. Salhi, S. Chaouf, M. Abou-Salama, A. El Idrissi, M. Zaghrioui, "Design, characterization and investigation of heavy metal ions removal by new cellulose-ether based adsorbent", *Moroccan Journal of Chemistry,* 8(1) (2020) 332-346.

[13] S. A. Jadhav, A. Rane, V. K. Abitha, P. S. Suchithra, S. S. Patil , S. T. Narute, "Polymeric particle board: a sustainable substitute to wooden boards', *Moroccan Journal of Chemistry,* 3(4) (2015) 723-729.

[14] Z. Bai, N. Fan, Z. Ju, C. Guo, Y. Qian, B. Tang, S. Xiong, "Facile synthesis of mesoporous Mn 3 O 4 nanotubes and their excellent performance for lithium-ion batteries", *Journal of Materials Chemistry A*, 1(36) (2013) 10985-10990.

[15] F. Triawan, A. B. D. Nandiyanto, I. O. Suryani, M. Fiandini, B. A. Budiman, "The influence of turmeric microparticles amount on the mechanical and biodegradation properties of cornstarch-based bioplastic material: from bioplastic literature review to experiments", *Materials Physics and Mechanics,* 46(1) (2020) 99-114.

[16] A. B. D. Nandiyanto, M. Fiandini, R. Ragadhita, A. Sukmafitri, H. Salam, F. Triawan, "Mechanical and biodegradation properties of cornstarch-based bioplastic material", *Materials Physics and Mechanics*, 44(3) (2020) 380-391.

[17] S. Anggraeni, A. B. D. Nandiyanto, A. M. Nurjami, S. N. Hofifah, S. R. Putri, G. C. S. Girsang, M. Fiandini, "Palm oil and cinnamon (anti-microbial agent) on the physicochemical, mechanical, and biodegradation properties of micrometer-sized cornstarch-based bioplastic", *Moroccan Journal of Chemistry,* 9(2) (2021) 3-9.

[18] S. S. Patil, A. Rane, V. K. Abitha, S. Jadhav, S. Narute, P. Jayaja, "Nanofillers in surface coatings: A review", *Mor J Chem.*, 3(4) (2015) 730-740.

[19] N. Permatasari, T. N. Sucahya, A. B. D. Nandiyanto, "Agricultural wastes as a source of silica material", *Indonesian Journal of Science and Technology,* 1(1) (2016) 82-106.

[20] J. Abutu, S. A. Lawal, M. B. Ndaliman, R. L. Araga, "An overview of brake pad production using non-hazardous reinforcement materials", *Acta Tech. Corvininesis – Bull. Eng.*, 11(3) (2018) 143-156.

[21] J. S. Bale, Y. M. Pell, M. Jafri, R. Selan, "Experimental investigation on mechanical joint of lontar (Borassus Flabellifer) fiber reinforced polyester composites under static flexural test", *Indonesian Journal of Science and Technology*, 4(1) (2019) 17-27.

[22] S. Sumarji, F. Ridha, D. Dwilaksana, A. Syuhri, R. Raihaan, "The effect of particle dispersion due to mixing speed on spent coffee ground composites", *Indonesian Journal of Science and Technology*, 4(2) (2019) 188-195.

[23] R. Dungani, P. Aditiawati, S. Aprilia, K. Yuniarti, T. Karliati, I. Suwandhi, I. Sumardi, "Biomaterial from oil palm waste: properties, characterization and applications", *Palm Oil*, 31 (2018) 1-6.

[24] S. Vasiljevic, J. Glišović, B. Stojanovic, N. Stojanovic, I. Grujic, "The analysis of the influential parameters that cause particles formation during the braking process: A review", *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, 236(1) (2022) 31-48.

[25] C. P. Bretotean, A. L. Craciun, A. Josan, E. Ardelean, "Testing of brake pads made of non asbestos organic friction composite on specialized station", *Mater Plast.*, 55(3) (2018) 389.

[26] U. Idris, V. Aigbodion, I. Abubakar, C. Nwoye, "Eco-friendly asbestos free brake-pad: Using banana peels", *Journal of King Saud University-Engineering Sciences*, 27(2) (2015) 185-192.

[27] Sutikno, B. Pramujati, S. D. Safitri, A. Razitania, "Characteristics of natural fiber reinforced composite for brake pads material", *AIP Conference Proceedings*, 1983 (2018) 050009.

[28] S. S. Lawal, K. C. Bala, A. T. Alegbede, "A review of the compositions, processing, materials and properties of brake pad production", *Leonardo J. Sci.*, 16 (2017) 47-56.

[29] A. I. Olabisi, A. N. Adam, O. M. Okechukwu, "Development and assessment of composite brake pad using pulverized cocoa beans shells filler", *International Journal of Materials Science and Applications,* 5(2) (2016) 66-78.

[30] A. B. D. Nandiyanto, D. N. Al Husaeni, R. Ragadhita, M. Fiandini, D. F. Al Husaeni, M. Aziz, "Resin matrix composition on the performance of brake pads made from durian seeds: From computational bibliometric literature analysis to experiment", *Automotive Experiences*, 5(3) (2022) 328-342.

[31] W. Solomon, M. Lilly, J. Sodiki, "Effects of fiber, fillers and binders on automobile brake pad performance: A review", *International Journal of Mechanical Engineering and Technology,* 4 (2018) 21-27.

[32] C. Achebe, J. Chukwuneke, F. Anene, C. Ewulonu, "A retrofit for asbestos-based brake pad employing palm kernel fiber as the base filler material. proceedings of the institution of mechanical engineers", *Proc. Inst. Mech. Eng. Part L: J. Mate. Des. Appl.*, 233(9) (2019) 1906-1913.

[33] A. B. D. Nandiyanto, "Isotherm adsorption of carbon microparticles prepared from pumpkin (Cucurbita maxima) seeds using two-parameter monolayer adsorption models and equations", *Moroccan Journal of Chemistry,* 8(3) (2020)

745-761.
[34] S. Anggraeni, A. B. D. Nandiyanto, A. M. Nurjami, S. N. Hofifah, S. R. Putri, G. C. S. Girsang, M. Fiandini, “Palm oil and cinnamon (anti-microbial agent) on the physicochemical, mechanical, and biodegradation properties of micrometer-sized cornstarch-based bioplastic”, *Moroccan Journal of Chemistry*, 9(3) (2021) 446-453.
[35] N. Permatasari, T. N. Sucahya, A. B. D. Nandiyanto, “Agricultural wastes as a source of silica material”, *Indonesian Journal of Science and Technology*, 1(1) (2016) 82-106.
[36] A. B. D. Nandiyanto, R. Ragadhita, I. Istadi, “Techno-economic analysis for the production of silica particles from agricultural wastes”, *Mor. J. Chem.*, 8(4) (2020) 801-818.
[37] D. Egeonu, C. O. P. Okolo, “Production of eco-friendly brake pad using raw materials sourced locally in Nsukka”, *J. Energ. Technol. Policy.* 5(11) (2015) 47-54.
[38] M. Patel, A. Karera, P. Prasanna, “Effect of thermal and chemical treatments on carbon and silica contents in rice husk”, *J. Mater Sci.*, 22(7) (1987) 2457-2464.
[39] E. Triwahyuni, S. Hariyanti, D. Dahnum, M. Nurdin, H. Abimanyu, “Optimization of saccharification and fermentation process in bioethanol production from oil palm fronds”, *Proc. Chem.*, 16 (2015) 141-148.
[40] A. B. D. Nandiyanto, R. Andika, M. Aziz, L. S. Riza, “Working volume and milling time on the product size/morphology, product yield, and electricity consumption in the ball-milling process of organic material”, *Indonesian Journal of Science and Technology*, 3(2) (2018) 82-94.
[41] A. B. D. Nandiyanto, F. Triawan, R. Firly, A. G. Abdullah, Y. Aono, K. Inaba, K. Kishimoto, “Identification of micro-mechanical characteristics of monoclinic tungsten trioxide microparticles by nanoindentation technique”, *Mater Phys. Mech.*, 42(3) (2019) 323-329.
[42] S. Anggraeni, S. F. Nadhira, N. N. Azizah, D. F. Al Husaeni, R. Ragadhita, S. N. Hofifah, A. B. D. Nandiyanto, “Teaching the effect of variations in types of flour on mechanical characteristics of chicken skin crackers through experimental demonstrations to senior high school students”, *Journal of Engineering Education Transformations*, 34 (2020) 102-107.
[43] S. Anggraeni, R. Maulida, R. Ragadhita, S. N. Hofifah, A. B. D. Nandiyanto, “Teaching the effect of liming concentration on mechanical characteristics of cowhide crackers for senior high school students”, *J. Eng. Edu. Trans.*, 34 (2021) 108-114.
[45] S. Anggraeni, A. P. Hotimah, G. C. S. Girsang, R. Ragadhita, S. N. Hofifah, A. B. D. Nandiyanto, “Teaching the effect of flour on mechanical properties of shrimp shell crackers ‘Kerupuk’to high school students”, *Journal of Engineering Education Transformations*, 34 (2020) 75-80.
[46] S. Anggraeni, H. Y. Abadi, S. N. Hofifah, R. Ragadhita, A. B. D. Nandiyanto, “Demonstration of making sago (Metroxylon sagu rottb.) crackers with variations in the comparison of sago flour and wheat flour to high school students”, *Journal of Engineering Education Transformations*, 34 (2020) 81-86.
[47] A. B. D. Nandiyanto, A. T. Simbara, G. C. S. Girsang, “Effects of particle size and composite composition of durian peels and banana midribs' as reinforcement components on resin-based brake pad performance”, *Journal of Engineering Research* 9 (sp issue ASSEEE) (2021) 1-15.
[48] R. Ragadhita, A. B. D. Nandiyanto, “How to calculate adsorption isotherms of particles using two-parameter monolayer adsorption models and equations”, *Indonesian Journal of Science and Technology*, 6(1) (2021) 205-234.
[49] A. B. D. Nandiyanto, R. Oktiani, R. Ragadhita, “How to read and interpret FTIR spectroscope of organic material”, *Indonesian Journal of Science and Technology,* 4(1) (2019) 97-118.
[50] R. Gunawan, A. B. D. Nandiyanto, “How to Read and Interpret 1H-NMR and 13C-NMR Spectrums”, *Indonesian Journal of Science and Technology*, 6(2) (2021) 267-298.

[51] M. Polajnar, M. Kalin, I. Thorbjornsson, J. T. Thorgrimsson, N. Valle, A. Botor-Probierz, "Friction and wear performance of functionally graded ductile iron for brake pads", *Wear*, 382 (2017) 85-94.
[52] V. S. Aigbodion, U. Akadike, S. B. Hassan, F. Asuke, J. O. Agunsoye, "Development of asbestos-free brake pad using bagasse", *Tribology Ind.* 32(1) (2010) 12-17.
[53] K. Shibata, T. Yamaguchi, K. Hokkirigawa, "Tribological behavior of RH ceramics made from rice husk sliding against stainless steel, alumina, silicon carbide, and silicon nitride", *Tribology International*, 73 (2014) 187-194.
[54] R. N. Mukti, A. Salsabilla, A. S. Muamar, E. C. Prima, M. N. Hana, "Biogas effectiveness test from household waste (vegetable waste) with cow dung starter and EM4", *Indonesian Journal of Multidiciplinary Research,* 1(1) (2021) 73-78.
[55] M. Pebrianti, F. Salamah, "Learning simple pyrolysis tools for turning plastic waste into fuel", *Indonesian Journal of Multidiciplinary Research,* 1(1) (2021) 99-102.
[56] M. O. Ramadhan, M. N. Handayani, "Anthocyanins from agro-waste as time-temperature indicator to monitor freshness of fish products", *ASEAN Journal of Science and Engineering*, 1(2) (2021) 67-72.
[57] S. Kantroo, A. Srivastava, A. Sharma, "Performance Assessment of Gravity Retaining Wall with Rubber Tyre Waste mixed in dry cohesionless Backfill", *ASEAN Journal of Science and Engineering*, 2(1) (2022) 9-18.
[58] F. Hidayah, F. Muslihah, I. Nuraida, R. Winda, V. Vania, D. Rusdiana, T. Suwandi, "Steam power plant powered by wood sawdust waste: A prototype of energy crisis solution", *Indonesian Journal of Teaching in Science*, 1(1) (2021) 39-46.
[59] E. S. Soegoto, J. M. Ramana, L. S. Rafif, "STEM training for lesson plan on bioplastic and environment: does it affect the teachers?", *ASEAN Journal of Science and Engineering Education,* 2(1) (2022) 135-140.
[60] M. R. Bilad, "Membrane bioreactor for domestic wastewater treatment: principles, challanges and future research directions", *Indonesian Journal of Science and Technology*, 2(1) (2017) 97-123.
[61] A. Haryanto, M. Telaumbanua, "Application of artificial neural network to predict biodiesel yield from waste frying oil transesterification", *Indonesian Journal of Science and Technology*, *5*(1) (2020) 62-74.
[62] A. Bhikuning, J. S. Senda, "The properties of fuel and characterization of functional groups in biodiesel-water emulsions from waste cooking oil and its blends", *Indonesian Journal of Science and Technology*, *5*(1) (2020) 95-108.
[63] S. Waqas, M. R. Bilad, Z. B. Man, "Performance and energy consumption evaluation of rotating biological contactor for domestic wastewater treatment", *Indonesian Journal of Science and Technology*, *6*(1) (2021) 101-112.
[64] A. Hidayat, W. Kurniawan, H. Hinode, "Sugarcane bagasse biochar as a solid catalyst: From literature review of heterogeneous catalysts for esterifications to the experiments for biodiesel synthesis from palm oil industry waste residue", *Indonesian Journal of Science and Technology*, 6(2) (2021) 337-352.
[65] A. Khelassi-Sefaoui, A. Khechekhouche, M. Z. D. Daouadji, H. Idrici, "Physico-chemical investigation of wastewater from the Sebdou-Tlemcen textile complex North-West Algeria", *Indonesian Journal of Science and Technology*, 6(2) (2021) 361-370.

(2022); https://revues.imist.ma/index.php/morjchem