Jurnal Asiimetrik: Jurnal Ilmiah Rekayasa Dan Inovasi
Terakreditasi "**Peringkat 3**" berdasarkan SK Dirjendiktiristek, Nomor: 225/E/KPT/2022
Volume 5 Nomor 2 Tahun 2023, Juli 2023, Halaman 293-304
Website : http://journal.univpancasila.ac.id/index.php/asiimetrik/

p-ISSN 2655-1861
e-ISSN 2716-2923

Pengaruh Penambahan Kulit Kerang Simping terhadap Sifat Mekanik pada Kampas Rem Cakram

The Influence of Simping Clamshell Addition on Disc Brake Pad Mechanical Properties

Agus Fikri, Firman Noor Hasan dan Riyan Ariyansah[*]
Universitas Muhammadiyah Prof. Dr. HAMKA, Jl. Tanah Merdeka, No.6, Ciracas, Jakarta Timur, Indonesia

Article information:

Received:
23/05/2023
Revised:
05/06/2023
Accepted:
13/06/2023

Abstract

The brake pads made from asbestos are environmentally hazardous due to the friction and abrasion occurring during braking, resulting in the release of airborne asbestos fibers. These fibers pose various health risks to humans and contribute to environmental pollution. This study aims to analyze the influence of adding clamshell waste material on the mechanical properties of motorcycle disc brake pads. The research utilized an experimental approach, conducting tensile and friction tests on six samples with different compositions: 100% brake pads, 40% brake pads, 60% simping clamshell, 60% brake pads, 40% simping clamshell, 20% brake pads, 80% simping clamshell, 50% brake pads, 50% simping clamshell, and 100% brake pads. The results indicate that the sample comprising 50% used brake pads and 50% simping clamshell exhibited the smallest difference in thickness, measuring 0.05 mm or 0.59%, indicating the strongest adhesive strength and wear resistance compared to other variations. Thus, a higher simping clamshell composition sacrifices some tensile strength but offers improved elasticity, benefiting specific braking conditions.

Keywords: *brake pads, simping clam shell, mechanical properties.*

***SDGs*:**

Abstrak

Kampas rem yang terbuat dari asbes merupakan bahan berbahaya bagi lingkungan karena adanya gesekan dan abrasi saat pengereman yang mengakibatkan pelepasan serat asbes ke udara. Serat-serat ini memiliki potensi risiko kesehatan yang beragam bagi manusia serta menyumbang polusi lingkungan. Penelitian ini bertujuan untuk menganalisis pengaruh penambahan limbah kulit kerang simping terhadap sifat mekanik kampas rem cakram sepeda motor. Penelitian ini menggunakan pendekatan eksperimental dengan melakukan uji tarik dan uji gesek pada enam sampel dengan komposisi berbeda: 100% kampas rem, 40% kampas rem 60% kulit kerang simping, 60% kampas rem 40% kulit kerang simping, 20% kampas rem 80% kulit kerang simping, 50% kampas rem 50% kulit kerang simping, dan 100% kampas rem. Hasil penelitian menunjukkan bahwa sampel dengan komposisi 50% kampas rem bekas dan 50% kulit kerang simping memiliki perbedaan ketebalan terkecil, yaitu 0,05 mm atau 0,59%, menunjukkan kekuatan rekat dan tahan aus yang paling kuat dibandingkan variasi lainnya. Dengan demikian, komposisi kulit kerang simping yang lebih tinggi mengorbankan sebagian kekuatan tarik namun memberikan elastisitas yang lebih baik, memberikan manfaat pada kondisi pengereman tertentu.

Kata Kunci: kampas rem, kulit kerang simping, sifat mekanik.

[*]Correspondence Author
email : riyan_ariyansah@uhamka.ac.id

1. INTRODUCTION

The braking system of automobiles plays a crucial role in ensuring the safety and comfort of road users in the automotive industry. One of the reasons disc brakes are frequently chosen is that they are more stable against vehicle acceleration or stopping (Sethupathi, Chandradass and Saibalaji, 2021). Brake pads are one of the main components in the braking system that function to generate frictional force to slow down the rotation of the vehicle's wheels (Borawski, 2019; Sinha *et al.*, 2020).

The disc-pad brake system experiences significant abrasive and adhesive wear processes during the production of wear debris, according to tribology. This process generates fine particle waste due to the continual abrasion, which is definitely harmful to the environment (Mulani *et al.*, 2022). However, the conventional manufacturing of motorcycle disc brake pads often utilizes synthetic or asbestos materials, which contribute to environmental pollution and waste (Dwiyati, Kholil and Widyarma, 2017).

Many previous relevan studies have been conducted to explore alternative materials derived from organic waste sources, aiming to obtain environmentally friendly motorcycle disc brake pad materials while maintaining or enhancing their mechanical properties (Jadhav and Sawant, 2019; Neis *et al.*, 2017; Pujari and Srikiran, 2019). Previous studies have uncovered the potential of specific organic waste materials to maintain or enhance the mechanical properties of motorcycle disc brake pads.

According to a study conducted by (Singaravelu *et al.*, 2019), their findings indicate that brake pads made from thermally processed crab shell powder exhibit improved thermal stability, resulting in a charcoal residue of 37%. Conversely, brake pads made from chemically treated crab shell powder demonstrate superior fade and recovery characteristics, with a fade rate of 1.71% and a recovery rate of 99.86%, attributed to better heat dissipation and a coarser structure.

In a separate study conducted by (Yudiono and Fuad, 2023), the objective was to examine the effect of varying volume fractions of Aegle marmelos shell particles on the hardness, toughness, and wear properties of epoxy matrix composites, considering their potential as alternative materials for motorcycle brake pads. The findings of their research revealed that the most optimal composition of Aegle marmelos shell particles were found at a volume fraction of 30%, resulting in a hardness value of 79.5 HRB, a toughness value of 0.01312 J/mm^2, and a wear rate of 2.008 x 10-6 mm^2/kg. Consequently, the utilization of Aegle marmelos shell particle composites can be recommended as a suitable alternative material for motorcycle brake pads.

According to the research conducted by (Sudarisman, Jati and Kamiel, 2018) it is shown that wood sawdust waste utilized as a filler material in disc brake pads exhibits a higher coefficient of friction and lower wear rate compared to the available materials in the market, although the Brinell hardness is lower. Another study conducted by (Ihsan, Wicaksono and Sehono, 2022) investigated the wear performance of brake pads made from organic waste material, specifically coconut coir fibers. The research findings revealed that as the composition of coconut coir fibers decreased in the formation of composite brake pad specimens, the wear value of the brake pads increased, indicating reduced wear resistance.

Additionally, (Arif, Irawan and Jainudin, 2019) examined the mechanical properties of composite brake pads composed of teak wood powder and polyester. The research findings elucidated that the composite brake pad composition containing up to 55% teak wood powder and up to 45% polyester yielded the highest maximum strength value. Furthermore, another study conducted by (Prabowo *et al.*, 2017) investigated the mechanical properties of composite brake pad materials using mahogany fruit husk charcoal powder as the main ingredient. The research results indicated that the most suitable composition was found to be 60% mahogany husk charcoal, 15% coconut shell charcoal, and 25% polyester resin, which exhibited hardness and wear mass values close to the Indonesian National Standard (SNI).

Despite several previous studies that have examined the influence of organic waste materials on the mechanical properties of motorcycle disc brake pads, there still exists a knowledge gap or a lack of research specifically analyzing the impact of adding simping clamshell waste on the mechanical properties of disc brake pads. Therefore, this study aims to fill this knowledge gap by analyzing the influence of adding simping clamshell waste material on the mechanical properties of motorcycle disc brake pads. By analyzing the mechanical properties resulting from the addition of simping clamshell waste material, it is anticipated that this research will contribute to knowledge insights by obtaining tensile and friction test values from several composite brake pad specimens made with simping clamshell waste material.

2. METHODOLOGY

The methodology utilized in this study is experimental, but it is not isolated; rather, it is interconnected with an analytical approach. This integration helps reduce or eliminate any inaccuracies or deficiencies in the parameter data during the experimental process (Ishak *et al.*, 2016). The research method for tensile testing is an approach employed in studies to examine the mechanical properties of a material or sample.

In this study, the tensile testing method is utilized to measure the tensile strength and elasticity response of each specimen to the applied tensile force. Initially, the sample preparation is conducted by selecting materials that are suitable for the research objectives. Subsequently, the samples are molded or shaped according to predetermined dimensions and geometries. This aims to ensure consistency and standardization in the testing process.

Next, the tensile testing apparatus is prepared by conducting inspections and calibrations before the testing is carried out. Testing parameters such as testing speed and load are determined according to the research requirements (Phillips, Kortschot and Azhari, 2022). Subsequently, the tensile testing is initiated by placing the sample onto the tensile testing apparatus according to the user manual instructions. Relevant data, such as the applied load on the sample and the change in sample length over time, are recorded during the testing process. This testing procedure aims to induce deformation or fracture in the sample, providing information about its mechanical properties.

Furthermore, friction testing is performed to evaluate the wear characteristics and frictional behavior of the samples (Elzayady and Elsoeudy, 2021). This test allows for the examination of the changes in thickness and provides valuable insights into the performance and durability of the brake pad material. The duration of 5 minutes for the friction test ensures an adequate period for the measurement of frictional forces and the assessment of any potential degradation in the samples. Additionally, the application of a 4kg load and a disc rotation speed of 900 rpm simulates real-world conditions and enhances the reliability and relevance of the results obtained from the friction testing.

2.1. The Equipment and Materials Specifications for the Research

2.1.1. To Fabricate Brake Pad Specimens

The specifications of the tools employed in fabricating tensile and friction test specimens are as follows:

a. The Makita HP 1630 electric drill, with a power rating of 710 W, is capable of drilling iron with a diameter of 13 mm. It has a no-load rotational speed ranging from 0 to 3200 rpm.
b. The Lakoni 205E electric welding machine has a power rating of 1100 - 1500 W, an output current ranging from 30 to 200 A, and can accommodate welding wire with a diameter of 2.0 - 5.0 mm. The socket size is 25 mm.
c. The Makita electric grinder, with a power rating of 840 W, operates at a no-load rotational speed of 11000 rpm. It features an M14x2 spindle size.
d. Iron hammer.
e. Sieve.

The materials utilized to produce brake pad specimens include simping clamshell waste, used brake pads, catalyst, fiber reinforcement, and polyester resin.

2.1.2. To Conduct Tensile Testing on the Brake Pad Specimens

The tensile testing machine used for the brake pad specimens is the HungTa HT-2402 series (1-20 kN), as shown in Figure 1.

Figure 1. The HT-2402 tensile testing machine

Its specifications are described based on data sourced from the product brochure (Ta, 2023) as shown in Figure 2.

HT-2402 Series (1 ~ 20 kN)

* S = Standard * SH = Special Height * SW = Special Width * SHW = Special Height & Width

Type		HT-2402 S05	HT-2402 SH05	HT-2402 SW05	HT-2402 SHW05	HT-2402 S1	HT-2402 SH1	HT-2402 SW1	HT-2402 SHW1	HT-2402 S2	HT-2402 SH2
Capacity Selection (kN)		1, 2, 5				10				20	
Force Resolution		1/200,000 (HUNG TA Interface card)									
The Force Relative Error		Class 0.5 ≤ ±0.5% or Class 1 ≤ ±1%									
Testing Speed Range (mm/min)		0.005 ~ 1000 mm / min				0.005 ~ 500 mm / min					
Crosshead Speed Relative Error		Class 0.5 ≤ ±0.5% or Class 1 ≤ ±1%									
Effective Testing Width (mm)		420		860		420		860		420	
Crosshead Working Table Distance (mm)		1270	1770	1305	1805	1270	1770	1305	1805	1305	1805
Power Supply		AC Servo Motor & Servo Driver									
Power		1-Phase 220V, 0.6 kVA									
Machine Dimension (W x D x H) (cm)		80 x 66 x 174.5	80 x 66 x 224.5	124 x 67.5 x 174	124 x 67.5 x 224	80 x 67.5 x 174	80 x 67.5 x 224	124 x 67.5 x 174	124 x 67.5 x 224	80 x 67.5 x 174	80 x 66 x 224.5
Machine Weight (Without Machine Stand) (kg)		130	150	150	180	130	150	150	180	160	180
Standard Accessories		Tool Kit x 1 Set, Operation Manual x 1 Set, Warranty Paper x 1 Set, TAF Certificate Report x 1 Set									
Optional Accessories	Extensometer	Refer to the specifications of HT-8160, HT-9160, HT-9161 (Optional)									
	Thermostat Chamber	Refer to the specifications of HT-8747 (Optional)									
	Grip	Refer to the brochure of grips and fixtures, or provide specifications or actual samples for design and manufacture (Optional)									
	Machine Stand	HT-2402 Machine Stand (Optional, around 40kg)									

Figure 2. The specifications of the HT-2402 tensile testing machine (Ta, 2023)

2.2. The Spesifications of the Brake Pad Specimens

The various specifications of the brake pad specimens, which serve as tensile test samples, can be observed in Table 1. The concept employed in this research is to investigate the cause-effect relationship among deliberately induced factors, specifically the main material composition. By varying the composition of the main material parameters, the researcher can analyze their individual and combined effects, leading to a better understanding of their contributions to the experimental objectives.

Table 1. The composition of the research test samples

Samples Name	The composition of the test sample materials.			
	Simping Clamsheel (%)	Brake Pad (%)	Polyester Resin (mL)	Catalyst (mL)
KS100	100	0	20	5
KS60KR40	60	40		
KS40KR60	40	60		
KS20KR80	20	80		
KS50KR50	50	50		
KR100	0	100		

2.3. The Samples Preparation

This study uses simping clamshell waste and used brake pads as primary materials for making brake pads. The method involves collecting dried simping clamshell waste and used brake pads as shown in Figure 3.

Figure 3. The main specimen materials are being collected

After collecting the simping clamshell and used brake pads, the next step involves the process of mashing or grinding the main materials for brake pad manufacturing using a crushing method until the desired fineness is achieved as shown in Figure 4. The particle size for the main material in mesh units refers to the main material sieving device that utilizes a 30-mesh size sieve.

Figure 4. Mashing of the main specimen materials

After the mashing stage, the next step is the sieving process using a sieve method to filter the crushed materials to achieve a fine texture. In this sieving process, a sieve tool with a size of mesh #30 is used as shown in Figure 5.

Figure 5. The main specimen materials are being collected

The next step is the process of material mixing, where all the main materials, including simping clamshell waste and used brake pads, are mixed with fiber reinforcement and then placed in a container. Subsequently, all the materials are combined and uniformly mixed manually, as depicted in Figure 6. Manual mixing was chosen due to the small-scale nature of this study, which involves a small volume of solution that can be easily mixed manually without the need for additional equipment.

Moreover, manual mixing enables greater control over the mixing process in small-scale experiments, allowing for adjustments in speed and intensity based on visual cues or other factors. In addition, cost considerations also come into play because using a tool such as a magnetic stirrer can be relatively expensive, considering that the laboratory does not currently have one.

Figure 6. Mixing of brake pads and simping clamshells

Figure 7. The process of mixing resin and catalyst

After performing the mixing process of the main materials for brake pad production, the next step involves mixing the chemical materials, resin and catalyst, using the mixing ratio of 20 ml resin and 5 ml catalyst. They are mixed simultaneously with the main materials until a uniform mixture is achieved, as shown in Figure 7. Several indications suggest that a uniformly mixed material can be observed. The surface of the mixture will appear uniform and homogeneous, without noticeable differences in color, texture, or visually distinct components. Additionally, it will exhibit consistent consistency, where there are no lumps or significant differences in texture when touched or felt.

The next step is the brake pad molding process. In this process, all the main materials for making brake pads, which have been mixed with a combination of resin and catalyst chemicals, are then inserted into the brake pad mold as shown in Figure 8.

Figure 8. Materials molding process

The next step is the pressing process. In this process, after the material has been placed in the mold, it requires pressing with a pressure force of 10 kg and takes 30 minutes. This is done to ensure that all the composition materials are evenly compacted and to obtain the desired mold result as shown in Figure 9. After completing the pressing process, the next step is to lift the mold and remove the disc brake pad casting. Subsequently, the sintering process is carried out by heating the casting using an oven at a temperature of 100 degrees Celsius for 15 minutes to achieve the desired result, as shown in Figure 10.

Figure 9. Material pressing process

Figure 10. Material sintering process

The final result of the disc brake pad fabrication process can be seen in Figure 11. The length of this brake pad size is 14.5 cm, with a top width of 2 cm, a middle width of 1.2 cm, and varying thickness.

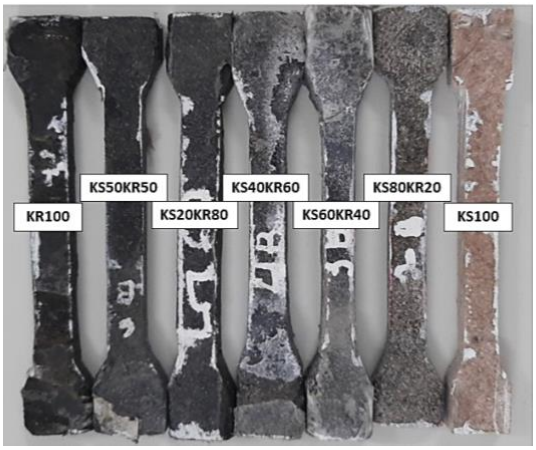

Figure 11. Research test sample

The final outcome of the specimen molding process involves machining using a manual grinder due to the specimen being made of a more brittle and fracture-prone organic composite material compared to steel or other metal alloys. This poses challenges in machining due to the material's characteristics. The use of a manual grinder enables us to carefully control the process and minimize the risk of damage to the specimen, ensuring that the required dimensions are achieved.

2.4. Data Collection Technique

The data collection techniques employed in the research are as follows:

1) Preparation of tools and materials for specimen fabrication.
2) Determination of the percentage composition of the main materials for specimen fabrication.
3) Preparation of six specimen samples.
4) Preparation of the tensile testing equipment. Conducting the tensile test.
5) Analysis and interpretation of the tensile test data.
6) Preparation of the friction testing equipment.
7) Conducting the friction test.
8) Analysis and interpretation of the friction test data.

2.5. Data Analysis Technique

The data analysis technique applied in this research is descriptive statistics, which aims to provide an objective and scientific overview of the characteristics of the data generated from this study (Hanifah, Sutedja and Ahmaddien, 2020). The descriptive statistical analysis techniques used to analyze the effect of simping clamshell waste on the mechanical properties of disc brake pads in this study include the following:

1) Data collection: The mechanical properties of each sample were tested using the tensile strength test method and the wear resistance test (friction test)
2) Data preprocessing: The data obtained from the disc brake pad's mechanical properties testing is processed before conducting descriptive statistical analysis. The data preprocessing steps include removing outlier data and eliminating invalid or inconsistent data.
3) Descriptive statistical analysis: Descriptive statistical analysis is performed to provide a comprehensive overview of the mechanical properties of disc brake pads using simping clamshell waste. Measures of central tendency, such as mean and median, are used to indicate the middle values of each mechanical property.
4) Data visualization: The results of the descriptive statistical analysis are presented in appropriate graphical forms, such as line charts, bar charts, or histograms. These graphs provide visual representations that facilitate the understanding of the characteristics of the disc brake pad's mechanical properties.

By applying the technique of descriptive statistical analysis in this study, a clear and scientific understanding of the influence of adding simping clamshell waste on the mechanical properties of disc brake pads can be obtained. Thus, the results of this descriptive statistical analysis make an important contribution to this research by providing information that can be objectively interpreted and leading to conclusions supported by data.

3. RESULTS AND DISCUSSION

From the measurements of mass and volume of each specimen, their physical properties such as density are determined, as shown in Table 2. From Table 2, it can be observed that the KS40KR60 specimen, which consists of 40% simping clamshell and 60% brake pads, has the highest density value compared to other specimens.

It can be observed from the table above that the KR40KS60 specimen has a higher density, indicating that this sample has more solid material within the same volume compared to other specimens. From this observation, it can be seen how changes in material composition affect its mass and density. In this case, the addition of more solid material (e.g., KR60 or KR80) leads to an increase in density, while the addition of lighter material (e.g., KS100) reduces its density.

This highlights the importance of the proportion and type of materials used in the formation of composite materials and their influence on their physical characteristics.

Table 2. Detailed data on friction test results for each sample

Samples Name	Mass (gram)	Volume (cm^3)	Density (gr/cm^3)
KS100	36,80	40	0,817
KS60KR40	42,17	40	1,054
KS40KR60	44,75	40	1,118
KS20KR80	41,37	40	1,034
KS50KR50	40,78	40	1,02
KR100	38,39	40	0,96

Then, based on the tensile strength testing conducted in this research, it is known that the tensile strength value of the KS100 sample with a composition of 100% simping clamshell is 6.5 MPa

Figure 12. Tensile strength graph of sample KS100

Additionally, the elasticity percentage of the KS100 sample can reach up to 8% before it fractures. The tensile strength test data of the KS100 sample is visualized using a line graph, as depicted in Figure 12. Next, the tensile strength testing on the KR60KS40 sample, composed of 60% used brake pads and 40% simping clamshell, yielded a tensile strength value of 4.7 MPa. Moreover, the elasticity percentage of the KR60KS40 sample can reach up to 10% before it fractures. The tensile strength test data of the KR60KS40 sample is visualized using a line graph, as depicted in Figure 13. Then, the tensile strength testing on the KR40KS60 sample, composed of 40% used brake pads and 60% simping clamshell, yielded a tensile strength value of 2.7 MPa. Moreover, the elasticity percentage of the KR40KS60 sample can reach up to 13% before it fractures. The tensile strength test data of the KR40KS60 sample is visualized using a line graph, as depicted in Figure 14.

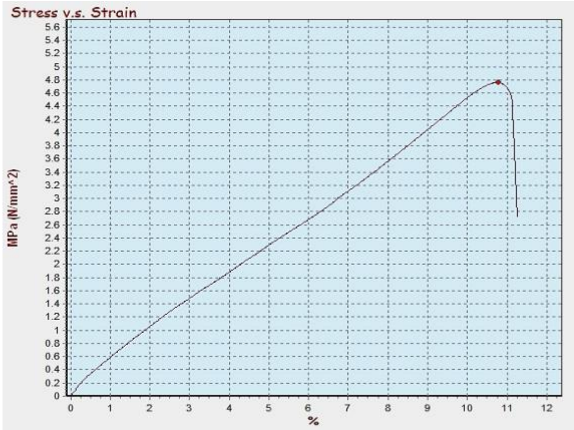

Figure 13. Tensile strength graph of sample KR60KS40

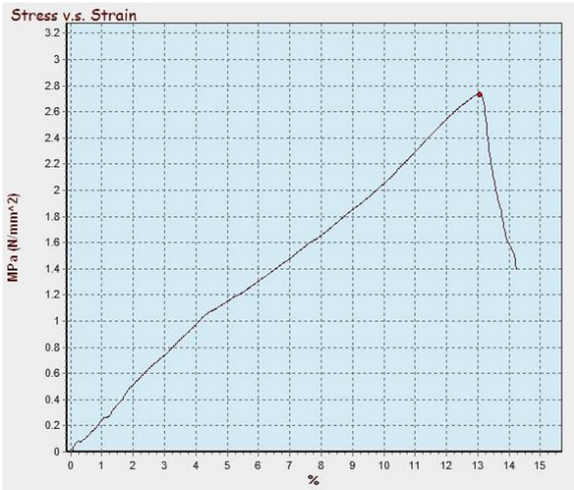

Figure 14. Tensile strength graph of sample KR40KS60

The tensile strength testing on the KR20KS80 sample, composed of 20% used brake pads and 80% simping clamshell, yielded a tensile strength value of 1.8 MPa. Moreover, the elasticity percentage of the KR20KS80 sample can reach up to 15% before it fractures. The tensile strength test data of the KR20KS80 sample is visualized using a line graph, as depicted in Figure 15.

Next, the tensile strength testing on the KR50KS50 sample, composed of 50% used brake pads and 50% simping clamshell, yielded a tensile strength value of 2 MPa. Moreover, the elasticity percentage of the KR50KS50 sample can reach up to 10% before it fractures.

The tensile strength test data of the KR50KS50 sample is visualized using a line graph, as depicted in Figure 16. Next, the tensile strength testing on the KR50KS50 sample, composed of 50% used brake pads and 50% simping clamshell, yielded a tensile strength value of 2 MPa. Moreover, the elasticity percentage of the KR50KS50 sample can reach up to 10% before it fractures. The tensile strength test data of the KR50KS50 sample is visualized using a line graph, as depicted in Figure 16.

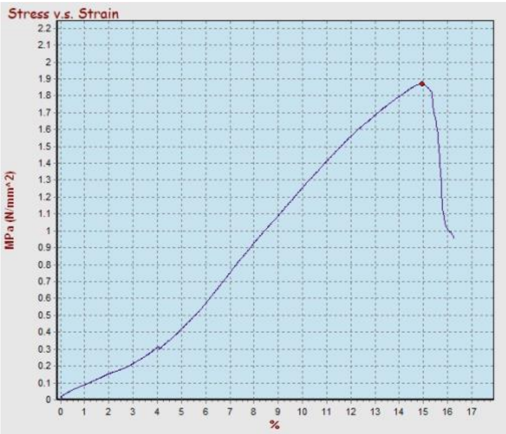

Figure 15. Tensile strength graph of sample KR20KS80

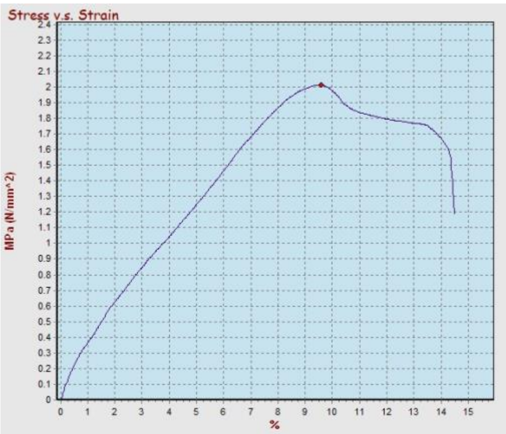

Figure 16. Tensile strength graph of sample KR50KS50

The tensile strength testing on the KR100 sample, consisting of 100% used brake pads, yielded a tensile strength value of 3.1 MPa. Moreover, the elasticity percentage of the KR100 sample can reach up to 12% before it fractures. The tensile strength test data of the KR100 sample is visualized using a line graph, as depicted in Figure 17.

The findings of the tensile testing in this study provide a detailed explanation of the trade-off between tensile strength and elasticity in each sample. This phenomenon is attributed to the influence of the percentage composition of added waste from simping clamshell. These findings align with relevant studies that elucidate how brake pads with higher organic composite compositions may sacrifice some strength but offer improved elasticity, which can be advantageous in certain braking conditions (Singaravelu *et al.*, 2019).

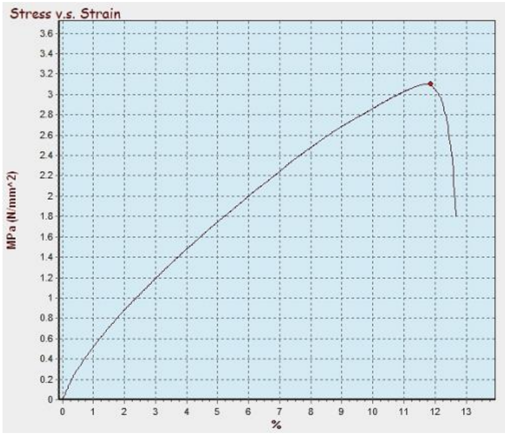

Figure 17. Tensile strength graph of sample KR100

Furthermore, the findings from the friction testing in this study indicate that the sample KR50KS50, consisting of 50% used brake pads and 50% waste from simping clamshells, exhibits the smallest difference in sample thickness, measuring 0.05 mm, or 0.59%. Conversely, the sample KR100, comprising 100% used disc brake pads, demonstrates the largest difference in sample thickness, amounting to 1.1 mm, or 12.5%. Detailed data regarding the friction testing results for each sample can be found in Table 3.

The graph of the friction test results, as shown in Figure 18, displays the percentage difference in thickness between the brake pads before and after the friction test. It can be observed that in sample KS100, with a composition of 100% simping clamshells, there is a percentage difference of 12%.

Sample KS60KR40, composed of 60% simping clamshells and 40% used brake pads, shows a difference of 5.47%. Similarly, sample KS40KR60, consisting of a mixture of 40% simping clamshells and 60% used brake pads, also exhibits a difference of 8%. Sample KS20KR80, with a composition of 20% simping clamshells and 80% used brake pads, shows a difference of 8%. Sample KS50KR50, composed of 50% simping clamshells and 50% used brake pads, has a difference of 0.59%. Finally, sample KR100, consisting of 100% used brake pads, shows a difference of 12.50%.

Table 3. Detailed data on friction test results for each sample after process

Samples Name	Initial Thickness (mm)	Final Thickness (mm)	Difference Thickness (mm)	(%)
KS100	8	7.04	0,96	12
KS60KR40	10.05	9.5	0.55	5.47
KS40KR60	11	10.12	0.88	8
KS20KR80	9	8.28	0.72	8
KS50KR50	8.50	8.45	0.05	0.59
KR100	8.8	7.7	1.1	12.50

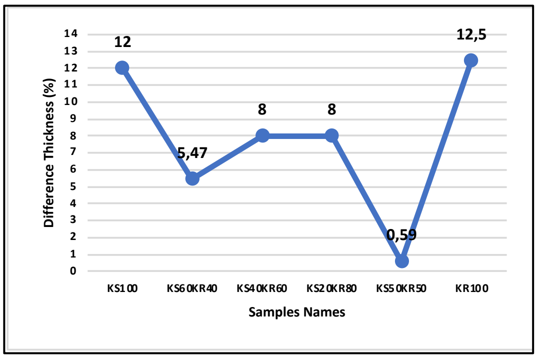

Figure 18. Percentage chart of friction test results on each sample

Based on the percentage difference values above, it can be concluded that the KS50KR50 sample has the lowest value, indicating strong adhesion that is resistant to wear, with a value of 0.59%. This finding is supported by relevant previous research references that explain how a composition proportion approaching balance between organic composite material and brake pad material can provide optimal friction performance (Yudiono and Fuad, 2023).

4. CONCLUSION

The comprehensive research findings and discussions in this study lead to the conclusion that the proportion of composition plays a crucial role in achieving the desired mechanical properties and performance in composite brake pads. Brake pads with a higher organic composition (simping clamshell) sacrifice some tensile strength but offer improved elasticity, which can be advantageous in specific braking conditions. Additionally, a balanced composition ratio between organic composite material (simping clamshell) and brake pad material can provide optimal friction performance.

The findings of this research contribute to the understanding of material selection and design considerations for composite brake pads, aiming to enhance the performance and safety of braking systems. Further research and experiments are recommended to explore additional factors and optimize the composition of composite materials for specific braking conditions and applications, considering other performance metrics such as thermal stability and durability.

REFERENCES

Arif, S., Irawan, D. and Jainudin, M. (2019) 'Karakteristik Sifat Mekanis Disk Pad Komposit Serbuk Kayu Jati - Polyester', in *Prosiding SENTRA (Seminar Teknologi dan Rekayasa). Seminar Teknologi dan Rekayasa (SENTRA)*, Malang: Fakultas Teknik Universitas Muhammadiyah Malang, pp. 1-8.

Borawski, A. (2019) 'Common Methods in Analysing the Tribological Properties of Brake Pads and Discs - A Review', *Acta Mechanica et Automatica*, 13(3), pp. 189-199.

Dwiyati, S.T., Kholil, A. and Widyarma, F. (2017) 'Pengaruh Penambahan Karbon Pada Karakteristik Kampas Rem Komposit Serbuk Kayu', *Jurnal Konversi Energi dan Manufaktur*, 4(2), pp. 108-114.

Elzayady, N. and Elsoeudy, R. (2021) 'Microstructure and wear mechanisms investigation on the brake pad', *Journal of Materials Research and Technology*, 11, pp. 2314–2335.

Hanifah, H., Sutedja, A. and Ahmaddien, I. (2020) *Pengantar Statistika*. Bandung: CV. WIDINA MEDIA UTAMA [Print].

Ihsan, M.N., Wicaksono, D. and Sehono, S. (2022) 'Uji Keausan Kampas Rem Berbahan Limbah Organik Menggunakan Metode Ogoshi', *Teknika STTKD: Jurnal Teknik, Elektronik, Engine*, 8(1), pp. 92–96.

Ishak, M.R. *et al.* (2016) 'Brake torque analysis of fully mechanical parking brake system: Theoretical and experimental approach', *Measurement*, 94, pp. 487–497.

Jadhav, S.P. and Sawant, S.H. (2019) 'A review paper: Development of novel friction material for vehicle brake pad application to minimize environmental and health issues', in *Materials Today: Proceedings*. *1st International Conference on Manufacturing, Material Science and Engineering*, India: Elsevier, pp. 209–212.

Mulani, S.M. *et al.* (2022) 'A review on recent development and challenges in automotive brake pad-disc system', in *Materials Today: Proceedings*. *International Conference on Materials, Machines and Information Technology-2022*, India: Elsevier, pp. 447–454.

Neis, P.D. *et al.* (2017) 'Towards a better understanding of the structures existing on the surface of brake pads', *Tribology International*, 105, pp. 135–147.

Phillips, C., Kortschot, M. and Azhari, F. (2022) 'Towards standardizing the preparation of test specimens made with material extrusion: Review of current techniques for tensile testing', *Additive Manufacturing*, 58, p. 103050.

Prabowo, H.T. *et al.* (2017) 'Sifat Mekanik Bahan Komposit Kampas Rem Berbahan Dasar Serbuk Arang Kulit Buah Mahoni', *Spektra: Jurnal Fisika dan Aplikasinya*, 2(2), pp. 127–132.

Pujari, S. and Srikiran, S. (2019) 'Experimental investigations on wear properties of Palm kernel reinforced composites for brake pad applications', *Defence Technology*, 15(3), pp. 295–299.

Sethupathi, P.B., Chandradass, J. and Saibalaji, M.A. (2021) 'Comparative study of disc brake pads sold in Indian market — Impact on safety and environmental aspects', *Environmental Technology & Innovation*, 21, p. 101245.

Singaravelu, D.L. *et al.* (2019) 'Development and Performance Evaluation of Eco-Friendly Crab Shell Powder Based Brake Pads for Automotive Applications', *International Journal of Automotive and Mechanical Engineering*, 16(2), pp. 6502–6523.

Sinha, A. *et al.* (2020) 'Experimental Characterization Protocols for Wear Products from Disc Brake Materials', *Atmosphere*, 11(10), pp. 1–23.

Sudarisman, S., Jati, S. and Kamiel, B.P. (2018) 'Pemanfaatan Limbah Gergajian Kayu Sebagai Bahan Pengisi Material Gesek Rem Cakram', in *Prosiding University Research Colloquium*. *The 8th University Research Colloquium 2018: Bidang Teknik dan Rekayasa & Bidang Teknik Kebencanaan*, Purwokerto: Lembaga Penelitian dan Pengabdian pada Masyarakat Universitas Muhammadiyah Purwokerto, pp. 75–82.

Ta, H. (2023) *HT-2402 Computer Servo Control Material Testing Machines*, *HUNG TA INSTRUMENT (THAILAND) CO.,LTD.*

Yudiono, H. and Fuad, M.T.N. (2023) 'The effect of Aegle marmelos shell particles volume fraction on hardness, toughness, and wear rate of epoxy matrix composites as motorcycle brake pads', *Journal of Mechanical Engineering and Sciences*, 17(1), pp. 9338–9348.