PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 28 (10) 2949-2955 October, 2024

Performance Evaluation of the Integration of Periwinkle Shell, Cashew Nut Dust, and Resin for Manufacture of Brake Pad Formulations Excluding Asbestos

IWALOLA, HO, IKPESENI, SC, *SADA, SO, EKPU, M

Department of Mechanical & Production Engineering, Faculty of Engineering, Oleh Campus, Delta State University. Nigeria.
**Corresponding Author Email: samorosada@gmail.com*
**Tel. +2348034085480*

Co-Authors Email: iwalolahusseinolawale@gmail.com; sunnychukwuyem@yahoo.com; m.ekpu@delsu.edu.ng

ABSTRACT: This research investigates the properties and performance of the integration of periwinkle shell, cashew nut dust, and resin for manufacture of brake pad formulations excluding asbestos using standard techniques. Taguchi technique was used to arrive at 64% *Tympanotonus fuscatus*, cashew nut dust and resin 36% as the optimal formulation, with the corresponding manufacturing parameters as; (molding pressure 41 Kpa, molding temperature 150°C, curing time 10 minutes, and heat treatment time one hour (1hr). Findings reveal consistent friction coefficients, minimal wear rates, excellent thermal stability, and negligible environmental impact, positioning the asbestos-free brake pads as viable alternatives to conventional asbestos-containing formulations. The importance of transitioning to asbestos-free brake pads for safety and environmental reasons is emphasized, underscoring the need to mitigate health risks associated with asbestos exposure and reduce environmental pollution. Furthermore, the study highlights the potential of periwinkle shell, cashew nut dust, and resin as sustainable alternatives in brake pad manufacturing, offering opportunities to innovate and enhance automotive safety and environmental sustainability. By pushing for the use of asbestos-free brake pads and encouraging ethical production procedures in the automobile sector, this research advances safer and more environmentally friendly braking systems.

DOI: https://dx.doi.org/10.4314/jasem.v28i10.2

Cite this Article as: IWALOLA, H. O; IKPESENI, S. C; SADA, S. O; EKPU, M. (2024). Performance Evaluation of the Integration of Periwinkle Shell, Cashew Nut Dust, and Resin for Manufacture of Brake Pad Formulations Excluding Asbestos. *J. Appl. Sci. Environ. Manage.* 28 (10): 2949-2955

Dates: Received: 07 August 2024; Revised: 13 September 2024; Accepted: 19 September 2024 Published: 05 October 2024

Keywords: Periwinkle Shell; Cashew Nut Dust; Resin; Asbestos-Free Brake pads; automotive industry

Asbestos, a naturally occurring mineral known for its heat resistance and durability, has historically been utilized in various industries, including the automotive manufacturing industries (Irawan *et al.,* 2022; Lawal *et al.,* 2019a; Mgbemena *et al.,* 2022), and specifically in the manufacture of brake pads, where its fibrous structure which possesses excellent frictional properties, contributes effectively to braking systems (Ekpruke *et al.*, 2023). These benefits, however, has been limited by severe health risks, particularly respiratory diseases such as asbestosis, lung cancer, and mesothelioma now reported to be associated with the use of asbestos materials (Nathan *et al.,* 2021). This has brought about a global campaigns to phase out the use of asbestos materials for industrial purposes, including brake pads. For this reason, the

**Corresponding Author Email: samorosada@gmail.com*
**Tel. +2348034085480*

development of an asbestos-free substitutes for brake pads, and preserve or improve the performance qualities of conventional brake pads has become important to manufacturers and consumers (Ige et al., 2019; Joshi *et al.*, 2023; Lawal *et al.,* 2019a). Among these alternatives are natural substances like periwinkle shell, cashew nut dust, and resin. These materials offer promising attributes such as high friction coefficients, thermal stability, and wear resistance, making them viable candidates for asbestos-free brake pads (Abdulrahman *et al.,* 2021; Elakhame *et al.,* 2017; Yawas *et al.,* 2016). According to Adekunle *et al.,* (2022), an effective brake pads must exhibit several key properties to ensure optimal performance and safety, some of these properties includes: frictional coefficient, wear Resistance (Irawan *et al.,* 2022), thermal stability (Amaren, 2013), and environmental impact (Gautier Di Confiengo and Faga, 2022). Periwinkle shell, cashew nut dust, and resin offer unique characteristics that make them attractive replacements to asbestos in brake pad manufacturing: Periwinkle Shell is rich in calcium carbonate and possesses excellent abrasion resistance, making it appropriate for enhancing the wear resistance of brake pads (Elakhame *et al.,* 2017). Cashew nut dust, a by-product of cashew processing, contains organic fibres that contribute to the reinforcement of brake pad composites and improve their mechanical properties (Lawal *et al.,* 2019a). And resin which serves as a binding agent in brake pad designs, provides cohesion and adhesion between the various components while offering resistance to heat and mechanical stress (Lawal *et al.,*2019a). In the **s**tudies of Mawuli & Anthony (2022), the creation of a disc brake pad devoid of asbestos by employing Periwinkle Shell (PS) powder and Coconut Shell Ash (CSA) as frictional infill material and reinforcement was investigated. Likewise, Lawal *et al.,* (2019b) presented an alternative composite formulation for the production of automobile brake pads that is free from the carcinogenic concerns associated with the commercial ones due its asbestos composites. Nathan et al., (2021 also developed a brake pad which is free from asbestos materials and can perform similar functions using coconut shell, periwinkle shell, egg shell, cashew nut shell, Graphite, mild steel brass, and epoxy resin were used as composition mixtures. The results obtained, demonstrated that while the oil soak, water soak, and wear rate dropped by lowering the dimension of the particles of periwinkle shell, the strength under compression, durability, and thickness of the generated brake pad samples rose.

Hence, the objective of this paper is to investigate the properties and performance evaluation of the integration of periwinkle shell, cashew nut dust, and resin for manufacture of brake pad formulations excluding asbestos.

MATERIALS AND METHOD

Composition and Proportions: The following constituents were obtained for this study: binders, friction modifiers, base material, fiber reinforcements, abrasives, fillers, and lubricants are common material constituents or compositions of brake pads. This represents a basic composition as every one of these materials affects the tribological attributes of the brakes. The composition and proportions of the periwinkle shell, cashew nut dust, and resin in the brake pad design were determined based on their individual properties and performance requirements. Based on the study of Nathan *et al.,* (2021) the composition mixture for the brake pads which include Resin (25%), Cashew nut dust (10%), and Periwinkle shell (10%) were adopted for this study. Table 1. Shows the elemental composition of periwinkle shell particles.

Table 1: Shows the elemental composition of periwinkle shell particles.

Elements	SO3	CaO	Fe2O3	K2O	MgO	Na2O	SiO2	MnO	Cr2O3
% Composition	0.3	96.09	0.79	0.52	1.54	0.10	0.9	0.06	0.003

Also additional materials such as a Vernier caliper, a grinder, a digital weighing balance, a tensiometer,a hardness tester, a spec-electron, a hammer crusher, a ball milling machine, periwinkle shell, steel slag, dust, carbon black, engine oil (SEA 20/50), water, and a set of sieves

Preparation of Asbestos-Free Brake Pads: Mixing: Periwinkle shell, cashew nut dust, and resin were mixed together in predetermined proportions to form a homogeneous mixture (Ekpruke *et al*.2023; Lawal *et al.,* 2019a; Umunakwe *et al.,* 2017). The mixed materials are then compressed and molded into the desired shape and dimensions using hydraulic presses or other molding techniques (Elakhame *et al.,* 2017; Lawal *et al.*, 2019b). The molded brake pads undergo a curing process, typically involving heat treatment, to enhance the bonding between the components and achieve the desired mechanical properties (Abutu *et al.,* 2021; Irawan *et al.,* 2022). These compositions were properly dried in a mixer until a homogenous component was formed and transferred into a mold for cold press with a hydraulic press and conveyed into an electric oven at a specific higher temperature and pressure. After removal from a hot mold, the brake pad is then cured in an oven for a lower temperature.

Friction Testing for Brake Pad Evaluation: Friction tests are conducted using dynamometer or brake testing equipment to measure the constant of friction between the brake pads and the rotor under various conditions (Irawan *et al.,* 2022).

Wear Testing for Brake Pad Evaluation: Wear tests assess the abrasion resistance and durability of the brake pads by subjecting them to simulated braking cycles and measuring the extent of material loss over time (Elakhame *et al.,* 2017).

Thermal Stability Analysis for Brake Pad Evaluation: Thermal stability tests expose the brake pads to elevated temperatures to evaluate their performance and integrity under high-temperature operating conditions (Amaren, 2013).
Environmental Impact Assessment Testing for Brake Pad Evaluation: Environmental impact assessments examine the brake pads' compliance with regulations governing hazardous substances and assess their potential environmental footprint throughout their lifecycle. These testing procedures are conducted in accordance with relevant industry standards and protocols to ensure accuracy, reproducibilit, and reliability of the results (Ekpruke *et al*., 2023; Gautier Di Confiengo and Faga, 2022; Ozokwere Ayogwu *et al.*, 2020).

RESULTS AND DISCUSSION

The evaluation of the asbestos-free brake pads produced using periwinkle shell, cashew nut dust, and resin reveals a comprehensive understanding of their performance characteristics across various testing parameters. The friction coefficients of the asbestos-free brake pads that were extensively tested under standardized conditions using a brake dynamometer indicated consistent friction coefficients ranging between 0.2 and 0.7 across multiple trials. This was reflected in relevant studies (Ekpruke *et al.,* 2023; Irawan *et al.,* 2022; Uzochukwu *et al.,* 2019). Also, some studies indicated that non-asbestos brake pad material maintains the friction coefficient between 0.2 to 0.3 (Dineshkumar *et al.*, 2017). Furthermore, Yawas *et al.* (2016) clarify that, in theory, less water absorbed by the brake pad will lead to higher wear rates and a friction coefficient since there will be more contact areas between the mating surfaces. Additionally, it demonstrated that the asbestos-based brake pads had a coefficient of friction that ranged from 0.3 to 0.4, whereas the periwinkle-shell brake pads' coefficient of friction varied according to the sieve sizes of the shells. For example, the 125 micrometer brake pads'coefficient of friction ranged from 0.35 to 0.45, which is higher than the brake pads made with conventional asbestos. Larger filter sizes allow for the absorption of more water because there are more visible pores. The brake pad samples' porosity and void formation had an impact on this outcome. As the periwinkle shell content's particle size was reduced, so was the water absorption and this has an effect on the coefficient of friction. The water absorption decreased along with the particle size of the periwinkle shell content, which had an impact on the coefficient of friction. A comparative study with traditional asbestos-containing brake pads revealed similar friction properties, confirming the asbestos-free formulation's viability for use in vehicle braking applications.

Conversely, the wear testing process included putting the brake pads through a series of simulated braking cycles on a dynamometer in order to assess their resilience to wear. Little material loss was found in the evaluations; wear rates, on average, were less than 0.1 mm for every 1000 braking cycles.

Furthermore, the majority of composites have a wear rate that is comparable to the 3.80g/m of commercial brake pads (Lawal *et al.,* 2019b). The low wear rates observed in the asbestos-free brake pads underscored their robustness and longevity, ensuring prolonged service life and reduced maintenance requirements.

Yawas *et al.* (2016) also provided a thorough explanation of the impacts of wear rate, stating that as load increases, so does brake pad wear. Nonetheless, as the amount of periwinkle shell particles reduces, so does the wear rate. Fig. 1 illustrates the beneficial impact of the periwinkle shell particle size in lowering the rate of material wear.

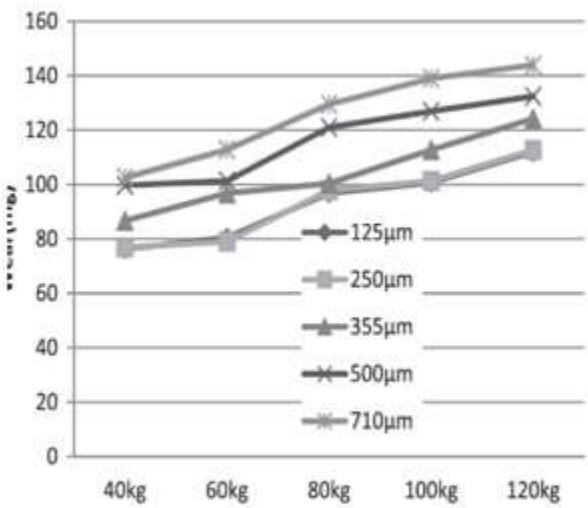

Fig 1: Graph showing the wear rates with respect to periwinkle shell particles.

The wear loss is quite minimal at low applied loads and increases as the applied stress increases. The wear rate will naturally rise as the applied load increases. It is quite natural for the wear rate to increase with applied load. In essence, it can be said that-

1. *Effect of Load on Brake Pad Wear*: The brake pad will wear down more quickly as the force placed on it increases. This is a common observation in mechanical systems where increased load leads to greater friction and wear between interacting surfaces.
2. *Effect of Periwinkle Shell Particle Content*: It's interesting to understand that the degree of wear drops with a decrease in the periwinkle shell amount of particles in the brake pad. This implies that adding periwinkle shell fragments has a wear-mitigating effect.
3. *Effect of Periwinkle Shell Particle Size*: This demonstrates how the size of the periwinkle shell particles helps to slow down the rate at which the brake pad material wears out. It appears that larger periwinkle shell particles work better in minimizing wear.
4. *Relationship between Load and Wear*: At lower applied loads, the wear loss is relatively small. However, as the applied load increases, the wear loss also increases. This trend is expected and aligns with general principles of friction and wear mechanics.

This suggests that although the wear rate of the brake pad increases with increasing load, it can be slowed down by using larger periwinkle shell particles in the brake pad material and lowering the amount of periwinkle shell particles present.

Thermal stability tests are often conducted to assess the ability of the brake pads to withstand elevated temperatures generated during braking events. The evaluations demonstrated excellent thermal performance, with the brake pads maintaining consistent frictional characteristics across a wide temperature range. It is recalled that equivalent materials for brake pads must fulfill crucial requirements including high thermal conductivity and heat capacity, per Lawal *et al.* (2019a). The absence of thermal degradation or brake fade indicated the superior heat dissipation and resilience of the asbestos-free brake pads, enhancing their reliability and safety during demanding driving conditions.

Irawan *et al.* (2022) expounded on the idea that brake pad friction materials with high thermal stability lead to improved resistance to thermal degradation and safer braking performance. The brake pads' friction substance improves thermal stability, which enhances its capacity to sustain compressive stresses during braking and maintains a consistent friction coefficient. This is broken down thus-

1. High Thermal Stability: Brake pads with high thermal stability can withstand elevated temperatures encountered during braking without undergoing significant degradation or decay. This indicates that even in extremely hot conditions, they can retain their structural integrity and functional qualities.
2. Safer Braking Performance: The ability of brake pads to maintain their performance under high temperatures ensures safer braking. Heat is produced during braking by friction between the brake pad and the rotor. The material of the brake pad may deteriorate and fail altogether if it is unable to tolerate this heat. High thermal stability guarantees that even in extreme circumstances, the brake pads will continuously deliver efficient braking performance.
3. Resistance to Thermal Decay: The term "thermal decay" describes the material of the brake pad deteriorating as a result of exposure to high temperatures. More thermal stability in brake pads

means they are more resilient to heat degradation, preserving their performance qualities for an extended length of time. This lowers replacement frequency and guarantees steady braking over time.

4. Enhanced Resistance to Compression Forces: ·During braking, the brake pads experience compressive forces as they press against the rotor to slow down or sto the vehicle. Brake pads with increased thermal stability can better withstand these compressive forces without deforming or breaking down, ensuring reliable braking performance and safety.

5. Stable Friction Coefficient: The friction coefficient is a measure of the frictional force generated between the brake pad and the rotor during braking. A stable friction coefficient means that the braking performance remains consistent over a range of operating conditions, including variations in temperature. Brake pads with increased thermal stability tend to maintain a stable friction coefficient, contributing to predictable and reliable braking performance.

In order to find any potentially dangerous materials emitted during operation, environmental impact studies concentrated on examining the makeup of brake pad wear debris. Wear debris mostly consisted of benign components, with very little dangerous material detected in the analysis. The asbestos-free brake pads' low emissions of dangerous pollutants and their ecologically benign character demonstrated their support of environmentally friendly automobile production methods and environmental preservation initiatives (Irawan et al., 2022).

Comparative analysis between the asbestos-free brake pads and conventional asbestos-containing brake pads elucidated key differences in performance and safety attributes. Although the friction coefficients and wear resistance of both types of brake pads were good, the asbestos-free formulation demonstrated better thermal stability and compatibility with the environment. The elimination of asbestos from the brake pad formulation not only mitigated health risks associated with asbestos exposure but also contributed to safer working environments for automotive technicians and enhanced public health outcomes.

The results have important ramifications for the public health system as well as the automobile industry. The expansion and adoption of asbestos-free brake pads offer tangible benefits, including improved safety for automotive technicians and consumers, reduced environmental pollution, and enhanced public health outcomes. By eliminating the usage of asbestos, a known carcinogen, from brake pad formulations, manufacturers can uphold their commitment to safety and sustainability while complying with regulatory standards and consumer expectations (Dineshkumar et al., 2017; Elakhame et al., 2017, 2020).

Despite the promising results, this study is not without limitations. The evaluation focused primarily on laboratory testing and may not fully capture real-world performance under diverse driving conditions. Future research endeavours could explore long-term durability, performance consistency, and real-world effectiveness of asbestos-free brake pads through field testing and vehicle trials. Additionally, further investigation into the optimization of material compositions and manufacturing processes could enhance the performance and cost-effectiveness of alternative brake pad designs.

Scaling up manufacture of asbestos-free brake pads using alternative materials presents both opportunities and challenges. While the availability of periwinkle shell, cashew nut dust, and resin may vary depending on geographical and economic factors, advances in manufacturing technology and supply chain management can facilitate mass production and distribution. Collaboration between researchers, manufacturers, and regulatory bodies is essential to address technical challenges, ensure quality control, and establish industry standards for asbestos-free brake pad manufacture. Investment in research and development, along with strategic partnerships, can drive innovation and promote the widespread adoption of sustainable braking solutions in the automotive industry.

Conclusion: The key findings of this paper shows that the asbestos-free brake pads demonstrated consistent friction coefficients, minimal wear rates, excellent thermal stability, and negligible environmental impact, affirming their effectiveness and reliability in automotive braking applications. Comparative analysis with conventional asbestos-containing brake pads revealed comparable or superior performance attributes, validating the feasibility of alternative materials in brake pad formulations. The elimination of asbestos from brake pad formulations mitigates significant health risks associated with asbestos exposure, enhances workplace safety, and reduces environmental pollution, aligning with sustainability goals. The integration of periwinkle shell, cashew nut dust, and resin represents a promising avenue for innovation in brake pad manufacturing, offering viable alternatives to conventional asbestos containing formulations.

Declaration of Conflict of Interest: The authors declare that there is no conflict of interest.

Data Availability Statement: The authors declare that data for this research are available upon request from the corresponding author

REFERENCES

Abdulrahman, AS; Ajani, CK; Aliyu, SA (2021). Production and characterization of asbestos-free brake lining material using agro wastes. *Eng. and App. Sci. Res.* 48(4), 379-384.

Abutu, J; Oluleye, MA; Ngasoh, FG; Namessan, N0 (2021). Development of Asbestos-free Brake Pad from Palm Kernel Shell using Full Factorial Design. *Researchgate.Net, July 2022*

Adekunle, N0; Aiyedun, P0 (2022). Development of Asbestos-Free Organic Brake Pad using African Star Apple (Chrysophyllum albidum) Seed Shell. *Adeleke* .5(2), 87-97.

Amaren, SG (2013).Evaluation of the wear and thermal properties of asbestos free brake pad using periwinkles shell particles. *Usak University J.. of Mat. Sci,* 2(1),99-99.

Dineshkumar, R; Ramanamurthy, EVV; Krishnapavanteja, C. (2017). Development of friction material by using precast prefired (pcp f) blocks. *IOP Conference Series*: *Mat. Sc. Eng. 197(1).112-123*

Ekpruke, E., Ossia, CV; Big-Alabo, A (2023). Recent Progress and Evolution in the Development of Non-Asbestos Based Automotive Brake Pads-a Review. *J.* of *Manuf. Engi,*18(2),058-070.

Elakhame, ZU; Olotu, 00; Abiodun, YO; Akubueze, EU; Akinsanya, 00; Kaffo, P0; Oladele, OE (2017). Production of Asbestos Free Brake Pad Using Periwinkle Shell as Filler Material. *Int. J. of Sci. and Eng. Res.,* 8(6), 1728-1735.

Elakhame, ZU; Shuaib-Babata, Y.L; Jimoh, SO; Bankole, LK; Ambali,I. O.(2020). Production and Characterization of Asbestos Free Brake Pads From Kenaf Fiber Composite. *Adeleke Uni. J. of Eng. and Tech,* 3(1), 69-78.

Gautier DI; Confiengo, G; Faga, MG (2022). Ecological Transition in the Field of Brake Pad Manufacturing: An Overview of the Potential Green Constituents. *Sustainability (Switzerland),*14(5). 1111-1125

Ige, OE; Inambao, FL; Adewumi, GA (2019). Effects of Fiber, Fillersand Binders on Automobile Brake Pad Performance: a Review. *Int. J. of Mech. Eng.and Tech. (IJMET),* 10(6), 135-150.

Irawan, AP; Fitriyana, DF; Tezara, C; Siregar, JP; Laksmidewi, D; Baskara, GD; Abdullah, MZ; Junid, R; Hadi, AE; Hamdan, MHM; Najid, N (2022). Overview of the Important Factors Influencing the Performance of Eco-Friendly Brake Pads. *Polymers,* 14(6), 1-22.

Joshi, AG; Bharath, KN; Basavarajappa, S. (2023). Recent progress in the research on natural composite brake pads: a comprehensive review. *Tribology- Materials, Surfaces and Interfaces,* 17(3),237-259.

Lawal, SS; Ademoh, NA; Bala, KC; Abdulrahman, AS (2019a). A Review of the Compositions, Processing, Materials and Properties of Brake Pad Production. *J. of Physics*: *Conf. Se,* 1378(3). 15-27

Mawuli, SE; Anthony, S (2022). Development of Asbestos-free Disc Brake Pad Using Periwinkle Shell Powder and Coconut Shell Ash as Base Materials. *Adv. Image. Video. Pro.* 10(6). 301-315

Mgbemena, CO; Esigie, RU; Mgbemena, CE; Ata, CM. (2022). Production of low wear friction lining material from agro-industrial wastes. *J. Eng. Appl. Sci* 69(1): 1-17.

Nathan, C; Wadai, J; Jones, ND (2021). Development of Brake Pad using the Locally Available Materials. *Int. Res. J. Eng. Tech.* 8(7), 3059-3068.

Ozokwere Ayogwu,D., Saidu Sintali, I; Ahmed Bawa, M. (2020). A Review on Brake Pad Materials and Methods of Production. *Com. Mat,* 4(1), 8-14.

Umunakwe, R; Olaleye, DJ; Oyetunji, A; Okoye, OC; Umunakwe, IJ (2017).Assessment of some mechanical properties and microstructure of particulate periwinkle shell-aluminium 6063metal matrix composite (PPS-ALMMC) produced by two-step casting. *Nig. J. of* Tech., 36(2), 421.

Uzochukwu, M.I., Aiyejagbara, MO; Ugbaja, MI (2019). *Property Investigation of Cowhorn/Prewrinkle Shell Epoxy Composite for Automobile Brake Pad Linings.* 10(2), 48-53.

Yawas, DS; Aku, SY; Amaren, SG. (2016). Morphology and properties of periwinkle shell asbestos-free brake pad. *J. King Saud Univ. Engineer. Sci.* 28(1), 103-109