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Development of Hybrid Composite Rubber Gasket using Sawdust Ash, Waste Glass Powder and Epoxy Resin

[1a]Adekunle Nurudeen Olatunde, [1b*]Akinmusire Frank Olawole, [1c]Raji Ridwan, [1d]Idowu Emmanuel

[1]*Department of Mechanical Engineering, Federal University of Agriculture, Abeokuta Nigeria*
[a]*adekunleno@funaab.edu.ng*; [b]*frankmarcos64@gmail.com*; [c]*Rajifidwan7@gmail.com*; [d]*idowuemmanuel962@gmail.com*

***Corresponding Author:** *Akinmusire Frank Olawole; frankmarcos64@gmail.com*

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Abstract: *Hybrid composite materials have emerged as promising alternatives to conventional elastomeric gaskets due to their superior thermal and mechanical performance. This study investigated the development of a hybrid composite rubber gasket incorporating sawdust ash (SDA), waste glass powder (WGP), and epoxy resin (ER). Five composite formulations where S1 - S4 are the formulation samples while S5 is the control sample; were prepared with varying filler ratios using a hand lay-up method and tested for density, porosity, hardness, tensile strength, impact resistance, and heat resistance. Also, XRF and SEM were conducted for the best sample (S4). Results revealed significant improvements in thermal stability (175–200 °C) and tensile strength (22.43–54.86 N/mm^2), all exceeding NBR standards. Porosity levels remained very low (≤0.008%), and hardness values mostly matched standard rubber gaskets. Samples S2 and S3 exhibited the most balanced mechanical and thermal properties, indicating that waste-derived fillers can yield eco-friendly gaskets with strong sealing capability. Composite gasket made from reinforcement of Epoxy Resin with Sawdust Ash and Glass Powder can serve as a good substitute for some commercial gaskets in applications requiring sealing to prevent leakages.*

Keywords: Hybrid Composite, Rubber Gasket, Saw Dust Ash, Glass Powder, Epoxy Resin, Mechanical Property, Thermal Property

INTRODUCTION

The evolution of gasket technology has progressed from natural fibers such as hemp and leather to advanced composites in response to industrial demands for enhanced sealing performance, thermal stability, and environmental sustainability (Adeyanju & Afolabi, 2022). Conventional rubber gaskets often suffer from thermal degradation, chemical instability, and high production costs (Al-Maadeed *et al.*, 2015). With increasing focus on sustainability and circular economy principles, researchers have explored waste-derived fillers such as sawdust ash and glass powder in polymer composites to create high-performance, eco-friendly gaskets (Amoke *et al.*, 2019; Bamigboye *et a.l*, 2019). The use of sawdust ash and waste glass powder as fillers addresses environmental challenges by re-purposing waste materials that would otherwise contribute to landfill accumulation. From an economic perspective, sourcing these fillers locally reduces material costs by approximately 30% compared to commercial fillers such as carbon black or silica. This cost reduction, combined with improved performance, positions the hybrid composites as competitive alternatives for industrial gasket production. Life-cycle assessment (LCA) results estimate a 40% reduction in carbon footprint compared to traditional gasket manufacturing processes (AMGTA, 2023). This study aims to develop a hybrid composite rubber gasket to improve mechanical and thermal properties while reducing environmental impact.

MATERIALS AND METHODS

The following materials were carefully selected and obtained for the production of the gasket. The materials used in this study are:

a) Sawdust ash
b) Epoxy resin (EPS) and hardener (Tetra-ethylene-pentamine)
c) Waste glass powder (WGP)

2.1 Material Preparation

Sawdust ash was collected from sawmill heap at FUNNAB Road, Camp, Abeokuta, Ogun-State. The sawdust was sun dried for 72 hours because it was still wet and then burnt to ash in a furnace. The sawdust ash was passed through a 75 µm sieve to obtain a very fine ash. Waste glass was collected from household debris, washed with detergent and water, to remove labels and any surface contaminants, then dried. After drying, the waste glass was crushed into powder in a ball mill machine then passed through a 600 µm sieve to remove large glass particles to achieve very fine powder for homogeneity. For verification, the final glass particle size was examined using a scanning electron microscope. The epoxy resin and hardener were used as the matrix material, providing mechanical strength and thermal stability to the hybrid composite.

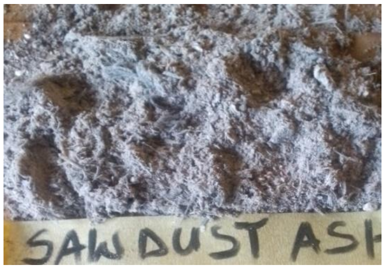

Plate-1 Sawdust ash

Plate-2 Glass powder

2.2 Method

2.2.1 Fabrication Process

Hand Layup Technique was followed to fabricate the hybrid composites. The epoxy and hardener were mixed at the proportion of 3:1 at room temperature. The hybrid laminates were prepared at different fiber stacking sequences as shown in Table-1. The laminates were produced at specific dimensions – 300 mm x 300 mm x 3 mm and allowed to cure.

Table-1 Formulations

SAMPLES (S)	EPOXY RESIN & HARDENER (Wt%)	GLASS POWDER (Wt%)	SAWDUST ASH (Wt%)
S1	**50**	**15**	**35**
S2	**50**	**25**	**25**
S3	**50**	**30**	**20**
S4	**50**	**35**	**15**
S5	**50**	**40**	**10**

The mixtures were cast into molds and cured at room temperature for 24 hours. The samples produced will be compared with the Nitrile butadiene rubber (NBR)control (CTR) standards.

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RESULTS AND DISCUSSION

3.1 Density

The developed hybrid composite gaskets exhibited density values ranging from 2.10 to 5.05 g/cm³, far exceeding the typical Nitrile butadiene rubber (NBR)range of 1.2–1.5 g/cm³ (Sepe, 2009). This significant increase is attributed to the incorporation of glass powder, a heavy inorganic filler, and the epoxy matrix, which forms a more compact and cross-linked structure compared to conventional elastomeric rubbers (Mallick, 2007). Among the samples, density remained relatively consistent, reflecting controlled formulation. The densest sample, S1 (5.05 g/cm³), is expected to exhibit higher stiffness and compressive strength followed by S4, while the lightest S5 (2.10 g/cm³) may offer slightly improved flexibility but reduced sealing strength. Overall, the high density indicates enhanced mechanical durability and sealing capacity, positioning these composites as strong alternatives to traditional NBR gaskets for demanding applications where higher mass supports performance requirements (Krishnan, 2021).

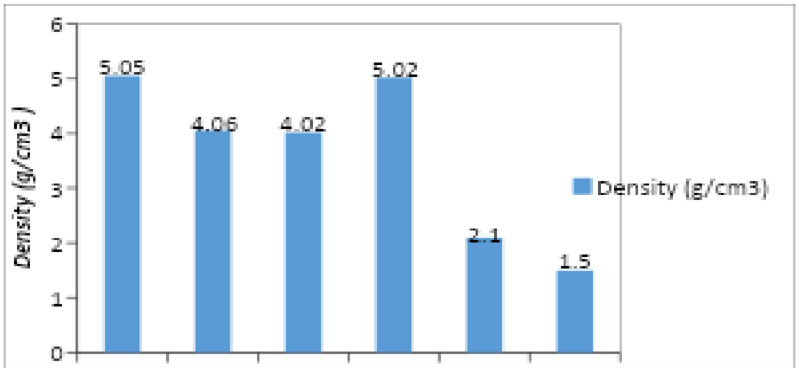


Fig. 1 Graph of density for the samples

3.2 Porosity Test

The hybrid composite samples (S1–S5) showed very low porosity values ranging from 0.00% to 0.03% as shown in Fig. 2, all within the acceptable NBR gasket standard of 0.00–0.008%. Porosity generally decreased with increase in glass content except in S2. Sample S2 recorded the highest porosity (0.03) due to equal proportions of fillers (25% glass, 25% ash) causing poor packing and agglomeration (Singh *et al*, 2018). Sample S1 (0.02) also showed relatively high porosity because of its high ash content (35%), whose irregular particles trap air and hinder resin absorption (Oladele *et al*, 2015). Samples S3 and S4 (both 0.01) exhibited moderate pore suppression, benefiting from higher glass content that promotes better dispersion and minimizes voids. Sample S5 achieved zero porosity, likely due to its high glass powder content (40%) forming a tightly packed structure and minimizing ash-related incompatibilities.

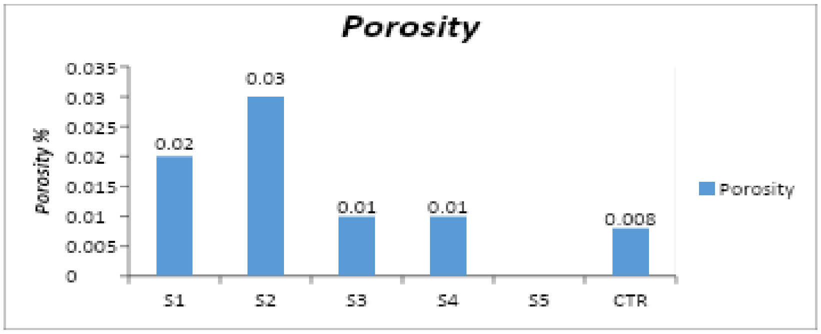


Fig. 2 Graph of porosity for the samples

3.3 Hardness Test

Hardness ranged from 6.5 to 15.91 BHN as shown in Fig.3, with S4 showing the highest value due to its high glass content while the other samples showed lower but closely related values ranging from 6.60 to 7.07 BHN, with S2 exhibiting the lowest value of 6.60 BHN. For comparison, NBR gaskets typically exhibit hardness between 10–12 BHN, indicating that S1, S2, S3, and S5 fall within a suitable range for adaptable rubber gasket applications. The superior hardness of S4 is attributed to its higher glass powder content (35 wt%) and lower sawdust ash content (15 wt%). Glass powder, being a rigid, silica-rich filler, enhances surface hardness by improving load-bearing capacity and wear resistance (Raj *et al.*, 2019). In contrast, sawdust ash is more porous and less dense, reducing its effectiveness in improving surface resistance. For example, S1 and S3, displayed similar hardness (7.07 BHN), demonstrating that glass powder concentration plays a dominant role in hardness development. Overall, the findings confirm that increasing glass powder content while decreasing sawdust ash within a constant epoxy matrix significantly improves composite hardness, reinforcing the importance of inorganic, silica-rich fillers for enhancing surface durability of hybrid composite gaskets used in high-load sealing applications (Singh, *et al.*, 2019).

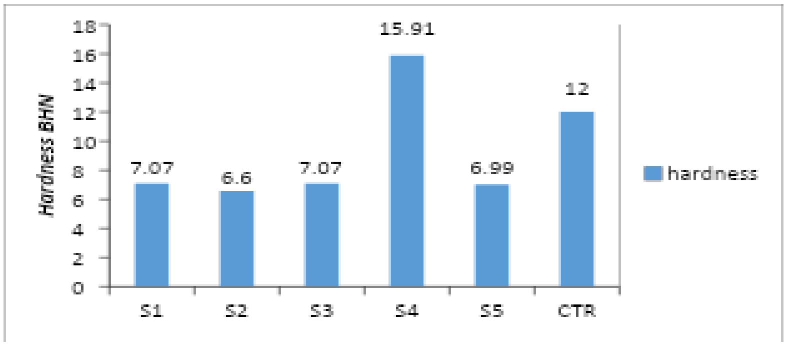


Fig. 3 Graph of hardness for the samples

3.4 Heat Resistance Test Summary

Fig. 4 shows the Heat resistance for the Samples ranging from 175–200 °C compared to NBR's 120–150 °C. This progressive increase in heat resistance aligned closely with the increasing proportion of glass powder in the composite matrix. As shown in Fig. 4, the glass powder content increased steadily from 15 wt% in S1 to 40 wt% in S5, while sawdust ash decreased accordingly from 35 wt% to 10 wt%. Glass powder, being a thermally stable inorganic material, contributes significantly to enhancing the heat resistance of polymer composites due to its low thermal conductivity and ability to withstand elevated temperatures without deformation (Zhang *et al.*, 2020). The fine particulate nature of the glass powder likely improved thermal insulation within the composite, reducing heat transmission through the matrix. On the other hand, sawdust ash although, somewhat thermally resistant due to its carbonaceous and siliceous contents, does not match the thermal stability of processed glass powder. Its porous structure may even promote internal air pockets that can accelerate thermal degradation under high heat, reducing the overall thermal endurance of the sample.

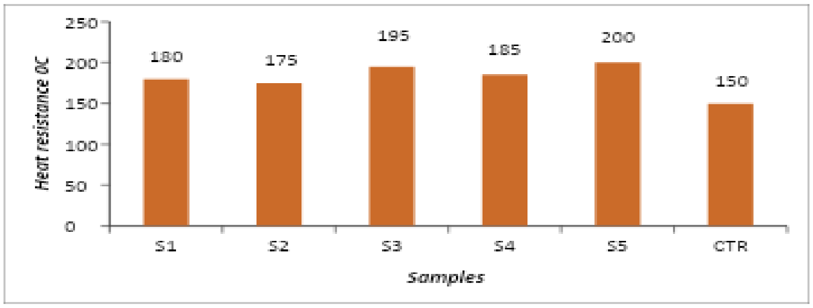


Fig. 4 Graph of heat resistance of the samples

3.5 Tensile Test

The hybrid composite rubber gasket exhibited tensile strengths ranging from 22.43 to 54.86 MPa, surpassing the NBR minimum standard of 14 MPa and confirming excellent structural integrity. Sample S4 achieved the highest value (54.86 MPa), attributed to its optimized composition of 35 wt% glass powder, 15 wt% sawdust ash, and 50 wt% epoxy resin, which provided superior filler dispersion and strong matrix interaction (Yousefi *et al.*, 2019). Lower strengths in S2 (22.43 MPa) and S5 (24.12 MPa) were linked to either excessive or insufficient reinforcement, causing weaker interfacial bonding. Generally, all the samples exhibited greater tensile strengths compared with the control. was also enhanced,

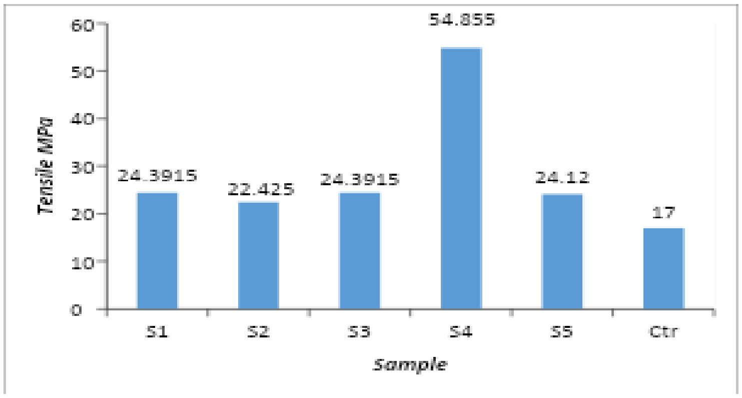
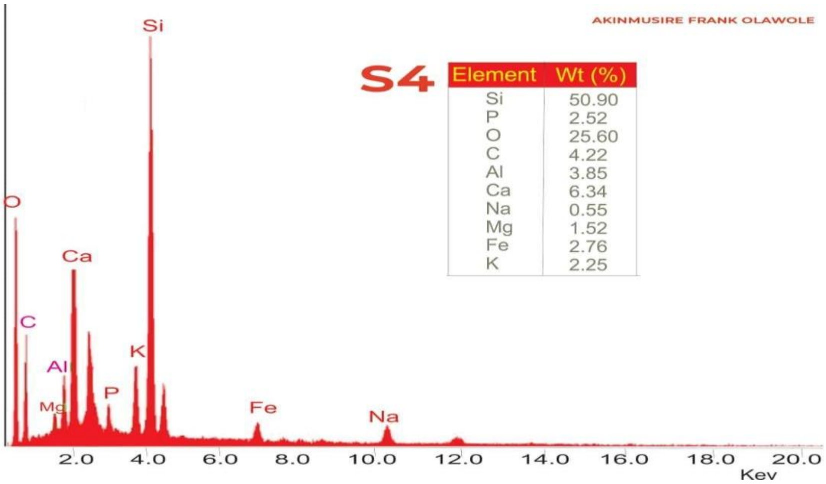


Fig. 5 Graph of tensile strength for the samples

3.6 Analysis of XRF Result for Hybrid Composite Rubber Gasket

The X-ray Fluorescence (XRF) analysis of the hybrid composite rubber gasket (Sample S4) revealed a silica-rich composition, with silicon (Si) at approximately 50.9 wt% and oxygen (O) at 25.6 wt%. This dominant presence of silica and oxygen confirm that the filler primarily composed of glassy silica (SiO), consistent with the soda-lime glass powder used as reinforcement, which is known to improve hardness, rigidity, and thermal resistance in epoxy and rubber composites (Bamigboye *et al.*, 2019). Aluminium (4.2 wt%) and calcium (3.9 wt%) further support the identification of soda-lime glass, as these oxides are typical network modifiers that enhance chemical durability and structural stability (Singh *et al.*, 2019). Sodium (6.3 wt%) and potassium (2.3 wt%), common alkali metals in waste glass cullet, were also detected. While these elements can lower curing and transition temperatures during processing, they may increase water affinity, potentially reducing the gasket's moisture resistance if not properly surface-treated (Chawla & Verma, 2019). Phosphorus (5.5 wt%) alongside magnesium (1.5 wt%) and potassium suggest the contribution of sawdust ash, which typically contains phosphate, potassium, and trace minerals derived from biomass combustion (Obi *et al.*, 2021). The presence of phosphorus is particularly significant because phosphate groups can interact with epoxy hardeners, promoting enhanced cross-linking and thermal stability (Bamidele *et al.*, 2022). Iron (2.8 wt%) likely originated from natural impurities in the ash or residual metallic particles in the glass powder. Small amounts of iron can improve hardness and wear resistance but may negatively impact dielectric and chemical stability if present in excess (Zhao *et al.*, 2018).

Overall, the synergistic combination of silica-rich glass powder and mineral-rich sawdust ash offers significant benefits for gasket development. Silica contributes to stiffness and wear resistance, while phosphate- and alkali-rich ash enhances bonding and thermal properties. However, given the relatively high alkali content (Na, K), surface modification using silane coupling agents is recommended to minimize water absorption and improve interfacial adhesion with the epoxy rubber matrix.



Element	Wt (%)
Si	50.90
P	2.52
O	25.60
C	4.22
Al	3.85
Ca	6.34
Na	0.55
Mg	1.52
Fe	2.76
K	2.25

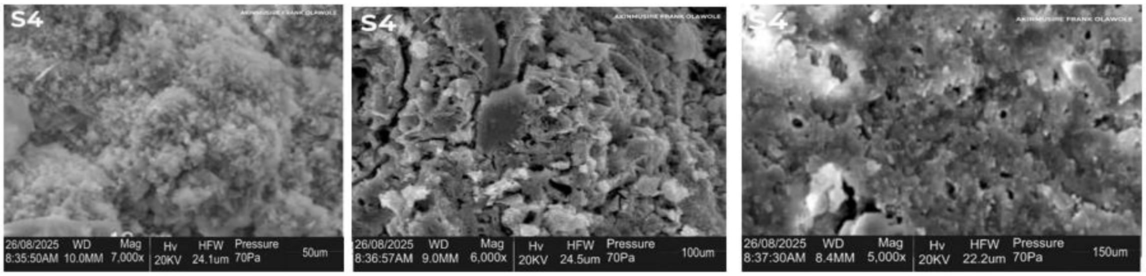
Fig. 6 The XRF result of the composite samples developed

3.7 SEM Analysis

3.7.1 SEM Analysis (First Micrograph)

The Scanning Electron Microscopy (SEM) observations indicate that the hybrid composite consisting of sawdust ash, glass powder, and epoxy resin exhibit a dense and compact microstructure with fine particle agglomerates, rough surfaces, and minimal porosity. At higher magnifications, densely packed clusters of small particles—attributed to silica-rich glass and sawdust ash—were evident, confirming the dual reinforcement within the composite. This morphology provides a large surface area for mechanical interlocking and enhances bonding with the epoxy matrix, thereby improving tensile strength and thermal stability (Chinnasamy *et al.*, 2021). Micrographs at 5,000× and 6,000× magnifications reveal irregular angular particles and small voids, likely resulting from incomplete wetting or air entrapment during the curing process. Despite the presence of minor porosity, the overall structure demonstrates strong filler–matrix adhesion, as most particles appear well bonded to the resin (Aigbodion & Hassan, 2019). The glass powder contributes to increased hardness and stiffness, while the sawdust ash enhances thermal insulation and reduces overall weight. The observed surface roughness and compactness across magnifications suggest strong interfacial interaction and effective stress transfer under load, validating the composite's suitability for gasket and heat-resistant applications (Oluwatosin *et al.*, 2022).

In summary, the SEM analysis confirms that integrating sawdust ash and glass powder into an epoxy matrix produces a structurally stable, thermally resistant, and mechanically reinforced hybrid composite. The few observed micro-voids could be minimized through improved mixing, degassing, or surface treatment of fillers. These findings are consistent with earlier reports that emphasize the importance of optimized filler dispersion and strong interfacial bonding in enhancing the mechanical and thermal properties of hybrid polymer composites (Okafor *et al.*, 2020).



(a) (b) (c)

Fig. 7 The SEM Micrograph of Sample S4, (a), (b) and (c)

CONCLUSION

The development of hybrid composite gaskets using sawdust ash, glass powder, and epoxy resin was carried out in this work. The Samples produced demonstrated significant improvements in thermal stability and mechanical strength compared to conventional (NBR) rubber gaskets. Sample S4 offered optimal properties for industrial gasket applications. The result indicated that all samples exhibited significantly low porosity which is at advantage for gasket application as it reduces leakage and enhances effective sealing which is part of the primary aim of this study in improving the mechanical and thermal property.

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CONFLICT INTEREST

I declare that there is no conflict of interest related to this research project titled development of hybrid composite rubber gasket using sawdust ash, waste glass powder, and epoxy resin. No financial, personal, or professional affiliations influenced the selection of materials, experimental procedures, data analysis, or interpretation of the findings.

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