INVESTIGATIVE STUDY ON THE ABSORPTION, MECHANICAL AND THERMAL BEHAVIOR OF GROUNDNUT/COCONUT SHELL POLYESTER COMPOSITE

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ABSTRACT

Agricultural waste such as groundnut and coconut shell accumulates in environment which takes a longer periods of years to degrade due to high lignin content leading to environmental pollution. Its utilization in hybrid composite is been investigated for a sustainable and ecofriendly composite there by adding value to coconut and groundnut shell as well as reducing environmental pollution and degradation. This study involved the crushing and grinding of the coconut and groundnut shell to particle size of 250µm and mixed (ranging from 0 to 40wt %) with polyester resin using hand layup techniques for the formulation of the composite samples. The research evaluated important physical properties such as density and water absorption, mechanical properties such as tensile, flexural, hardness and impact tests and its thermal properties across the produced samples. It was observed that the density result shows an optimal value at Sample ´C´ with density of 2.8g/cm^3.The water of absorption increases as the weight of groundnut shell particles (GSP) /coconut shell particles GSP/CSP increases. The tensile strength decreases with increase in groundnut shell particles (GSP) /coconut shell particles (CSP)loading while the percentage elongation increases at low weight percent of GSP/CSP and decreases on further increase in weight fraction of groundnut shell particles (GSP) /coconut shell particles (CSP) with an optimal value 5.97% at Sample ´B´. Sample ´C´ demonstrated an impact strength of 0.23 KJ/m². The flexural modulus increases at low weight percent of GSP/CSP with maximum value at Sample ´B´ with 14552MPa while the flexural strength showed an optimal value at Sample ´C´ with 24526.91MPa. The result further revealed that the hardness also increases at low weight percent of fillers but decreases gradually on further increase in the filler with an optimal value observed at Sample ´B´ of 10Hv.The thermal stability of the composite was experimented using Dynamic Mechanical Analysis (DMA) with Sample 'C' showcasing excellent and optimal output with a storage modulus of 654Mpa-665Mpa at 41.9°C- 47.3°C, loss modulus of 267Mpa – 285Mpa at 80°C - 91.0°C and a loss factor (tan δ) of 0.390 – 0.399 with a glass transition temperature (Tg) at 119°C-124°C. Hence this results establish the utilization of groundnut and coconut shell powder in hybrid composite which enhances its absorption, stiffness, impact, ductility, hardness and thermal properties but reduces the tensile strength of the composite which can be utilized in mechanical, automotive, safety protective equipment, and sustainable construction contributing to advancement of engineering materials.

Keywords: Composite, Polyester, Hybrid composite, Fillers, Coconut shell, Groundnut shell

1 INTRODUCTION

Composite materials have developed a wide area of application in science and technology due to their excellent properties ranging from ecofriendly, biocompatibility, ease of processing or fabrication, light weight, low cost of materials, biodegradability, non-carcinogenic, improved strength to weight ratio e.t.c., when compared to conventional metals, carbon fibers ,glass fibers e.t.c. such as rice husk, bamboo wood fiber, banana leaf fiber, cow bone, cellulose, jute, hemp, straw, sisal, kenaf, coir,

groundnut shell, coconut shell, chitosan, chitin, coconut fiber e.t.c. [1].Composites are engineering materials consisting of two or more materials with improved characteristics when compared to its individual components [2].Composite materials can be reinforced with natural fibers or fillers with improved mechanical properties than synthetic fibers there by reducing cost and creating an ecofriendly environment. Groundnut shell and Coconut shell are natural lignocellulose and dominant agro-waste materials commonly found in Nigeria which constitute a menace to the environment which can be reprocessed and used for development of engineering materials. Groundnut shell (*arachis hypogea*) and coconut shell (*cocosnucifera*) are natural lignocellulose. Groundnut shell and coconut shell contains hemicellulose, cellulose, lignin, pectin and water of varying composition respectively [2, 3]. Many researchers have been exploring lignocellulose fillers such as groundnut shell and coconut shell powder in place of synthetic fillers as reinforcement with different matrix materials.[4] studied the mechanical properties of groundnut shell powder/calcium carbonate/vinyl ester composites which revealed that the calcium carbonate increases the tensile and flexural strength of the composite.[3] studied the effect of groundnut shell particles on physical and mechanical properties of jute–epoxy hybrid composite. The findings showed that 15wt% of groundnut shell particles showed excellent result for tensile, flexural and shear strength of the composite while hardness value of 21 Hv showed best result on addition of 20wt% of filler in the composite. [5] evaluated the mechanical and sound absorption of groundnut shell and coir reinforced gypsum hybrid bio composites for gypsum tiles. They concluded that the developed hybrid composite had high flexural strength of 3.6 MPa and modulus of 234 MPa when compared to pure gypsum materials while the sound absorption test revealed a sound absorption coefficient between 0.1 and 0.75, thermal conductivity between 0.06 and 0.12 W/mK which suggest the reinforced composites suitable for use over the gypsum based tiles. [6] investigated coconut shell (CS) as a partial substitute for fine aggregates on sidewalk pavement. The coconut shell showed high water absorption percentage at 2.6% compared to 0.5% sand which makes it a viable partial replacement to fine aggregates with a blending of 10% (CS): 90% (Sand), the 20% blend has strength of 17.33 Mpa which was within the acceptable range of lightweight concrete. [7] studied the mechanical properties of epoxy/coconut shell filler particle composite. The result revealed that increase in filer content increases the strength of the composite. [8] evaluated the mechanical properties and absorption behavior of coconut shell powder-epoxy composites. They reported the density of the composites increases as the as the wt% of the filler increases, the tensile strength decreases as the filler volume increases, the flexural strength increases at low wt% of filler volume and decreases on increasing filler volume, while water absorption increases as filler volume increases. [2] studied the mechanical properties of Polyester/Coconut Shell /Wood Dust Particles Hybrid Composite. The result showed that the composite containing fresh fillers has a good mechanical strength in terms of impact and hardness property when compared with composite with ashed filler while there was general decrease in percentage elongation of the both hybrid composite. The present study focus on the development of hybrid composite which comprises of with unsaturated polyester resin (UPR) as matrix coconut shell and groundnut shell particles as fillers.

2 MATERIALS AND METHODS

The materials used in this research include unsaturated polyester resin (UPR), cobaltnaphthenate as accelerator, methylethyl ketone peroxide (MEKP) as catalyst, coconut shell, groundnut shell, steel metal mould and release agent.

2.1 Composite Preparation

The coconut shell and groundnut shell were sourced from a local vendor in Kaduna State, cleaned, dried in open air and grounded in a laboratory grinding mill to 250μm particle size as displayed in plate 1 to 4 below. A 100 g of unsaturated Polyester resin was mixed with cobalt naphthenate (catalyst) and Methyl Ethyl Ketone Peroxide (MEKP) (accelerator) in the ratio 2:1 until a homogeneous mixture was obtained. The mixture was thereafter poured into a steel mould of 18mm x 18mm x 3mm. The prepared sample was ejected from the mould, heated in the oven at 300°C for 3 hours for curing to take place which served as the control samples. This procedure was further repeated for other samples with varying content of filler as

specified in Table 1 below and subjected for further characterizations. The final composite products are displayed in Plate 5.

Plate 1. Coconut shell

Plate 2. Coconut shell powder (CSP)

Plate 3. Groundnut shell

Plate 4. Groundnut Shell Powder (GSP)

Plate 5. Developed control sample and coconut /groundnut shell polyester composite samples

Table 1. Formulation for coconut shell/groundnut shell polyester composite

Sample	UPR wt%	GSP (wt%)	CSP wt%
A	100	0	0
B	80	10	10
C	60	20	20
D	40	30	30
E	20	40	40

2.2 Physical Test

The following physical properties were carried out on the developed composite samples;

2.2.1 Water absorption

The initial weight of the composites samples was weighed before immersion in distilled water (W1), and after immersion in distilled water (W2) for each of the samples for period of 14days at 2days interval and taken out to determine the percentage water absorption of the composite using the equation 1 below;

$$\% \text{ Water Absorbed} = \frac{w2-w1}{w1} \times 100 \quad (1)$$

2.2.2 Density

The densities of the specimens were obtained using equation 2 below;

$$\rho = \frac{m}{v} \quad (2)$$

where; ρ = density (g/cm^3); m = mass of the specimen in grams; v = volume of the specimen in cm^3.

$$V = lbt \quad (3)$$

where V = volume of the specimen in cm^3; L = length of the specimen in cm; b = breadth of the specimen in cm; t = thickness of the specimen in cm.

2.3 Mechanical Testing

The following mechanical test were carried out on the composite samples;

2.3.1 Tensile test

Tensile strength was performed based on the ASTM D303-08 standard method using a universal tensile test machine with a load cell of 5 KN and regular speed rate of 2 mm/min to determine the tensile value of the composite. The samples were machined into dumb bell shaped tensile specimen with a dimension of 150 mm x 10 mm x 3 mm at a gauge length of 150 mm. Tensile tests were conducted using a computerized universal testing machine with a cross head speed 2 mm/min. The result was reported in MPa.

2.3.2 Flexural test

Three-point bending test was used to determine the flexural strength of the specimen composite using a computerized universal testing machine. The specimen composite was prepared according to ASTM D790 with a dimension of 125 mm × 15 mm × 3 mm and a crosshead at 3 mm/min. and supported by a beam with the point load was exerted in the center of the composite specimen. The flexural strength was reported in MPa.

2.3.3 Impact test

The charpy impact test was carried out on the samples using ISO179 standard. Samples were cut into dimension 80mm × 10 mm × 2 mm were placed horizontally on the machine. The gauge length and the thickness of the sample were recorded. The machine pendulum was released freely 180° so as to fractured the sample. The average mean of the three samples specimen was evaluated and recorded.

2.3.4 Hardness Test

Hardness tests were carried out on three sectional surfaces of each test specimen of dimension 30mm x 30mm x 5mm, in order to determine the level of the composite hardness. The average hardness values of all sample specimen were evaluated and recorded.

3 RESULTS AND DISCUSSION

3.1 Density Property of the neat unsaturated polyester and the Developed Composite

Figure 1 below shows the relationship between the density and the percentage weight of filler content of the hybrid composite. The density value of the hybrid composite increases above the neat sample A (complete UPR) which can be attributed to the increase in weights of the fillers resulting in higher density than unsaturated polyester which are in agreement with findings from existing literature [2]. Optimal value is observed at sample C with density of 2.8g/cm^3 while minimum value is observed at sample A with density of 1.65 g/cm^3.

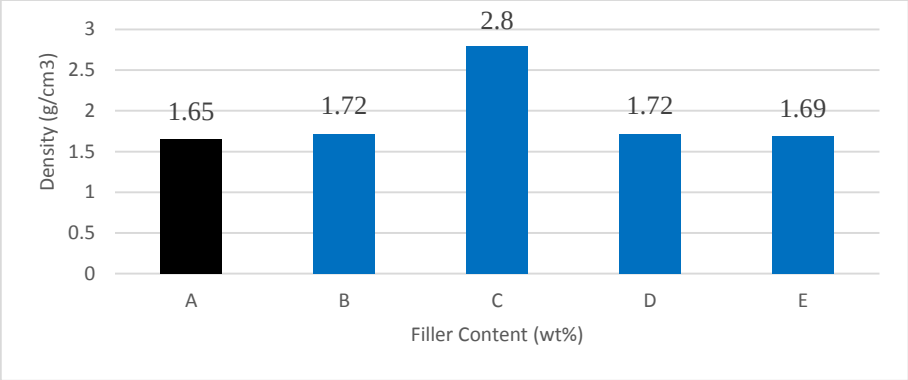

Figure 1. Variation of density with filler content

3.2 Water Absorption Property of neat polyester and the developed Composite

The water absorption increases with corresponding increase in percentage weight of fillers than the matrix materials as displayed in Figure 2 below which can be attributed to diffusion of water as a result of increased porosity and inter-particle spacing between the filler (CSP and GSP) and matrix. Maximum value can be observed at sample E (20wt% UPR +40wt%GSP+40wt%CSP) with 8.93% which is higher than the percentage of water absorption sample A (100wt%UPR+0wt%GSP+0wt%CSP) with a value of 1.6% which showed similar findings with other researchers [9, 10].

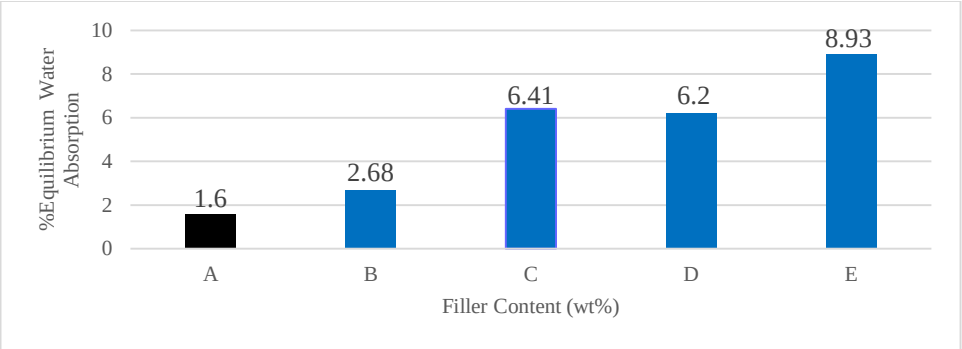

Figure 2. Variation of Equilibrium % Water Absorption with varying weight percentage of filler content (wt.%)

3.3 Hardness Property of neat polyester and the developed composite

Figure 3 below shows the variation of the hardness with the weight percent of filler loading. The hardness value of the composite at sample B (80 wt% UPR+ 10wt% GSP+10wt%CSP) with 10.0HV tends to increase more than the neat polyester matrix (sample A, 100% UPR) with hardness of 8.23HV value while the hardness value of the composite experienced a sudden decline as the weight fraction of the filler increases which might be attributed to absence of porosity, increased load transfer between the matrix and reinforcement thereby offering resistance against indentation, presence of refractory element such as Al_20_3, Fe_2O_3, SiO_2 e.t.c., as reported from existing literature [3, 8] and in congruent findings with existing literatures that continual rise in the percentage of filler in hybrid composite at some point lead to a decrease in hardness value [11].

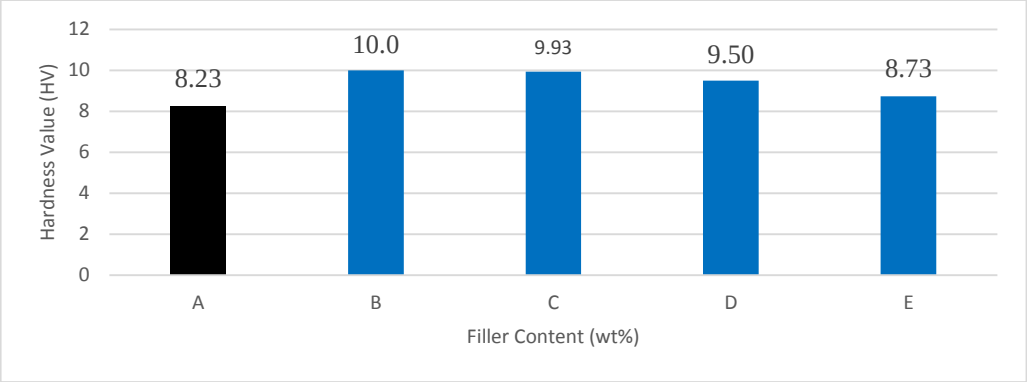

Figure 3. Variation of Hardness with filler content

3.4 Flexural Modulus of neat polyester and the developed hybrid composite

From the graph in Figure 4 below, it can be observed that the flexural strength increased at low filler content as shown in sample B (80wt% UPR+10wt%GSP+CSP) with an optimal value of 14552MPa which can be attributed possibly to high particle adhesion, high stiffness and slightly reduces as the weight percent of the filler content reduces but still within an acceptable limit above when compared to sample A (complete UPR) with 10895.4MP while further increase which might be attributed to uneven dispersion of the groundnut and coconut powder particles. This result is similar to previous work investigated by other researchers [1, 12].

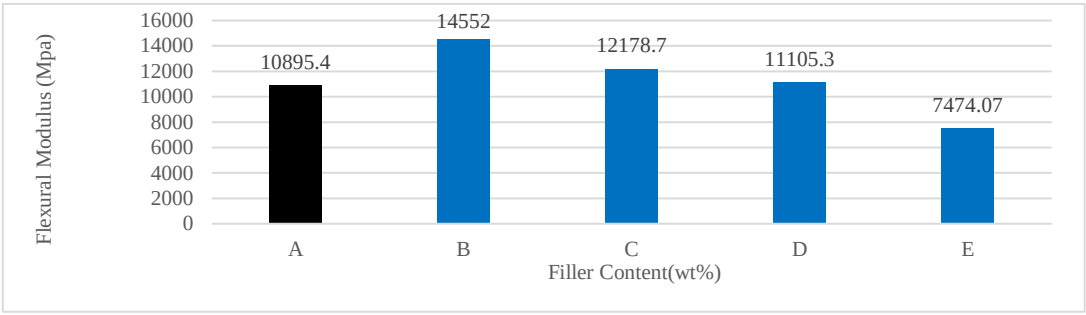

Figure 4. Variation of Flexural Modulus with filler content

3.5 Flexural Strength of neat polyester and developed hybrid composite

Figure 5. below shows the variation of flexural strength with filler content. The flexural strength of the composite increases linearly as the weight fraction increases up to sample C (60wt% UPR+20wt%GS+20wt%) when compared to the matrix material and decreases further with increase in the filler content which might be due to voids, shrinkages and weak interfacial bonding as the fillers increases which resulted to weak bending load carrying capacity by the polyester matrix which are similar to finding from existing literature [5,13].The highest flexural strength is observed at sample C with 24526.91MPa which is about 68.6% increase over sample A.

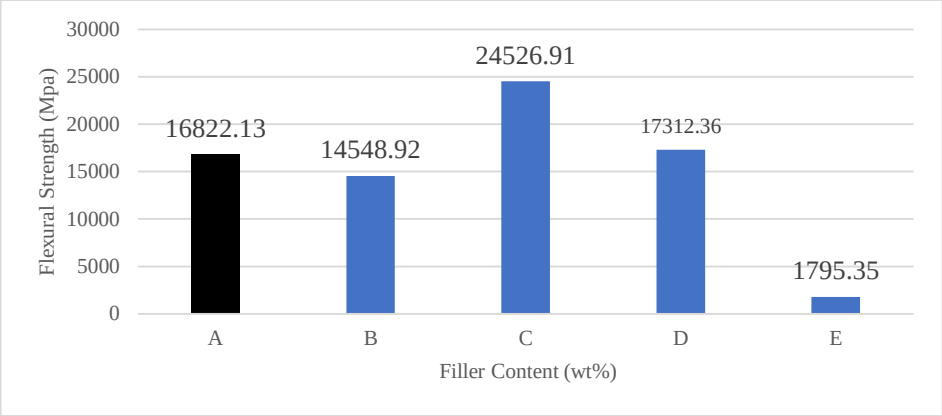

Figure 5. Variation of Flexural Strength with filler content

3.6 Tensile Strength of neat polyester and developed hybrid composite

Tensile strengths of lignocellulose particulate composites in Figure 6 decrease due to the irregularity in shape of fillers there by preventing uniform dispersion of fillers within the matrix leading to a decline in the tensile properties of the composite [14,15,16]. Tensile strength of the composite decreases as the filler particle increases blow the tensile of the complete matrix material, however, sample B shows a fair strength in comparison to other samples.

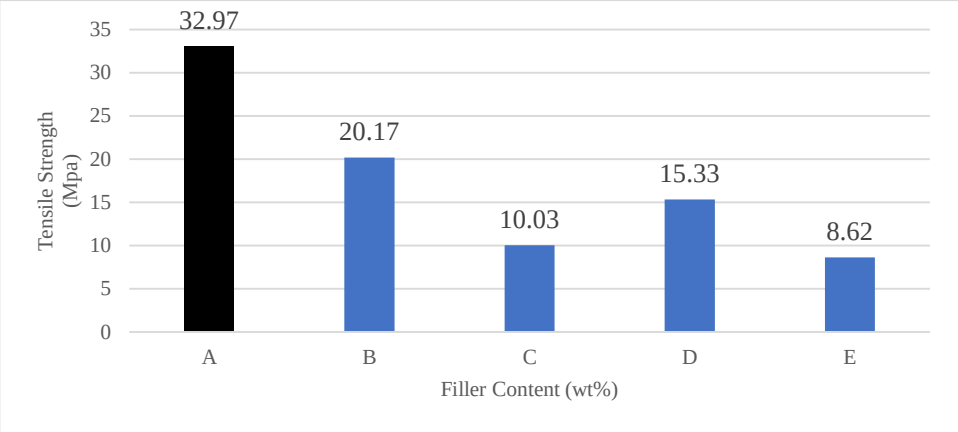

Figure 6. Variation of Tensile Strength with filler content

3.7 Percentage Elongation of neat polyester and developed hybrid composite

The effect of GSP and CSP on the composite when compared to the matrix material is shown in Figure 7 below. The percentage elongation at break tends have a highest value at sample B (80 wt% UPR+ 10wt% GSP+10wt% CSP) and sample E (20wt% UPR+10wt%GSP+10wt%CSP) with 5.97% and 5.78% respectively than sample A (100% polyester resin) with 5.72% which might be due to toughening effect leading to increase in materials resistance to cracking,, improved interfacial bonding, e.t.c. Percentage elongation at break tends to decreases at sample C (60wt%UPR +20wt.%GSP +20wt.% CSP) and sample D (40wt%UPR+30wt%GSP+30wt%CSP) below values of sample A with a percentage break of 5.39% and 5.25% respectively which might be due to poor interfacial bonding, high stress concentration point e.t.c., which are similar to findings from existing literature [17].

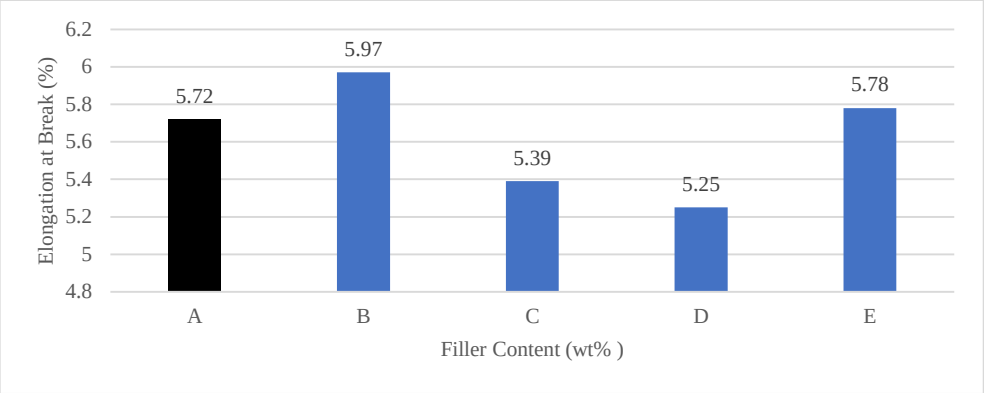

Figure 7. Variation of percentage elongation with filler content

3.8 Impact Strength of neat polyester and hybrid composite

The impact strength of the composite is shown in Fgure 8 below. It can the observed that the impact strength of the hybrid composite samples exhibit a slight increase of about 35% on addition of GSP and CSP to sample C (60wt%UPR+ 20wt% GSP+20wt%CSP) haven an impact strength of 0.23 KJ/m when compared to the sample A with complete polyester resin which might be due to increase in concentration energy, high particle to matrix adhesion while further addition in the filler content lead to a gradual decline in the impact strength of the composite which can be attributed to agglomeration, cracks, fracture e.t.c., which are similar to results from existing researchers [11, 18, 19].

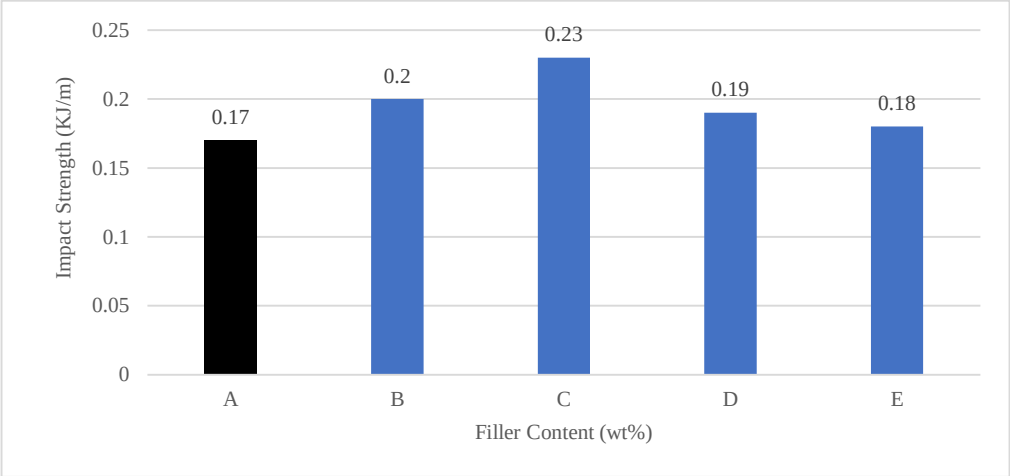

Figure 8. Variation of Impact Strength with filler content

3.9 X-Ray Fluorescence (XRF)

X-ray fluorescence analysis (XRF) was used to determine the elemental and chemical composition of coconut shell and groundnut shell particles. The result revealed the dominant oxide present in the filler as shown in Table 2 and Table 3 below. Silicon dioxide (SiO_2,29.58 % and 25.43%), Aluminum oxide (Al_2O_3,11.61% and 8.24%), Magnesium oxide (MgO, 3.25%) and potassium oxide (K_2O 5.40% and 13.23%), contributes to the rigidity, matrix to filler adhesion, hardness of the composite and also suggests that GSP and CSP could be used in ceramic matrix composites, refractory linings, and heat-resistant coatings [20]. The presence of metal oxides such as iron oxide (Fe_2O_3, 24.58% and 24.57%) suggest potential catalytic activity in redox reactions, pollutant degradation, and also enhances the toughness and hardness of polymer composite [20,21]. The presence of phosphorus pentoxide (P_2O_5 0.90% and 1.33%) and sulfur trioxide (SO_3, 5.61% and 4.43%) further supports its adsorption potential [20]. Trace amount of tantalum oxide (Ta_2O_5 ,0.24% and 0.07%) and copper oxide (CuO,0.928% and 0.54%) provide catalytic and

electrochemical properties, enabling hybrid composites with combined structural and functional capabilities [20]. Inaddition, titanium Oxide (TiO_2 ,0.85% and 1.23%) also exist in trace percentage with wide aerospace application for development of aircraft components and automotive coatings to prevent colour degradation [21]. The presence of Calcium oxide (CaO,14.00% and 12.37%) also suggest its application as filler in polymer composites to improve their mechanical properties, thermal stability and heat resistance [21]. Groudnutshell and coconut shell particles (Cl, 5.81% and 3.15%) shows the presence of chlorides which helps to improve the reactivity and microbial property of hybrid composite.

Table 2. Chemical composition of coconut shell particles

Chemical component	Concentration (%)
SiO_2	25.43
Fe_2O_3	24.58
SO_3	5.61
CaO	14.00
MgO	3.25
K_2O	5.40
Al_2O_3	11.61
Cl	5.81
P_2O_5	0.90
TiO_2	0.85
Ta_2O_5	0.24
CuO	0.928

Table 3. Chemical composition of groundnut shell particles

Chemical component	Concentration (%)
SiO_2	29.58
Fe_2O_3	24.57
SO_3	4.43
CaO	12.37
P_2O_5	1.33
K_2O	13.23
Al_2O_3	8.24
T_iO_2	1.23
Cl	3.15
Ta_2O_5	0.07
CuO	0.54

3.10 Thermal Properties of Groundnut shell/ coconut shell Polyester composite

Thermal Analysis was carried out using Dynamic Mechanical Analysis (DMA). Fig.9 to fig.23 show the DMA traces of groundnut/coconut shell polyester composite at different parameters showing the storage modulus (E´), loss modulus (E″), loss factor (tan δ) against temperature. The storage Modulus (E´) deals with the stiffness of the material, the Loss Modulus (E″) studies the viscous response of the material in relation to the energy dispersed in the composite material loss factor (tan δ) shows the equilibrium point between the rubbery and the plastic region which are mostly determine by the addition of fibers to the composite against temperature [22]. Figure 9 to Figure 13 shows DMA traces of storage modulus of sample A-E. Figure 9 revealed that sample A exhibits an initial high stiffness of approximately 240 MPa, with the peak recorded at 70.5 °C. The onset of thermal softening is observed at around 61.6 °C, indicating the beginning of the glass transition region where polymer chains gain mobility. The inflection point, located at 67.4 °C, represents the steepest rate of modulus reduction, revealing a rapid change in stiffness. Beyond

125–128 °C, E′ falls to approximately 8 MPa, the stiffness reduces due to relaxation in the molecular chains at elevated temperatures and reduced load-bearing capacity. Figure 10 shows that the storage modulus of the composite sample B decreases at onset of 71.0 °C – 76.2°C and the inflection point at 103.8°C – 105.6°C while further increase in temperature at peak value of 131.4°C – 132.9°C reveals a considerable increase in storable modulus from 84MPa – 105Mpa which suggests improved thermal stability compared to Sample A. Although the overall modulus is lower than the control, the delayed softening and sustained modulus in the high-temperature region indicate better retention of stiffness at elevated temperatures which restrict polymer chain movement and enhance the load-bearing capacity of the composite which are similar to findings carried out by existing researchers [22,23] while figure 11 shows that the storage modulus of sample C increases at onset of 41.9°C- 47.3°C and inflection 44.3°C-51.1°C while further increase at peak 56.2°C shows a storage modulus of 665Mpa and 654Mpa respectively , as the temperature increases the storage modulus decreases drastically up to 8Mpa at peak of 145.4°C.Figure 12-figure 13 shows that the storage modulus of the composite reduces as the temperature increases. Figure 12 shows that sample D occurs at onset of 86.0°C,88.2°C and 91.4 °C with an inflection temperature of 112.5°C,112.2°C and 110.3°C respectively which increases progressively approaching a peak temperature of 143.5°C, 19Mpa;142.6Mpa,16Mpa;145.1°C,17Mpa this same trend is observed at Figure13 for sample E showing a peak value of 117Mpa at 142.2°C,105Mpa at 143.6°C,94Mpa at 145.1°C respectively. Generally, studies have shown that the storage modulus of composite reduces as the temperature increases which may be attributed to relaxation process due to the glass transition, movement of molecular chains which reduces the stiffness of the composite, type of fillers or fiber used for the formulation of the composite and fiber, matrix interactions e.t.c., [24].

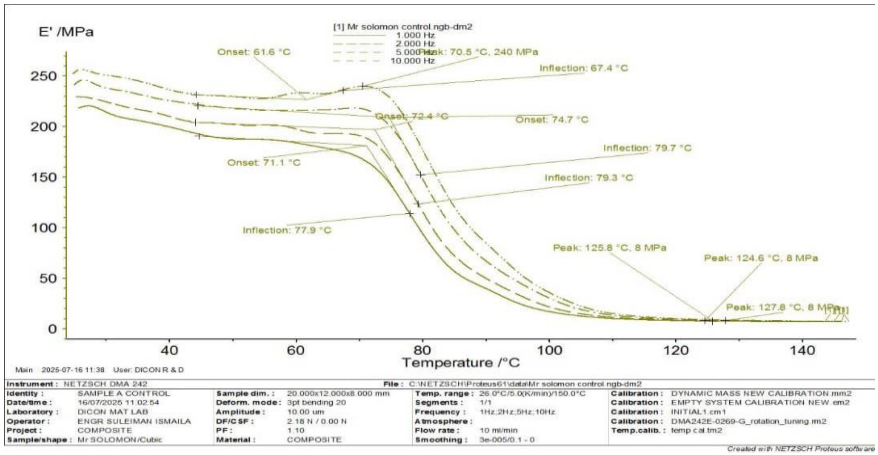

Figure 9. A graph showing DMA trace for the Storage Modulus (E'), against Temperature for Sample A

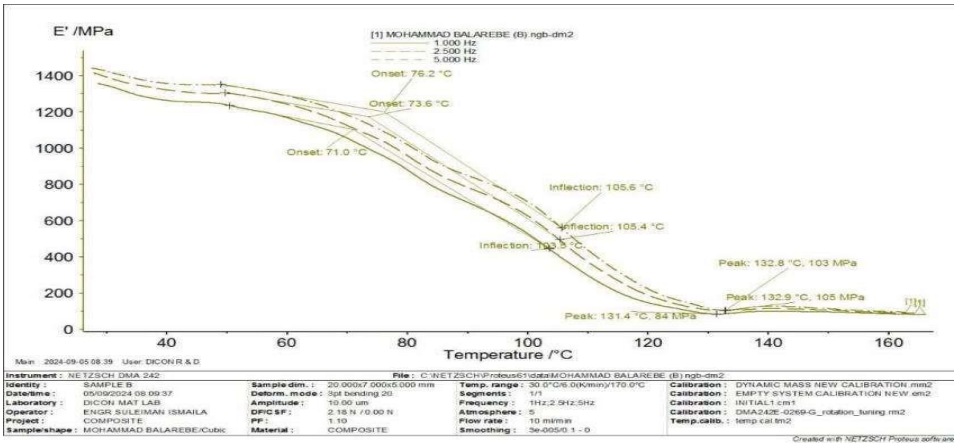

Figure 10. A graph showing DMA trace for the Storage Modulus (E'), against Temperature for Sample B

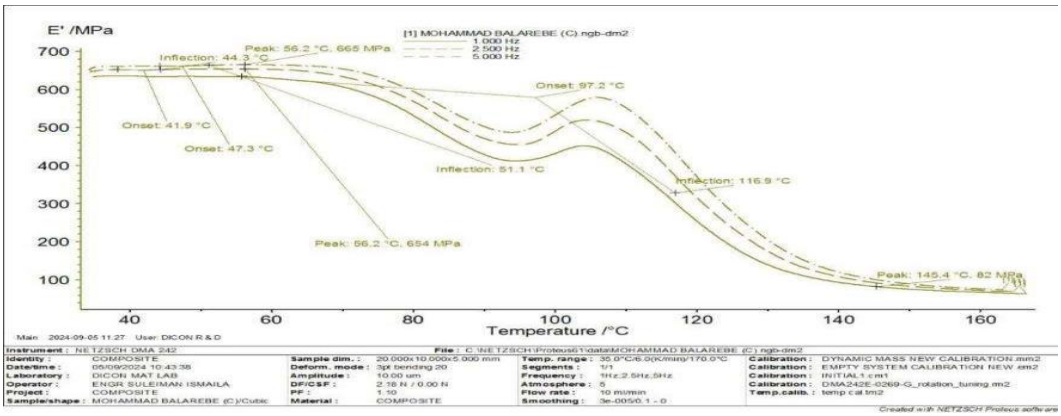

Figure 11. A graph showing DMA trace for storage modulus against temperature for Sample C

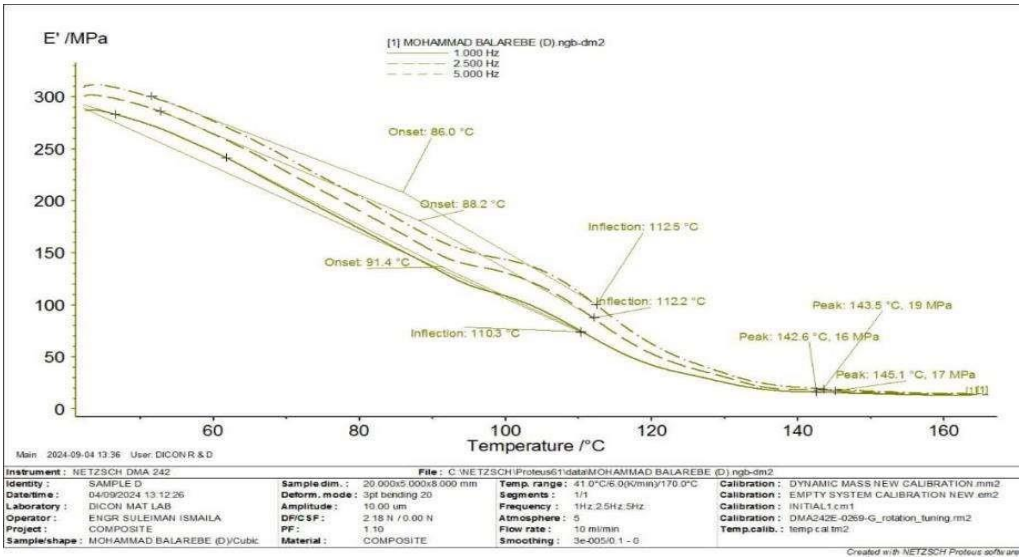

Figure 12. DMA trace for the storage modulus against temperature for Sample D

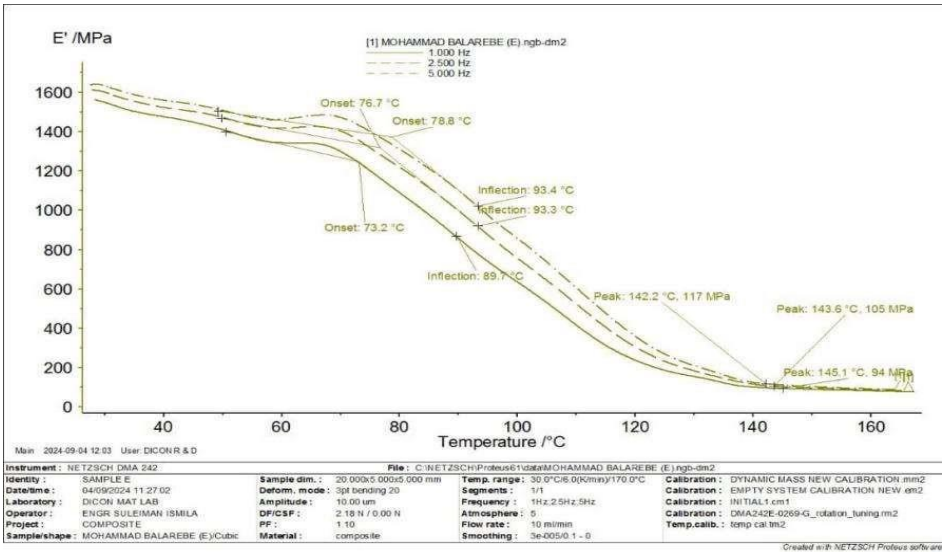

Figure 13. A graph showing DMA trace for the storage modulus against temperature for Sample E

Figure 14 below shows the loss modulus of the control sample A carried out at 1.0Hz, 2.00Hz, 5.00Hz and 10.00Hz while Figures 15-18 shows the loss modulus of the composite materials (sample B-sample E) at 1.00Hz,2.5Hz and 5.00Hz. Sample B-Sample E reveals that the loss modulus increased significantly above sample A. The loss modulus of the composite increased significantly above the control samples which shows likelihood of limited movement of the polymer chains within the composite leading to low energy dissipation however has the material reaches the glass transition temperature the molecular movement of the polymer chains increases resulting in high energy dissipation. In addition, each samples tends to broaden which might be due to some impediments in the relaxation process within the composite. The loss modulus of the composite increases at high temperature which implies that at high temperature the composite which contributed its improved mechanical properties which had showed similar findings with existing research work [24]. Sample A reveals loss modulus of 57Mpa at 74.4°C (peak), 75.2Mpa at 64°C (peak), 76Mpa at 76.3°C(peak) and 89Mpa at 77.0°C(peak) respectively. Sample B has a loss modulus of 208Mpa at 68.2°C (peak), 211Mpa at 61.8°C(peak), and 223Mpa at 100.3°C(peak) respectively. Sample C shows a loss modulus of 148Mpa at 107.7°C(peak), 167Mpa at 109°C (peak) and 185Mpa at 110.5°C (peak) respectively. Sample D showed a loss modulus of 41Mpa at 62.5°C(peak), 41Mpa at 67.0°C(peak), 3Mpa at 143.7°C and respectively. Sample E has a loss modulus of 267Mpa at 80.4°C (peak),274Mpa at 84.9°C (peak) and 285 Mpa at 91.0°C (peak) respectively.

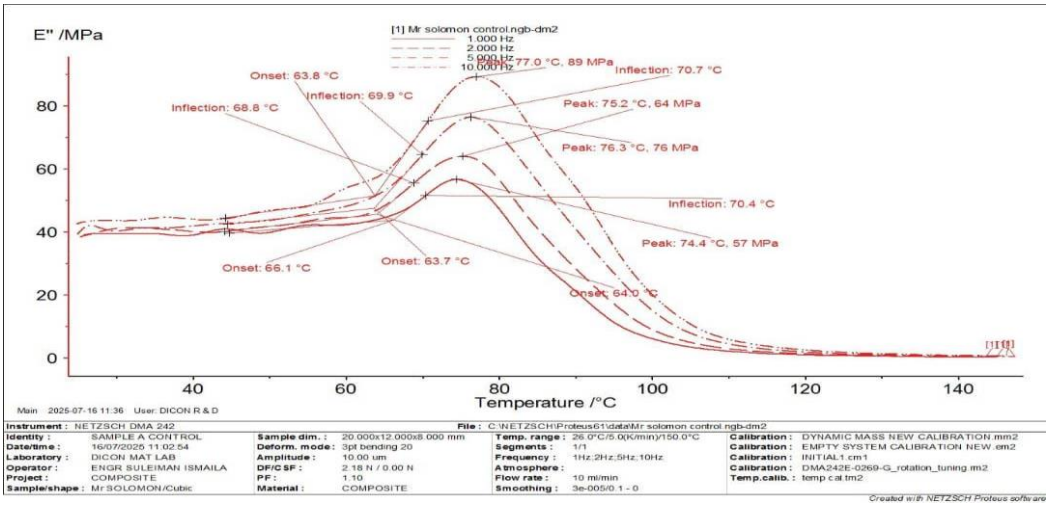

Figure 14. A graph showing DMA trace for the Loss Modulus (E'), against Temperature for Sample A

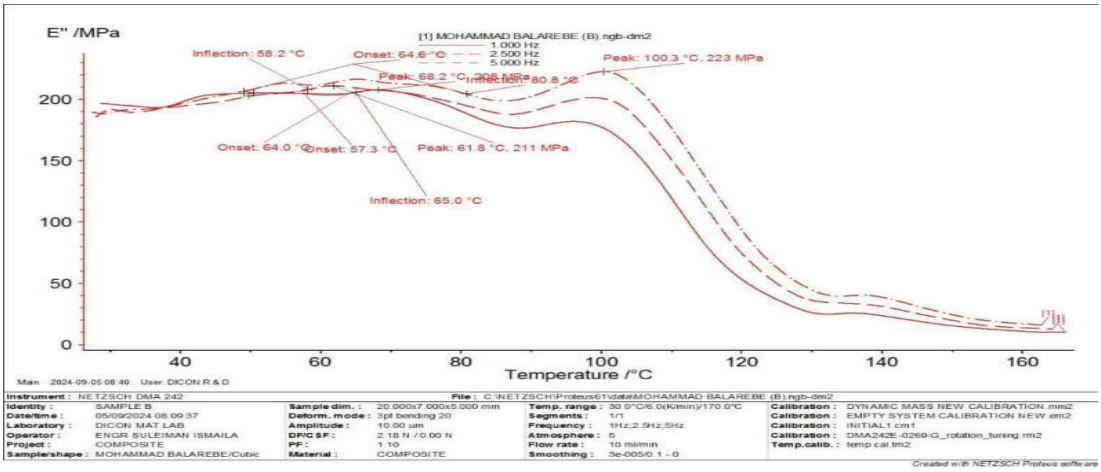

Figure 15. A graph showing DMA trace for the Loss Modulus (E''), against Temperature for Sample B

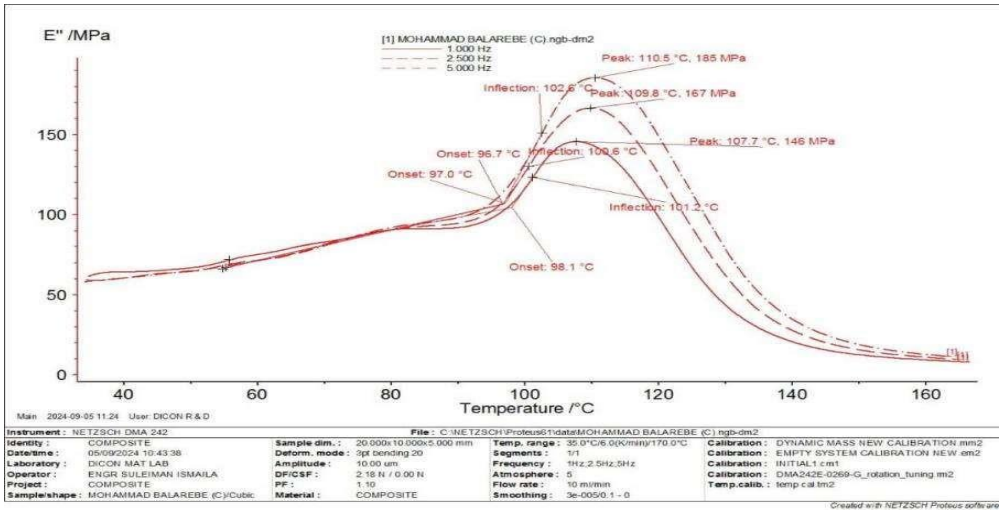

Figure 16. A graph showing DMA trace for the loss modulus against temperature for Sample C

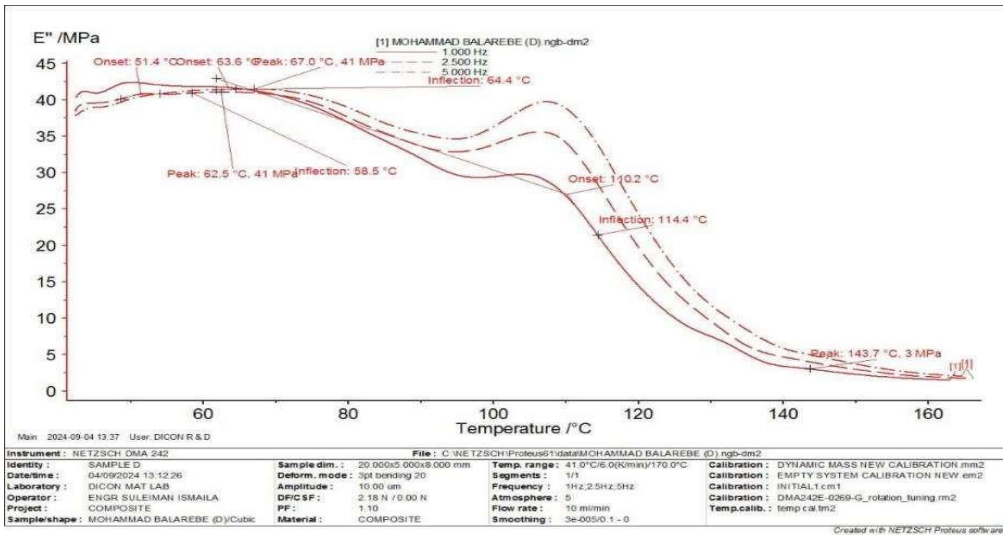

Figure 17. A graph showing DMA trace for the loss modulus against temperature for Sample D

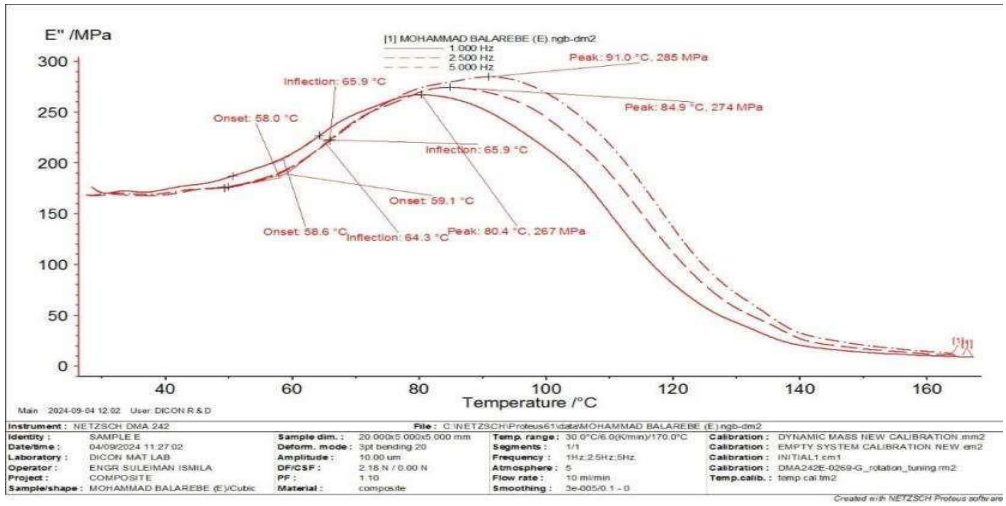

Figure 18. A graph showing DMA trace for the loss modulus against temperature for Sample E

Figure 19 to 23 below represents the loss factor (tan δ) of the control and composite samples carried out at 1.0Hz, 2.00Hz, 5.00Hz and 10.00Hz and 1.00Hz,2.5Hz and 5.00Hz respectively. The tan δ curve for Sample A shows a prominent peak at 0.643 at 91.7 °C (1 Hz), with slightly reduced values at higher frequencies: 0.610 (2 Hz), 0.577 (5 Hz), and 0.561 (10 Hz). A high tan δ value indicates greater damping capacity, which is typical for polymer matrices without fiber reinforcement. The high peak also confirms the occurrence of Tg within the 85–92 °C range, where the polymer transitions from a glassy to a rubbery state with increased energy dissipation. The loss factor for Sample B reveals low tan δ peak of 0.4023 at 110.5 °C, 0.415 at 113.8 °C, 0.425 at 117.1 °C which implies that the Tg is within 111°C -117.1°C. Sample C reveals peak value of 0.390 at 118.5 °C, 0.399 at 121.5°C,0.410 at 123.5°C with Tg between 119°C-124°C.Sample D reveals also a low loss factor of 0.362 at 113.2°C,0.379 at 116.7°C and 0.390 at 118.7°C with Tg within 113°C -119°C while sample E showed a loss factor of 0.380 at 110.6°C,0.381 at 118.1°C and 0.372 at 115.4°C with Tg. between 111°C -118°C.The loss factor reduces as the temperature increases when compared to the control sample which might be as a result of the filler preventing molecular motion and reduce energy loss in form of heat. Although damping capacity is lower than in Sample A, this behavior is beneficial for structural performance, as it signifies better stiffness retention and reduced viscous deformation.

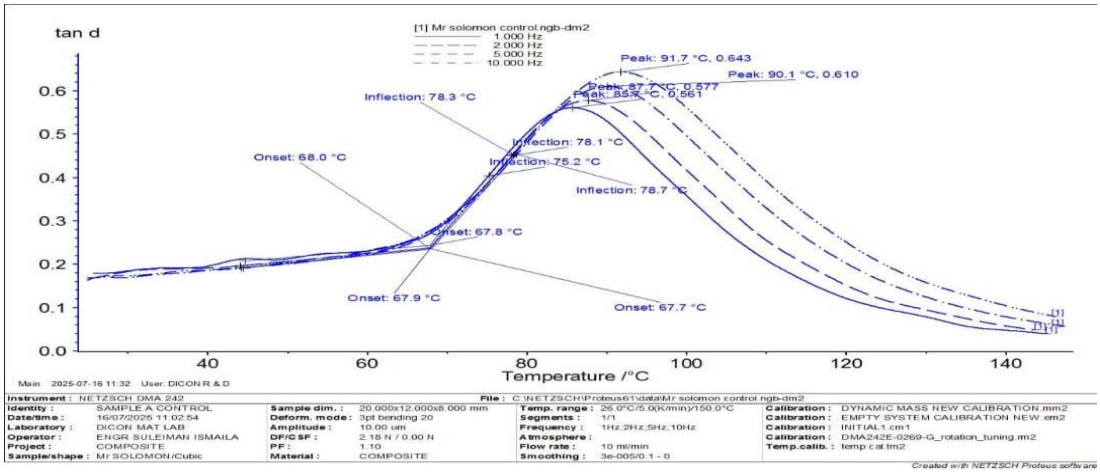

Figure 19. DMA trace for the Loss factor (tan δ) against Temperature for Sample A

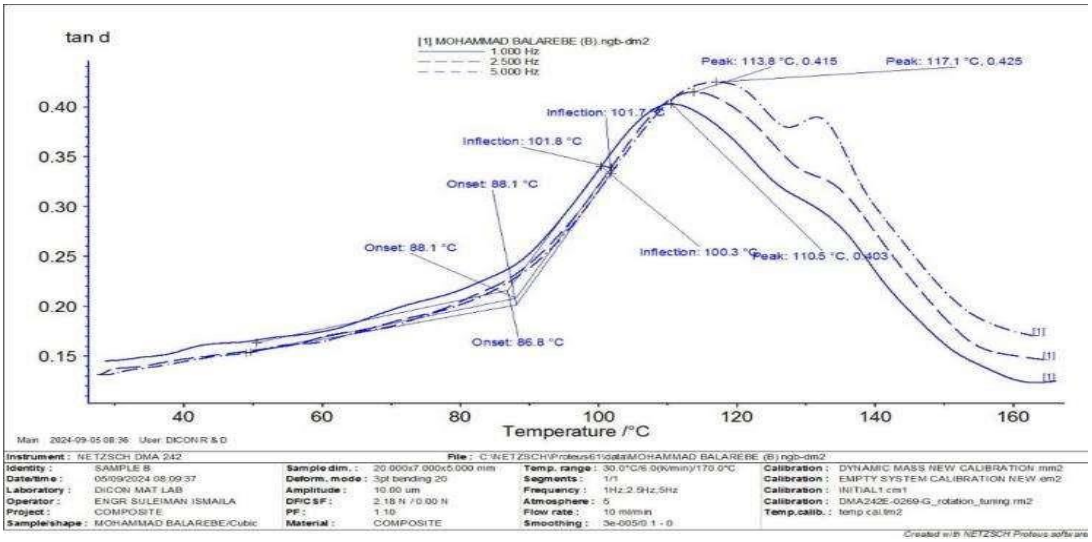

Figure 20. DMA trace for the Loss factor (tan δ) against Temperature for Sample B

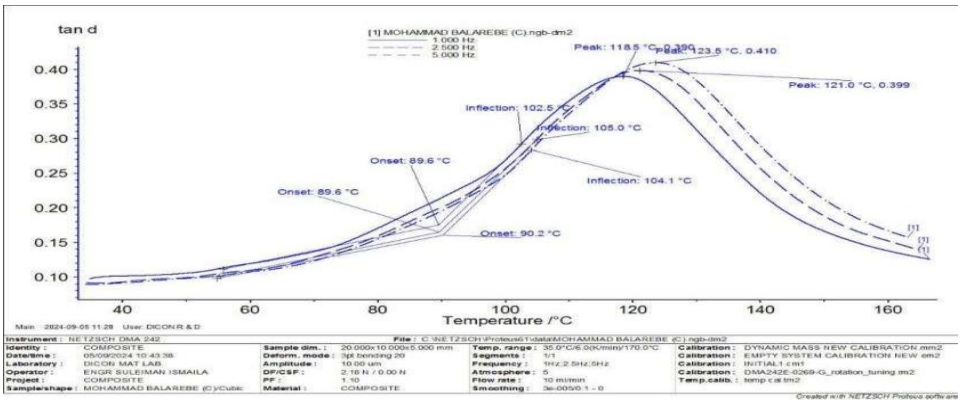

Figure 21. A graph showing DMA trace for the Loss factor (tan δ) against Temperature for Sample C

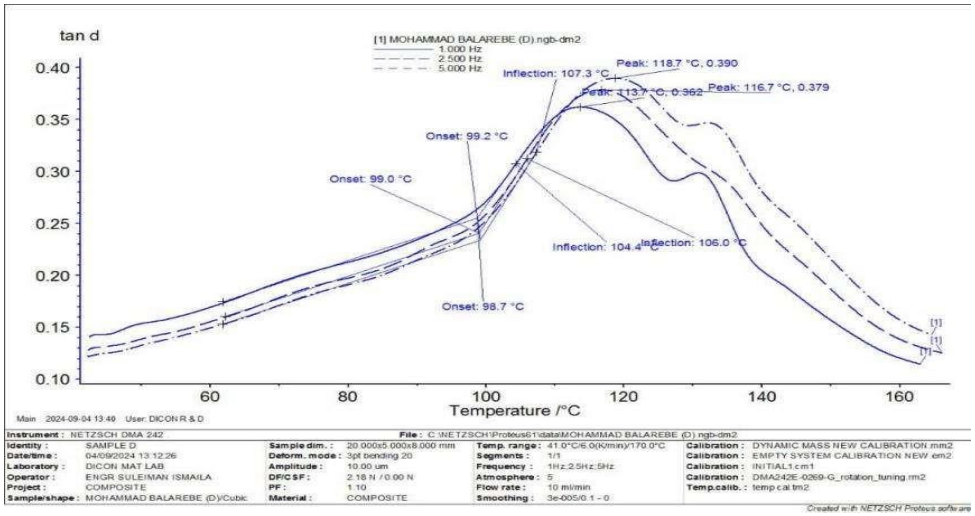

Figure 22. A graph showing DMA trace for the loss factor against temperature for Sample D

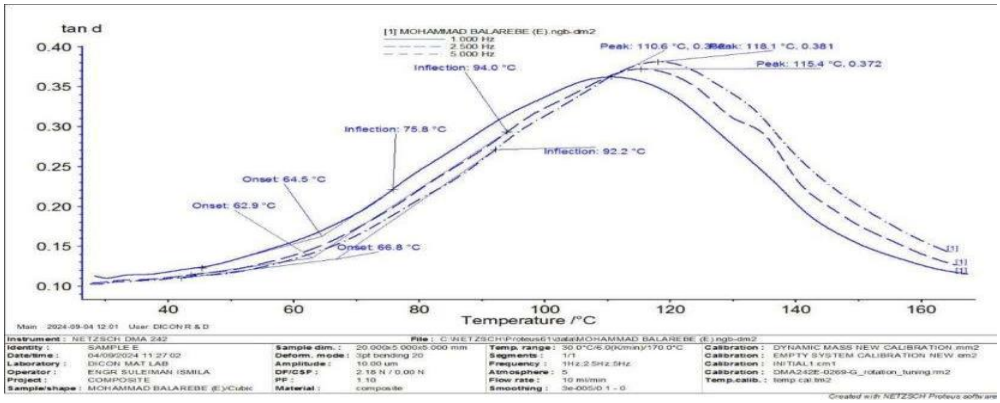

Figure 23. A graph showing DMA trace for the loss factor against temperature for Sample E

4 CONCLUSIONS

After a comprehensive investigative study on the absorption, mechanical and thermal behavior of groundnut /coconut shell particles polyester composite it can be concluded the application of groundnut and coconut shell for composite development is of great importance. Sample C with a value of 2.8g/cm^3 showed the best composition for density test while the water increases as the weight of the and further increases. The flexural test reveals that sample C also showed optimal result with a flexural strength of 24,526.91 MPa, which is a substantial improvement over the pure polyester sample with a flexural strength of

16,822.13 MPa while the flexural modulus shows an optimal value at sample B 14552MPa.The hardness value of the hybrid composite at Sample B has an optimal value of 37.30HV when compared to sample A with hardness value of 26.00Hv. Further increase in the filler loading lead to a decrease in hardness value of the composite. Impact strength of the composite increases with a corresponding increase in weight of the filler to Sample C while further increase lead to a gradual reduction in the impact strength of the composite. The tensile strength of the hybrid composite tends to decrease below the unreinforced matrix as the weight percent of the filler increases. The percentage elongation at break showed that Sample B and Sample E have an optimal value of 5.97% and 5.78% respectively. Hence, the fabricated hybrid composites can be recommended as a promising material for engineering application where hardness, impact strength and flexural strength is required. The Dynamic Mechanical Analysis of the composite demonstrated that Sample 'C' experienced a storage modulus of 654Mpa-665Mpa 41.9°C- 47.3°C at 665Mpa and 654Mpa, Sample 'C' with a loss modulus of 267Mpa – 285Mpa at 80°C - 91.0°C and Sample C reveals a loss factor (tan δ) of 0.390 – 0.399 and a glass transition temperature (Tg) at 119 °C-124°C approximately.

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