A STUDY ON THE DYNAMIC MECHANICAL PROPERTIES OF RECYCLED POLYPROPYLENE FILLED GROUNDNUT FILLER COMPOSITE

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ABSTRACT

The recycled polypropylene groundnut filler composite was prepared with the aid of the two-roll and compression moulding machines. Tensile strength/elastic modulus/elongation at break tests and dynamic mechanical analysis tests were done on the material. The obtained results showed that the sample without groundnut filler gave a better tensile strength of 33.33 N/M^2 when compared with composite compositions of 95/5, 90/10 and 85/15 that had low tensile strength results of 23.73 N/M^2, 22N/M^2 and 24.93N/M^2 respectively. The elastic modulus control sample was 43.11N/M^2, and this was also higher than the compositions with groundnut filler which recorded 27.72 N/M^2, 24.33 N/M^2 and 32.96 N/M^2 respectively. The sample without filler had high elongation at a break of 179.16 % and less elongation at a break of 95.21 %, 74.03 % and 66.49 %. The Storage modulus of the sample without groundnut filler at 10 Hz was 1500 Mpa at onset transition temperatures of 48.2 ^{0}C and 51.8 ^{0}C. The increase of thermal energy to a temperature of 114 ^{0}C decreased the storage modulus to 200 Mpa at 2 HZ. The matrix/filler compositions of 80/20 and 75/25 recorded a storage modulus of 880 Mpa and 1300 Mpa at 5 Hz. The control sample (sample without groundnut filler) recorded a loss modulus of 157 Mpa and this decreased to 127 Mpa and 83 Mpa at 10 Hz for the 80/20 and 75/25 matrix/filler compositions. The damping factor at 100/0 was 0.196 while the 80/20 and 75/25 showed damping coefficients of 0.205 and 0.200 respectively. The material can, therefore, be utilized at a higher damping coefficient of 0.205.

Keywords: Reinforced-polypropylene, Groundnut filler, Tensile-strength, Thermal-energy,

1. INTRODUCTION

The importance of particulate fillers used for polymer processing cannot be overemphasized. Natural fibres are readily available, environmentally friendly, cheap and biodegradable (Jacob *et al*., 2019). Polypropylene has wide applications in the polymer and textile industries. The polymers can also be recycled. The recycled polypropylene deteriorates very fast as a result of recycling (Khanam *et al*., 2015). The current agricultural initiatives of the Nigerian government will increase the production of groundnut. This plan is part of a holistic diversification drive in the face of the plummeting crude oil price (Usman *et al*., 2016). This work was limited to studying the mechanical and viscoelastic properties of recycled polypropylene-filled groundnut shell filler. Dynamic mechanical analysis is an effective method to analyze the correctness of reinforcement in composites. The influence of the filler addition on storage modulus, loss modulus and tan delta were checked through dynamic mechanical analysis (*Et al*., 2014) and Palanivel et al., 2017). When hydrophilic organic fibre`s are added in a thermoplastic polymer, the mechanical properties of the composites can undergo biodegradation if they are thrown away (Ibe *et al*., 2019). Due to natural fibre`s availability, light weight and corrosion resistance, manufacturing industries now have given much consideration using natural fibre-reinforced composites (Usman *et al*., 2016). Biocomposites can be used in the development of structures like amours, buildings, automotive, fishing and sports equipment (Ilyas *et al*., 2021).

2. METHODOLOGY

The groundnut shells were sourced at Zaria, Kaduna State Nigeria. Recycled polypropylene (RPP) was purchased at Kano, Nigeria. The groundnut shells were washed with very well with water and allowed under the sun to dry for three for three days. The Premier food grinding machine model number: PG-503 was used to grind and reduce the groundnut shells to powdered particles. The ground filler was sieved with 180 μm sieve size and treated with 5 % sodium hydroxide solution by dissolving 100 g of sodium solution in 2000 cm^3 of distilled water. 100 g dilute hydrochloric acid was used to remove excess NaoH that would have adhered to the surface of the filler. The filler was finally washed again severally with water, dried at oven temperature of 70 ^{0}C (Shanmugam *et al*., 2013). Two-roll mill with model number: XH-401 CE and Compression molding machine model number: FCP-30 were used to compound and compress the six compositions of the fillers and the matrices. The tensile strength of the various compositions of the composites was done with the Electronic Universal testing machine (EUTM) model number: WDW-100KN. The characterization was done following the American standard testing method (ASTM D 638). Test samples were cut to dumbbell sizes and each of the samples was separately held securely in the upper and lower wedge grips of the machine. Tensile strength, elongation at the break and elastic modulus of each of the samples was recorded when the materials attained their breaking points.

Table 1: FORMULATION TABLE FOR COMPOUNDING AT VARIOUS RATIOS

S/N	SAMPLES OF COMPOSITE	RPP (g)	FILLERS (g)
1.	A	100	0
2.	B	95	5
3.	C	90	10
4.	D	85	15
5.	E	80	20
6.	F	75	25

3. RESULTS AND DISCUSSION

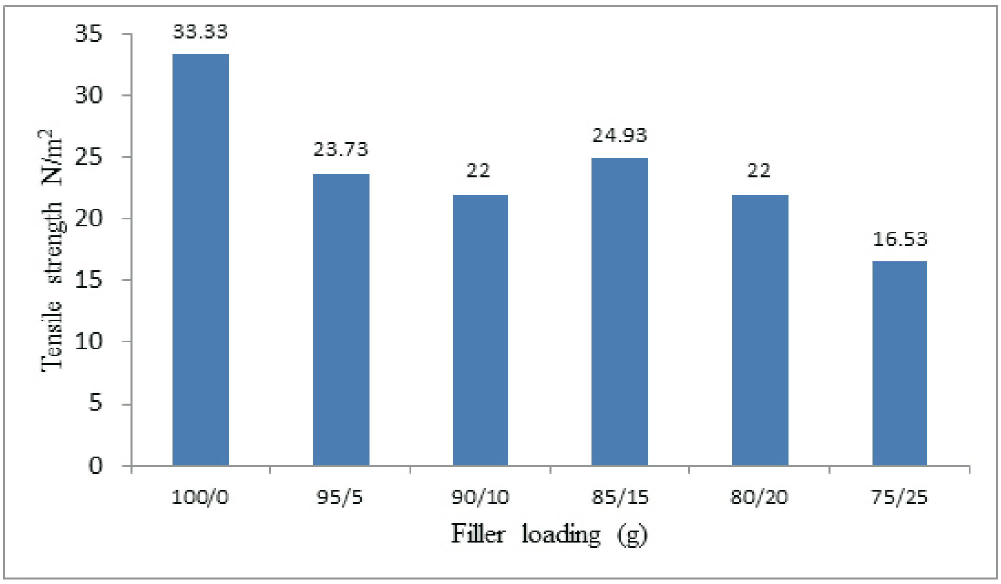


Figure 1: The Tensile Test Results on Filler Loading.

The tensile strength of the polymer material without filler was 33.33 N/mm^2. It was observed that when 5 % groundnut filler was added to the matrix, the tensile strength reduced to 23.73 N/mm^2 and further when 10 g of groundnut filler was added to 90 g reinforced polypropylene, the tensile strength decreased to 22.00 N/mm^2. Further loading of 15 g groundnut filler to 85 g reinforced polypropylene increased the tensile strength to 24.93 N/mm^2. When 20 g of groundnut filler was added to 80 g reinforced polypropylene, the tensile strength reduced to 22 N/mm^2. The tensile strength finally decreased to 16.53 N/mm^2 when 25 g of groundnut filler was incorporated into the matrix. These reports are in line with the works done by (Joseph *et al*., 2012 and Rahman *et al*., 2018).

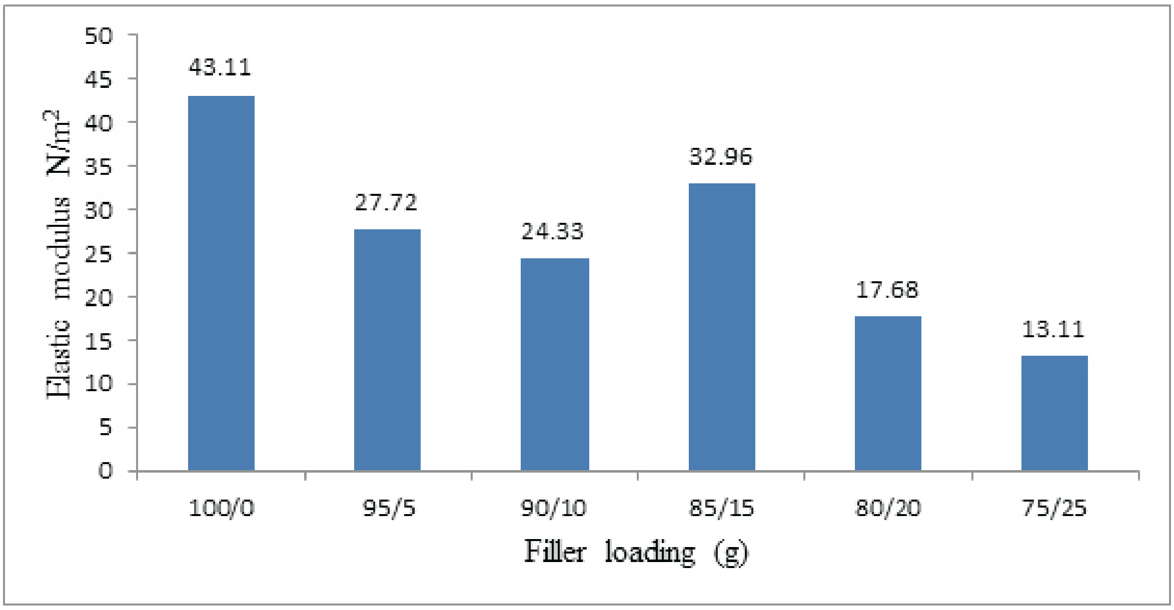
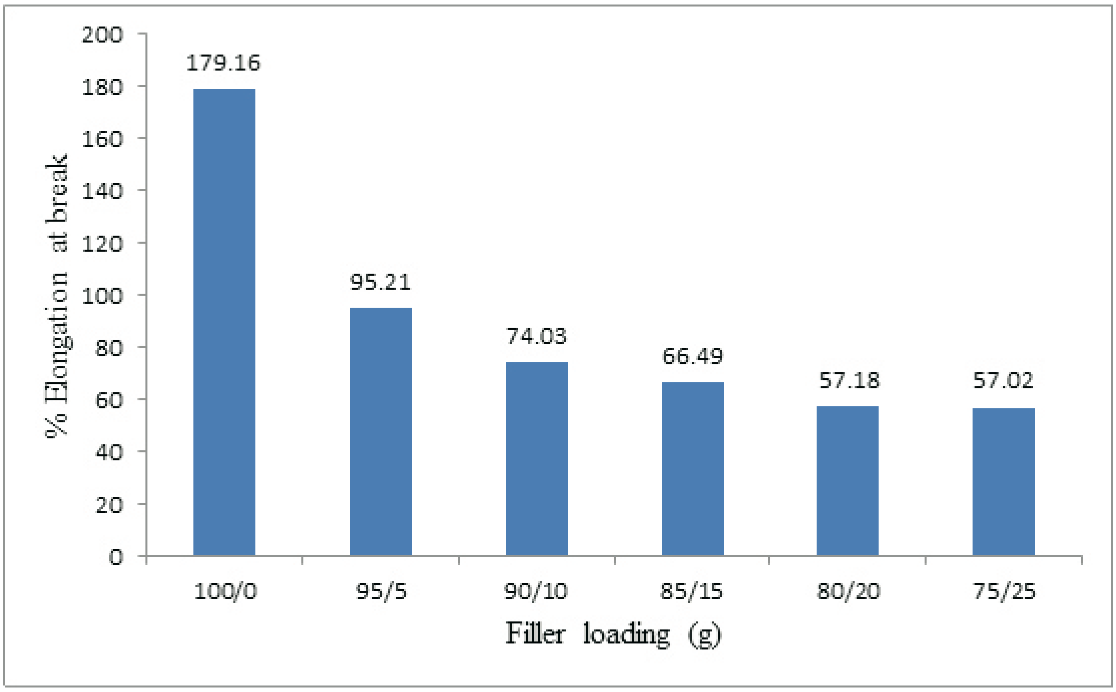


Figure 2: The effect of filler loading on elastic modulus.

The elastic modulus of recycled PP (sample A) increased with the zero addition of groundnut shell powder to 43.11N/mm^2. The 75/25 g of the composite recorded the least elastic modulus of 13.11 N/mm^2. This was a result of poor interfacial contact between the filler and the matrix.



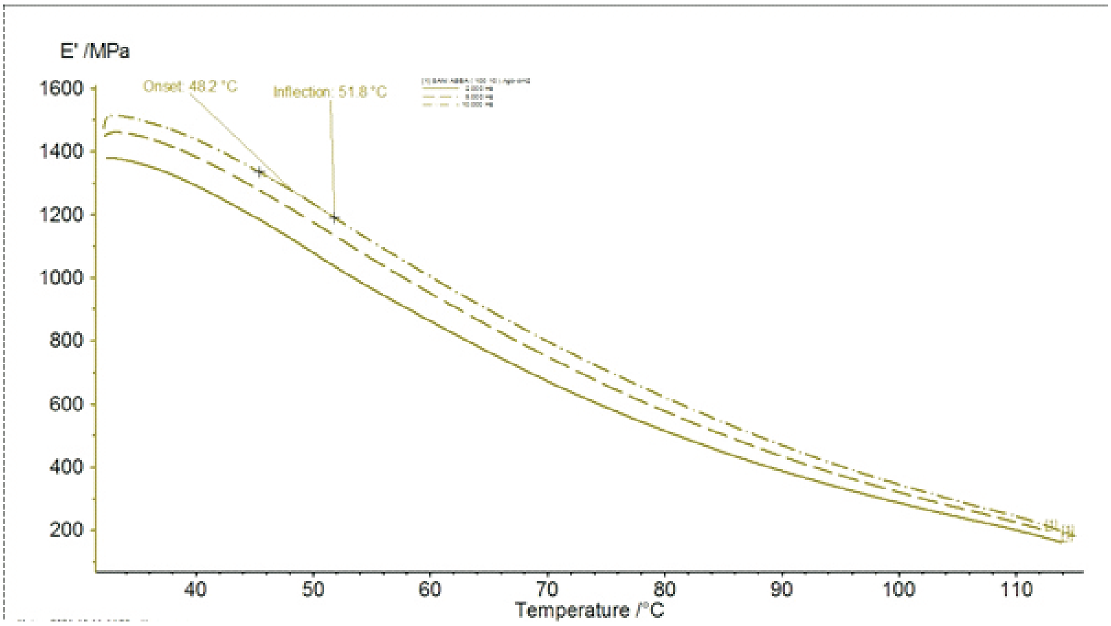


Figure 4: The Storage Modulus/Temperature plots of material without filler (100/0).

When the composite material was heated, it gains thermal energy. The material was subjected to thermal energy at a frequency of 2 Hz at operational temperatures of 10 ^{0}C to 110 ^{0}C. At a storage modulus of 1500 Mpa, the material was in its glassy state. An increase in the thermal energy of the material caused an increase in free volumes of the molecular chains. Therefore, at 48.2^{0}C, there was an increase in flow of polymer molecules. The free volume was high in the rubbery state and higher in the liquid regions of the composite material. However, a reduction in temperature would reduce the amount of thermal energy available for molecular motion. This happened at the glassy state of the composite material (Robert and Peter, 2011).Therefore, at 48.2 ^{0}C, the composite material reached its rubbery state and in this state, there was an increase in flow of Polymer molecules. The material retained its rubbery state from 48.2 ^{0}C to 51.8 ^{0}C. At temperatures above the glass transition zones, there was decline in the storage modulus from 1300 Mpa to 200 Mpa. At storage modulus of 200 Mpa, the material got to its terminal stage. This was in line with the work carried out by (Gupta, 2018).

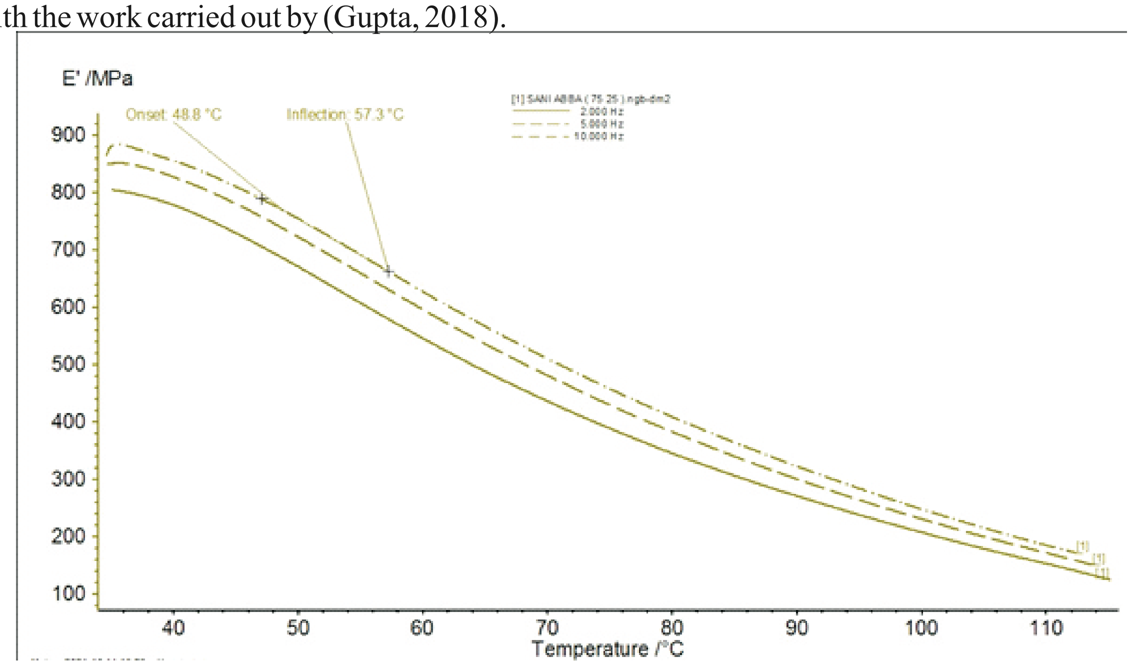


Figure 5: The Storage Modulus of GSP Reinforced RPP Composites (80/20) Composition.

Incorporation of 20g of groundnut filler in the 80 g matrix caused a further decrease in storage modulus of the composite. At the glass transition region of 48.8 ^{0}C and a frequency of 2 Hz, the storage modulus was 900 Mpa. The storage modulus decreased more when the material deviated from the transition region. A fall in value of the energy absorbed by the composite was due to a rise in the mobility of the chain molecules above glass transition zones. Therefore, there was a decline in the rate at which the material absorbed thermal heat energy.

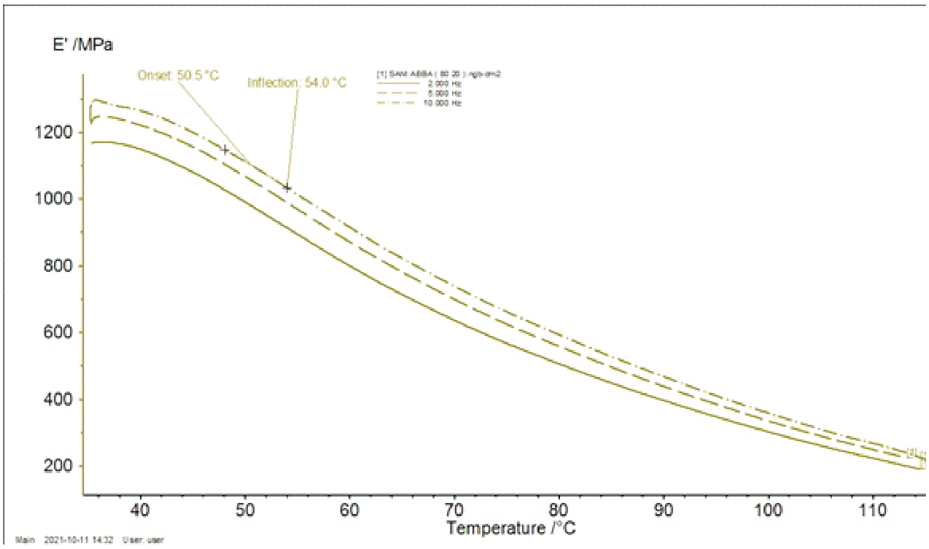


Figure 6: The storage modulus of GSP-Reinforced RPP composites (75/25)

It was observed that increase in the filler percentage on the matrix, reduced the storage modulus more and more, although the decline in the storage modulus was less than that in 80/20 matrix/filler addition. The increase in the filler loading blocked more pores in the filler/matrix interface, thus increasing the rate of heat absorption by the polymer composite. The storage modulus, reduced from 1100 Mpa to 200 Mpa. The glass transition temperature of 50.5 ^{0}C for the composition showed at the frequency of 5Hz at a storage modulus of 1100 Mpa. The 50.5 ^{0}C is the onset temperature which is the temperature at which the polymer can be used. The introduction of more heat energy on the composite at frequencies of 2 Hz, 5 Hz and 10 Hz led to a decrease of the storage modulus to 200 Mpa at a frequency of 5 Hz. This decline in the storage modulus was reported by (Jacob *et al*., 2018) ; (Palavinelet *et al* ., 2017) and (Zhang *et al.,* 2017) ; (Paiva &Frollini, 2016).

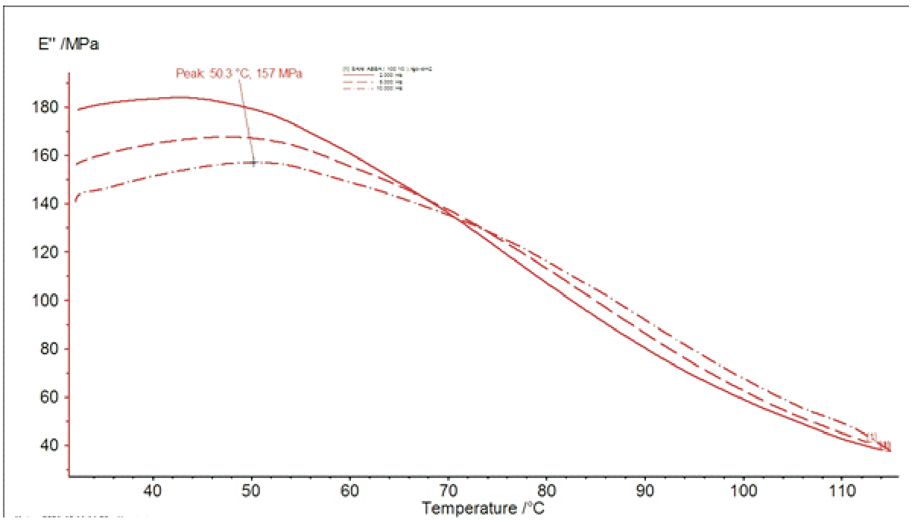


Figure 7: The Loss Modulus with Temperature of Unreinforced Composite (100/0) at Frequencies of 2, 5 and 10 Hz respectively.

The amount of heat energy dissipated from the material is the loss modulus. The glass transition of 50.3 ^{0}C was attained by the composite at loss modulus of 157 Mpa at 10 Hz. This was in line with the work reported by (Zhang *et al.,* 2017).

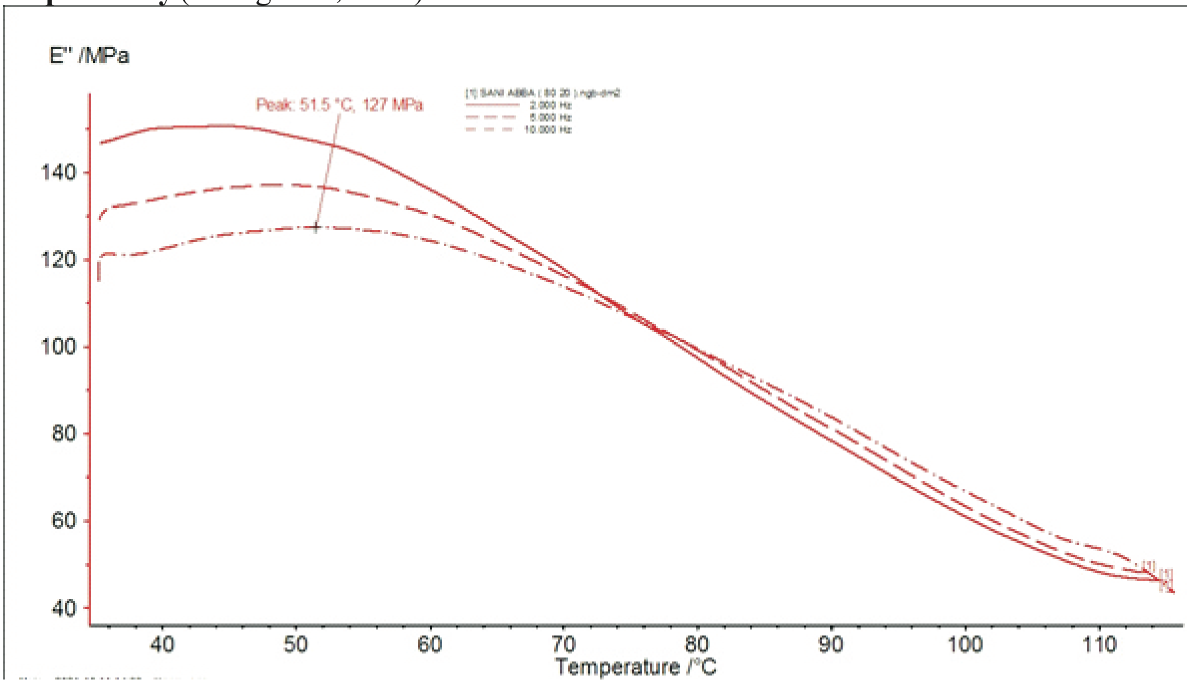


Figure 8: The Loss Modulus/Temperature of Reinforced RPP/Groundnut filler Composites at (80/20) g Compositon.

The energy dissipated by the polymer composite due to the application of thermal heat is the loss modulus. 127 Mpa was the amount of energy dissipated (loss modulus) at a peak transition temperature of 51.5 ^{0} C and this was recorded at a frequency of 10 Hz. An increase in the temperature of the system caused a decline in the loss modulus from 120 Mpa to 40 Mpa.

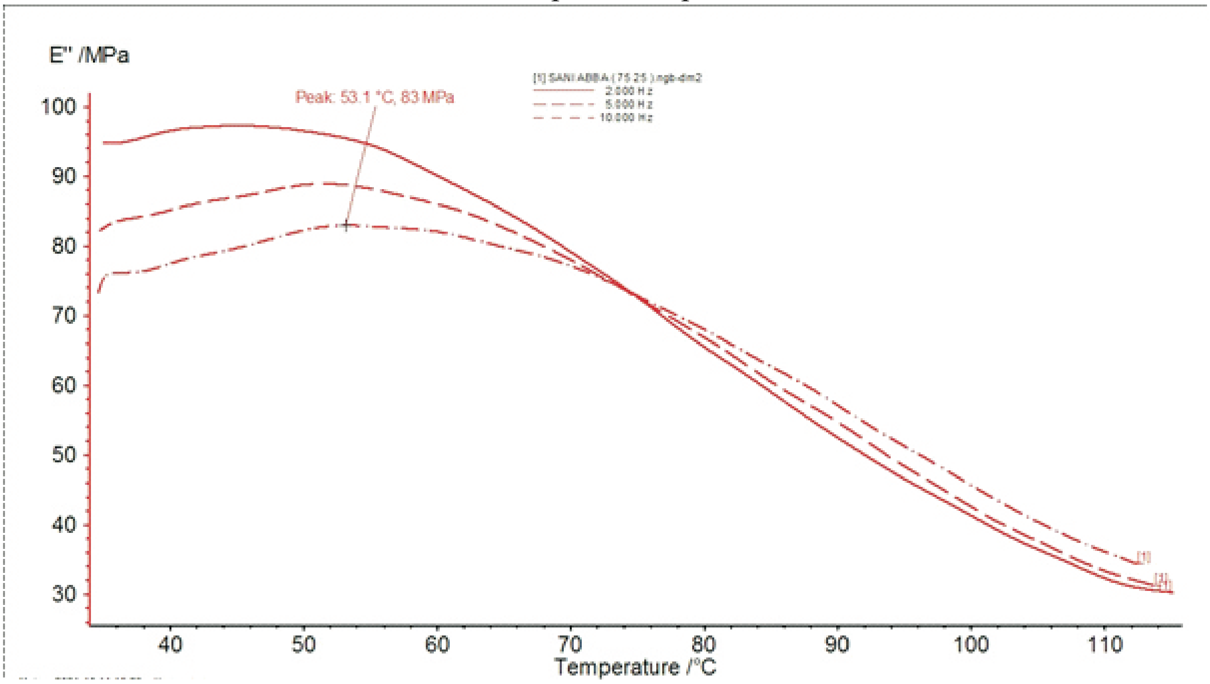


Figure 9: The Variation of Loss Modulus with Temperature of GSP Reinforced RPP Composite (75/25) at 10 Hz.

In the figure above, there was a reduction in the heat dissipated by the composite sample from 100 Mpa to 74 Mpa at frequencies of 2 Hz, 5 Hz and 10 Hz respectively. The energy that was dissipated from the material reduced to 30 Mpa when more heat energy was introduced on the polymer composite.

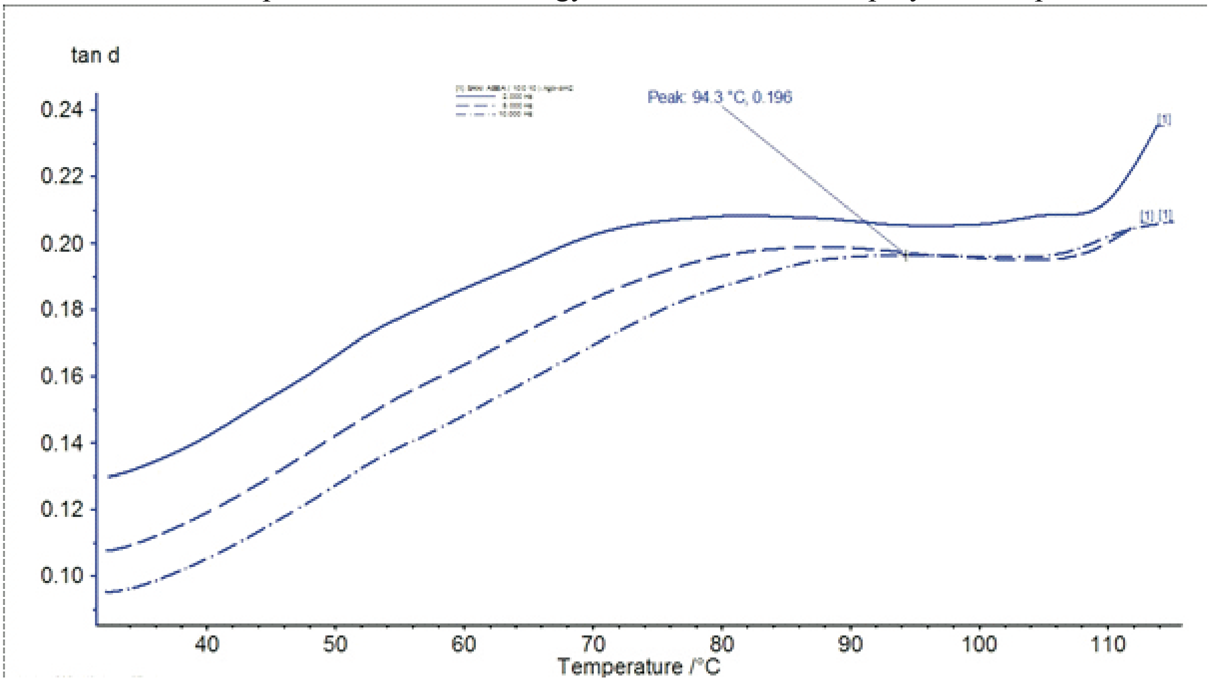


Figure 10: Tan D with Temperature of Unreinforced Sample (100/0).

The damping factor for the matrix at 10 Hz was found at 0.196 a temperature of 94.3 ^{0}C. The damping coefficient improved to 0.23 when the material rose to a temperature of 110 ^{0}C.

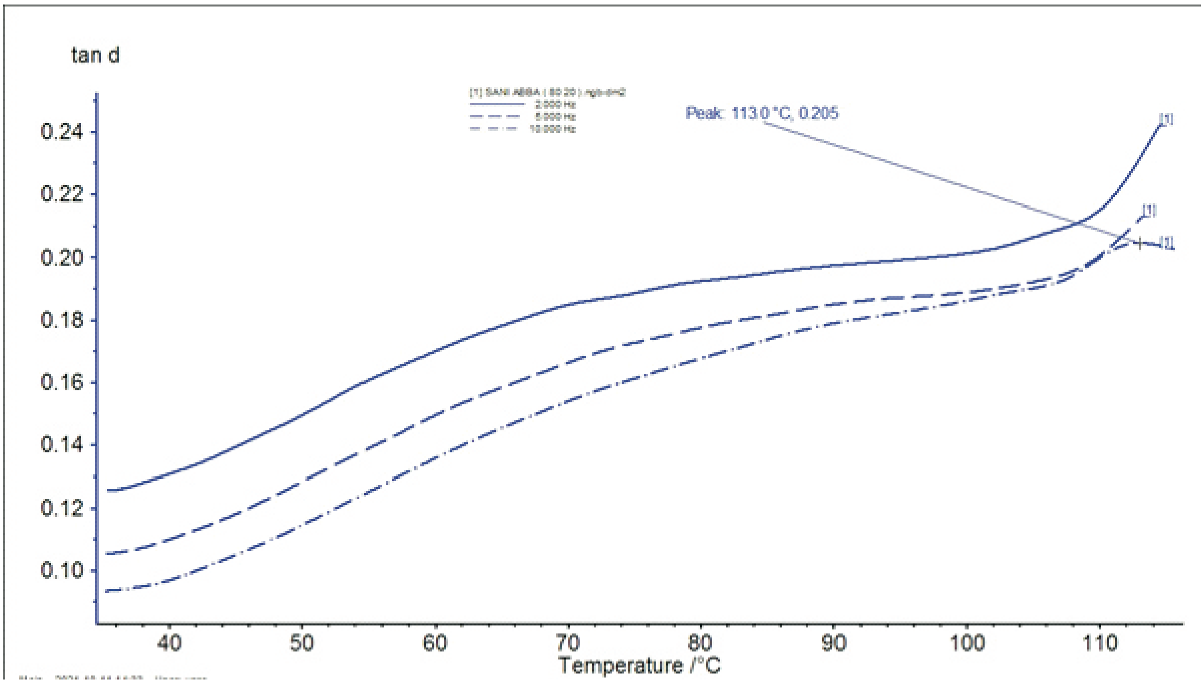


Figure 11: The Tan d with Temperature of Reinforced Sample (80/20)

When groundnut shell filler was incorporated into the matrix, the glass transition temperature increased to 113 ^{0}C and also the damping coefficient increased to 0.205.

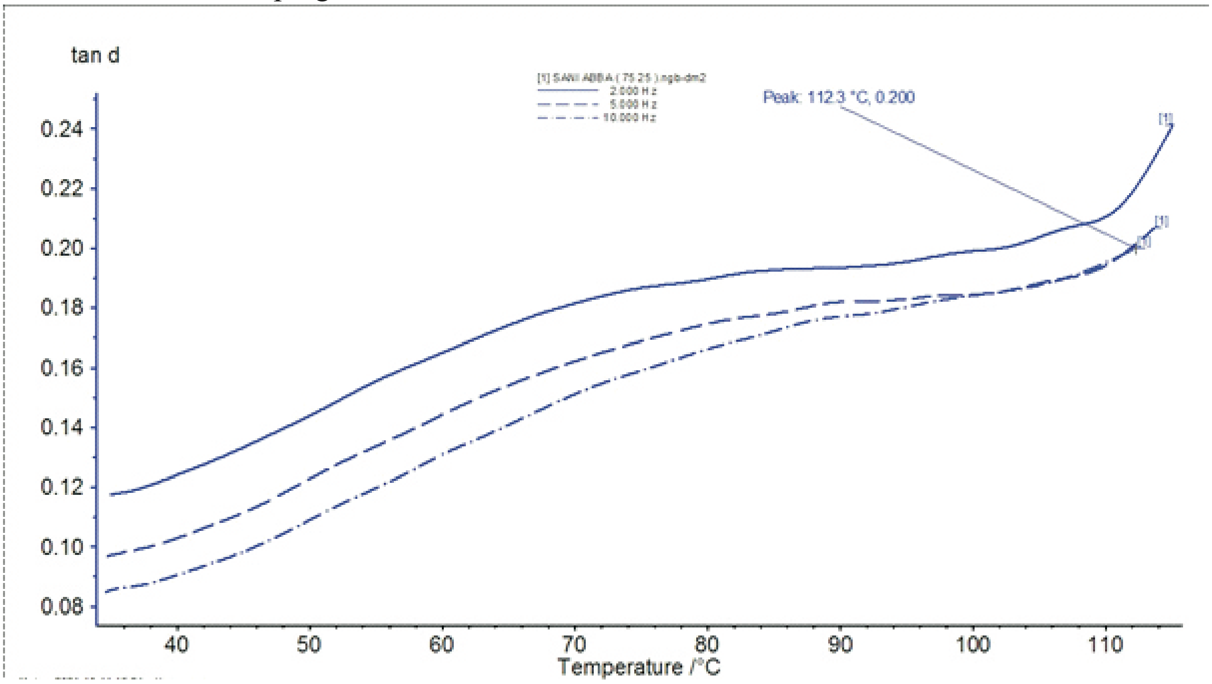


Figure 12: Tan d/Temperature Plots of 75/25 Composition.

The damping factor reduced a little bit to 0.200 with an increase in the filler loading. It has also been established in the literature that the lower the damping factor, the more efficient the material can be used for an insulator. The 100/0 which is the control sample showed a good damping and this was an indication that the control sample had high load bearing capabilities. This was in line with the work done by (Jacob, 2023)

5. CONCLUSION:

The following conclusions were drawn from the results of this work:

1. Higher tensile strength of 33.33 Mpa and elastic modulus/elongation at the break of 43.11 %/179.16 % was recorded for the control samples and the ductility of the materials decreased drastically as follows 95.21 %, 74.03 %, 66.49 %, 57.18 % and 57.02 % with the addition of groundnut shell filler. The same trend happened in the tensile strength and elastic modulus.

2. Addition of fillers into the matrix elevated the glass transition temperature to 112 ^{0}C and 113 ^{0}C.

3. Inclusion of filler restricted the dissipation of much energy (loss modulus) from the material leading to a reduction of the glass transition temperature from 53.1 ^{0}C to 51.5 ^{0}C

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