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Dynamic Mechanical Analysis of *Irvengia Gabonensis* Shell Particles Reinforced Polypropylene Composite

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***Abstract**: Heat generated as a result of friction and dynamic loads on automobile components affects the performance and life of the components. Dynamic mechanical analysis (DMA) is a versatile technique that provides information on loss modulus, storage modulus and the damping behavior of material under dynamic loading condition as a function of temperature and frequency. Most of the components used in automobile are subjected to heat and some dynamic loads; hence it is pertinent to conduct a study for determining their relevant stiffness and damping characteristics for intended purposes. Dynamic mechanical analysis of Irvengia gabonensis shell particles was conducted it was found that Composites with fiber composition of 20/80 wt. % exhibit the highest storage modulus and loss modulus both at low and high temperature up to 92.1º C. This shows that the composite of 20/80 wt. % Irvengia gabonenesis shell particle and polypropylene has the highest thermal stability load bearing capacity. As for the loss modulus composite containing 10/90 and 20/80 wt. % shell particles and polypropylene have almost the same loss modulus. Damping unlike storage modulus is inversely proportional to frequency in all the three compositions of shell particles and the polypropylene.*

***Keywords:** Shell, Polypropylene, Ivengia gabonensis, Frequency and temperature.*

Introduction

In the past few decades, there has been a renewed interest in the use of natural fibers as reinforcements and as result of this, a lot of researches and innovations had been carried out on natural fiber reinforced composites because of their economical and environmental benefits (Jamshaid, *et al*., 2016). Some of the advantages of natural fibers include; low density, high specific strength and modulus, relative non-abrasiveness, ease of fiber surface modification, and they are abundant in nature. Natural fibers are also much cheaper than synthetic fibers and can replace synthetic fiber in so many applications where cost savings is more of priority than high composite performance requirements.(Mehdi *et al*., 2006). Use of natural fiber-reinforced composites in the production of vehicle components helps control of CO_2 emission through reduction in the weight of the components. By the year 2025, the US wants to reduce net green house gas emission to 26–28% compared with the levels observed in the previous years. Automotive original equipment manufacturers aim to reduce the weight by at least 100 kg per year for their entire fleet weight (Kathiresan, S. and M., 2018). Akampumuza, *et al*., (2017) reviewed application of biocomposites in the automotive industry and reported that 23% of total global carbon emission was from the usage of automotive vehicles. Several researchers have successfully investigated and concluded based on the outcome of their investigation that the substitution of conventional metallic components by bio composite components can reduce fuel consumption of vehicles and by extension lead to the reduction in CO_2 emission level

(Oliveux *et a*l., 2015). Apart from emission control and fuel economy, a single composite molding can substitutes up to 15–20 individual steel components and fasteners. Use of fewer components can reduce inventory and make assembly easier, the net result is tighter tolerances, better fit and finish and reduced labor cost. The composites do not rust nor do they corrode when exposed to moisture and road salt. They practically replace most of the steel components on a vehicle. The dynamic loads on the composite components due to sound, live loads, friction between two components and the nature of the terrains road may reduce the life of the component. Proper selection of material for this kind of application plays very important role in automotive industries. Heat cause by friction and dynamic loads on the components affects its performance and life. Dynamic mechanical analysis (DMA) is a versatile technique that gives information on loss modulus, storage modulus and the damping behavior of material under dynamic loading condition as a function of varying temperature and frequency. Most of the components used in automobile are subjected to heat and some dynamic loads; hence it is pertinent to conduct a study on Viscoelastic behavior of the natural fiber reinforced composites for determining their relevant stiffness and damping characteristics for intended purposes.

Dynamic mechanical analysis (DMA) or dynamic mechanical thermal analysis (DMTA) is a sensitive technique that describes the mechanical responses of materials by monitoring property changes with respect to the temperature and frequency of oscillation. The dynamic responses of materials are separated into two distinct parts: an elastic part and a viscous or damping component. The elastic process describes the energy stored in the system, while the viscous component describes the energy dissipated during the process. Both phases in natural fiber-reinforced thermoplastic composite exhibit time dependent properties. Generally, three different tests are performed to study the time-dependent properties of viscoelastic materials. These include creep, stress relaxation, and DMA. While the first two are usually considered to have the same basis and often only one of them is chosen to describe property changes over the time, the latter can give invaluable information on the viscoelastic properties of the materials over a relatively short time. Therefore, a clear understanding of dynamic mechanical properties of natural fiber thermoplastic composites is necessary to determine the mechanical performance of the end product. Some of the works reported on the development and characterization of polymeric composites have thus been summarized. Dan-asabe *et al.* (2016) determined the dynamic mechanical analysis of aluminium reinforced PVC composite as a feasible alternative material for automotive bumper application. Dynamic mechanical analysis and crystalline analysis of hemp fiber reinforced cellulose filled epoxy composite was investigated by Palanivel *et al*. (2017) and reported that alkali and benzoyl chloride treatment of fiber resulted in improved DMA results. Pothan *et al.,* (2002) studied the influence of banana fiber on the viscoelastic properties of polyester with special reference to the effect of fiber loading, frequency and temperature. They reported that at lower temperatures, the storage modulus values were maximum for the neat polyester, while at temperatures above glass transition temperature (Tg), the storage modulus values were found to be maximum for composites with the highest fiber loading. This indicates that the incorporation of banana fiber in polyester matrix induced reinforcing effects appreciably at higher temperatures, while the loss modulus and damping peaks were found to be lowered by the incorporation of fiber. Furthermore, Gassan and Bledzki, (2018) carried out dynamic mechanical analysis of jute fiber reinforced epoxy composites and reported improvement in dynamic modulus by the incorporation of treated jute fiber in the epoxy. Saha *et al*., (1999) investigated Cyanoethylation of jute fibers in the form of nonwoven fabric in jute–polyester composites. Their results suggested that at lower temperatures, increased storage modulus and thermal transition temperature of the composites with respect to cyanoethylation of the fiber resulted in higher stiffness when compared to a composite prepared from unmodified fiber. However, incorporation of jute fiber in both cases reduced the tan d peak height remarkably. At higher temperatures, a contrary result was, observed. Essabir, *et al*., (2016) reported that there was increase in storage modulus with increasing frequency, whereas the loss factor value decreases with increasing frequency. This is due to the inadequacy of time for accumulating the molecules together and undergoing permanent deformation. Moriana, *et al.,* (2014) studied the chemical, thermal, and structural properties of polymer composites reinforced with different natural fibers. Jute fiber having the highest cellulose content and therefore has a greater reinforcing effect with polymers. Pistor *et al.*, (2012) reported that the glass transition temperature (Tg) for pure epoxy under different frequencies was around 708 ^{o}C. Jawaid *et al.*, (2013) also concluded reinforcing polymer matrix with jute fiber increases storage modulus value and a damping factor shift towards a higher temperature region. Indra Reddy and Srinivasa Reddy (2014) reported that hybridization effects on dynamic mechanical behavior of polymer composite increase the stiffness of the matrix leading to a greater degree of stress transfer at the interface. Mehdi *et al.*, (2006) also reported an increase in storage and loss moduli and a decrease in the mechanical loss factor for all composites indicating more elastic behavior of the composites as compared with the pure PP. Tang and Yan (2018) reported that incorporation of the filler particles improves the interfacial connection between the fiber and the matrix, which in turn improved the loss modulus.

Materials and Methods

Materials/Equipment

Materials

- *Irvengia gabonensis* shells collected at galtimari, Jere L.G.A, Borno state
- Polypropylene (PP) resin
- Sodium hydroxide (NaOH) granules
- Distilled water

Equipments

- Carver-3851, pressure compression molding machine of 30tonn capacity
- Two roll mill
- Digital weighing balance
- Specimen mould
- NETZSCH DMA 242

Methodology

Fabrication of the composites

Composites were fabricated in the size of 300 × 300 mm square mold with 5-mm thickness using the using compression molding technique. Composites of three different compositions were fabricated. The formulation of the composites prepared for this work are listed in table 1

Table 1:

Sample	Weight % shell particles	Weight % Polypropylene
10/90	10	90
20/80	20	80
30/70	30	70

Dynamic mechanical analysis

The dynamic mechanical analyzer (DMA) is used to analyze the modulus of the material (stress/strain) and viscoelastic properties like energy storage modulus (E'), loss modulus (E") and damping factor characteristics of the composite. The NETZSCH DMA 242 Machine was used to analyze the viscoelastic properties at three different frequencies (2Hz, 5Hz and 10Hz) with varying temperature and time. The three-point bending technique was used to analyze the composite. The dynamic mechanical properties are estimated at the operating temperature range between 25^{o}C and 150^{o}C.

Results and Discussion

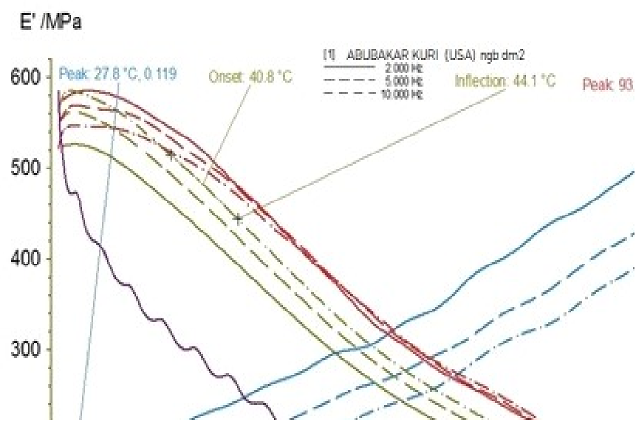

Figure 1 Variation of Storage modulus Loss modulus and Damping temperature and frequency of sample containing 10 wt. % *Irvengia gabonensis* shell particles.

Figure 1 shows variation of storage modulus, loss modulus and damping factor with temperature and frequency of 10 wt % *Irvengia gabonensis* shell particles loading. The storage moduli at three different frequencies (2 Hz, 5Hz and 10 Hz) were 520 MPa, 560 MPa and 580 MPa respectively. This also shows that the storage modulus is dependant of frequency. It can also be seen that the storage modulus here is higher than that of 40 wt. % *Irvengia gabonensis* shell particles loading but lower that of 20 wt % shell particles loading. The loss modulus at the three frequencies was between 68 and 76 MPa and it decreased to 20 MPa at the temperature of 93.5 ^{o} C. The damping increases as the temperature increases and it is higher at low frequency.

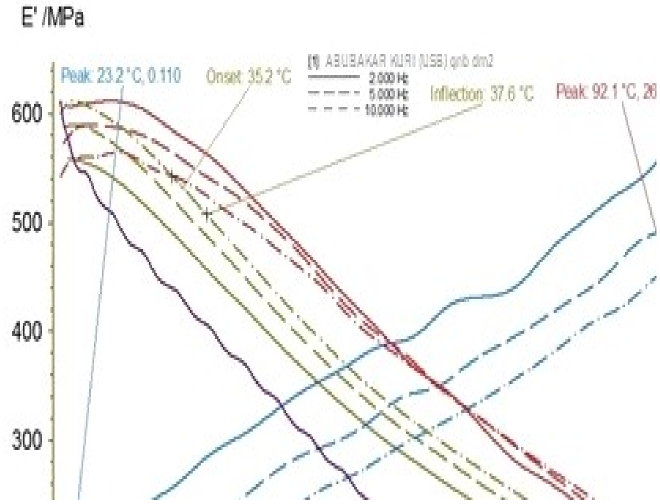

Figure 2 Variation of storage modulus, loss modulus and damping factor with temperature and frequency of 20 wt% *Irvengia gabonensis* shell particles loading

Figure 2 shows variation of storage modulus, loss modulus and damping factor with temperature and frequency of 20 wt % *Irvengia gabonensis* shell particles loading. The storage moduli at three different frequencies (2 Hz, 5Hz and 10 Hz) were 560 MPa, 580 MPa and 600 MPa respectively. This shows that the storage modulus is directly proportional to frequency which is associated with the fact, that at higher frequencies, the relaxation time of the molecular chains is higher than the time of oscillation, which makes the material highly elastic.. It can also be seen that the storage modulus here is higher than that of 40 wt. % shell particles loading. The loss modulus for the three frequencies was between 66 MPa and 76 MPa but as the temperature increases the modulus decreases until it dropped to 26 MPa at the temperature of 92.1 °C. The peak of damping was 0.110 at temperature of 23.2 °C.

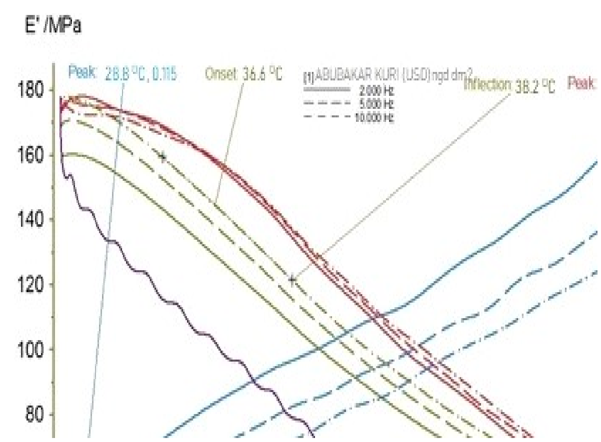

Figure 3 variation of storage modulus, loss modulus and damping factor with temperature and frequency of 40 wt % *Irvengia gabonensis* shell particles loading

Figure 3 shows variation of storage modulus, loss modulus and damping factor with temperature and frequency of 40 wt % *Irvengia gabonensis* shell particles loading. It can be seen that the storage modulus at the three different frequencies (2 Hz, 5Hz and 10 Hz) were 160 MPa, 170 MPa and 178 Mpa. This is indicative that as the frequency increases the storage modulus also increases but this is not so for temperature, because as the temperature increases the storage modulus decreases at all the three different frequencies. The loss modulus which is the amount of energy dissipated in form of heat by materials during one cycle of sinusoidal load was between 20 and 22 MPa for all the three frequencies at temperature of 30^{o} C but the loss modulus decreased to less than 8 MPa when the temperature reached 90 ^{o}C. the loss modulus unlike storage modulus is higher at frequency of 2Hz. Damping increased to 0.25 at the temperature of 90^{o}C. The peak of the damping was 0.115 at temperature of 28.8 ^{o}C.

Conclusion

The storage modulus values are higher for all the composites at the initial stage then the E' values were decreased gradually when experimental temperature increases. Composites with fiber composition 20/80 wt. % exhibit the highest storage modulus and loss modulus both at low and high temperature up to 92.1^{o}C. This shows that the composite of 20/80 wt. % *Irvengia gabonenesis* shell particle and polypropylene has the highest thermal stability load bearing capacity. As for the loss modulus composite containing 10/90 and 20/80 wt. % shell particles and polypropylene have almost the same loss modulus. Damping unlike storage modulus is inversely proportional to frequency in all the three compositions of shell particles and the polypropylene.

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