Dynamic Mechanical Analysis of Polypropylene Reinforced Doum Palm Shell Particles Composite

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ABSTRACT :- Polymeric composite materials have been studied in many fields of engineering with the aim of replacing other materials and reaching better performance when applied. Dynamic Mechanical Analysis (DMA) is among the existing techniques use to evaluate composites properties, especially when viscoelastic parameters need to be studied. Properties, such as storage modulus, loss modulus, damping factor and transitions temperatures can be determined by this technique. In this study, DMA was conducted on Doum palm shell particles reinforced polypropylene composite. Effects of Doum palm shell particles loading and temperature on the dynamic mechanical properties of the composites were studied. The results showed that Doum palm shell particles had a positive effect on the moduli and damping factor of the composites. The storage and loss modulus of the composite decreases with increase in temperature while tan δ increases as the temperature increases. The study indicates that the increased modulus is attributed to the physical interaction between the polymer and Doum palm Shell particles that restrict the segmental mobility of the polymer chains. The increase in damping factor with temperature and showed no significant effect with particles loading.

Keywords *– Dynamic mechanical analysis, Doum palm shell, polypropylene, composite.*

1. INTRODUCTION

The introduction of various types of fillers into polymer matrices to produce polymer composites with improve properties is gaining attention in recent years. Organic fillers have become strong competitors compared to their traditional inorganic filler due to their advantage of low densities, very low cost, non-abrasiveness, recyclability, biodegradability and renewable nature [1].

Polymer matrices as is the case of polypropylene as well as most natural fillers are low dense materials: Composites based on them usually show excellent specific properties. A number of lignocellulosic fillers have been exploited including coconut shell [2], Doum palm shell [3], Sisal [4], Egg shell [5] and others.

Composites of natural fillers and thermoplastics are finding places in many industries, particularly in the automotive industry. The continuous demand for more and new materials with low density, low cost and environmentally friendly by different industries has led to the study of new polymer composites containing easily available organic fillers. The mechanical, physical and dynamic Mechanical Characterization of such composites is determine to ascertain its suitability as new material for different application [3].

Dynamic Mechanical Analysis (DMA) is a widely used technique to determine the temperature dependencies of the modulus and damping properties of materials [6, 7]. DMA measures the modulus and damping properties of materials by applying sinusoidal force. Modulus is divided into two parts, storage modulus (E´) and loss modulus (E´´). The storage modulus of polymers decreases with increasing temperature whereas the loss modulus and tan δ increase up to the glass transition (T_g) region [8]. In DMA measurement technique, different deformation modes are used such as three-point bending, single cantilever, dual cantilever, torsion, compression, shear and tension depending on the materials properties. For composite materials, three-point bending configuration is mostly preferred due to the fact that this configuration creates measurable strains in stiff materials and removes the combined loading induced by single/double cantilever mode [7].

The objectives of this study is to determine the dynamic mechanical properties of polypropylene reinforced Doum palm shell composites and to study the influence of the Doum palm shell particles loading and temperature on the modulus and damping factor of the composites.

2. MATERIAL AND METHODS

2.1 Material

The material used for the study were Doum palm shell particles prepared from doum palm shell and

Polypropylene with Density 0.905 g/cm^3, Melt flow index 12 g/10 min, and melting temperature of 135 – 171.

2.2 Composite Preparation

The Doum palm for the study was collected from Ashaka Gari, Gombe state. The edible part of the fruit and the seed was removed, and shell was dried in an oven for 24 hrs to remove residual moisture from it. The dry doum palm shell was crushed to smaller pieces, grind to powder and sieved using standard sieves 150 µm sizes.

The composite was prepared by blending together the Doum palm shell particles and polypropylene in a two-roll mill at 180 ^{o}C and rotational speed of 45rpm. Polypropylene was first melted to allow for adequate flow of the molten Polymer before pouring the doum palm shell particles used as reinforcement in the composite. Cross mixing of the molten polypropylene and the doum palm shell particles was done until uniformity was obtained. The composite blend was removed from the mixer and compressed by an electrically heated hydraulic press in 100 x 100 x 5 mm mould and allowed to cool to room temperature at 8 MPa pressure before the sample was removed from the press. The composite test spacemen were sliced to 40 x 20 x 5 mm size for dynamic mechanical analysis as presented in fig. 1.

Figure 1: Test Spacemen for dynamic mechanical analysis.

2.3 Determination of Dynamic Mechanical Analysis

Dynamic Mechanical Analysis (DMA) was carried out using DMA 242E machine. The test parameters were first configured via the Proteus software using computer. Instruments set up included the sample holder (3-point-bending), furnace temperature (range of 20–150 °C), furnace thermocouple and measurement mode (dynamic load at ±4 N, frequency range of 1–10 Hz and heating rate of 5 K/min.) as shown in fig. 2 were configured. The sample specimens were loaded on to the machine using a three-point-bending sample holder and subsequently locked into the furnace. The storage, loss modulus and damping factor of the composite were determined.

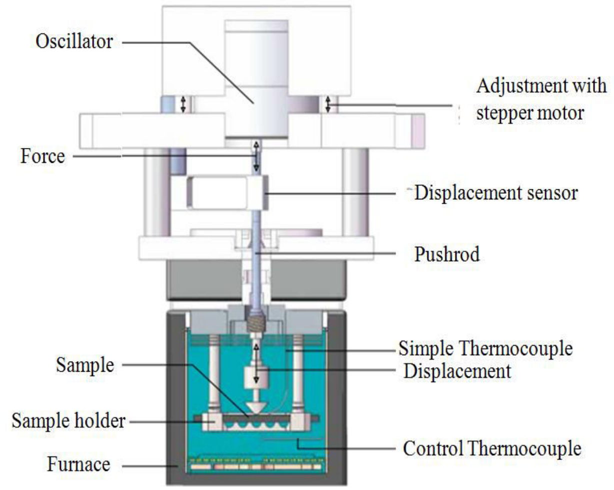

Figure 2: DMA 242E Principle.

3. RESULT AND DISCUSSION

3.1 Effect of Temperature and Particles Loading on Storage modulus

Storage modulus (E’) of polymer materials imparts how materials are stiffer. Fig. 3 shows the variation in storage modulus of Doum palm shell particles composites with increase in particles content in the matrix. Storage modulus of Doum palm shell composites were found to decrease with increase in weight percentages of Doum palm shell particles up to 20 % then increases with the particle loading up to 40 wt. %. This is because the introduction of the particles in the matrix stiffens the composite and gives better storage modulus. The highest value of E' was shown by composite at 10 wt. % particles loading whereas its lowest value was shown by composite of 20 wt. %. Similar types of results had been previously reported by Gupta *et al.,* [9] and Samal e*t al.,* [10]. On the other hand, the storage modulus was found to decrease with increase in temperature as presented in Fig. 4 due to loss in stiffness of fibres at high temperature Jawaid *et al.,* [11]. It could be credited to increase in molecular mobility after softening of polymeric composites with increase in temperature (Jawaid *et al.,* [11] and Hameed *et al.,* [12].The value of E' is directly proportional to the adhesion between particles and matrix. This fact shows that Doum palm shell composite at 40 wt. % showed better interface bonding as compare to other particle loading composites. On the other hand, composite 20 wt. % had its lowest value. This is because at high temperature the particles don’t contribute much to the materials.

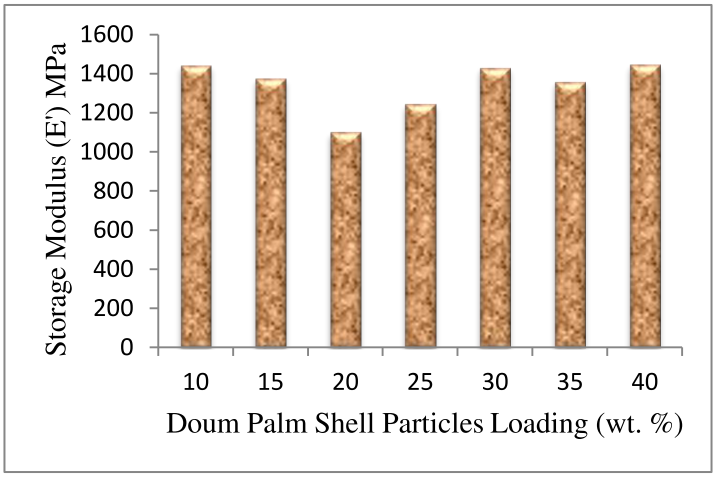

Figure 3: Influence of doum palm shell particulate loading storage modulus.

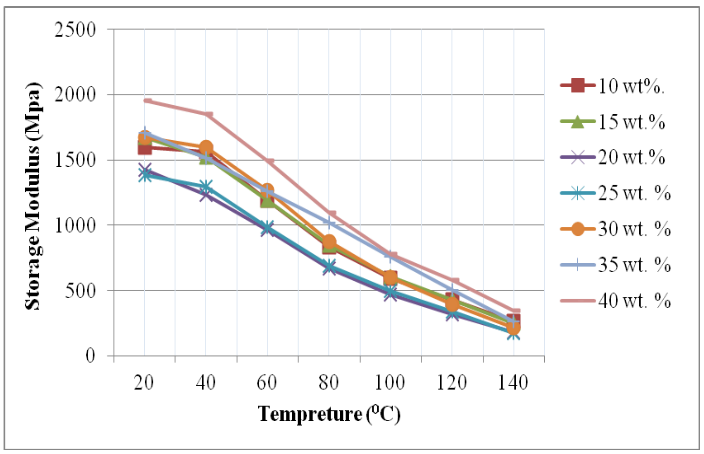

Figure 4: Influence of Temperature on storage modulus (E')

3.2 Effect of Temperature and Particles Loading on Loss Modulus

Loss modulus is defined as maximum energy released by composite materials during deformation. It presents the viscous response of the materials which depends upon motion of polymeric molecules in the composites Hameed *et al.,* [12]. The effect of Doum palm shell particles loading on loss modulus of the composite is illustrated in Fig 5. The loss modulus decreases with increase in particles content up to 20 wt. % reinforcement where it started increasing with the particles loading until it attained a maximum value at 35 wt. %. This shows that the incorporation of the Doum palm shell particle in the matrix decrease the mobility of matrix which improves the loss modulus and thermal stability of the composites Nair, *et al.,* [13]. However, the loss modulus of the composites decreases with increase in temperature as shown in fig. 6. This is because as the temperature increases, the molecular mobility of the polymer increases.

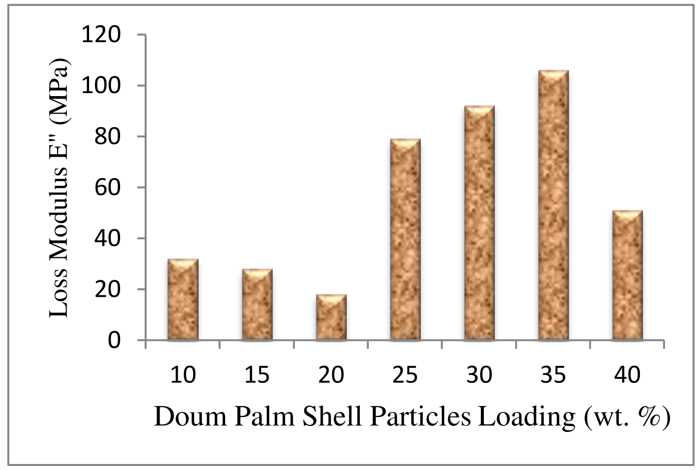

Figure 5: Variation of Loss modulus (E') with doum palm shell particles loading.

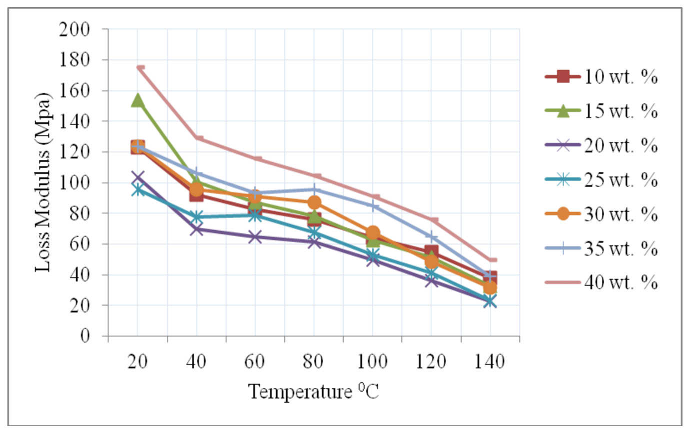

Figure 6: Variation of Loss modulus (E') with temperature.

3.3 Effect of Temperature and Particles Loading on Damping Factor

The damping factor or tan δ can be used to measure the potential of a material to dissipate and absorb energy. It gives the balance between the elastic and viscous phase in a polymeric structure Gupta, *et al.,* [14]. Damping is the ratio of loss modulus and storage modulus which is related to impact resistance of the materials. It depends upon adhesion between fibres and matrix and adequate reinforcement could impart higher impact strength to composites than those of its parent matrix. In addition, fibres carry the greater part of the stress in service and higher damping values means loaded matrix strained the interface. Energy dissipation will take place at the stronger interface, which is characterized by less energy dissipation Aji *et al.,*[15] Poor fibre-matrix adhesion is associated with higher damping and vice-versa Gupta *et al.,*[16]. This fact can be explained as strong fibre-matrix adhesion could reduce the mobility of polymer chain which in turn reduces damping Shanmugam, *et al.,* [17]. Fig. 7 shows an increase in damping factor with increase in Doum palm shell particles loading except for 20 wt. % where there is reduction in the damping value. The introduction of the particles in the matrix reduces the mobility of the polymer thereby given lower values for damping factor. Fig. 8 depicts the temperature dependence of tan δ for the Doum palm shell particle composites. The change trend in the tan δ curve was quite similar for all test samples. Tan δ increases with increase in temperature shows that the viscoelastic property of the material increases.

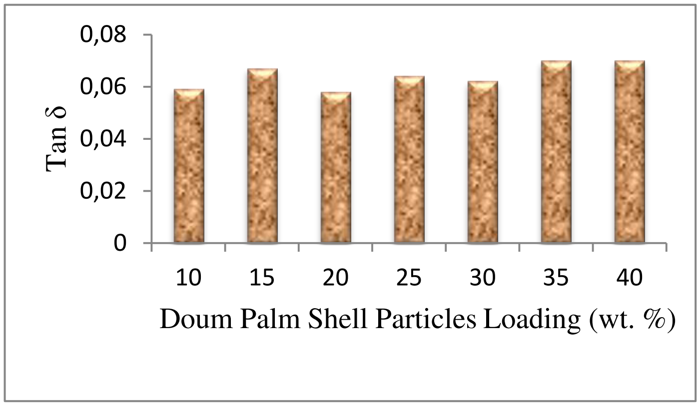

Figure 7: Variation of damping factor with Doum palm shell particles loading.

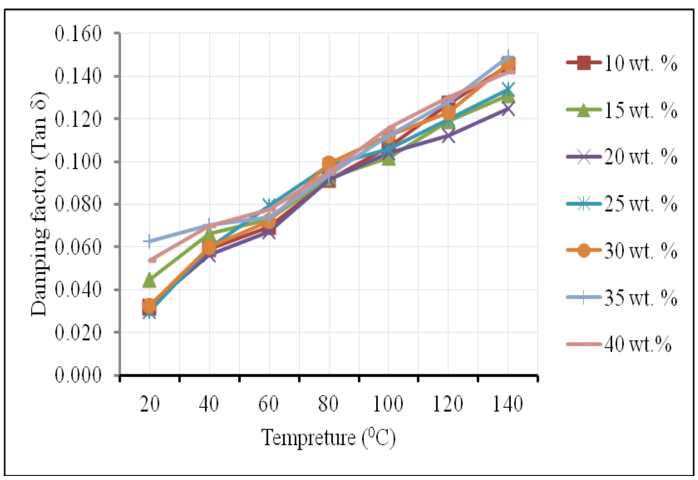

Figure 8: Variation of damping factor with temperature.

4. CONCLUSION

The Dynamic Mechanical properties of polypropylene filled Doum palm shell composites investigated showed that Doum palm shell particles composites have greater effect on the properties of the composites. The storage and loss modulus of the composite decreases with increasing temperature and this should facilitate internal damping. The DMA study indicates that the increased modulus, together with the decrease in tan delta values, was attributed to good interaction between the polymer and Doum palm Shell particles that restrict the segmental mobility of the polymer chains and gives thermal stability to the composites.

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