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Dynamic Mechanical Properties and Surface Morphology of Glass/Jute/Kevlar Fibres reinforced Hybrid Composite

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Abstract: *The strength and application of polymers can significantly be affected by their mechanical properties, which indicates that measures aimed at altering their mechanical properties will also affect their strength and possible applications The purpose of this study is to investigate the dynamic mechanical properties of the glass/jute /Kevlar hybrid fibres reinforced polypropylene using dynamic mechanical analysis, (DMA) to establish the interfacial bond in relation to storage modulus, loss modulus and damping factor. The samples were prepared using Carver Press at a temperature of 190 °C and a pressure of 500 psi using 1 mm thin films of polypropylene. The results obtained showed that the hybrid composites have a poor interfacial bond which led to molecular motion as the temperature was increasing. The loss modulus was also high, likewise the damping factor. The Scanning Electron Microscope (SEM) micrograms also supported these findings by showing the delamination on impacted samples. These make the hybrid composite a good material for rigid body armor application.*

Keywords: *DMA, SEM, Jute fibre, Glass fibre, Kevlar* fibre

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1.0 Introduction

Polypropylene has excellent physical and chemical properties and is also widely used due to its low cost of production, recyclability and superior processability (Zhang *et al*., 2017; Law and Hussain, 2019). Jute fibre is said to be available, environmentally friendly and relatively cheap (Ajith *et al*., 2014). Glass fibres have found applications in the automobile industry due to design flexibility, high strength to weight ratio, corrosion resistant and high stiffness (Patcharaphun and Opaskornkul, 2008). Kevlar fibres have excellent mechanical and thermal properties, chemical stability and lightweight (Singh and Samanta, 2015).

Composite materials are defined as a combination of two or more materials (one being the matrix and the other being reinforcement) to form a new material (Potluri *et al*., 2018). Hybridization also helps in producing materials at relatively low cost and desired properties. Hybridization of synthetic and natural fibres offers an opportunity to fabricate a material that offers a combination of the properties of the two fibres (Safri *et al*., 2018). A lot of work has been done on hybrid composites but to the knowledge of the authors, none has been reported on the dynamic mechanical properties of Glass/Jute/Kevlar hybrid composites. Hybrids of Kevlar/natural and Kevlar/Synthetic fibres have been reported (Yahaya *et al*., 2015; Isa *et al*., 2013; Valença *et al*., 2015).

Humans have always produced materials for defending themselves in battle and dangerous situations. The concept of armor can be classified into personal armor (body armor), light armor (vehicular and aircraft) and heavy armor (tank armor) according to Sorrentino *et al*., 2015. Kevlar reinforced composites for ballistic applications have been studied and reported (Sorrentino *et al*., 2015; Bandaru *et al*., 2016; Bandaru and Ahmad, 2017).

Carrillo *et al.*, 2012; Bandaru and Ahmad, 2017 reported that thermoplastic reinforced composites for ballistic application is preferable because it does not brittle during impact and it keeps the fibres in place, energy absorption on impact is done by delamination (when a projectile hits the armor, the armor absorbs the energy of the projectile by delamination). Weak-fibre matrix adhesion allows for maximum energy absorption, hence allowing absorption of more impact energy. Carrillo *et al*., 2012 also reported that the matrix can protect the fibres from environmental factors such as high humidity which can lead to a reduction in impact resistance and also protection from ultraviolet radiation which can lead to a reduction in mechanical properties.

2.0 Materials and Methods

2.1 *Materials*

HLR 102 grade of Isotactic Polypropylene homopolymer, with Melt flow rate, MFR of 5.3 g/10 min and density of 0.905 g/cm^3. The reinforcing materials used in the study are shown in Table 1 below.

Table 1: Reinforcing materials

S/N	Materials	Area density	Weave structure
1	Glass mat	200	Plain/Twill
2	Jute mat	250	Plain
3	Kevlat mat	110	Twill

The following equipment was useful during the study, namely, Carver Press, DMA 2000 and JEOL JSM-7500F Field Emission Scanning Electron Microscope. The method used for blending the materials was as described in Danladi et al. 2020a; Danladi et al. 2020b.

3. The methods used for characterization are as described in Danladi *et al.* 2020a; Danladi *et al*. 2020b.

4.0 Results and Discussion

4.1 *Storage modulus*

The dynamic mechanical properties of the hybrid composites were determined using Dynamic Mechanical Analysis, DMA. Dynamic Mechanical Analysis gives the viscoelastic properties of a polymeric material under study. Figure 1 shows that there was a poor fibre-matrix interfacial bond, this is exhibited in the closeness of the storage moduli results (Danladi *et al*., 2020a) shown in Fig. 1. Despite the poor interfacial bond, the storage modulus and when subjected to sinusoidal loading at a fixed frequency (1 Hz) and over a temperature range, showed a value of 1.5 GPa at 25 ^{o}C.

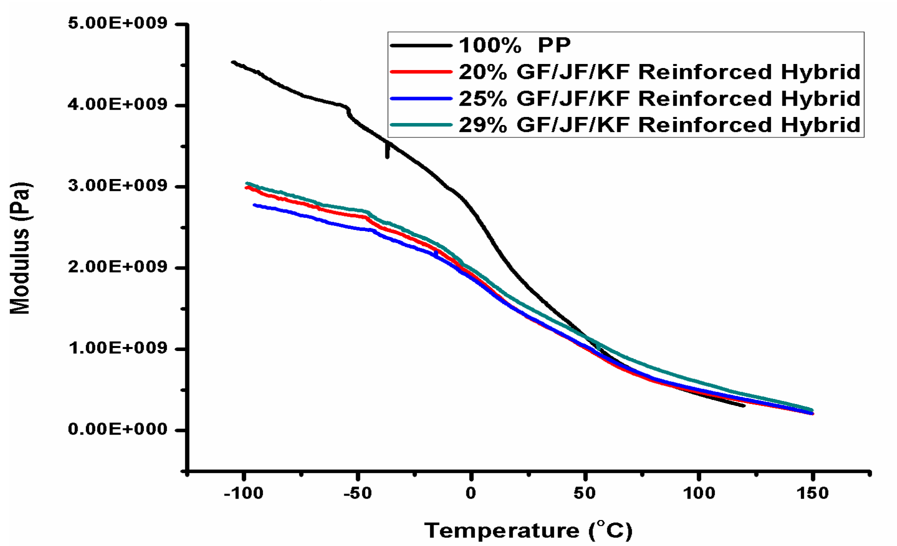

Fig.1: Storage modulus of the hybrid composites at different fibre loadings

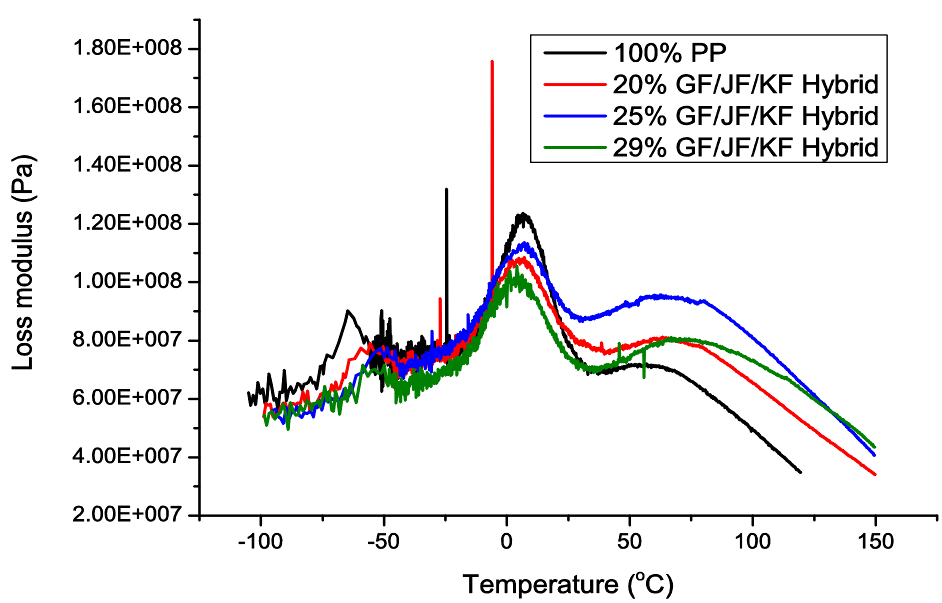

Fig. 2: Loss modulus of the hybrid composites at different fibre loadings

4.2 *Loss modulus*

Fig. 2 shows the loss modulus of the hybrid composites. Loss modulus results show the interfacial bonds between reinforcements and matrix material. The lower the loss modulus, the higher is the expected interfacial bond. Loss modulus is also an index for the measurement of the energy dissipated by a material (Jesuarockiam *et al*., 2019).

4.3 *Damping factor*

Fig. 3 shows the damping factor of the hybrid composites. The damping factor is a function of the ratio of loss modulus to storage modulus. The higher the damping factor, the lower is the expected interfacial bond. These results also in agreement with those obtained from loss modulus analysis.

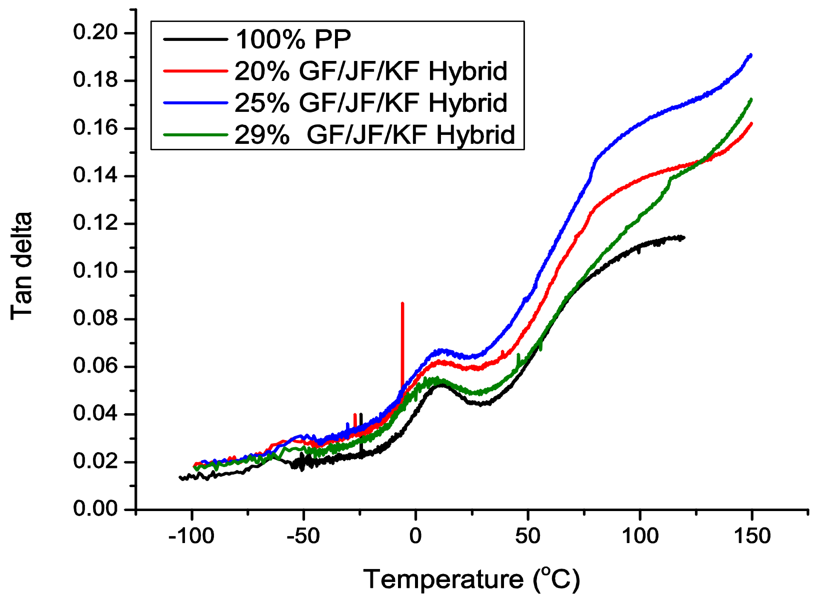

Fig. 3: Damping factor of the hybrid composites at different fibre loadings

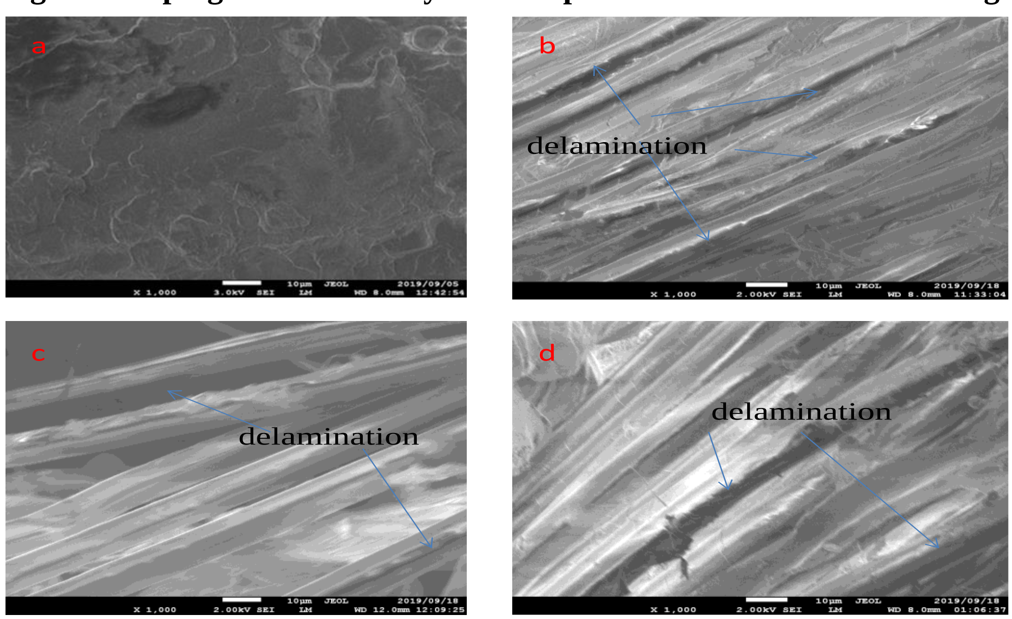

Fig. 4: Scanning electron micrographs of the hybrid at (a) 100 % PP (b) 20 % GJ/JF/KF (c) 25 % GF/JF/KF (d) 29 % GF/JF/KF

5. 0 Conclusions

4.4 *Scanning Electron Microscopy*

Fig. 4 shows the scanning electron micrograph of the hybrid composites. The results showed delamination between the matrix and the fillers, which further supports the results that were obtained from the dynamic mechanical analysis.

The results and findings of the study reveal that the fabrication and characterization of the hybrid composites are feasible. The hybrid composites have a storage modulus of 1.5 GPa at 25 ^{o}C and have a poor interfacial bond as shown by the molecular motion in the storage modulus results, there was an increase in loss modulus due to poor interfacial bond and high damping factor necessitated by the high loss modulus. The scanning electron micrograms showed that there was delamination as a result of the poor interfacial bond; this supports the results from the Dynamic Mechanical Analysis. Therefore, the hybrid composite material can be used for rigid body armor.

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7.0 Reference

Ajith, G., Senthil, K. M & Elayaperumal, A. (2014). Experimental investigation on the mechanical properties of jute fibre reinforced composites with polyester and epoxy matrices. *Procedia Engineering*, 97, pp. 2052- 2063

Bandaru, A. K., Chavan, V. V., Ahmad, S., Alagirusany, R. & Bhatnagar, N. (2016). Ballistic impact response of Kevlar reinforced thermoplastic composite armors. *International Journal of Impact Engineering*, 88, pp. 1- 13.

Carillo, J. G., Gamboa, R. A., Flores- Johnson, E. A. & Gonzalez- Chi, P. I. (2012). Ballistic performance of thermoplastic composite laminates made from aramid woven fabric and polypropylene matrix. *Polymer Testing*. 31, 4, pp. 512- 519. DOI :10.1016/j.polymertesting.2012.02.010

Danladi, E., Mamza, P.A.P., Yaro, S.A., Isa, M.T., Sadiku, E.R. & Ray, S.S. (2020a). The effect of Glass – Kevlar 49 fibre loading on the mechanical, thermal and physical properties of polypropylene hybrid Composites. *Communications in Physical Sciences*, 5, 2, pp. -99 – 105

Danladi, E., Mamza, P. A. P., Yaro, S. A., Isa, M. T., Sadiku, E. R. & Ray, S. S. (2020b). Reinforcing effect of Kevlar 49 fibres on the mechanical properties of Polypropylene. *Nigerian Journal of Polymer Science and Technology*, 15, pp. 12- 28.

Isa, M. T., Ahmed, A. S., Aderemi, B. O., Taib, R. M. & Mohammed, I. A. (2013). Effect of fibre type and combinations on the mechanical, physical and thermal properties of polyester hybrid composites. *Composites: Part B*, 52, pp. 217- 223

Jesuarockiam, N., Jawaid, M., Zainudin., E. S., Sultan, M. T. H., & Yahaya, R. (2019). Enhanced thermal and dynamic mechanical properties of synthetic/natural hybrid composites with graphene nanoplatelets. *Polymers*, 11, 1085; doi:10.3390/polym11071085

Law, C. and Hussein, M.A. (2019). Modeling of metallocene catalyzed propylene polymerization in a fluidized reactor. *MATEC Web conference* 268, 02002

Patcharaphun, S. & Opaskornkul, G. (2008). Characterization of fibre length distribution in short and long glass fibre reinforced polypropylene during injection molding process. *Kaetsart Journal of Natural Sciences*, 42, pp. 392- 397.

Potluri, R., Dheeraj., R. S. & Vital, G. V. N. G. (2018). Effect of stacking sequence on the mechanical & thermal properties of hybrid laminates. *Materials Today:Proceedings*, 5, pp. 5876-5886.

Safri, S. N. A., Sultan, M. T., Jawid, M. & Jayakrishna, K. (2018). Impact behaviour of hybrid composites for structural applications: A review. *Composites: Part B*,133, pp.112- 121.

Sorrentino, L., Bellini, C., Carrado, A, Polini, W. & Aricò, R. (2015). Ballistic performance evaluation of composite laminates in Kevlar 29. *Procedia Engineering*, 88, pp. 255- 262.

Valença, S. L., Griza, S. de Oliveira, V. G., Sussuchi, E. M. & de Cunha, F. G. C. (2015). Evaluation of the mechanical behaviour of epoxy composite reinforced with Kevlar plain fabric and glass/Kevlar hybrid fabric. *Composites: Part B*, 70, pp. 1- 8.

Yahaya, R. Sapuan, S.M., Jawid, M., Leman, Z. & Zainudin, E.S. (2015). Effect of layering sequence and chemical treatment on the mechanical properties of woven kenaf – aramid hybrid laminated composites. *Materials and Design*, 67, pp. 173- 179.

Zhang, H., Zhang, X. & Yoon, K. (2017). Preparation of isotactic polypropylene/exfoliated MoS_2 nano composites via In Situ interactive polymerization. *Polymers*, 9, *Doi: 10.3390/polym9100.490.*

Conflict of Interest

The authors declared no conflict of interest