https://chemclassjournal.com/
ChemClass Journal Vol. 9 Issue 4 (2025); 320 - 329
e-ISSN:3092-8214 p-ISSN:3092-8206
doi.org/10.33003/chemclass-2025-0904/24

Physico – Mechanical Properties and Dynamic Mechanical Analysis of Glass Mat Reinforced Unsaturated Polyester Composite for Car Bumper Application

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Abstract

The aim of the present work was to determine the physical, mechanical and dynamic mechanical properties of glass mat reinforced unsaturated polyester for car bumper application. The composites were fabricated using hand lay – up method. The physical, mechanical and dynamic mechanical properties were investigated. The results showed that there was significant increase in tensile and flexural properties (tensile strength of 129.73 MPa, tensile modulus of 1979.01 MPa; flexural strength of 134.28 MPa, flexural modulus of 7.59 GPa at 27% fibre loading) and relatively good impact strength of 12.427kJ/m^2 at 27% fibre loading. The DMA results also show good interfacial interaction with 27% fibre loading having storage modulus of 350 MPa at 35 ^{o}C, loss modulus of 32.5 MPa at 35 ^{o}C and damping factor of 0.30 at 92.5 ^{o}C. The density and water absorption did not change significantly; these made it a good material for car bumper application. The findings showed that reinforcing unsaturated polyester with glass mat significantly improved the properties of interest in the present work.

Keywords: DMA, Glass mat, Mechanical properties, Physical properties, Unsaturated polyester.

Introduction

Unsaturated polyester resin falls into a class of highly cross - linked thermosetting polymers. Another example is epoxy resin. Their compact cross – linked structure stands them out and may lead to several superior characteristics such as glass transition temperature, high specific nature and strength, high creep resistance, good solvent resistance and dimensional stability at high temperature. Thermosets are also use in composite material as matrix [1].

Unsaturated polyester is widely used due to its properties such as chemical resistant, excellent moldability, dimensional stability and relative low cost. Unsaturated polyester finds limited use in dynamic and load bearing applications due to its brittleness and limited impact resistance hence the need for reinforcement [2].

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Unsaturated polyester is among the first commercialized polymer matrices for reinforcement with glass fibre and has remain relevant to date. Their environmental impact is reduced by reinforcing with natural reinforcements. Researchers World over are still investigating these composites and a lot of work has been carried out in the last forty years as reported by [3].

Glass fibre reinforced polyester has found applications in fabrication of wind turbine blades and water tanks as reported by [4]. Their work centred on the tensile and charpy impact strength at elevated temperature.

Their findings showed that the mechanical properties of the composites decreased with increase in temperature from 30 ºC – 70 ºC, the failure mechanism varied from delamination and fibre breakage at high temperature to matrix cracking at room temperature.

Taurino *et al* [5] reported their findings on the glass-stalks – unsaturated polyester hybrid composites; their findings showed that presence of grape stalks increased mechanical properties, the physical and chemical properties showed poor interfacial adhesion. Silanization led to improved fibre- matrix adhesion, leading to decrease in absorption of composites in water and acid.

The hybrid composite of Kenaf/Glass reinforced Polyester mechanical properties such as tensile, compressional, flexural and interlaminar shear strength was investigated by [6]. Their findings showed that the hybrid gave the highest tensile property compare to other hybrid composites but lower than the unidirectional fibre roving composite. Alternating the Kenaf/Glass/unsaturated composite exhibited higher compressive strength compared to other specimens but little lower than the glass unsaturated polyester composites.

Sapuan *et al.* [7] work focused on mechanical properties of longitudinal basalt/woven glass reinforced unsaturated polyester resin hybrid composites. Their findings revealed addition of basal fibre to glass reinforced unsaturated polyester increased its density, tensile and flexural strength. The following weight ratios were used for the reinforcements; UP; G; B7.5/G22.5; B15/G15; B22.5/G7.5. and B respectively. The mechanical properties varied as follows; The tensile and flexural properties increased with the proportion of basalt fibres, the tensile strength was increased at 69% for B composites in relations to G composites.

Ali *et al* [8] worked on the animal fibre reinforced unsaturated polyester. They used chicken feathers, cow hair and leather scraps as reinforcements. 5% natural fibre loading led to increase in tensile and flexural strength and modulus respectively.

Negawo *et al* [9] reported the mechanical, morphological and dynamic mechanical properties of alkali treated ensete stem fibres reinforced unsaturated polyester composites.

Jiang *et al* [10] reported their work on mechanical and thermal properties improvement of unsaturated polyester by incorporation of TiO_2 surface modified with titanate.

Das *et al* [11] investigated the mechanical and water swelling properties of waste paper reinforced unsaturated polyester composites.

Samsudin *et al* [12] reported their work on the mechanical properties of unsaturated polyester composites reinforced with acid treated palm kernel shell at various filler loading.

Al -Mufti *et al* [13] worked unsaturated polyester resin filled with cementitious materials: A comprehensive study of filler loading impact on mechanical properties, microstructure and water absorption.

Abdel- Rahman *et al* [14] reported their findings on Physico – mechanical properties of Clay/Unsaturated Polyester nanocomposites.

Garcia *et al* [15] worked on the physical and mechanical properties of unsaturated polyester resin matrix from recycled PET with corn straw. Gedif and Atalie [16] worked on recycling 100% cotton fabric waste to produced unsaturated polyester-based composite for false ceiling board application.

Materials and Methods

Woven glass mat 200g/m^2 procured from AMT Composites, Kempton Park, South Africa, Unsaturated polyester, Methyl Ethyl Ketone peroxide catalyst, Cobalt accelerator were sourced from Nigerian Institute of Leather and Science Technology, Zaria, Teflon sheet (2mm thick) were sourced from Council for Scientific and Industrial Research, Pretoria – South Africa, 250 ml beakers, glass rod, pair of scissors, hand brush 2.5 inch, Vaseline, 100mm x 100mm x 3mm.

Matrix preparation

The matrix was prepared by measuring 100ml of the unsaturated polyester into the 250ml beaker, followed by 2cm^3 of the Methyl Ethyl Ketone peroxide catalyst and stirred with a glass rod before adding 2cm^3 of Cobalt accelerator and further thoroughly stirred for about two minutes.

Mold preparation

The mold was prepared by applying Vaseline on the surface of the Teflon sheets and the mold for ease of removal after curing the composite.

Woven glass mat preparation

The woven glass mat was cut into the dimension of the mold, 100mm X 100mm using a pair of scissors.

Fabrication of the composite

The composite was fabricated by applying a thin coat of Vaseline on the pair of Teflon sheet , followed by a coat of the matrix using the 2.5 inch bristle brush, followed by a sheet of the woven glass mat, then another coat of the matrix, followed by another sheet of the woven glass mat and another coat of the matrix and finally a coat

of the matrix to give three sheets of woven glass mat reinforcement and finally applying a coat of the matrix before covering with the second cover of the Teflon sheet and then covering with the mild steel. The whole arrangement was under a load of 2kg for 12 hours at room temperature before oven drying for another six hours at 60 ºC. Same procedure was used for five and seven sheets of the woven glass mat.

Table 1: Fabrication of the composite plates

S/N	Unsaturated Polyester (%)	Glass mat (%)	Number of layers
1.	86	14	3
2.	80	20	5
3.	73	27	7

Characterisation of the Composites

Tensile properties

These were at Department of Polymer and Textile Engineering, ABU, Zaria according to ASTM D638 – 14

Flexural properties

These were carried out at Department of Mechanical Engineering, ABU, Zaria according to ASTM D790 – 03.

Impact strength

The impact strength was determined at Nigerian Institute of Leather and Science Technology, Zaria, Polymer Technology lab according to ISO 179 – 01.

DMA

This was carried out according to ASTM E1640 – 04 at Defence Industry Corporation laboratory, Kaduna using double cantilever and gas flow rate of 10mL/min and temperature range of 30 ºC – 100 ºC and frequency of 1 Hz.

Water absorption

The water absorption was determined according to ASTM 570 - 98 for 48 hours immersion and results determined according to the formula:

$$\text{Water absorption} = \frac{W - W_O}{W_O} \text{ X } 100\%$$

Where W = mass of sample after immersion for 48 hours

W_o = mass of sample before immersion.

Density

The density was determined according to ASTM D792 – 08

Results and Discussion

Tensile strength

The tensile strength is as shown in Figure 1. The fibre loading showed increase in the tensile strength of the composite. Fibre loading of 27% gave a tensile strength of 129.73 MPa. Samsudin *et al* [12] reported a tensile strength of 30 MPa at 30 % fibre loading for acrylic acid treated palm kernel shell and 29 MPa for untreated palm kernel shell. Unlike the present work, as the fibre loading increased there was continuous decrease in the tensile strength for both treated and untreated palm kernel shell. The difference could be attributed to the nature of the reinforcement used (natural fibre) whereas the present work used synthetic fibre. This led to over 400 % increase in the tensile strength. Garcia *et al* [15] reported a tensile strength of 5.58 MPa at 30% fibre loading. This goes to show how better glass fibre is compared to corn straw fibre. Gedif and Atalie [16] had to use a thickness almost five times the present work thickness to achieve a similar result. Ali *et al* [8] also reported a lower result in their work using animal fibre.

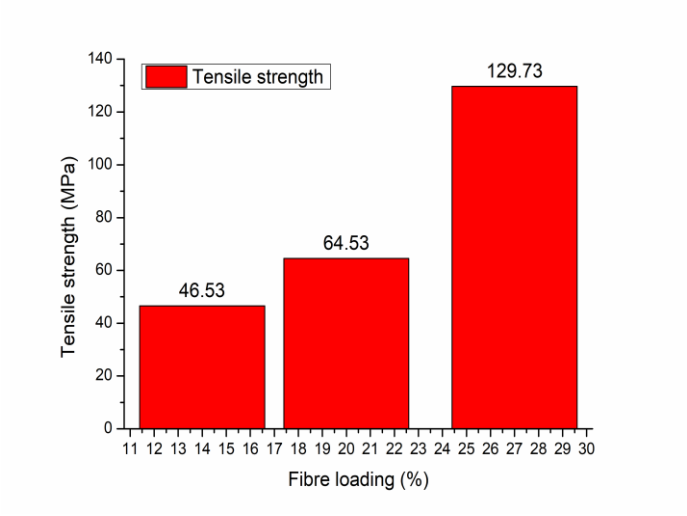


Figure 1**:** Tensile strength

Tensile modulus

The fibre loading had an incremental effect on the tensile modulus, reaching a peak at 27% fibre loading. The tensile modulus appeared to be similar to what [11] found. But Garcia *et al* [15] found a tensile modulus of 0.72 GPa at 30 % fibre loading. The tensile modulus is higher than the value of [16]; ~1.00 GPa at 27 % fibre loading using same fibre using polypropylene.

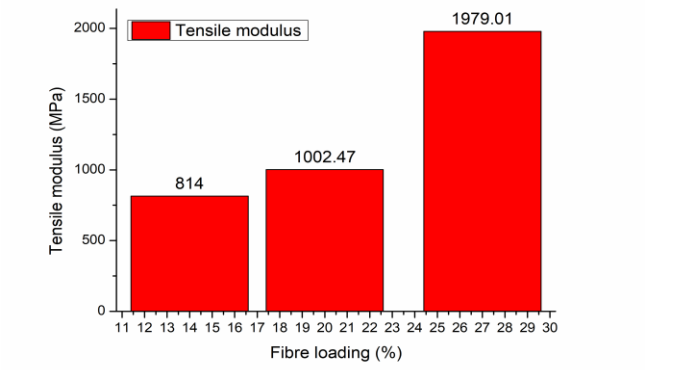


Figure 2: Tensile modulus

Flexural strength

Figure 3 shows the effect of fibre loading on the flexural strength of the composites. There was steady increase in flexural strength with fibre loading of 27 % being the highest. Good impregnation leads to better interfacial interaction and stronger flexural strength. The value obtained here is greater than what [17] got at same fibre loading using polypropylene, indicating a better flexural strength with unsaturated polyester matrix. Flexural strength reported by [15] at fibre loading of 30 % using corn straw fibre was far less than the present work, indicating the advantage of a synthetic woven fibre.

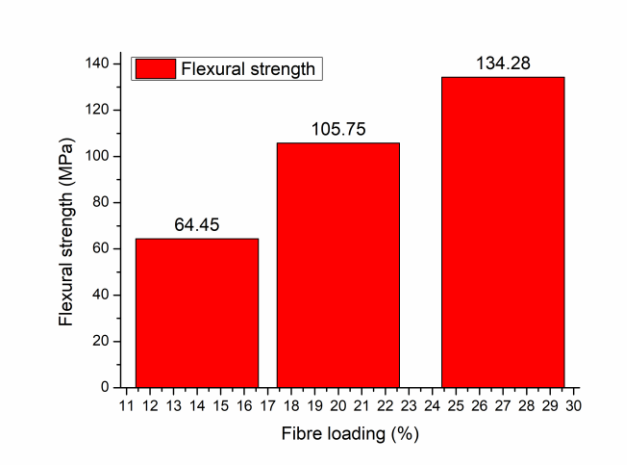


Figure 3: Flexural strength

Flexural modulus

The flexural modulus was quite significant with 27 % fibre loading giving 7.59 GPa. This is significantly greater than the result of [17] using polypropylene and same fibre loading. This shows that there was better impregnation of the reinforcements in the present work. The flexural modulus from [15] was also lower even though same unsaturated polyester was used. The present work exhibited a relatively excellent flexural modulus compared to other reported work [13, 15].

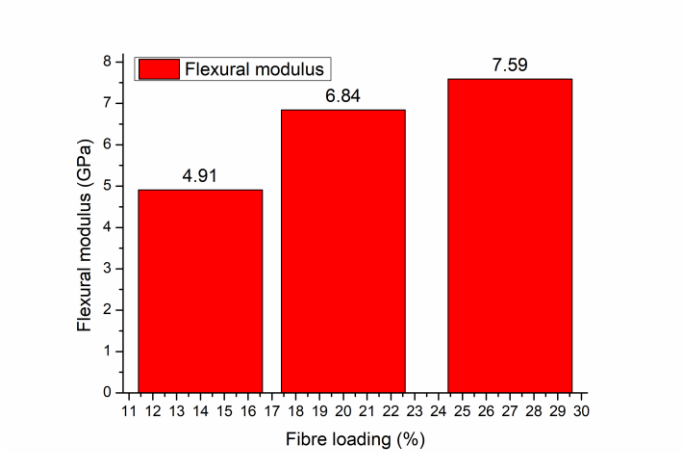


Figure 4: Flexural modulus

Impact strength

The impact strength was quite significant because there was an incremental result in impact strength as fibre loading increases. This value at 27% fibre loading is lower than the value obtained by [17] using same fibre and different matrix, Polypropylene. This could be attributed to unsaturated polyester being brittle in nature while polypropylene is thermoplastic. It also reflects the fact that matrix and reinforcement both play a role in the impact strength of a polymeric composite material.

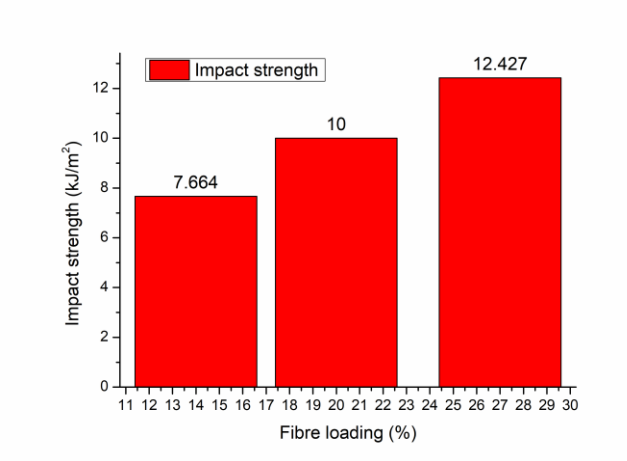


Figure 5: Impact strength

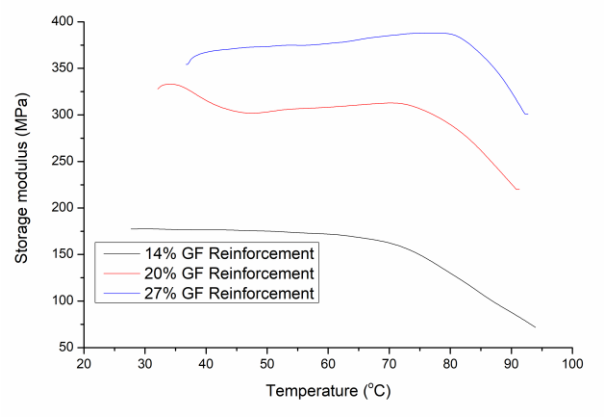


Figure 6: Storage modulus

Dynamic Mechanical Analysis (DMA).

Dynamic Mechanical Analysis reveals the viscoelastic properties of a material; these include storage modulus, loss modulus and damping factor as shown in Figure 6, 7 and 8 respectively. The results show that the composite material is stiff and of good interfacial interaction as shown in Figure 6. As the temperature increases there is decrease in the storage modulus. The stiffness is seen in the wide gap between the storage modulus results from 14 % - 27 % fibre loading. As the temperature rise above 65 ºC, there was a decrease in the storage modulus, rise in loss modulus damping factor signifying molecular motion leading to high damping. This agrees to the literature knowledge that increase in loss modulus leads to high damping factor.

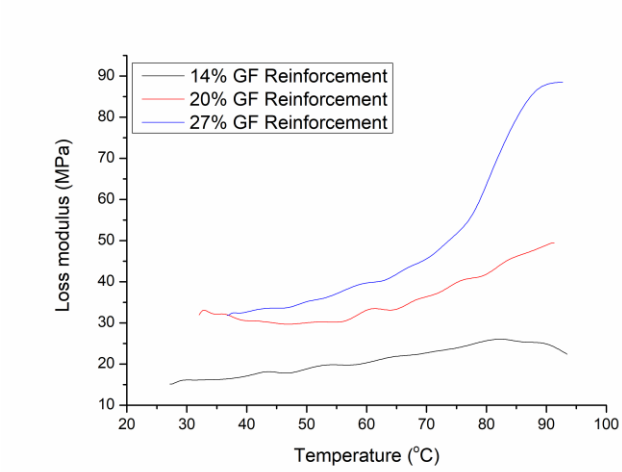


Figure 7: Loss modulus

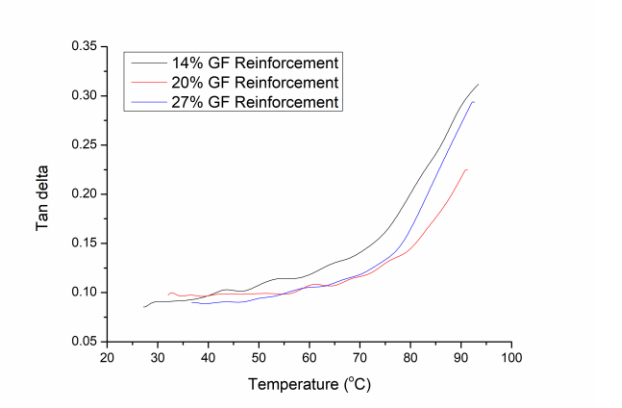


Figure 8: Damping factor

Density

The results showed that the reinforcement has little effect on the density of the matrix material. This makes it ideal for light weight application. Garcia *et al* [15] reported a density of 1.16 g/cm^3 at fibre loading 0f 30 %.

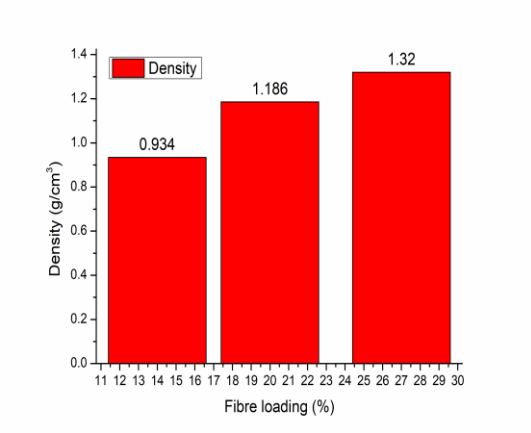


Figure 9: Density

Water absorption

The findings from water absorption after 48 hr of immersion (Figure 10) showed that the material doesn't have high water intake. This characteristic is good for outdoor application where it could be subjected to moisture/water. Garcia *et al* [15] reported a water absorption of 2.18 % at 30 % fibre loading using Corn straw fibre. Here the type of reinforcement is responsible for the higher water absorption.

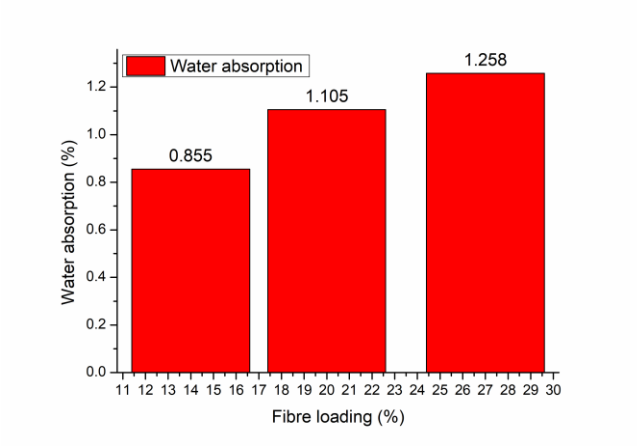


Figure 10: Water absorption

Conclusions

The tensile properties and flexural properties were enhanced by the increase in fibre loading, this could be due to the interfacial adhesion and proper impregnation of the woven glass by the unsaturated polyester matrix. The impact strength was also increased as the fibre loading increased, in a progressive pattern. The DMA results further showed the morphology of the composite in terms of interfacial interaction between the woven fibre and the matrix with wide gap between the storage moduli indicating stiffness. The density and water absorption results showed relatively good characteristics for light weight and outdoor applications. These findings can add to literature details regarding the mechanical and Dynamic Mechanical properties of the composite as well as the physical properties for possible end use application and further research.

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