SWELLING CHARACTERISTICS AND TENSILE PROPERTIES OF NATURAL FIBER REINFORCED PLASTIC IN SELECTED SOLVENTS

BY

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ABSTRACT
The swelling behavior and tensile strength of natural fiber-reinforced plastic in premium motor spirit (PMS), dual purpose kerosene (DPK) and sea water have been studied. Composite formed by reinforcing polyester resin with Okam fibers was immersed in the selected solvents for 16 weeks (4 months). Swelling characteristics of samples of this composite material were determined by monitoring- forth nightly, changes in weight of the samples within the test period and tensile test was conducted on the samples after 16 weeks using Hounsfeild (Monsanto) tensometer. The results show that the solvents reduced the strengths of the composite with PMS giving the highest reduction in strength followed by DPK and then sea water. Reduction in strength was attributed to the weakening of the interfacial bonding between the polyester matrix and reinforcing okam fibers.

Key words: **Natural fiber; Reinforced plastic; Swelling; Tensile strength**

1.0 INTRODUCTION

Composite materials comprising polymer matrices reinforced with fibers usually of glass fiber, Kevlar and carbon have gained considerable applications in automotive, aerospace, marine and construction industries (1). Glass reinforced plastic was originally developed in the United Kingdom during the Second World War as a replacement for moulded plywood used in aircraft Radom. Its first civilian application was for building of boats where it gained acceptance in the 19550's. Its use has broadened over the years especially in the automotive, sport equipment sectors and construction industries (1). According to Jayamol et al (2), fibers made of Kevlar and carbon are strong, high temperature resistant, expensive and are nowadays limited to high performance applications such in aerospace.

Since the development of reinforced concrete over a century ago, engineers have constantly studied the problem of steel reinforcement of concrete due to its poor resistance to corrosion. The new advances in the field of materials science have resulted in the development of fiber-reinforced plastic (FRP) materials that could potentially be used as bars in reinforced concrete structures. The attractive features of this type of bar (made of FRP) include: high strength; light weight and resistance to electrochemical corrosion (3).

Philip Ritche et al (4) reported that

whereas polymer resins are strong in compressive loading and relatively weak in tensile strength, the glass fibers are strong in tension and weak in compression. Thus by combining the two materials, glass reinforced plastic is better material in compressive and tensile loading.

Researches on natural fibers as a substitute for glass fibers in composite materials have gained momentum in the last decade due to ecological concerns since glass fibers are non-degradable and their disposal after use causes environmental problems (5). It is for this reason that natural fibers based on lingo-cellulose are considered as interesting and environmentally safe alternative to the use of glass fibers as reinforcement in engineering polymeric materials. According to Jarrod Schemenauer (6), plant fibers like flax, hemp, kenaf, jute and sisal have a number of techno-economic and ecological advantages over glass fibers and are being considered as potential candidates to replace them (glass fibers). Moreover, plant fibers are abundant, renewable (sourced from annual plant), cheap, recyclable, exhibit low density and the extent of its environmental pollution is less compared to synthetic fibers (7).

Generally, natural fibers are categorized according to their origin: plants; animals and minerals (3). Plant fibers, however, can be grouped into: Bast (jute, banana, flax, hemp, kenaf, mesta); Leaf (pineapple, sisal, screw pine) and Seed or Fruit (coir, cotton, palm oil). According to Youngquist, J. A et al (8), cellulose is the main component of plant fibers and it (cellulose) consists of other natural substances such as lignin and waxes.

Cheremisinoff (9) reported that the mechanical and physical properties of plant fibers are influenced by the following structure parameters: degree of polymerization; void structure and size; crystal structure; degree of crystallinity; specific interface and fiber diameter. The ultimate mechanical properties of composites are influenced mainly by the adhesion between matrix and fibers (2). A strong adhesion at the interface is needed for effective transfer of stress and load distribution throughout the interface.

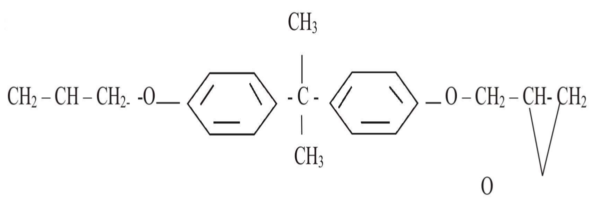
The primary drawback of agro-based fibers is associated with their inherent polar and hydrophilic nature and the non-polar characteristics of most thermoplastics which results in difficulties in compounding of the fiber and the matrix. Also plant fibers have poor resistance to moisture absorption and this causes swelling and quality variation in plant fiber-based composites (10). Possible solution to this problem is by treating the fibers with appropriate chemicals. Various chemical agents have been employed to enhance the compatibility between the constituent materials (11).

Despite these drawbacks, the renewability and biodegradability of natural fibers make them very attractive as reinforcements of engineering polymer systems (5, 6). As fiber reinforced plastics are gradually replacing steel in pipeline applications, this research aims at studying the swelling characteristics of “Okam” fiber-reinforced-polyester composite immersed in petroleum product media and sea water and the effects of its exposure to these environment on the tensile strength of this material under uniaxial tension.

2.0 MATERIALS AND METHOD

The composite was made from polyester resin which served as the matrix and okam fiber-serving as the reinforcing material. Polyester resin is a thermosetting polymeric material consisting of linear polyester in styrene (C_8H_8) monomer. The structural formula of polyester is shown below.

The polyesters are formed by the polycondensation of decarboxylic acid with dihydric alcohols. In the composite, the fibers provide stiffness and strength while



the resin provides a matrix to transfer load to the fibers, give stability to the fibers and provide relatively impermeable and chemical resistant surface. Okam is a fibrous plant grown in abundant quantities in some parts of Nigeria. The ones used in this work are sourced from Kogi state. Other additives in the polyester-okam fiber composite include a catalyst (methyl ethylketone peroxide) and an accelerator (cobalt nephthenate). The catalyst is a cross-linking agent which when added in small quantities to the unsaturated polyester resin initiates the reaction of the styrene monomers contained in the resin with other ingredients to produce a molecular cross-linked polymer. The accelerator activates the catalyst at lower temperatures and allows polymerization to take place at lower temperatures.

2.1 Fiber Preparation

Stems of okam plants were soaked in flowing stream and dried in ambient condition. The okam fiber was, thereafter, soaked in chemical solution of composition: vinyl triethoxy saline, methanol and water for 3 hours and dried. The fibers were later soaked in sodium hydroxide (NaOH) solution for 2 hours and finally washed with water and dried. The above surface treatments were performed to modify the physico-chemical properties of the okam fibers and make them chemically compatible with the polyester resin.

2.2 Sample Preparation

Laminates of polyester-okam fiber composite were produced by compression moulding of polyester resin with the additions of methyl ethylketone peroxide and cobalt nephthenate catalyst and accelerator respectively. Chopped strand mats of the okam fibers were embedded inside the "resin mix". A resin-fiber ratio of 60:40 was used. The whole arrangement was allowed to cure in wooden mould and was subjected to mild pressure by placing of loads on the upper mould. Test coupons were cut from the laminate, initially weighed and immersed in petrol, kerosene and sea water for 16 weeks. The samples were re-weighed after every 2 weeks. Standard testpieces (prepared according to ASTM standard D 638) were cut for tensile test. They were immersed in separate bath of petrol, kerosene and sea water for 16 weeks and, thereafter, tested for ultimate strength.

2.3 Tensile Test

Sample specimens measuring 300mm × 16.85mm × 5.75mm were cut from the polyester-okam fiber composite and tested for tensile strength using the Hounsfield (Monsanto) tensometer. The test was performed on the samples which were not immersed in the selected solvent and on those immersed. The test pieces were securely clamped on he holding devices of the tensometer and subjected to a gradually increasing uniaxial load until they fractured. The force applied to the specimens and the corresponding extension on the samples were monitored and recorded. The tensile strength of the composite was estimated using the formula:

$$\text{Tensile Strength} = \frac{\text{Maximum Load}}{\text{Original Cross Section Area}}$$

Whereas strain was calculated using the relationship given below:

$$\text{Strain} = \frac{\text{Extension}}{\text{Original Length}}$$

3.0 RESULTS AND DISCUSSIONS

Figures 1.0 shows the Results of Percentage Swelling Index of composite material in the solvents. Swelling Index (S.I) was calculated using the formula:

$$S.I = \frac{W_1 - W_0}{W_0} \times 100$$

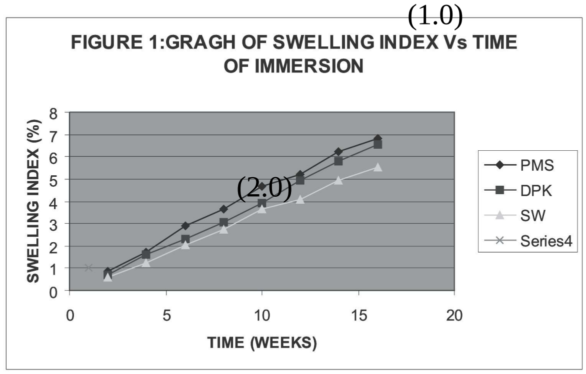
Where Wo and W1 are initial and final weights of samples.

3.1 Swelling of Polyester-okam Fiber Composite in Selected Solvent

Figures 1 is the graph of swelling index of the polyester-okam fiber composite in petrol, kerosene and sea water after every 2 weeks for 16 weeks. Results show that the swelling index of the samples increased as the time of immersion was increased. Swelling of the samples in sea water could be attributed to the interaction between the hydrophilic cellulose molecules of the okam fibers and water molecules. According to Jayamol et al (2), cellulose which is the main constituent of plant fibers contain three hydroxyl (-OH), groups. These hydroxyl groups form hydrogen bonds between the cellulose molecules and exposing these bonds to humidity causes them to be broken. The hydroxyl groups then form new hydrogen bonds with water molecules which induce swelling.

In the case of the petroleum products, Jiagun li et al (12), suggested that the

(1.0)



organic liquids penetrate and swell the polymeric composite through diffusion and absorption phenomena. Hence allowing crazing (formation of micro voids) to take place at lower stresses and once a craze has formed; the active environment is able to diffuse along the craze more easily than through the bulk material.

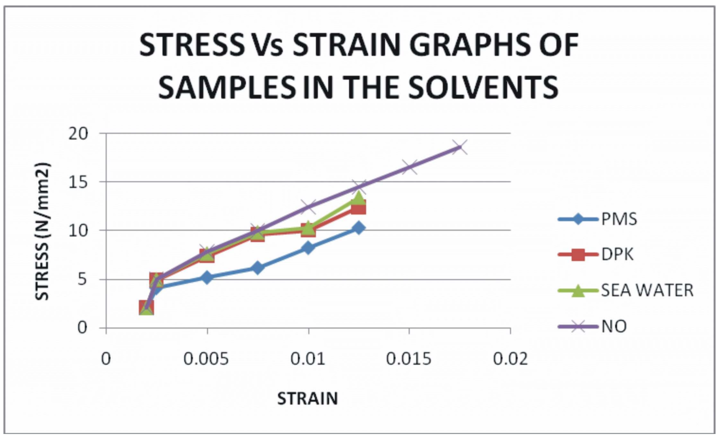
(3.0)

Calculation of percentage Solvent Absorption and Swelling index of the composite material shows that these parameters are highest for samples immersed in premium motor spirit and least for those immersed in sea water.

3.2 Tensile Strength of Okam Fiber-reinforced Composite Immersed in Selected Solvent

Figure 2.0 shows the tensile stress Vs strain curves of the samples before and after their immersion in the solvents for 16 weeks. It can be deduced from the graph that the samples degraded in strength as a result of their interaction with these media.

According to Ko (13), the strength and other mechanical properties of a composite material depend on a number of microstructural parameters which include: volume fraction of the constituents; shape of second phase (particulate, platelet or fiber), dimensions of second phase constituents (diameter, length and aspect ratio), orientation of fibers with respect to the loading direction and the properties of the interface between the constituents. For a uniaxially loaded composite, the ultimate strength can be calculated from the rule of mixture approach given by:



$$\sigma_c = \sigma_f V_f + \sigma_m (1 - V_f) \quad (4.0)$$

Where σ_f is the tensile strength of the fibers, σ_m is the tensile strength carried by the matrix when the fibers are strained to their ultimate strength and V_f is the volume fraction of the fiber. The critical fiber volume (V_{fc}) which must be exceeded for fiber strengthening to occur is:

$$V_{FC} = \frac{\sigma_U - \sigma_m}{\sigma_f - \sigma_m} \quad (5.$$

Where σ_u is the ultimate strength of the matrix. For a composite to develop its full strength, a critical length

$$L_c = \frac{\sigma_f d}{2\tau_0} \quad (6.0)$$

Must be exceeded. Where τo is shear yield stress of the matrix and d is the fiber diameter. Figure 2.0 again revealed that the greatest reduction in strength was noticed in samples immersed in petrol followed by the ones immersed in kerosene. Sea water produced the least effect on the strength of the composite material. Reduction in strength of the composite material could be attributed to the weakening of interfacial bond between the matrix and fiber and the fact that the presence of the solvents lowers the surface energy of the composite material and makes deformation easier at lower stresses (13).

4.0 CONCLUSIONS

1. The solvents investigated reduced the tensile strength polyester- okam fiber composite.
2. Swelling of the composite material was greatest in petrol, followed by kerosene and was least in sea water.

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