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Micro-Structural Characterization of Sisal/Jute Hybrid Fibre-Reinforced Polyester Composites

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ABSTRACT

This research investigated the micro-structural characterization of sisal/jute hybrid fibre reinforced polymer. Sisal/Jute hybrid polymers composite are of low cost, light weight, and possess satisfactory mechanical properties. In this research work, hand layup technique was used to produce the hybrid composites using percentage combination of sisal and jute fibres at a ratio of 33:67, 67:33, 50:50 in the form of laminates prepared with unsaturated polyester at different orientations of $90^0/90^0, 90^0/0^0, 45^0/-45^0$. *Optical microscopy (OPM), scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) tests were carried out on the samples. The micro-structures of the sisal/jute hybrid were observed to have a good interfacial bonding.*

1. INTRODUCTION

Advances in the development of natural fibres-reinforced polymers as a suitable alternative to synthetic fibres is gaining attention in engineering application due to their environmental friendliness and strength to weight ratio (Mohammed et al., 2015). The combination of different natural fibres as reinforcement in polymers tends to improve the mechanical properties of the composite material produced. Hence, the incorporation of different types of fibres into a single matrix has led to the development of hybrid bio-composites (Maya et al., 2017). A hybrid composite is a weighed sum of the individual components in which there is a more favorable balance between the inherent advantages and disadvantages. Also, using a hybrid composite that contains two or more types of fibre, the advantages of one type of fibre could complement what is lacking in the other. As a consequence, a balance in cost and performance can be achieved through proper material design. The properties of a hybrid composite mainly depend upon the fibre content, length

of individual fibres, orientation, extent of intermingling of fibres, fibre to matrix bonding and arrangement of fibres (Brijesh et al., 2014). The strength of the hybrid composite is also dependent on the failure strain of individual fibres, and desirable results are obtained when the fibres are highly compatible (Brijesh et al., 2014).

Attempts have been made by researchers on natural fibre composites. Yan et al. (2000) investigated the behavior of sisal fibre and glass fibre polymer hybrid composite. They observed that the addition of sisal to glass fibres produced hybrid composites which took advantages of the best properties of the constituents. Saranya, (2018) studied the characterization and synthesis of nano sisal fiber reinforced composites. In their study, they compared the tensile properties of sisal nano fibre-reinforced polymer composites to glass fibre reinforced polymer composites and found that the tensile strength of sisal nano fibre-reinforced polymer composites were higher compared to glass fiber reinforced polymer composites. Ravi et al. (2013) examined the mechanical characterization of banana/sisal fibre-reinforced polylactic acid (PLA) hybrid composites for structural application. They found that the tensile strength of the treated banana/sisal fibre reinforced PLA bio-composites materials were significantly higher than those of untreated banana/sisal fibre reinforced PLA bio-composites. The fibres treated with NaOH had the best mechanical properties compared to pure PLA and the untreated fibre bio-composites. Venkata Reddy et al. (2008) investigated the compressive strength, modulus, chemical resistance and thermal characteristics of unsaturated polyester resin based kapok/sisal hybrid composites developed by the hand lay-up technique at room temperature. The variations in mechanical properties of these composites were evaluated as a function of fabric/fiber content and different volume ratios of fabrics. They observed that the addition of a relatively small amount of sisal fiber to kapok reinforced polyester matrix, enhanced the compressive properties of the resulting hybrid composites. Oreko et al. (2018) evaluated the compressive and impact strength of plantain fibre-reinforced polyester composite, and they observed that increase in the volume fraction addition of plantain fibre significantly increased the compressive and impact strength and they developed same for automobile fender. Ramesh et al. (2014) studied the impact behavior and analysis of sisal/jute and glass fiber reinforced hybrid composites. They found that the inclusion of sisal and jute fibres with glass fibre reinforced polymer (GFRP) composites gained good impact properties.

The properties and behavior of different fibre plants reinforced in polymeric have also been reviewed and studied (Edelugo, 2004; Edelugo, 2010; Ravi et al., 2013; Gupta and Srivastava, 2016; Anaidhuno et al., 2017a; Anaidhuno et al., 2017b; Palpandi et al., 2018). However, from literature it has been observed that limited work has been done on polyester reinforced with locally grown sisal/jute hybrid fibres. Hence, this work seeks to investigate the micro-structural characteristics of sisal/jute hybrid fibre-reinforced polyester composites.

2. MATERIALS AND METHODS

2.1. Sourcing of Materials

The materials used for the preparation of the composite were unsaturated polyester resin (matrix), methyl ethyl ketone peroxide (catalyst), cobalt naphthalene (accelerator), Vaseline (releasing agent) bought from Pascal Scientific Laboratory, Akure, Ondo State, Nigeria. Sisal plant fiber was obtained from Ogbemena garden, in Nneni town, Anambra State, Nigeria. Jute plant was obtained from Tiawo Farm, Owode, Ogun State, Nigeria.

2.2. Extraction of the Fibres

The process involved steeping and keeping the bast plant of jute and the leaf plant of the sisal in submerged in water for a period of time not less than 30 days, allowing the immersion to be 10 - 15 cm from the top. Through this process, bacteria act on the soaked plant. The bacteria acting on it release enzymes which also act and allows the plant to soften as much as possible. The fiber was properly washed with ordinary water and re-soaked for total removal of the lignin still attached. The fibres were dried, brushed and sorted into various grades.

2.3. Fibre Surface Treatment

The treatments of sisal/jute fibres was done with alkali, the process is called mercerization wherein 5%w/v sodium hydroxide was used to break hydrogen bonding in the network structure of the fibre's cellulose, thereby increasing the fibre's surface roughness. This treatment also removes lignin, wax and oils covering the external surface of the fibre's cell wall, de-polymerizes the native cellulose structure and exposes short length crystallites.

2.4. Sisal/Jute Hybrid Composite Specimen Preparation

The productions of the various composite materials were carried out through hand lay-up technique. Sisal and jute fibre strands were reinforced in unsaturated polyester, methylethylketone catalyst and cobalt accelerator at a ratio of 10:1:0.5. Each composite was loaded in 0.40 volume fraction, which means 0.4 of fibre volume and 0.6 of resin (polyester) or matrix composition by volume weight (Anaidhuno et al., 2017a). They were arranged in the orientation of $90^0/90^0, 90^0/0^0, 45^0/-45^0$ with a fibre combination percentage ratio (sisal to jute) of 50:50, 67:33, 33:67, with reference to a control sample of non-fibre (resin alone) and mild steel sample. The casting of the composites samples were cured under room temperature / consolidate with a roller load weight of 50 g, at 4 hours before samples were removed from the mould. Thereafter, specimens were further cured in the air for 12 hours. Table 1 depicts the samples designation, percentage combination, orientation and plies while Figure 1 is the laminated samples of sisal/jute hybrid fibre-reinforced polyester composites. A scanning electron microscope and energy dispersive spectroscope was used to study the morphology and compositional characteristics of the sample (Figure 2). An optical microscope (OPM) was used for the creation of a magnified image of the specimen (Figure 3). The material features were viewed under a micro-scale. The magnification of an OPM focuses the images up to 1000X resolution.

Table 1: Samples designation

Sample designation	Sisal/jute percentage combination	Lay-up orientation	Number of plies
F0	NIL	NIL	NIL
MS	NIL	NIL	NIL
T10	33:67	90º/90º	4
I15	67:33	45º/-45º	4
C10	33:67	90º/0º	4
B4	50:50	45º/-45 º	4
M3	50:50	90º/90º	4

MS = Mild steel (standard of comparison) and F0 = Control sample

The control sample is an unreinforced polyester (without sisal or jute reinforcement) used as a basis for comparison and drawing conclusion on the behavior and level of changes in the other samples.

Figure 1: Sample of laminates

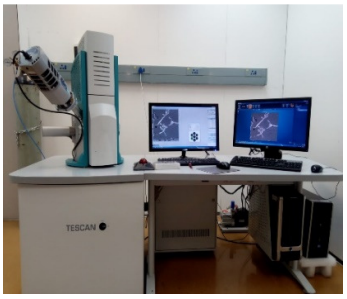

Figure 2: Tescans scanning electron microscope

Figure 3: Optical microscope (olympus BX51 model)

3. RESULTS AND DISCUSSION

Figures 4 to 10 are the micro-structural examination of the specimens viewed under an optical microscope at 200 µm with a magnification of 5X. Figure 4, designated sample A -MS, is a mild steel observed under optical microscope, with the main constituents as Iron and carbon, seen as brown and white flakes of Iron-Carbide bond. Figure 5 designated as sample B - F0, is an unreinforced polyester (without sisal or jute fibre reinforcement). In this sample, no strands of fibre were seen, indicating the brittle characteristic of plastic. Sample C, designated as T10 revealed the fibre strands reinforced in the matrix (figure 6) and the blur area indicates the existence of a strong bond between the fibre and matrix at 33% sisal and 67% jute. Figure 7, Sample D, designated I15, shows fibre strands orientated at 45°/-45° having a constituent of 67% sisal and 33% jute, reinforced with polyester resin. Close examination also indicate strong bond as in sample C. Figure 8, sample E, designated C10 under the optical microscope view, shows fibre/matrix bonding with a constituent of 33% sisal and 67% jute at 90°/0° orientation. Close examination shows strong bond between the fibre and matrix. Figure 9, sample F, designated B4 shows fibre strands reinforcement with polyester resin and the blur area indicate strong bond between the fibre (50% sisal and 50% jute) and the matrix at 45°/-45° orientation. Figure 10, sample G, designated M3 shows fibre strands reinforcement and the blur area around the fibre also indicate strong interfacial bond between the fibre and the matrix at 50% sisal and 50% jute, orientated at $90^0/90^0$.

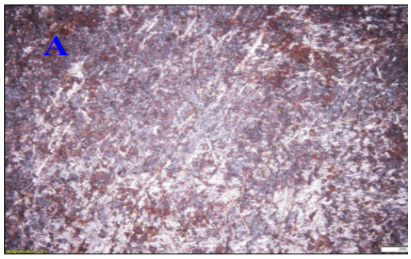

Figure 4: Sample A designated MS optical micrograph

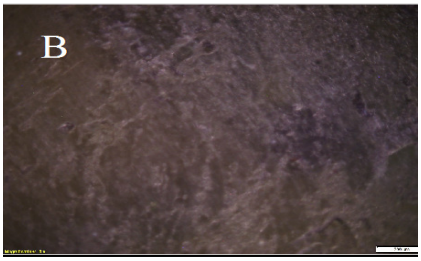

Figure 5: Sample B designated F0 optical micrograph

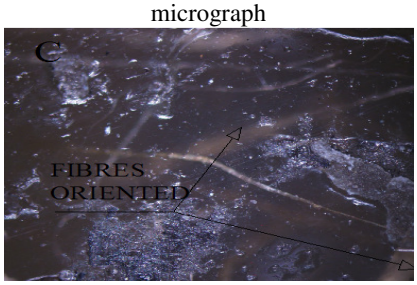

Figure 6: Sample C designated T10 optical micrograph

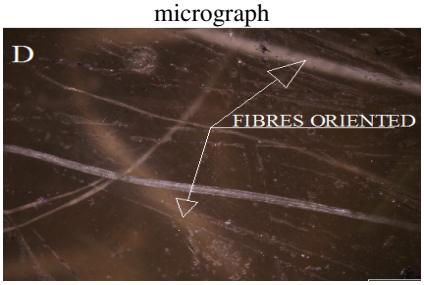

Figure 7: Sample D designated I15 optical micrograph

Figure 8: Sample E designated C10 optical micrograph

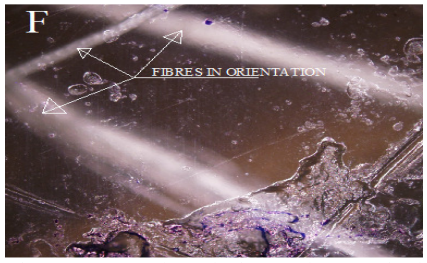

Figure 9: Sample F designated B4 optical micrograph

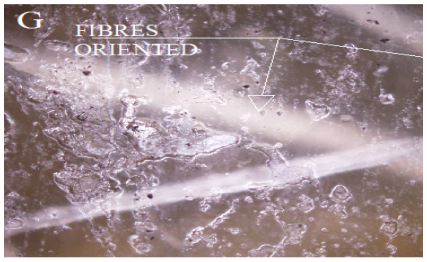

Figure 10: Sample G designated M3 optical micrograph

Figures 11-17 show the micro-structure of the specimens viewed under the scanning electron microscope. Figure 11, sample A, designated MS is a mild steel, with the main constituents Iron and carbon depicted with dark and white flakes of Iron-Carbon bond, evenly arranged in crystalline form. Figure 12, sample A designated F0 under the scanning electron microscope (SEM), is an unreinforced polyester (without sisal or jute fibre reinforcement). A little consideration shows no evidence of bonding within the specimen which also agreed with optical microscope scanning result in Figure 5. Figure 13, sample C, designated T10 shows fibre/matrix agglomeration indicating strong interfacial bonding between the fibre and the matrix, at 33% sisal and 67% jute. Likewise, sample D, designated I15 shows matrix/fibre agglomeration, indicating interfacial bond, at fibre constituent of 67% sisal and 33% jute. However, a close examination shows some voids which indicate defect around the bond in the specimen (Figure 14). This defect may be as result of 'air-trap' during lamination of sample, which could weaken the strength of bond. And this could lead to mirocracks at a very small load at that region and the failure of the entire material (Mehdikhani el at., 2019; Zenker et al., 2019). Figure 15, sample E, designated C10, shows matrix/fibre agglomeration between the fibre (consisting of 33% sisal and 67% jute) and the polyester matrix, orientated at $90^0/0^0$. Close examination shows strong bond between fibre and the matrix with no void seen. Equally too, in figure 16, sample F designated as B4, fibre (50% sisal/50% jute) and matrix agglomeration was observed with strong interfacial bond existing between the fibre and matrix, at $45^0/-45^0$ orientation. Figure 17, sample G, designated as M3 (consisting of 50% sisal and 50% jute) shows the same fibre/matrix agglomeration, indicating a strong bond between the fibre and matrix.

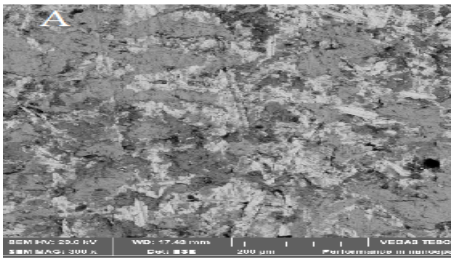

Figure 11: Sample A designated MS scanning electron micrograph

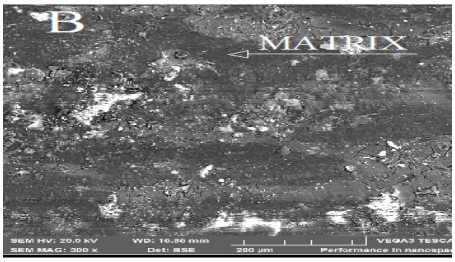

Figure 12: Sample B designated F0 scanning electron micrograph

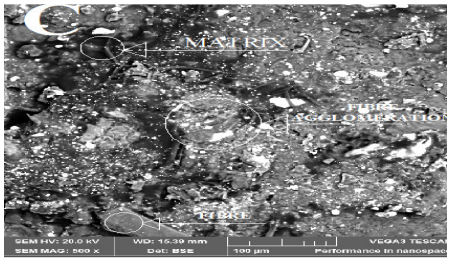

Figure 13: Sample C designated T10 scanning electron micrograph

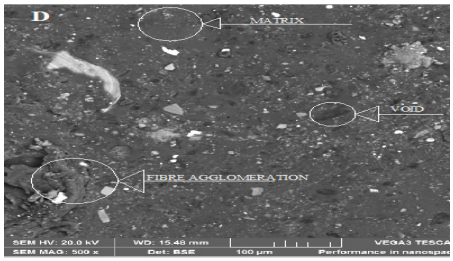

Figure 14: Sample D designated I15 scanning electron micrograph

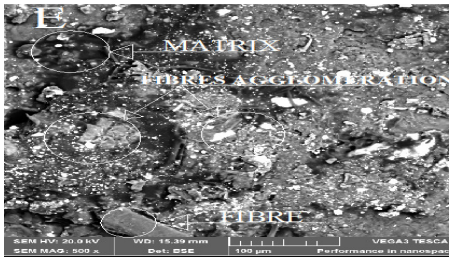

Figure 15: Sample E designated C10 scanning electron micrograph

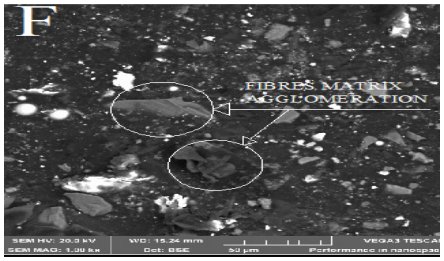

Figure 16: Sample F designated B4 scanning electron micrograph

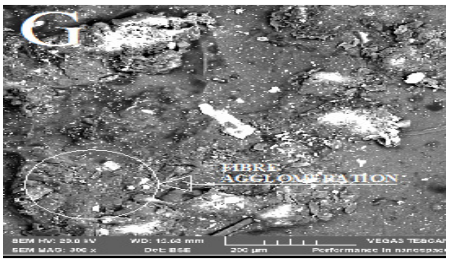

Figure 17: Sample G designated M3 scanning electron micrograph

Figures 18-23 show the micro-structure of the specimens done with Energy Dispersion Spectroscope (EDS). Figure 18 (sample A), designated sample MS, is a mild steel observed under the energy dispersion spectroscope. It consists of the following main constituents; Fe-77.6%, C-14.1%, Al-4.3% composition by weight. Figure 19, (sample C) designated T10 shows C-69.4%, O-27.9%, Na-1.2%, Al-0.7, Si-0.7% composition by weight, with fibre constituent of 33% sisal/67% jute. Figure 20 (sample D) designated I15 shows C-69.3%, O-25.9%, Si-2.7%, Ca-2%, Al-0.2% composition by weight, with fibre constituent of 67% sisal/33% jute. Figure 21 (sample E) sample designated C10 shows C-82%, O-16.1%, Si-0.8%, Ca-0.6, Al-0.5% composition by weight, with fibre constituent of 33% sisal/67% jute. Figure 22 (sample F) designated B4 shows C-62.1%, O-30.1%, Fe-4.5%, Si-1.8%, Al-1.2%, S-0.1%, Ti-0.1% composition by weight. Figure 23, (sample G) designated M3 shows C-76.1%, O-21.2%, Si-1.4%, Cl-0.7%, Ca-0.5%, Al-0.2% composition by weight with fibre constituent of 50% sisal and 50% jute.

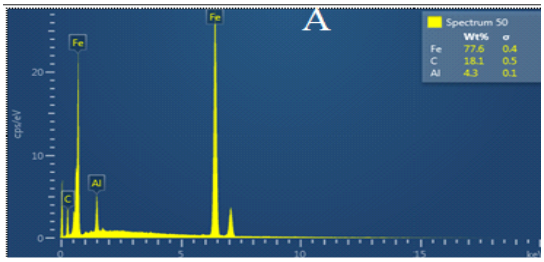

Figure 18: Sample A designated MS EDS composition

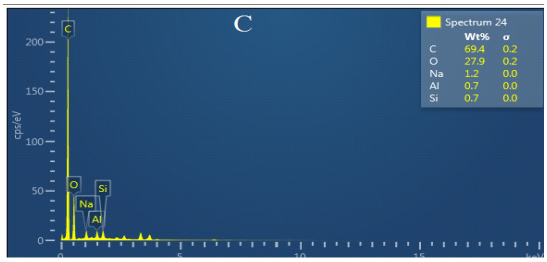

Figure 19: Sample C designated T10 EDS composition

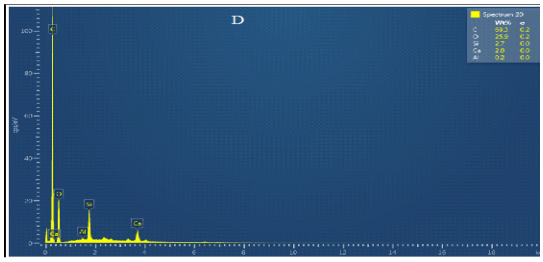

Figure 20: Sample D designated I15 scanning electron micrograph

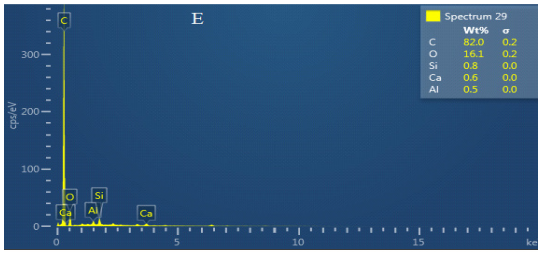

Figure 21: Sample E designated C10 EDS composition

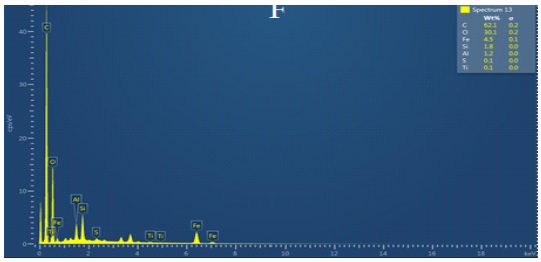

Figure 22: Sample F designated B4 EDS composition

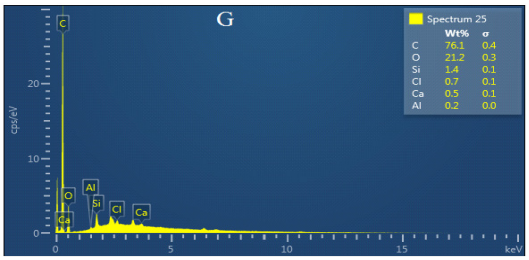

Figure 23: Sample G designated M3 EDS composition

4. CONCLUSION

This research investigated the micro-structural analysis of sisal/jute hybrid fibre-reinforced polyester composites. A hybrid composites was developed using hand layup technique based on percentage combination of sisal and jute fibers at; 33:67, 67:33, 50:50 in the form of laminates prepared with unsaturated polyester at different orientations $-90^0/90^0$, $45^0/-45^0$, $90^0/0^0$. Optical microscope, scanning electron microscope and energy dispersive spectroscopy were used to assess the properties of the sisal/jute hybrid composites samples. The micro-structure of the sisal/jute hybrid were observed to have a good interfacial bonding.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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