The Influence of Fibre Weight (wt%) Content and Fibre Size on The Mechanical Properties of Locally Fabricated Rice Husk Fibre Reinforced Polyester Composite Laminates

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ABSTRACT

This study conducted an investigation to determine the effect of fibre weight (w%) content and the fibre particle size on the mechanical properties of composite laminated produced polymer resin material reinforced with rice husk fibres. Rice husk were obtained from rice mill in Birnin Kebbi, Nigeria. The rice husk was grinded and sieved to obtain different grades of particles sizes ranging from 16.7 mesh size, 15 mesh size (finest), 6.5 mesh size, (fine) and 4.61 mesh size (coarsest). Composite laminates with different particles sizes were fabricated using locally assembled wooden mould and with different fibre content of 30, 40 and 50 weight percent (wt%). The fabricated laminates were then subjected to mechanical testing using Instron Mechanical Testing Machine at a crosshead speed of 5mm/min to determine their mechanical properties. Mechanical properties measured included modulus of elasticity, tensile modulus and tensile strength. From the results, it was found that, within the limit of experimental errors, there was a general trend in the mechanical behaviour of the laminates that shows that the laminate with the lowest fibre content (30 wt%) exhibited maximum mechanical properties compared with the other samples containing 40 wt% and 50 wt% fibre contents respectively. Beyond the 30 wt% fibre content, the mechanical properties of the composites start to slope downward towards lower values. With regards to changes in the fibre particle size, the results reveal that as the particle size increases the mechanical properties of the composites start to decrease downward to lower values. It can, therefore, be concluded that both the fibre particle size and the fibre weight (wt%) content play a significant influence in optimization of the mechanical performance of composite laminates which were fabricated from rice husk fibre reinforced polyester resin matrix.

Keyword: Rice husk fibres, finest size, finer size, fine and coarsest size.

1. INTRODUCTION

In several structural and other engineering applications, there has been an increasing interest in using natural fibers or particles as reinforcement in polymers rather than the more traditional synthetic reinforcements. This is due to the fact that synthetic fibres or particle reinforced polymer composites, such as those made of aramid fibres, glass fibres, carbon fibres, etc., have a number of advantages over more traditional materials like steel and wood concrete (high stiffness, high strength-to-weight ratio, etc.), their high initial cost and negative environmental impact are restricting their use [21, 22]. The development of composites is currently shifting from synthetic fibres to natural fibres, which is due to the fact that composite materials made with synthetic more adaptable, and can be customized to satisfy a variety of performance needs and intricate design specifications. The simplicity of creating composites with natural fibres is due to the ease with which the materials may be obtained from fibres, including glass fibres, are not eco-friendly and produce issues with waste glass fibres that cannot be broken down naturally [23]. Natural fibre composites have a number of noteworthy advantages over synthetic fibre composites. These benefits include low cost, lighter weight, do not irritate the skin, high strength-to-weight and stiffness-to-weight ratios, elimination of corrosion and stress corrosion, availability in the form of plants and wastes, non-toxicity, improved control of surface contour and smoothness, higher fatigue endurance limit (up to 60% of ultimate tensile stress), and 30-40% lighter than any specific aluminum, as well as structures designed to meet the same functional requirements. Compared to metals, they are less loud when operating, transmit vibrations at a lower rate, are agricultural or natural wastes, making it possible to make the composites relatively quickly [23]. It is possible to produce natural fibres to ensure their continued availability. Natural fibres do, however, have a number of flaws, including uneven

dimensions, stiffness, heat sensitivity, water absorption easiness, and rapid obsolescence [23]. Composite materials are best utilized in structures where strength-to-weight ratio is a key factor. The use of natural fibres composites in non-structural applications has also been attempted. Many vehicle parts that were formerly constructed with glass fibre composites are now being produced with the help of eco-friendly composites. The use of natural fibres composites in the automotive sector has two key benefits, including enhanced fuel efficiency due to less weight and increased production sustainability due to the ability to grow natural fibres [24, 25]. Nigeria now produces the the largest amount of rice in west africa, averaging 3.2 million tons of paddy rice or 2.0 million tons of milled rice each year, with a rising demand for 4.1 million tons of rice in 2002. It is also the top consumer in the area [26]. In many rice-producing nations worldwide, rice husk is one of the most readily available agricultural byproducts. Every year, paddy rice production reaches about 600 million tons worldwide. On an average 20% of rice crop is made up of husk, producing 120 million tons annually [27]. The majority of rice husk generated during processing is either burned or thrown as garbage in the majority of rice-producing nations. Rice husk ash (RHA) is the by-product of burning rice husk in an environment with no added oxygen. Around 220 kg (22%) of rice husk is produced for every 1000 kg of milled rice paddy, and when this husk is burned in the boilers, approximately 55 kg (25%) of rice husk ash (RHA) is created. The removal of rice husks (RH) during milling causes disposal issues because there is less commercial interest. RHA, also known as rice husk ash, is a menace to the environment that harms nearby land and ecosystems when it is discharged [9]. The utilization of rice husks for commercial purposes would also mitigate open burning, contributing to environmental protection. Moreover, employing these natural fibers would prevent harmful substances from off-gassing. As a result of the processing of these wastes for use as natural fibres and the subsequent application in various applied technologies for the production of new products, the use of rice husks will result in the creation of jobs. The use of these natural fibres as reinforcements would improve local content for other structural and engineering components as well, helping to conserve foreign currency. In India, for instance, rice husks are being used as materials to make the rear bumpers for Bajaj RE tricycles and hence, the mechanical characteristics of composites made are intensively studied. In this study, an investigation was carried out to determine effect of both the fibre weight content and the fibre particle size on the mechanical properties of composites produced from rice husk fibres reinforced polyester resin matrix at the longitudinal and the transverse directions.

2. MATERIAL AND METHOD

Materials used for this investigation include rice husk fibres, collected from Labana Rice Nigeria Ltd, Birnin Kebbi, Polyester resins, Methy Ethyl Ketone (MEKP) ($[(CH_3)(C_2H_5)C(O_2H)]_2O_2$) hardener and Cobalt dryer, purchased from Nycil Nigeria limited, Otta, Ogun state, Nigeria and diesel oil release agent.

2.1 Sample Preparation

The collected rice husk fibres were sun dried using a local grinding machine, to obtain sample materials with distinct particle size portions and for fabrication of composite laminates. Subsequently, the grounded fibre particles underwent further sieving initially with a 16.7 mesh sieve to isolate the finest particles. The left over particles were then subjected to further sieving using a 15 mesh size sieve to obtain finer particles. The residue remaining in the sieve after the second sieving step was collected to pass through a 6.5 mesh size sieve as the fine fraction. Additionally, the fibers collected without grinding were utilized in their original form, used as the coarsest fraction to pass through a 4.61 mesh size sieve.

2.2 Preparation and casting of the laminates

The weight of polyester/rice husk fibre was determined through thorough adherence to ASTM D638-14 standards. The volume of the mould was calculated using dimensions of the mould by multiplying the length by the width and the thickness. The volume was converted to mass by weighing weighing a correspondingvolume of water on a precision analytical weighing balance. The measurements were conducted for various chosen fiber/matrix mass ratio, which are 30/70, 40/60 and 50/50 weight fractions, resulting in a total of three distinct composite formulations. Each constituent contains 101g of the material and equivalent of the required percentage of resin prepared was thoroughly mixed manually and carefully dispensed into a wooden mould measuring 320mm in length, 165mm in breadth, and possessing a thickness of 3.4mm.

Fig. 1: Locally Constructed Wooden Mould and Roller used in the Fabrication of the Composite Laminates

The mould was carefully lined with thin film polyethylene lining treated with diesel oil as a release agent, to facilitate the easy extraction of the composite material. While in the mould, the material was gently spread with a hand roller and made to fill the mould cavity and take up required shape of the mould. The mixture material was enveloped in thin film polyethylene lining to prevent air contact and later a male cover was used to cover the cavity for further curing. A pressure of 30 kg was applied for duration of about 24. During moulding process, the composite material heats up and flows within the mold cavity, conforming to the desired shape. Subsequently, the mould underwent a cooling phase and the resulting sample was carefully extracted from the thin film polyethylene lining and systematically labelled with masking tape. Consistent procedural steps were followed for each composition. The prepared sample was then poised for mechanical and physical testing.

The dog bone specimens (fig.2, below) for both the longitudinal and transverse directions were cut from the composite laminates

and subsequently subjected to mechanical testing under an Instron mechanical testometric meter machine.

Fig. 2: Rice Husk Laminate Specimens for Mechanical Tensile Tests

2.4 Mechanical Tensile Testing

The tensile tests were conducted on flat composite samples following the ASTM D638-03 standard for testing of moulded composite, with a gauge length of 57mm, width of 19mm, and thickness of 3.4mm. The machine was initially configured with a loading speed of 5mm/min. Throughout the experiment the specimen was securely affixed between the machine's two jaws and subjected to gradual tension at 5mm/min until reaching the point of rupture. Concurrently, the machine generated a force deformation curve, which was displayed on the screen attached to the machine. From the curve, the force applied (in KN) and elongation at break (in mm) were automatically extracted, by the microprocessor attached to the machine.

Fig 3: Composite Specimen Clamped on the Instron Tensile Testing Machine

The relationship between the stress and strain that a particular material displays is known as that particular material's stress–strain curve. It is unique for each material and is found by recording the amount of deformation (strain) at distinct intervals of tensile or compressive loading (stress). These curves reveal many of the properties of a material (including data to establish the Modulus of Elasticity (E). The tensile properties were calculated by using the formula below:

$$\text{Stress } (\sigma) = \frac{\text{Force}}{\text{Cross sectional area}} = \frac{F}{A}$$

where, cross-sectional area = width of the specimen × thickness

$$\text{Strain}(\varepsilon) \frac{\text{Extension at break}}{\text{Length of the narrow section}} = \frac{\Delta L}{L} \text{Young modulus}$$

$$(E) = \frac{\text{Stress}}{\text{Strain}}$$

and strain at the longitudinal and transverse directions of composite specimens with different fibre particle sizes.

3.   RESULT AND DISCUSSION

3.1   Tensile Test Results

Table 1 is the summary of the results of the mechanical properties (elastic modulus, Tensile strength, tensile modulus,

Table 1: Result of the Mechanical Properties of the Composite Laminates Tested

Material	MECHANICAL PROPERTIES					
	Test Direction	Peak Load	Strain	Elastic Modulus (MPa)	Tensile Modulus (MPa)	Tensile Strength (MPa)
RFN50/50L	Longitudinal	101.5	0.028	1156.1	718.731	2.44
RFNR50/50L	longitudinal	57	0.021	603.34	312.923	1.37
RFNST50/50L	longitudinal	261	0.0069	980.978	987.901	6.274
RFN30/70L	Longitudinal	201	0.023	2080.64	430.274	4.832
RFNR30/70L	Longitudinal	448	0.011	3045.61	1029.94	10.769
RFNST30/70L	Longitudinal	399	0.012	3157.32	1642.11	18.581
RFN40/60L	Longitudinal	51.5	0.0198	345.596	430.274	1.238
RFNR40/60L	Longitudinal	300	0.01	2551.02	925.896	7.212
RFNST40/60L	Longitudinal	399	0.01	2285.33	1097.81	9.591
RFN40/60T	Longitudinal	51.5	0.0198	408.14	436.65	0.6971
RFNR50/50T	Transverse	552	NIL	NIL	NIL	NIL
RFNST50/50T	Transverse	183	0.007	NIL	NIL	NIL
RFN30/70T	Transverse	233	0.010	2904.81	1440.66	13.269
RFNR30/60T	Transverse	448	0.015	4577.69	1588.6	20.457
RFNST30/70T	Transverse	552	0.012	2678.96	1484.14	13.478
RFN40/60T	Transverse	160	0.010	1162.59	525.73	13.269
RFNR40/60T	Transverse	160	0.010	1614.87	642.91	3.846
RFNST40/60T	Transverse	843	0.010	2207.53	1386.6	20.264

RFN=rice fine, RFNR=rice finer, RFNST=rice finest, L=longitudinal, T=transverse

While figures. (4-6) below represent the stress-strain curves of the samples that were subjected to tensile mechanical tests under the Instron Machine.

3.1.1   Stress-strain curves

Figures 4-6 display the stress-strain curves of the samples tested along the longitudinal and transverse directions. The curves

were obtained from the data at table 1. Observation from the figures has shown that the stress- strain deformation of the samples follows the same characteristics behaviour for all the samples. As reported in previous investigations [3] as the load is applied the samples steady undergo deformation by elongating along the direction of the applied load. The elongation continues with the applied load until a break point is

reached and the fibres reach maximum extension, whereby, the load starts to drop down. Simultaneously, the deformation at first falls down instantaneously before reverting to time dependent steady deformation. It continues to go down until the remaining residual load gets exhausted and the elongation is at its maximum point.
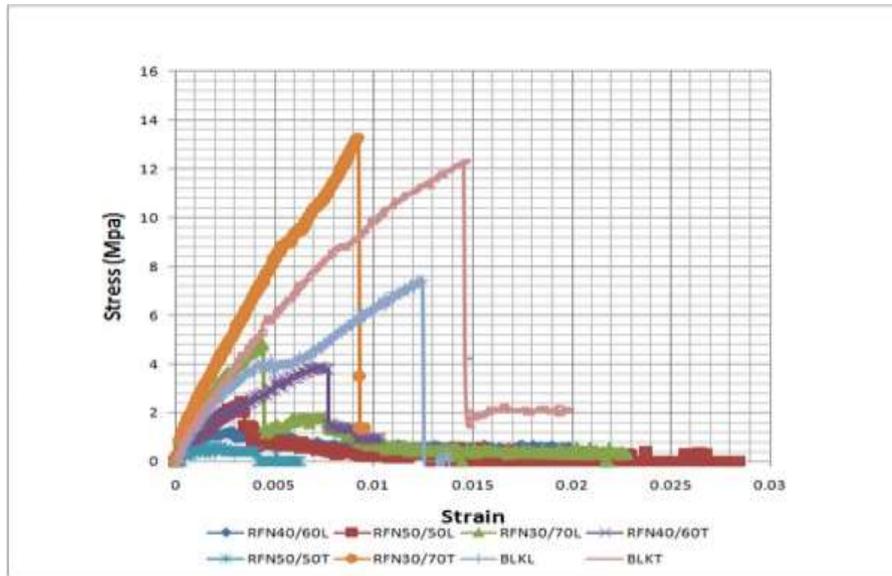

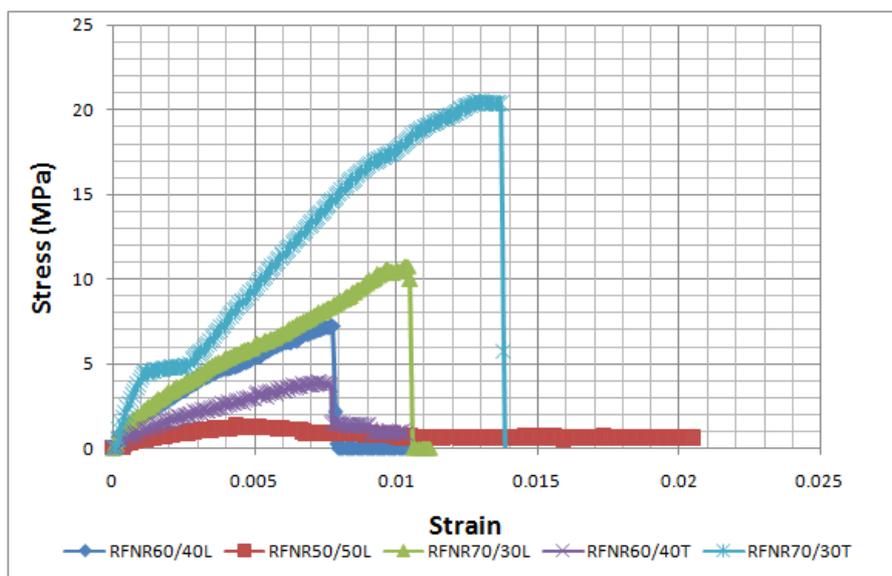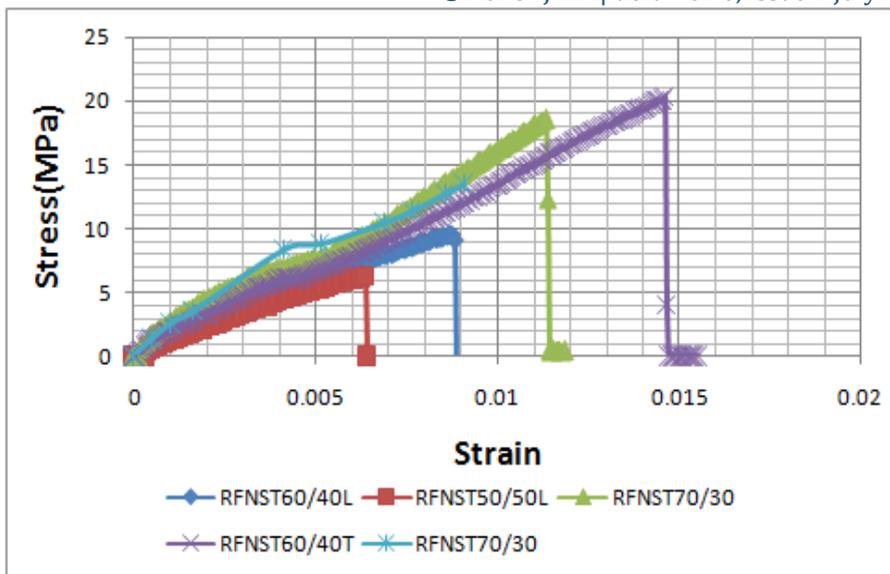**Fig. 4:** Stress-Strain Curves of the Fine Composites Samples

Fig. 5: Stress-Strain Curves of the Finer Composites Samples

Fig. 6: Stress-Strain Curves of the Finest Composites Samples

From table 1, the data of the strain values of the samples under investigation can be seen. It can be seen that the highest tensile strain (0.012) was recorded by the longitudinal 16.7 mesh size fibres with 30 wt.% fibre content. It can be considered as having the maximum ductile property amongst the samples. The other samples have the same strain values ((0.01) and therefore have similar strain properties for laminates of this category.

Considering the samples with 15 mesh size fibres, observation has shown that the longitudinal 50 wt.% fibre content sample recorded the maximum strain (0.021) amongst the samples. The lowest strain (0.02) was recorded by the longitudinal and transverse 40 wt.% fibre content samples. Among the samples in this category, we can consider these samples to be the most brittle samples and least ductile.
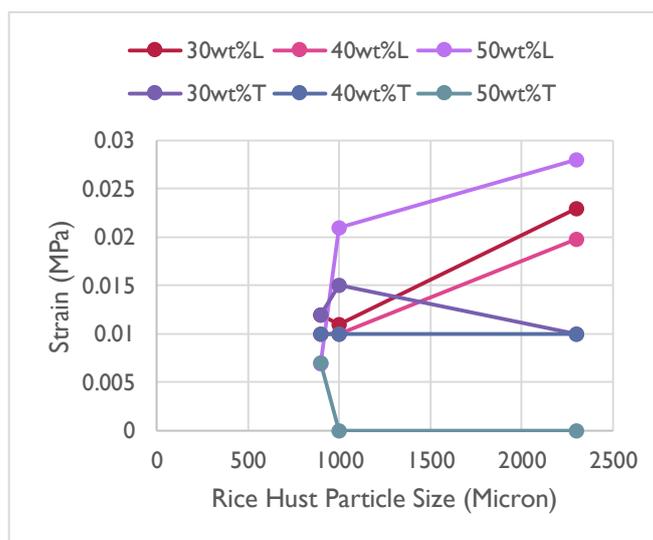
Fig. 7: Effect of Fibre Weight (wt%) Content on Strain of the Composites

3. 2 The effect of Fibre Weight (wt.%) Content on the Mechanical properties of the laminates.

The effect of fibre weight (wt.%) content on the mechanical properties of the composite laminates has been studied and is shown in figures 7-11. The. characteristic curves display the changes in the mechanical properties as a result of increases in particle size of the composite samples from the 16.7, 15, 5 and 4.61 mesh sizes.
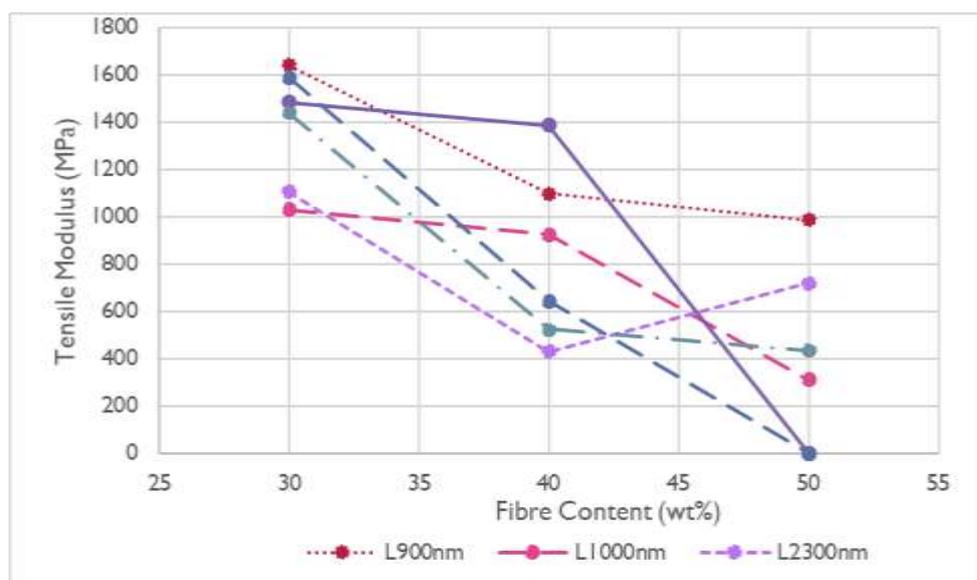
3.2.1 Effect on Tensile Modulus

Figure 8 is a graphical representation of the effect of particle size on the tensile modulus of the rice husk polyester composites (RHPECs). It can be seen that at a fibre weight content of 30 wt.%, the value of the tensile modulus of the longitudinal samples are 1642.11 MPa, 1029.94 MPa and 1106.06 MPa for the finest, finer and fine samples. At the transverse direction the composites samples produce a tensile modulus of 1484.14 MPa, 1588.6 MPa and 1440.66 MPa respectively. When the RHF content increased to 40 wt.% the value of the tensile modulus for the longitudinal samples decreased to 1097.81 MPa, 925.89

MPa and 430.27. At the transverse direction, the modulus recorded a decrease of 1386.6 MPa, 643.91 MPa and 525.73 MPa. When the rice husk fraction (RHF) increases to 50 wt.% the longitudinal tensile modulus deceases to 987,90 MPa, 312.92 MPa and 718.78 MPa for the finest, finer and fine particle size samples, while for the transverse samples the tensile modulus of the rice husk polyester composite (RHPECs) could not be tested because the samples cut from that direction were too fragile to withstand tensile loading and crumbles into pieces when the load was applied to them. Generally, from the graphical behaviour of the samples, it can be seen that there a general trend has emerged which shows that at fibre weight (wt.%) content below 30 wt.% fibre content the tensile modulus of the samples increases to higher values. At a threshold value of 30 wt.% fibre content the tensile modulus reaches a maximum value and at values beyond the threshold value, the tensile modulus starts to decrease to lower values.. This type of behaviour has been reported in in previous investigations [2, 13]. However, this observation was found to be contradict the

findings of other previous researchers that shows that the tensile modulus of composites increases as the fibre content increases beyond the threshold value [4, 6,15, 19].

One of the major reasons as put forward that accounts for the decrease in the modulus of the samples due to increase in fibre weight (wt.%) content was attributed to the fact that increasing the fibre content can cause air entrapment during mixing process. This in turn can cause the formation of voids in the cured composites, which increases the brittleness and susceptibility of the composite to early cracks development of the material [2]. In another contribution the decrease in tensile modulus was also reported to be caused by overcrowding of the fibres, which can cause low fibre orientation and lack of uniform stress transfer from the continuous polymer matrix to the dispersed fibre phase [11]. Conversely, the increase in the tensile modulus as a result of the increase in fibre content was said to be attributed to the increase in rigidity of the matrix when there is addition of more fibres [15].
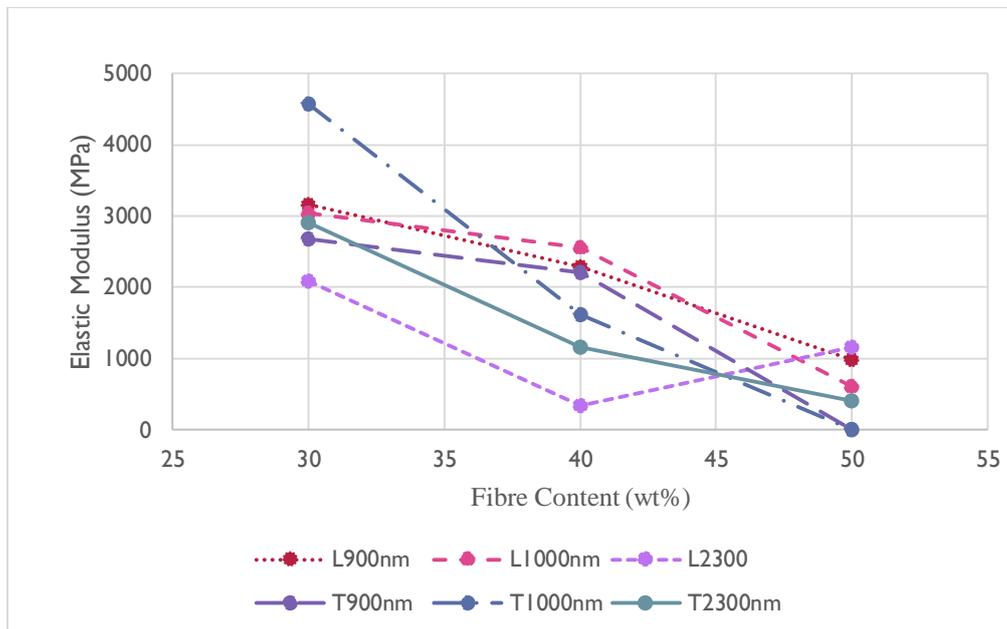

Fig. 8: Effect of Fibre Weight (wt.%) Content on Tensile Modulus of the Composites

3.2.2   Effect on Elastic Modulus

The effect of fibre weight (wt.%) content on the elastic modulus of the composite samples is illustrated graphically at Figure 9, below. From the figure, it can be seen that a characteristics general trend in the behaviour of the samples as reported for the tensile modulus has emerged. Data obtained from the curves show that at a fibre weight content of 30 wt.%, the elastic moduli recorded at the longitudinal directions are, 3157.32 MPa, 3045.60 MPa, 2080.64 MPa for the finest, finer and fine samples. For the transverse samples, the elastic moduli recorded are 2678.96 MPa, 4576.7 MPa and 2904.81 MPa.

When the RHF content increases to 40 wt.%, the elastic modulus value decrease to 2285.33 MPa, 2551.02 MPa and 345.60 MPa for the longitudinal samples and decreases to decreases to 2207.53 MPa, 1614.87 MPa and 1162.59 MPa for the transverse samples. At 50 wt.% fibre content the elastic moduli for the longitudinal direction sample decreases to 980.98 MPa, 603.34 MPa and 1156.1 MPa for the samples, while, for the transverse samples, the mechanical properties could not be obtained due to the failure of the samples to withstand the mechanical test due low adhesive bonding between the fibres and the matrix.

From the behaviour of the samples in this category, it can be asserted that as the RHF content is increased the value of the elastic modulus decreases. This result was in tandem with the finding reported in earlier study [2], which contradicts other finding reported elsewhere [14]. In the latter finding the increase in the elastic modulus due to fibre content increase was attributed to the reduction in the mobility of polymer chains as a result of the increase in fibre/filler content.
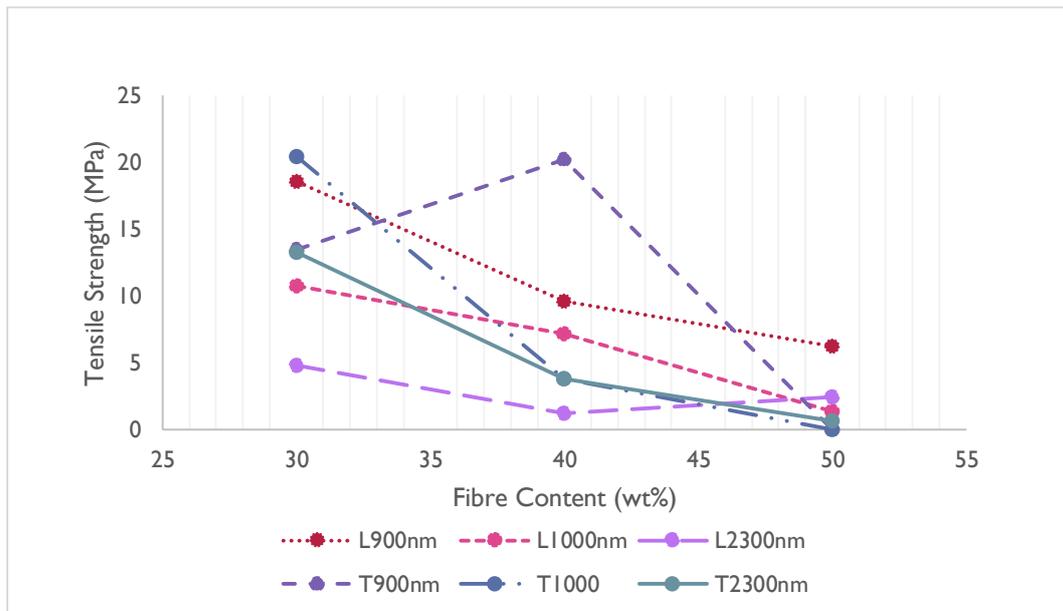

Fig. 9: Effect of Fibre Weight (wt.%) Content on Elastic Modulus of the Composites

3.2.3 Effect on Tensile Strength

Figure 10 below, displays the effect of fibre weight (wt.%) content on the tensile strength of composite samples. From curves it can be seen that the trend in the characteristic behaviour of the samples indicates that as the fibre weight (wt.%) content increases the tensile strength of the composites decreases to lower levels. By considering the longitudinal sample at 30 wt.% fibre content for example, we can see that the registered tensile strengths are 18.58 MPa, 10.77 MPa and 4.83 for the finest, finer and fine samples in that order. The same samples recorded tensile strengths of 13.48 MPa, 20.46 MPa and 13.27 MPa at the transverse direction respectively. By increasing the fibre content to 40 wt.%, the tensile strength at the longitudinal directions decrease to 9.6 MPa, 7.21 MPa and 1.23 MPa. These represent a decrement of 48.3%, 33.1% and 74.5%. While at the transverse directions the decrements are 33.5%, 81% and 71%. As the fibre weight content increases to 50 wt.%, the tensile strengths decreases to 6.27 MPa, 1.37 MPa and 2.44 MPa for the longitudinal samples. While for the transverse samples the decrease in tensile strengths are 0.7 MPa for the only fine sample that could be tested. The finest and finer samples could not be tested because they were to0 fragile to withstand the mechanical load. The decrease in the tensile strength for the fine sample is about 86%. The finding is similar to the results obtained by many previous investigators such as; Joshi et al. [8] who reported similar drop in tensile strength of rice husk reinforced polymer composite laminate and attributed it to the decrease in fibre-matrix homogeneity at high fibre content. Mishra et al. [16] equally conducted a similar study using jute reinforcement epoxy polymer matrix. The investigation found that the tensile strength of the composite laminate decreases as the fibre content (wt.%) reaches a threshold value of 50 wt.% and attributed this the poor wetting of the reinforcement by the matrix. Similarly, Divya et al. and Khan et al. [4, 5] also reported similar findings as reported by Mishra et al. The reason for decrease in tensile strength with increase in fibre content was also attributed to be due to low fibre orientation and lack of uniform stress transfer from the continuous polymer matrix to the dispersed fibre phase [17]. In addition, high fibre agglomeration within the matrix, which leads to poor mechanical properties was suggested to be the possible reason for the decrease in tensile strength when the fibre weight (wt.%) content is increased.

Fig. 10: Effect of Fibre Weight (wt.%) Content on Tensile Strength of the Composites

3.3 Effect of Particle Size on the Mechanical Properties of the Composites

3.3.1 Effect on Tensile Modulus

Figure 11 is a graphical illustration of the effect of particle size on the modulus of the composite samples. Observation has shown that there is a similar behaviour in the response of the samples to the changes in the particle size at different fibre weight (wt.%) content. The behaviour shows that as the particle size increases from 16.7, 15, 5vand 4.61 mesh sizes the tensile modulus decreases to lower values at fibre weight fractions of 30, 40 and 50 wt.%. Considering the longitudinal sample with the 16.7 mesh size (finest), the tensile modulus recorded are 1642.11 MPa, 1097 MPa and 987.9 MPa for the 30, 40 and 50 wt.% fibre contents, while at the transverse direction, the tensile modulus reached are 1484.14 MPa, 1386.6 MPa and **0 MPa** for the 30 40 and 50 wt.% fibre contents. By increasing the particle size to 15 mesh size (finer), the tensile modulus for the longitudinal samples decreases to 1029.94 MPa, 925.9 MPa and 0 MPa for the 30, 40 and 50 weight fraction (wt.%) samples. While for the transverse samples, the tensile modulus decreases to 1588.6 MPa, 642.91 MPa and 0 MPa respectively. As the particle size increases to 4.61(coarsest), the tensile modulus decreases to 1106.06 MPa, 430.27 MPa and 718 MPa for the longitudinal samples with 30, 40 and 50 weight fraction (wt.%)

samples. While for the transverse samples the tensile modulus decreases to 1440 MPa, 525.73 MPa and 436.65 MPa for the 30, 40 and 50 weight fraction (wt.%) samples. This trend is in good agreement with previously reported findings. Dikote et al. investigated the effect of wood fibre particles size on the tensile modulus of a compatibilised ethylene vinyl acetate copolymer-wood-fibre composite and found that the modulus decreases with increasing particle size [12]. They attributed this findings to the fact that the composite with smaller particle sized filler show better filler dispersion and filler-matrix interaction than composite made from large sized particles. Furthermore, the report noted that interaction and interfacial adhesion, which contributed to the increase in the strength of the bond was normally stronger for small particles than for larger particles. Similarly, Wycliffe et al. [2] investigated the effect of particle size on the tensile modulus of rice husk reinforced polyester matrix composite. In their findings they discovered that the tensile modulus of the composite laminates decreases as the particle size of the rice husk increases. Arif et al. [20] reported also that the tensile modulus of the wood-plastic composite laminates decreases as the particle size increases. These findings, however, contradict the one reported by Hassine et al. [6] that showed that the tensile modulus of the wood-plastic composite laminate exhibited a steady increase as the particle size of the fibres increases.
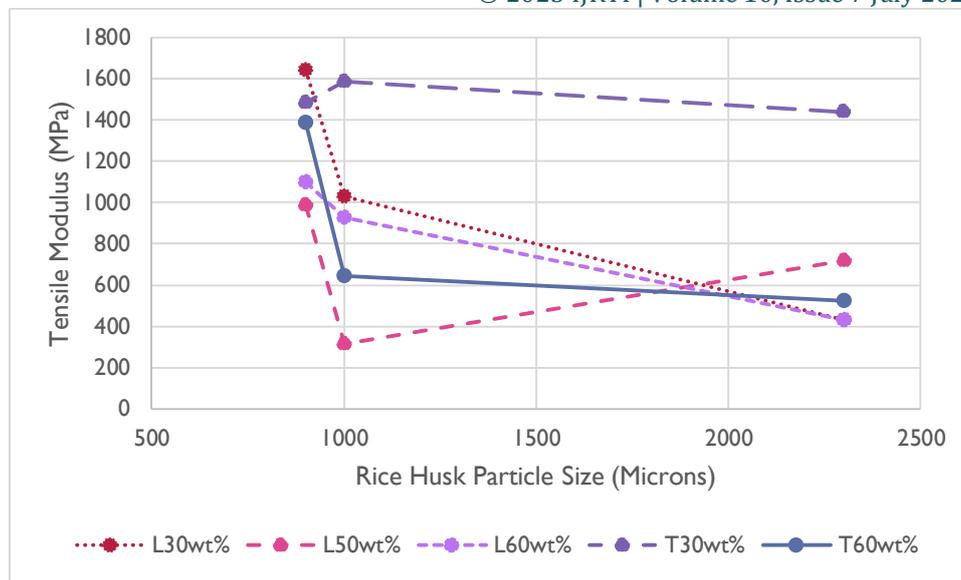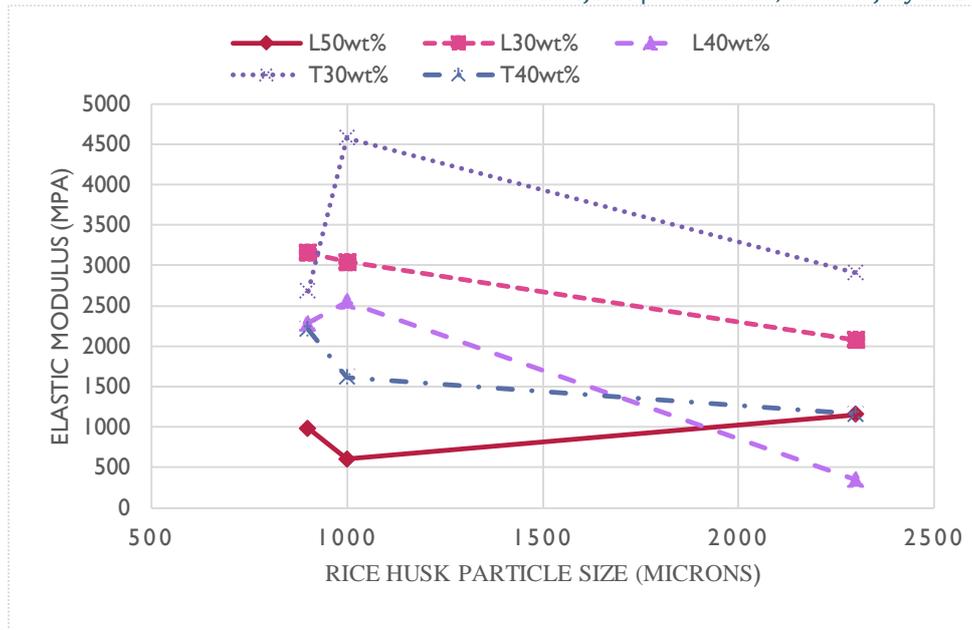
Fig. 11: Effect of Particle Size on Tensile Modulus of the Composites

3.3.2 Effect on Elastic Modulus

Figure 12, below displays the characteristics curves of the modulus of elasticity of the samples. A general trend can be seen that shows that as the particle size increases there was a uniform decrease in the value of the elastic modulus of the samples. A significant response was obtained from the finest (smallest) particle size sample at the longitudinal direction. It can be seen that for the longitudinal finest particle size sample, the modulus of elasticity recorded are 3157.32 MPa, 2285.33MPa and 980.98 MPA at weight fractions (wt.%) of 30, 40 and 50 respectively. while for the transverse samples the values are 2678.96 MPa, 2207.53 MPa and 0 MPa for the 30, 40 and 50 weight fraction (wt.%) fibre contents. As the particle size increases to 15 mesh size, the elastic modulus of the longitudinal samples decreases to 3045.61 MPa (3.5%), 2551.02 MPa (11.6% increase) and 603.34 MPa (38.5%) for the 30, 40 and 50 weight fraction (wt.%) fibre contents. While for the transverse samples the decrease in the elastic modulus

values are; 4577.69 MPa (44.5% increase), 1614.87 MPa (22.3%) and 0 MPa (0%) for the 30, 40 and 50 fibre weight (wt.%) content samples. As the particle size of the fibres increased to 4.61 mesh size (coarsest), the elastic modulus of the longitudinal samples decreases to 2080.64 MPa (34%), 345.6 MPa (84.96%) and 1156.1 MPa (17.8%) for the 30, 40 and 50 fibre weight (wt.%) content samples. While at the transverse direction, the decrease in elastic modulus are 2904.81 MPa (8%), 1162.59 MPa (49%) and 408.14 MPa (58.4%).

This type of trend in the decrease of elastic modulus as a result of the increase in the particle size of the fibre is a very unusual phenomenon and contradicts the result reported previously [6, 15, 18], that show that as the particle size increases the elastic modulus of the laminates increases. The reason for the decrease in the elastic modulus due to increase in particle size may not be, as reported above, unconnected to the fact that composites made from smaller particle sized fibres show better fibre dispersion and fibre matrix interaction than composites made from large large particles [12]. Interaction and interfacial adhesion is normally stronger for small particle than for larger ones.

Fig. 12: Effect of Particle Size on Elastic Modulus of the Composites

3.3.3 Effect on Tensile Strength

Figure 13, below, shows the graphical representations of the characteristic effect of particle size on the tensile strength of the composites laminates. The results show a similar trend in behaviour as reported for the tensile and elastic moduli, whereby, as the particle size increases the tensile strength decreases at all the different fibre weight contents (wt.%). The result also shows that maximum tensile strengths were recorded for the composites with lower fibre weight content. By considering the longitudinal samples with the finest (16.7 mesh size) particle size, the tensile modulus recorded are 18.58 MPa, 9.59 MPa and 6.27 MPa for the 30, 40 and 50 fibre weight contents. While for the transverse samples the tensile strength achieved were 13.18 MPa, 20.26 MPa and 0 MPa (that Cannot undergo mechanical testing) for the 30, 40 and 60 fibre weight (wt.%) content samples respectively. As the fibre size was increased to 15 mesh size (finer), for the longitudinal samples, the tensile modulus decreases to 10.77 MPa (42%), 7.21 MPA (25%) and 1.37 MPa (78%) for the 30, 40 and 50 fibre weight (wt.%) content samples. For the transverse samples the tensile

modului increase/decreases to 20.46 MPa (35.5%) (increase), 3.85 MPA (81%) (decrease) and 0 MPa (the sample was too fragile to be tested) for the 30, 40 and 50 weight (wt.%) fibre contents respectively. By further increasing the size of the fibres to 4.61 mesh size (coarsest) the value of the tensile moduli of the composites from the longitudinal direction decreases to 4.85 MPA (74%), 1.24 MPa (61%), 2.44 MPa (87%) for the 30, 40 and 50 fibre weight (wt.%) contents. While for the transverse samples, the tensile modulus decreases to 13.27 MPA (1.5%), 3.84 MPa (81%) and 0. 6971 MPA (100%) (increase). These results are in consistent with the result obtained by previous investigation [2] and as reported aforementioned was attributed to the fact that increasing particle size can cause air entrapment during mixing process, which can result in void formation of the fabricated laminates thereby making them to become brittle. Another invention also shows that as the particle size decreases the tensile strength of polymer composites increases until a threshold limit is reached, whereby, as the particle size decreases further the tensile strength starts to decrease to lower values [20].
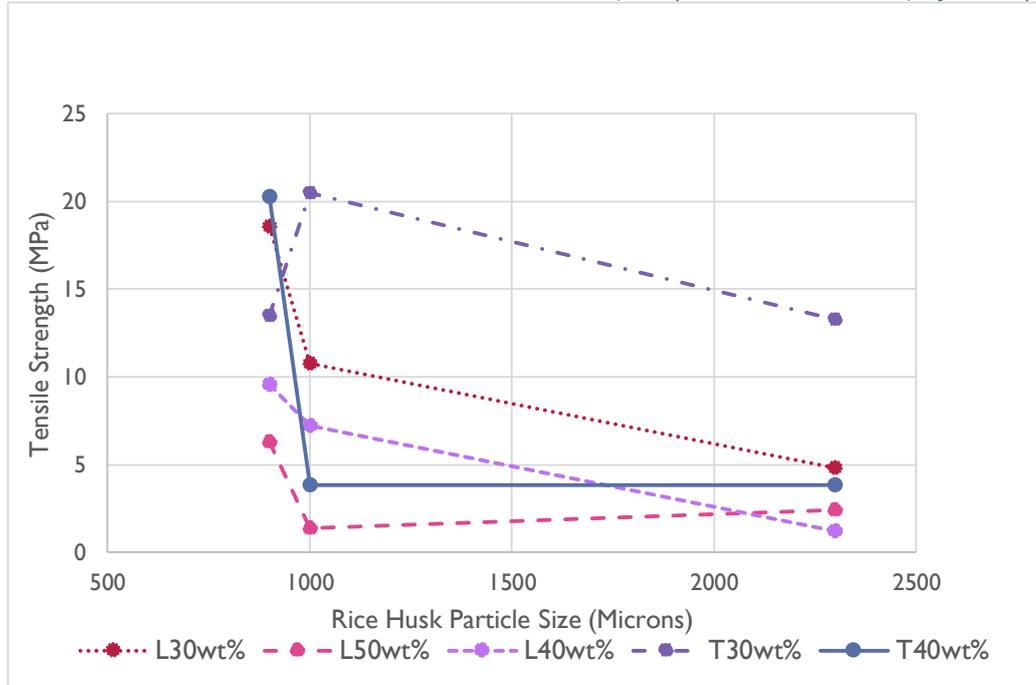
Fig. 13: Effect of Particle Size on the Tensile Strength of the Composites

3.4 ANOVA Analysis

The study performed a two-way ANOVA analysis with replication on the effect of the particle size and weight fraction on the mechanical properties of the samples tested. For this purpose, the particles sizes of the fibres were grouped into two major groups; (i) the smallest particles size, consisting of the finest and the finer samples and (ii) the largest particles size, consisting of the coarsest sample. The result of the ANOVA for the elastic modulus shows that there is no significant variation in the means of the elastic modulus of the smallest particle size samples and the largest particle sized samples.

Furthermore, there is a significant variation in the elastic modulus of the samples across the different fibre weight (wt.%) contents and that the effect of weight fraction on the elastic modulus of the samples is not dependent on particle size and vice versa.

Also, for the tensile strength, the ANOVA result shows that there is no significant difference in the average values of the tensile strength between the smallest and largest particle size samples. It shows that there is a large variation in the average tensile strengths across the different fibre weight (wt%) content and that the effect of weight content (wt.%) on the tensile strength is not dependent on the particle size and vice versa.

Lastly, on the tensile modulus, the result of the ANOVA test shows that, again, there is no significant variation on the average tensile modulus of the smallest and largest particle size samples. The analysis also confirmed that there is significant variation between the tensile modulus across the different fibre weight (wt%) content of the samples and that the effect of particle size on the tensile modulus is not defendant on the fibre weight (wt%) content and vice versa.

4. CONCLUSION

This study was able to establish that the variation of reinforcement fibre size and fibre weight (wt.%) can have a significant influence on the mechanical properties of composite laminates produced from rice husk fibre reinforced polyester resin. The investigation found that in most cases, at a threshold fibre weight (wt.%) content of 30, the samples record the maximum values of their mechanical properties (elastic modulus, tensile strength and tensile modulus) at both the longitudinal and transverse directions of the laminates. As the fibre weight content shifts to higher values to 40 and 50 wt.%, the mechanical properties start to decline to lower values. The study also found that in the case of the fibre size, the the same trend as observed with the fibre weight content was also observed. It can therefore be concluded, generally, that increasing both the fibre weight (wt.%) content and the fibre size have negative influence on the mechanical properties of

composite laminates fabricated from rice husk fibres reinforced with polyester resin matrix.

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