Analysis and Development of Military Helmet Using Date Palm Fibre Reinforced Epoxy Composite

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ORIGINAL RESEARCH

Abstract- The study discusses on analysis, fabrication and characterization of military helmet using date palm fibre reinforced with epoxy. The study is aimed at identifying the possibility of using the locally available material such as date palm fibre for the production of military protective helmet. Composite plates were prepared using Date palm fibre (DFE) reinforced with epoxy with varying composition. Six samples were produced and cut into the required size and shape for testing mechanical properties (impact strength ASTM D-156, Hardness ASTM D-2240, tensile strength ASTM D-638 and flexural strength ASTM D-790) of the material. Based on the result obtained, sample label S_3 has 20% DFE and 80% epoxy has the highest impact strength of 0.225 J/mm^2, hardness 70 Hv, tensile strength 25.87 N/mm^2 and flexural strength. The scan electron microscopy (SEM) was carried on the selected sample in which voids were observed in the image which could be instrumental to air trapped in the composite during mixing which might have escaped during curing at high temperature living the void in the sample. The helmet was produced using the selected sample with a thickness of 8mm while these previously existing one has a thickness of 6.94mm.

Keywords-Date palm, fibre, helmet, military

1 INTRODUCTION

Composite material was defined as a structural material that consist of two or more joint constituents united at an infinitesimal level and are not solvable in each other. The first constituent is called reinforcing phase while the other constituent is called the matrix (Subramanya R. 2018). Examples of composites system are epoxy reinforced with graphite fibres; concrete reinforced with steel etc. Composite materials are multiphase materials achieved from non-natural mixture of dissimilar materials in order to get properties that the individual constituent themselves cannot obtain (Abdullahi, 2022). In the previous three decades, composite materials, ceramics and plastics have been the overriding materials. The application of composites materials has developed fast, composite material has today encompassed large percentage of engineering materials. Nevertheless, composite material is considered as weight saving material, there is need to make them cost effective.

Figure 1 show the classification of composite materials which is classified either based on the geometry of the reinforcement or based the type of matrix. Composite materials can be classified based on matrix and this classification include the polymer (thermoset and thermoplastic), metal, ceramic, carbon and graphite. It can also be classified based on the form of reinforcement as fibre, whiskers, particulate and flakes.

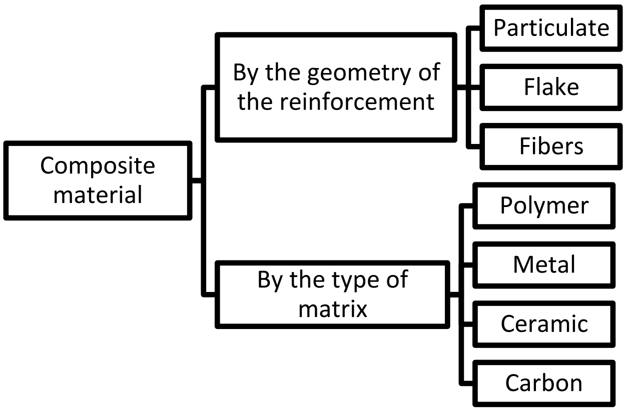

Fig. 1: classification of composite material

Fibres are classified as advanced fibres such as carbon, glass, organic, and ceramic, natural fibres such as animals' fibres (silk, wool, spider, silk, sinew, camel hair, etc.), vegetable fibres (cotton, jute, bamboo, sisal, maize hemp, sugarcane, banana, ramie, kapok, coir, abaca, kenaf, flax, raffia palm) and mineral fibres (asbestos, basalt, mineral wool, glass wool).

The following materials were used for the experiment fabrication of the helmet; Date Palm fibres, Epoxy resin, Hardener (tetra ethylene pentamine), Hemihydrated calcium sulphate (plaster of Paris) and Aluminium foil, Compression Moulding Machine, Universal Testing Machine, Resil Impact Tester, Universal Material Testing Machine, Digital Weighing Balance, Microhardness Tester and Electron Microscopic Scan. Rahmani et al, (2017) developed motor cycle helmet using carrot fibre and polymer matrix. The model was design using Pro-E software and analyse using ANSYS. The helmet shell fabricated using carrot fibre showed desirable properties. In the work 20% of carrot fibre served as reinforcement and 80% polymer as matrix and developed modulus much higher than those with other natural fibre. Yadav &

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Section C- MECHANICAL/MECHATRONICS ENGINEERING & RELATED SCIENCES
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Kumar, (2019) designed and carryout impact analysis of motorcycle helmet using composite material. Natural fibre and epoxy resin are used as raw material to fabricate industrial helmet and analysed using CREO simulate 2.0 software. The Natural fibre used are coconut fibre and banana fibre. The stress of the material ranges from 6.09-91.88Mpa while the strain was 0.009-0.0432 depending on fibre content natural fibre helmet has greater stress capability than the polypropylene helmet.

Fejdyś et al. (2015) fabricated and analysed a glass/Jute/Epoxy composite based industrial helmet. Hand lay-up techniques was used to manufacture five different composites. The work emphasized on the fabrication and characterization of hybrid jute/glass as reinforcement and epoxy as matrix for safety helmet. The percentage of matrix are varying while the reinforcement (fibres layers) remains fixed. Hybrid contained three layers of jute and one layer of glass reinforce epoxy composite obtained maximum flexural strength of 100.78Mpa. On the other hand, one layer of jute and three layers of glass reinforce epoxy achieved highest impact strength of 72.24J/m. According to the study one jute, three glass fibre reinforced with epoxy matrix composite has highest impact strength therefore can be used instead of the current one. From the previous studies, mechanical properties of the composite material for helmet application can be improved by using natural fibres with higher mechanical properties such as date palm fibre

2 Materials and Methods

2.1 Materials

The following materials were used for the experiment fabrication of the helmet; Date Palm fibres, Epoxy resin, Hardener (tetra ethylene pentamine), Hemihydrated calcium sulphate (plaster of Paris) and Aluminium foil, Compression Moulding Machine, Universal Testing Machine, Resil Impact Tester, Universal Material Testing Machine, Digital Weighing Balance, Microhardness Tester and Electron Microscopic Scan.

2.2 Methods

The date palm fibre was sourced from Danbarau area of Batsari local Government in Katsina state, crushed and sieve to a size of 0.2mm in NILEST and Panteka market of Kaduna state and mix with the epoxy resin and the hardener to a required proportion. The composite plate was also prepared using compression Mold and hand lay-up method respectively and cut to the required size for mechanical test such as impact test, tensile strength test, hardness test and flexural strength test. Electron microscopic scanning of the selected blend sample was carried out according to ASTM E986. The Mold for the fabrication of the helmet was prepared using aluminium alloy in Panteka market of Kaduna State and helmet was prepared using hand layup technique of making composite materials.

2.3 Mechanical Analysis

Various mechanical analysis such as tensile strength, impact strength, hardness and percentage elongation were carried out on the prepared samples.

2.3.1 Tensile Strength

The tensile strength was done in accordance with ASTM D-638. A dumbbell formed models were subjected to a tensile force and tensile strength, tensile modulus percentage elongation at beak for each sample were calculated and noted automatically by the machine and the results stayed on the certificate (Olaitan et al., 2017).

2.3.2Impact Strength

The impact test was done in accordance with ASTM D-156. The sample was cut to dimensions 64 mm x 12.7 mm x 3.2 mm and 45^o notched was inserted at the central of the test specimens from all the produced composite samples. The impact energy test was done using Izod Impact Tester and the result was calculated using equation 3.1 and 3.2 respectively. (Olaitan et al., 2017).

2.3.3Hardness

The hardness test was done in accordance with ASTM D2240 on a Mico Vicker Harness Tester. The test was carried out at different locations on each sample and average hardness was determined using equation 3.3 (Saba N. 2019).

2.3.4 Flexural Strength

The flexural strength test on the samples was carried out in accordance with ASTM D-790. The specimen with size 100 mm x 25 mm x 3.2 mm was placed on a support span horizontally at 80 mm gauge length and a steady load was added to the centre by the loading nose creating three-point bending until the sample specimen failed (Seleem, et al., 2019). The flexural strength and flexural modulus were calculated.

2.4 Scanning Electron Microscopy

Electron microscopic scanning of the selected sample was done in accordance with ASTM E986. A part of cross section of the blend weighing 0.5g was cut and fixed on the sample holder. The sample holder was sensibly inserted beneath the magnification screen of the apparatus and the cavity was closed. The microscopic features of the sample were viewed and a specific area of the microscopic feature was magnified under electron microscopy at different magnifications until clear electron features of the sample was viewed and recorded.

Table 1. Impact Strength

Sample	Impact Energy			Impact Strength (J/mm)
	1ST (J)	2ND (J)	Average (J)	
S_1	0.684	0.679	0.682	0.213
S_2	0.691	0.697	0.694	0.217
S_3	0.728	0.709	0.719	0.225
S_4	0.604	0.623	0.609	0.190
S_5	0.582	0.586	0.584	0.183
S_6	0.536	0.558	0.547	0.171

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Table 2. Hardness

Sample	Hardness Strength 1st (Hv)	2nd (Hv)	3rd (Hv)	Average Hardness Strength (Hv)
S1	56.1	55.6	56.0	55.90
S2	58.4	56.8	56.8	57.33
S3	70.2	69.7	70.1	70.00
S4	65.8	65.9	65.4	65.70
S5	64.0	64.8	63.4	64.07
S6	62.6	62.2	63.0	62.60

3 Result and Discussion

3.1 Mechanical Test Results

Mechanical properties of the date palm fibre reinforced epoxy were determined using the desired equipment and machines as reported earlier and the detail of the result obtain was presented in this section.

3.1.1 Tensile Strength Result

Table 1 present the result of the tensile test of different samples and it can be seen that sample number three has the highest tensile strength among other samples. From the result of the tensile strength test, tensile strength increased with increase in fibre content up to sample 3 again which has highest value of tensile strength of 25.87Mpa from there the value continue to decrease due to insufficient resin to bind properly together.

Table 3. Tensile Strength Results

Sample	Tensile Strength (MPa)	Elastic Modulus (MPa)	Elongation at Break (%)
S_1	24.34	231.08	12.47
S_2	25.40	212.80	10.46
S_4	23.04	181.54	10.98
S_5	22.55	141.12	8.96
S_6	18.41	144.34	10.52

3.1.2 Impact Strength Test Results

It can be seen from the result of the impact test in Table 2, impact strength increased with increase in fibre content. Sample number 3 which has fibre content of 20% and 80% epoxy has the highest impact strength of 0.225J/mm. However, this result incompliance with the report by Somto et al (2022) in which coir fibre composite has the highest value of impact strength of 8.733J/mm. In the work as reported, coir fibre was used as matrix material while epoxy serve as reinforcement and the fibre content was 70% by 30% epoxy. After reaching the highest value of the impact strength, the drop in value was noticed because of the poor bonding force between the matrix (fibre) and the reinforcement (epoxy).

3.1.3 Hardness

Consider the result of the hardness test shown table 3.3, it can be seen that the hardness increased with increase in fibre content from 0% to 80% and then decreased up to 50%. As hardness is the ability of the material to resist penetration, as the fibre content increased the material resist penetration and then decreased when the fibre content is sufficient enough in the resin. Moreover, the results reported by Samto K. et al (2022) illustrated a steady growth in hardness as the fibre content increased and also drop when the matrix material is too much that resin available was not enough to bond them and produce a lose composite with low hardness.

3.1.4 Flexural Strength Test Results

Elastic modulus and elongation at break decreased with increase in fibre content up to sample 5 of fibre content 40% and epoxy 60%, this is because elastic modulus of the epoxy is greater than that of the date palm fibre. Furthermore, from the result of the tensile strength reported by Samto et al (2022) the tensile strength increased steadily with increase in fibre content from 20% to 50% there by decreased in the rest of the composition.

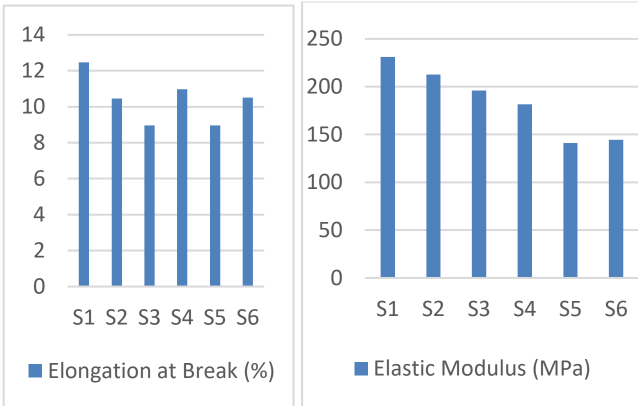

Fig. 2: Elongation at Break and Elastic modulus Results

3.2 Scanning Electron Microscopy (SEM)

The uniform distribution of the filler in the matrix could be due to homogeneity mixing of the sample's composition while the non-uniform distribution observed in image c and d could be due to non-homogeneity mixing of the fibre and the matrix. However, voids were observed in the image. This could be instrumental to air trapped in the composite during mixing which might have escaped during curing at high temperature living the void in the sample. Consequently, the uniform fibre distribution in the matrix could be responsible for the performance of the samples the physio-mechanical properties among others.

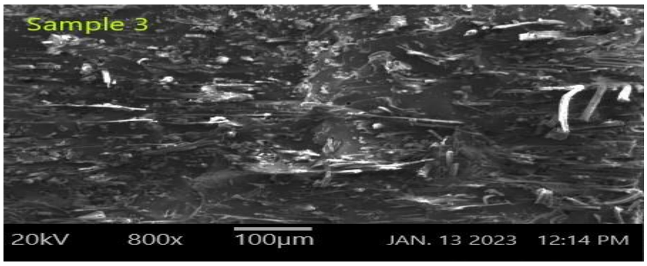

Fig. 3: Scanning Electron Microscopy (SEM)

3.3 Fabrication Process of the Helmet

The helmet was prepared using hand layup method as well as compression technique of making composite. Sample three which comprise of 30% date palm fibre and 70% epoxy was selected for the development of the Helmet. The fibre and the resin were mixed thoroughly at the required proportion and poured inside the aluminium alloy mould and load was applied to compress this mixture until it is completely solidified. Load was applied

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and then allow to cure for about 12 hours until it is completely cured and removed from the mould as shown in figure below.

Fig. 4: Fabrication Process of the Helmet

4 Conclusions

The study aimed to developed new material (DPF/Epoxy Composite) for the production of military Helmet with low weight and cost effective. The composite plate has been developed in which 100g of epoxy resin and hardener was poured in to a mixing vessel and mix thoroughly until a homogenous mixture is obtained, this composition was varied for five samples at a ratio of 10/90, 20/80, 30/70, 40/60 and 50/50 respectively. The samples were transferred in to a prepare mould and cured at temperature and pressure of 130^0c and 2.5MPa respectively for 5 minutes and allow to completely cured for about 24 hours and thickness of 3.2mm.

The samples have been cut into different sizes and shapes for mechanical test and characterization. The impact and hardness test which are the most important in this study showed considerable improvement across the samples as fibre content increased up to S_3 (0.225J/mm and 70Hv) and when compared with coconut Helmet developed by Akindapo (2017) it has highest impact strength of 8.733J/mm and Hardness of 30.00HRF respectively and which shows that coconut fibre has high impact strength compared Date palm fibre while the date palm fibre has better Hardness property. The new material was then taken for SEM to see he structure and uniform distribution of the two materials which was done for the selected sample among others after tensile strength test. The helmet was prepared using hand layup method and compression technique respectively and it has weight of 3.05kg and thickness of 8mm this is lighter in weight compare to Chinese helmet of weight 3.56kg and thickness 3mm and US ballistic helmet 10mm thick and weight of 2.12kg

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