Investigation on Pineapple and Pirambu Natural Fibres Reinforced with Polyester Hybrid Composite

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Abstract. Composite materials have gained their presence in several industrial sectors. New materials, advanced material treatments and manufacturing methods have been introduced in research and developments today. Experimentation in composite materials has changed the people to come up with new innovations and alternative ideas in day today applications. This work focuses on obtaining the mechanical characterization and morphological study on composite materials which are prepared by compression moulding. The prefabrication tests were conducted to know the specific nature of each fibre material by conducting single fibre and FTIR test. This experimental measurement was observed the better mechanical properties from Tensile, Flexural and Impact test with the specimens of the prepared composite lamina of composite. The morphological study in fractured specimens was observed by using Scanning Electron Microscope and Energy Dispersive X-ray Analysis. This research work were represented the mechanical characteristics and morphological behaviour of pirambu pineapple hybrid polyester composite and also will help us for implementation of new manufacturing applications with composite materials.

Keywords: Composite lamina, Tensile strength, Flexural strength, Impact test, Compression Moulding

1. Introduction
Due to the environment awareness and sustainability issues, remarkable achievements were attained in last decade, particularly in the area of material science. The two different natural fibres are used in the composite system forming a hybrid composition of reinforcement. The natural fibres are obtained from the raw material through mechanical and water retting methods. Single polymer is used as matrix over here. Fibres are cut into small segments and packed into the composite system with random orientation. A catalyst with octane solution is used as an interface between the matrix and the reinforcement in the composite system to speed up the rate of the reaction. Sabbie A. Miller et al. [1] has presented an experimental report with bio-based composite material which are used as an alternative for unconventional materials to study its mechanical properties, environmental impacts and creep. MohitSood et al. [2] conducted a review on flexural properties and its effect on fibre treatment with natural fibre reinforced composite. B.K. Kandola et al. [3] conducted mechanical and fire performance study on natural fibre reinforced thermoplastic composites and found out that woven and nonwoven technology can be used to prepare synthetic and natural fibre composite which has good
mechanical properties. Swagata Dutta et al. [4] presented a numerical and experimental analysis on fire reaction properties and made a comparative analysis with flax and wool based composites. A. Quintana et al. [5] conducted an comparative analysis between traditional plastic board and bio based composite board based on life cycle assessment and the results converged have showed that the environmental impact is approximately same in both types of boards. Yingji Wu et al. [6] have made an experiment by introducing magnesium hydroxide into the natural fibre reinforced composite for improving the mechanical properties which can be used in automotive applications. Anna Bernstad Saraiva et al. [7] conducted life cycle assessment by comparing cardboard material with natural fibre composite and the results showed that the use of cardboard material has less environmental impact than the composite material. William T. Kern et al. [8] made microscopy and finite element analysis on natural fibre composites to get a view of microcellular voids since voids would cause stress intensity and it would change the properties of non-brittle material to brittle material. N.K. Kim et al. [9] have performed review on thermal behaviour and flammability of natural fibres. Bartosz Zukowski et al. [10] conducted alkali treatment in caraua fibre to check the durability of strain hardening cement based composite by exposing it to natural weathering.

WassamonSujaritjun et al [11] conducted experimental analysis tensile properties of bamboo fibre, vetiver grass fibre and coconut fibre reinforced PLA composites were compared with each other. It is found that Bamboo fibre has most effective improvement in reinforcement of tensile properties of natural fibre reinforced PLA composite. Vivek Mishra et al [12]. Found that the hardness, tensile and impact strength of jute-epoxy composites increases with the increase in fibre loading and they also found that the void content decreases with increase in fibre loading.K Deepak et al [13]. Has made comparative analysis with Bio composite material using coir as fibres and general polyester resign as matrix with the addition of nano clay material. They found out that the composites which are prepared with and without clay mixture have produced similar results. They also found that use of clay material has improved the interaction between the clay and the resin. They suggested that the use of composite do not meet the strength parameters of conventional composites, and so they can be used for architectural equipments. AshwinSailesh et al [14]. Preformed an experimental work, depending upon the result obtained they found out that the stalking sequence and the interaction between the fibre and the reinforcement plays a vital role in determining the properties of the composite material. G Bujjibabu et al [15]. Conducted experimental analysis on mechanical behavior of banana/coir reinforced polypropylene hybrid composites and found out that the tensile and flexural strength decreases with increasing coir fibre percentage, where the impact strength increases upto certain extent and then it decreases. Ashik K P et al [16]. Conducted experimental analysis and found out that increase in cocknut coir in the glass/coir composite specimen increases water absorption, flexural strength increases at higher proportion of glass fibre and impact strength increases when percentage of epoxy increases.Vijay R et al [17]. Conducted comparative analysis between the stalking sequence with 2 symmetric material layer and one intermediate layer. Here the replaced the intermediate layer with kenaf, sisal and jute fibre for undergoing the comparative experiment. From the results obtained they found out that the stalking sequence which is having the kenafibre as its intermediate layer has good performance in mechanical properties and characteristics. Sabbie A. Miller et al [18]. Conducted experiment on natural fibre textile reinforced bio-based composites, they found out that jute burlap composites displayed high off-axis and on-axis stiffness and the creep deformation is dependent on the stress level and the orientation of textiles. B.K. Kandola et al [19]. Have conducted experiment from the result they found out that woolen and non-woolen technology can be used to prepare composites with good mechanical properties and this technology can be used for preparing natural-synthetic fibrous performs.Yingji Wu et al [20]. Conducted experimental analysis and found out that the comparable mechanical properties, reduced energy consumption and environmental impacts have the potential to NFRC by replacing it with GFSMC in automobile applications. Bakare et al. [21] studied the mechanical properties of the sisal fibre rubber seed oil polyurethane composite, with and with-out water treatment process. Gonzalez and Ansell [22] suggested that the mechanical properties of chemically treated henequen fibre epoxy composite produces similar results as like the untreated fibre
composite. Silva et al. [23] investigated the tensile properties of the sisal fibre for the different fibre gauge length. Herrera-Franco and Valadez-Gonzalez [24] concluded that the stress distribution between the fibres and matrix for a short discontinuous fibre were better than the continuous fibres. Igor et al. [25] investigated the importance of phormium (flax fibre)/epoxy laminated composite with short fibre and long fibre. Various chemical compositions of the fibres were compared with the other natural fibres.

The focus on this work would gain the attention of researchers in implementation of research and several manufacturing applications. The reinforced composite materials are low cost composite materials. The major perspective of this work is to focus on preparing a highly economical material with enhanced mechanical properties for gaining durable manufacturing applications with good safety factor.

2. Methodology

2.1 Materials and Fabrication

Two different fibres were used. The materials used for fabrication are pineapple [ananascomosus] and pirambu [arundinaria] fibres. The fibre of pineapple is obtained from the leaves of the pineapple plant by mechanical retting with rolling crushing machine and the fibre of pirambu sticks by water retting method through hand stepping technique. The polyester GP51 matrix was used to fabricate natural fibre reinforced composites to evaluate the fibre performance under different percentage compositions. These are prepared as small fibres which have a length between them 15mm to 20mm. The selected fibres are different from region and they exhibit variability in their physical and mechanical properties. The natural fibre composite with 20% pineapple [Ficusreligiosa], 10% pirambu [arundinaria], 69.5% polyester GP51 resin, 0.25% of MERP catalyst and 0.25% of octane solution is kept as composition. These two fibres are mixed with polyester matrix with hardener solution.

![Figure 1. Pineapple-10% and Pirambu-20% composite lamina](image1)

![Figure 2. Compression molding machine](image2)

Compression moulding machine were used for the fabrication of natural fibre composite material. The machine consists of a fixed lower die and the upper die attached to the hydraulic actuation system. A digital control panel with upper and lower die settings and timer settings are used to control the moulding machine. The fabrication processes is executed by starting the machine followed by setting the layup plate for preparing the lamina. The composition for preparing the composite lamina includes 10% pineapple fibre and 20% pirambu fibre as reinforcements, 69.5% polyester GP51 resin, 0.25% of octane solution and 0.25% of MEKP catalyst as matrix. A mixture of matrix and reinforcement is embedded over the layup plate and introduced into the moulding machine. The machine set up is checked for its position before the compression task is executed. Once the position of the layup plate over the lower die is checked the upper die is moved slowly at 2bar pressure until the layup plate is
The hot composite lamina is removed from the layup plate and placed under some load for natural cooling in atmosphere.

3. Result and discussion

The composite lamina fabricated with the help of compression molding machine. The single fibre test and FTIR were observed to determine the mechanical ability of the individual fibre. The composite lamina was prepared as per ASTM standard to identify the mechanical properties and morphological behavior. Tensile, Flexural and Impact tests were conducted to check the mechanical properties and Scanning electron microscopy and Energy Dispersive X-ray Analysis were studied to point out the morphological behaviour of the composite.

3.1 Single fibre strength for Preprocessing

Pre-processing studies were conducted to identify the material characteristics and properties before implementing them into the fabrication work. The individual examination of these materials would help us in preceding the fabrication processes with effective methods. Single fibre test was conducted to check the strength of individual fibre. The single fibre is loaded gradually at 100N at a displacement of 10mm/min with the help of universal testing machine. The fibre is tested within the closed boundary of a paper frame by sticking the single fibre with adhesive. The specimen is tested under 100mm grip to grip separation from its starting position. The results are obtained in graphical format through computer integrated universal testing machine.

The results obtained by testing single pineapple fibre are plotted in the graphical representation. It shows that the maximum force attained by testing the single pineapple fibre is 2.467766N with the corresponding elongation of 0.945653%. The same force and elongation is obtained at the breaking point.

![Figure 3. Single fibre test for pineapple fibre](image1)

![Figure 4. Single fibre test for Pirambu fibre](image2)

The results obtained by testing single pirambu fibre are plotted in the graphical representation for visualization. It shows that the maximum force attained by testing the single pirambu fibre is 15.697418N with the corresponding elongation of 11.493111%. The same force and elongation is obtained at the breaking point.

3.2 FTIR Test

Fourier transform infrared spectroscopy was studied to obtain the molecules and chemical compound of fibre element. It helps to identify the chemical substance present in the material. The thin beam of infrared light were made to pass through the specimen, if the wavelength of infrared light matches the wavelength of the specimen then the light rays will be observed by the specimen otherwise the light rays would fall on detector behind the specimen. The results obtained through plots of graphical representation.
3.2.1 FTIR test with Pirambu fibre
The obtained results of pirambu fibre shows that, the specimen has obtained about 95% of transmittance approximately in the functional group region which shows that only 5% of light beam coincides with the wave length of the molecules present in the specimen. The wave numbers 3338.09 and 2918.67 shows the presence of strong, broad alcohol (O-H) group which is exhibiting stretching vibration at a transmittance of almost 89% and strong alkane (C-H) group which is exhibiting stretching vibration at a transmittance of almost 92% respectively. The wave number of 2116.33 and 2035.28 shows the presence of alkyne (-C≡C-) group with variable intensity at weak or medium level, exhibiting stretching vibration at a transmittance of 95% and the presence of weak nitrile (-C≡N-) group which is exhibiting stretching vibration at a transmittance of 96%. From the observed results that noted 1-Hydroxy-4-Nitrile-2-Butyne is the maximum chemical compound present in pirambu fibre.

![Figure 5. FTIR graph for Pirambu fibre](image)

3.2.2 FTIR test with pineapple fibre
The obtained results of pineapple fibre shows that, the specimen has obtained about 80% of transmittance approximately in the functional group region which shows that only 20% of light beam coincides with the wave length of the molecules present in the specimen. The wave numbers 3299.17 and 2915.33 shows the presence of strong, broad alcohol (O-H) group which is exhibiting stretching vibration at a transmittance of almost 65% and strong alkane (C-H) group which is exhibiting stretching vibration at a transmittance of almost 88% respectively. From the observed results that noted formaldehyde is the maximum chemical compound present in pineapple fibre.

![FIGURE 6. FTIR graph for Pineapple fibre](image)
3.3 Tensile Test
The tensile test was conducted to check the mechanical response of the composite material by applying tensile load through universal testing machine. The results are obtained in graphical representation of stress strain curve and force length curve as per ASTM D638 standard. From the observations of stress strain and force length graph it is noted that the specimen has obtained ultimate stress at 10.5MPa with 54% of strain, the ultimate force of 394N is obtained at 0.546mm of length, the specimen breaks at 0.561mm of length at a force of 199N.

![Stress Strain graph for Tensile test](image1)

![Force Length graph for Tensile test](image2)

3.4 Flexural Test
The Flexural test was conducted to find the ability of the flexural resistance on the fabricated material by applying bending load. This test was conducted with three point bending set up through universal testing machine. The results are obtained in graphical diagram through stress strain as per ASTM D790 standard. The results obtained in the graphical form shows that the specimen were obtained flexural strength of 40.89MPa at 1.08% of strain. The ultimate force is obtained at 30.67N. The specimen breaks at a load of 32.5MPa at 1.215% of strain respectively.

![Stress Strain graph for Flexural test](image3)

3.5 Impact Test
Izod impact test was conducted as per ASTM D256 standard. The specimen which is to be tested is placed vertically with one end fixed and the other end facing the striking edge. The specimen obtained that the internal energy of 27.449J, external energy of 2.229J and total energy of 25.2198J. The maximum strength of 178.341J/m were obtained from the tested specimen.

3.6 Analysis of SEM Images
The fractured surface of the Pirambu and Pineapple fibre reinforced composite was analyzed using scanning electron microscope. The observed SEM images shows that the fibre and resin compatibility in natural fibre polymer composites. The SEM image of tensile fractured specimen shows uniform
crack propagation due to better mixing of the fibre and matrix. The observed images present the random orientation of fibre packed with resin, having void content over it. The porous spot over the merged fibre shows the presence of optimal level of impurities over the composite material. Fibre segregation was found to be good in the fractured region due to the improvement in compatibility between the fibre and resin matrix.

![Figure 10. SEM image of Pirambu and Pineapple fibre composition for 500 µm, 200 µm, 100µm](image)

### 3.7 Energy Dispersive X-ray Analysis
From the obtained results of the Energy Dispersive X-ray analysis, Carbon element contains the maximum level of un-normalised concentration in weight percent of the element, normalised concentration in weight percent of the element, atomic weight percentage and the error in the weight percent concentration at the 1 sigma level and also the observed results showed that, Zink element contains the minimum level of un-normalised concentration in weight percent of the element, normalised concentration in weight percent of the element, atomic weight percentage and the error in the weight percent concentration at the 1 sigma level.

**Table 1. EDX chemical composition for Pirambu and Pineapple fibre**

| Sl.no | El | AN | Series | Unn.C (wt. %) | Norm.C (wt. %) | Atom.C (at. %) | Error (1 sigma) |
|-------|----|----|--------|--------------|---------------|---------------|----------------|
| 1     | C  | 6  | K-series | 54.07        | 54.07         | 61.86         | 7.26           |
| 2     | O  | 8  | K-series | 42.74        | 42.74         | 36.71         | 6.29           |
| 3     | Si | 14 | K-series | 0.86         | 0.86          | 0.42          | 0.07           |
| 4     | Ca | 20 | K-series | 0.65         | 0.65          | 0.22          | 0.05           |
| 5     | Na | 11 | K-series | 0.34         | 0.34          | 0.21          | 0.06           |
| 6     | Mg | 12 | K-series | 0.36         | 0.36          | 0.20          | 0.06           |
| 7     | Al | 13 | K-series | 0.38         | 0.38          | 0.20          | 0.05           |
| 8     | Fe | 26 | K-series | 0.26         | 0.26          | 0.06          | 0.04           |
| 9     | Cl | 17 | K-series | 0.15         | 0.15          | 0.06          | 0.03           |
| 10    | K  | 19 | K-series | 0.12         | 0.12          | 0.04          | 0.03           |
| 11    | P  | 15 | K-series | 0.03         | 0.03          | 0.01          | 0.03           |
| 12    | Zn | 30 | K-series | 0.04         | 0.04          | 0.01          | 0.03           |
4. Conclusion

The mechanical properties and morphological behavior of pirambu and pineapple polymer matrix composite were studied by preprocessing and post processing evaluation. The better tensile, flexural and impact behaviors of 10.5 MPa, 40.89MPa, and 178.341J/m were obtained pirambu (20%) and Pineapple (10%) reinforced polymer composites. The microstructure and chemical composition were studied by scanning electron microscope through SEM and Energy Dispersive X-ray analysis. The presence of cellulose, hemi-cellulose and lenin contents are observed in detail with some fractures and crack propagations. The mechanical behaviors studied through real time experiments witnessed that both composition of Pirambu and Pineapple reinforced polymer composites can be utilized as the replacement of plastics because of its ease of decomposability and low cost. The obtained result shows that, the specimen is malleable with high bending stress with good elastic and plastic behavior.

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