MECHANICAL CHARACTERIZATION OF BASLAT BASED NATURAL HYBRID COMPOSITES FOR AEROSPACE APPLICATIONS

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Abstract: Advanced composites have attracted aircraft designers due to its high strength to weight ratio, high stiffness to weight ratio, tailoring properties, hybridization of opposites etc. Moreover the cost reduction is also another important requirement of structural components. Basalt fibers are new entry in structural field which has excellent properties more or less equivalent to GFRP composites. Using these basalt fibres, new hybrid composites were developed by combining basalt fibres with natural fibres. The mechanical and thermal properties were determined and compared with BFRP and GFRP composites. Results proved that hybrid composites have some good qualities.

1. INTRODUCTION

High strength to weight ratio and high stiffness to strength are the major design factors for aircraft components. The aircraft undergoes through various loads, especially air loads. These loads are static and dynamic. A suitable high strength, lightweight and low cost materials are required. In this point of view, composite materials are selected. This composite materials can be fabricated using artificial and natural fibres. Advanced composites are derived using artificial fibres like Kevlar fibre, carbon fibre, Kevlar fibre and basalt fibres. To vary the strengths, based on applications, hybrid composites are preferable. [1] M.Sakthivel et al have done a research on hybrid composites with natural fibres like sisal, banana fibres, hemp and jute. They proved that polymer banana reinforced natural composites is the best natural composites among the various combinations. [2] Alexander.J et al have investigated about basalt fibre reinforced composites at various curing conditions and proved that basalt fibres re the best composites that can be used for aerospace applications. [3] Alexander et al also have done a study on tensile analysis of BFRP composites. [4] Kuruvila joseph et al reviewed the sisal fibre composite and concluded their results with there will be a good scope and better future for sisal fibre. Therefore addition of natural fibre with artificial fibre improves the quality of the composites as well as reduce the cost. This work or project we have selected three different fibers (Basalt, Sisal and Glass) and matrix Epoxy (LY556). The laminates were prepared by using hand layup process and then the specimens were cut as per ASTM standards. The tensile, bending, impact and DMA tests were conducted to get the mechanical properties of the composites.

2. EXPERIMENTAL
Three laminates were prepared for conducting experimental tests and all of them were done in the Aircraft structures lab of Aeronautical department, at Sathyabama University. Laminates were prepared by hand layup. 7 layers of basalt and 2 layers of sisal laminate, 5 layers of glass and 2 layers of sisal laminate and 4 layers of basalt, 2 layers of glass and 2 layers of sisal laminate with resin named epoxy LY556 with their hardener. The basalt fiber is bought from the Germany, Sisal and glass fibers are from, Chennai. Laminates were prepared by using hand lay up process.

2.1 TENSILE TEST

This test was conducted using the UTM machine (1000 KN capacity) in the Aircraft structures lab of Aeronautical department, Sathyabama University. This testing helped in determining the mechanical characteristics of the material. The specimens were cut for tensile test according to the ASTM standards (D3039) shown in fig 2.1.

![Tensile test Specimen as per ASTM standards](image)

2.2 BENDING TEST

This test was conducted using the UTM machine in the Aircraft structures lab of Aeronautical department, Sathyabama University. The specimens were cut for bending test according to the ASTM standards (D790). The specimen was kept under 3 point setup at the edge and a compressive load was made to act at the middle from the top. The values were transferred to the system through the serial ports and they were taken down with the help of WIN UTM software. All the results were tabulated.

2.3 IMPACT TEST
The specimens were cut for impact test according to the ASTM standards (D790). The specimen was fixed in the machine and the handle is pulled down and the readings from the dials are noted.

Range : 0J to 14J.

Dead weight in the oscillator : 8Kg

Model & Make : K-1.4 & KrystalEquipments, India.

The un-notched specimens were kept in a cantilever position, and a pendulum has swung around to break the specimen. The impact energy (J) was calculated using a dial gauge that was fitted on the machine. Five samples were taken for each test, and the results were averaged.

2.4 DYNAMIC MECHANICAL ANALYSIS

Dynamic mechanical analysis also known as dynamic mechanical spectroscopy is a system used to study and illustrate materials property. It is mainly helpful for studying the viscoelastic performance of polymers. A sinusoidal stress is applied and the strain in the material is measured, allowing individual to verify the complex modulus. The temperature of the sample or the frequency of the stress are often varied, leading to variations in the complex modulus; this advance can be used to position the glass transition temperature of the material, as well as to recognize transitions corresponding to other molecular motions.

2.4.1 STORAGE MODULUS ($E'$):

The viscoelastic property of a polymer is calculated by dynamic mechanical analysis where a sinusoidal force (stress $\sigma$) is applied to a material and the consequential displacement (strain) is calculated. For a perfectly elastic solid, the resultant strain and the stress will be perfectly in phase. For a purely viscous fluid, there will be a 90 degree phase lag of strain with respect to stress. Viscoelastic polymers have the characteristics in between where some phase lag will occur during DMA tests.

\[
\text{Stress: } \sigma = \sigma_0 \sin(\omega t + \delta) \\
\text{Strain: } \varepsilon = \varepsilon_0 \sin(\omega t)
\]

Where,
\[\omega \rightarrow \text{is frequency of strain oscillation,}\]
\[t \rightarrow \text{is time,}\]
\[\delta \rightarrow \text{is phase lag between stress and strain.}\]

The storage modulus measures the stored energy, in lieu of the elastic portion, and the loss modulus measures the energy dissolute as heat, in lieu of the viscous portion.
\[ E' = \frac{\sigma_0}{\xi_0} \cos \delta \]

2.4.2 GLASS TRANSITION TEMPERATURE (\(T_g\)):

In a composite material, the temperature at which the matrix material changes from a glassy to rubbery state or vice versa is termed the glass transition temperature. This change in condition may effect in a two to three orders of extent change in modulus. The transition is characteristic of the detailed molecular structure of the matrix polymer. As well as modulus the heat capacity and thermal expansion coefficient also change at the glass transition temperatures. As shown in the schematic diagram, the transition is not sharp but occurs progressively over a temperature range which may be up to some tens of degrees wide. The quoted is usually the mid-point of the range. Different methods of measuring may give somewhat different values, so the method used should always be quoted.

2.4.3 LOSS MODULUS (\(\tan \delta\)):

Polymer matrices will absorb moisture and become plasticised. Plasticisation can reduce the leading to a 'wet' value. The reduction in depends on the initial crosslink density of the matrix material. Measurement of for a composite matrix material requires the specimen to be heated, which in turn, removes the absorbed moisture and hence affects the wet value by increasing it slightly. It is possible to seal the specimens to prevent moisture loss. Also in thick specimens, moisture may be lost on the outside surfaces resulting in a wider glass transition range perhaps with two inflection points representing the inner wet material and the drier outer material. Polymer matrices in composites are rarely used at temperatures above their because they cannot effectively transfer load in their rubbery state

\[ E'' = \frac{\sigma_0}{\xi_0} \sin \delta \]

3. RESULTS AND DISCUSSIONS

Mechanical static tests like Tensile test and Bending Test were conducted for all three types of hybrid composites and the results are tabulated in Table 3.1 and 3.2.
Table 3.1 Result of tensile test results of various hybrid composites

| Hybrid composite name          | Tensile Strength (N/mm²) | Tensile Modulus (N/mm²) | % Of Strain |
|--------------------------------|--------------------------|-------------------------|-------------|
| sisal/glass/epoxy              | 583                      | 116                     | 6.7         |
| sisal/basalt/epoxy             | 402                      | 193                     | 7.5         |
| basalt/sisal/glass/epoxy       | 414                      | 236                     | 5.9         |

Tensile strength of Sisal/Glass/epoxy hybrid composites is found to be excellent. But the tensile modulus of Basalt/glass/sisal/epoxy composite is found to better when compare with other combinations. This is due to the cross linking between the fibers and matrices are improved due to different fiber combinations. The bending strength and interlaminar shear strength are very high for sisal/basalt/epoxy composites. This shows a very good bond is generated between the basalt fibre and epoxy and sisal. This is due to the surface behavior of the fibre mats. Bond between the glass and sisal is weaker than this.

Other important dynamic property composites are Impact strength. Specimens are prepared as per the ASTM standard. Charpy impact machine was used. The initial energy of the material at the beginning of the test was noted down. Then the Impact load were applied and the amount of Energy Absorbed during the breakage of a specimen in a standardized test was noted down, and using the area of the specimen the impact strength of that specimen was determined with the help of the following formula and were shown in fig 3.1. Impact strength of sisal/basalt/epoxy composites are much better than the other combinations. From the SEM images taken for all types, the bond between the fibres and the matrix for sisal/basalt/epoxy is good. This improved the bending strength.

\[
\text{Impact strength} = \frac{E}{A}
\]  

(3.1)

Where

\[E = \text{Initial Energy-Final Energy}\]
\[A = \text{Width x Thickness}\]
3.1 DYNAMIC MECHANICAL ANALYSIS RESULTS

From the dynamic mechanical analysis the storage modulus, loss modulus and glass transition temperature of any materials can be determined. The results of all composites are shown in fig 3.2 - 3.4. Table 3.2 gives the tangent modulus, loss modulus and glass transition temperature of all materials.

![Fig 3.1 Impact test strength of various Hybrid composites](image)

**Fig 3.1 Impact test strength of various Hybrid composites**

![Fig 3.2 DMA result for glass/sisal/epoxy laminate](image)

**Fig 3.2 DMA result for glass/sisal/epoxy laminate**

![Fig 3.3 DMA result for basalt/sisal/epoxy laminate](image)

**Fig 3.3 DMA result for basalt/sisal/epoxy laminate**
Fig 3.4 DMA result for basalt/sisal/glass/epoxy laminate

The results shows even the thermal properties also good for Sisal/basalt/epoxy composites. The storage modulus and loss modulus are higher than the other two composites. Even glass transition temperature is higher than sisal/ glass/ epoxy composites.

Table 3.2 DMA test results for different materials

| Composite name               | Storage modulus (gpa) | Loss modulus tan δ (gpa) | Glass transition temperature T_g°C |
|------------------------------|-----------------------|--------------------------|-----------------------------------|
| sisal/glass/epoxy            | 8.009                 | 0.030845                 | 70.9                              |
| sisal/basalt/epoxy           | 9.309                 | 0.032281                 | 71.1                              |
| basalt/sisal/glass/epoxy     | 6.705                 | 0.023961                 | 72.2                              |

When a material is operated beyond glass transition temperature, all the mechanical properties will decrease. Mechanical properties will not always increases with glass transition. Mechanical properties vary with respect to bond strength between the matrix and the fibre.

4. CONCLUSION

Mechanical and thermal properties of sisal/basalt/epoxy, sisal/glass/epoxy and sisal/glass/basalt/epoxy composites were determined and the corresponding strengths were determined. The following observations were made.
1. Addition of natural fibres with advanced fibres like glass and basalt improves the quality of the composites in all respect.

2. When the sisal fiber is added with basalt and glass separately, the bond strength between the sisal and basalt is better than that of sisal/glass due to the cross linking between the basalt epoxy sisal fiber is better than that of glass and epoxy sisal.

3. Thermal behavior of basalt, sisal combination is excellent than that of glass, sisal combination.

4. Combining basalt with sisal fibers gives a good performance. Therefore sisal/basalt/epoxy composites can be used in aircraft structural applications.

References

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