Structural Analysis of Natural Fiber Reinforced Epoxy-Hybrid Composites

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Abstract **- The use of natural fibers as reinforcement in polymers has gained importance in recent years due to their eco-friendly nature. Thus, an investigation has been undertaken on coconut-coir and sisal fiber, which is a natural fiber abundantly available in India. Natural fibers are not only strong and lightweight, but also relatively very cheap. Composite plates were prepared with resin 442 g, coir 150g, and sisal 75 g.In addition to that Glass fiber will be added to obtain more efficiency it weighs 100g each. The purpose of this work is to establish the tensile, flexural, and impact properties of hybrid epoxy reinforced composite materials. The resin used was epoxy (LY556). The tensile and impact tests showed that this hybrid composites have higher tensile strength and impact strength. Experimental Result compared with Cessna 172 Aircraft wing Material "al"&hybrid composites shows higher results than "al" structural analysis using "FEA MODEL" software has proved the results. software FEA MODEL has been employed successfully to evaluate the properties. The model output was compared with the experimental results and found to be close. This analysis is useful for realizing the advantages of hybrid fiber reinforced composites in structural applications and for identifying where the stresses are critical and damage the interface under varying loading conditions.**

Keywords: Sisal-fiber; coir-fiber; Glass fiber; tensile; flexural; impact; FEA MODEL.

INTRODUCTION

Nowadays, the natural fibers such as Sisal, Coconut coir have the potential to be used as a replacement for carbon or other traditional reinforcement materials in composites (Abrao et al., 2006) Other advantages include low density, high toughness, comparable specific strength properties, reduction in tool wear, ease of separation, decreased energy of fabrication. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix).

COMPOSITE MATERIALS

A composite material is composed of at least two materials, which combine to give properties superior to those of the individual constituents. A **composite material** (also called a **composition material** or shortened to **composite,** which is the common name) is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials.

Material selection:

The structural materials used in airframe and propulsion systems influence the cost, performance and safety of aircraft, and an understanding of the wide range of materials used and the issues surrounding them is essential for the student of aerospace engineering. Introduction to aerospace materials reviews the main structural and engine materials used in aircraft, helicopters and spacecraft in terms of their production, properties, performance and applications.

Advanced Composite Materials

An advanced composite material is made of a fibrous material embedded in a resin matrix, generally laminated with fibers oriented in alternating directions to give the material strength and stiffness. Fibrous materials are not new; wood is the most common fibrous structural material known to man. A matrix supports the fibers and bonds them together in the composite material.

Advanced composite materials of the future in aerospace industry:

Since Orville and Wilbur Wright first decided to power their Flyer with a purpose built, cast aluminium engine to meet the specific requirements for power to weight ratio, new materials have been necessary to improve and advance aviation. This improvement in material properties has helped us to travel quickly and inexpensively around the world, by improving the performance and operations of modern aircraft. In the first part of this study the author introduces the composites materials with their advantages and disadvantages.

Airbus and its innovation in composite materials are introduced in the second part of the thesis. Composite technology continues to advance, and the advent of new types such as nanotube forms is certain to accelerate and extend composite usage.

SISAL FIBER

With the botanical name *Agave sisalana*, is a species of Agave native to southern Mexico but widely cultivated and naturalized in many other countries. It yields a stiff fibre used in making various products. The term sisal may refer either to the plant's common name or the fibre, It is sometimes referred to as "sisal hemp", because for centuries hemp was a major source for fibre, and other fibre sources were named after it.

Sisal is a hard fibre extracted from the leaves of sisal plants which are perennial succulents that grow best in hot and dry areas. Sisal is an environmentally friendly fibre as it is biodegradable and almost no pesticides or fertilizers are used in its cultivation. World production is about 300,000 tones.

Sisal Fiber is one of the most widely used natural fiber and is very easily cultivated. It is obtain from sisal plant. The plant, known formally as Agave sisalana. These plants produce rosettes of sword-shaped leaves which start out toothed, and gradually lose their teeth with maturity. Each leaf contains a number of long, straight fibers which can be removed in a process known as decortication.

Properties of Sisal Fiber:

Sisal Fiber is exceptionally durable with a low maintenance with minimal wear and tear.

1. It is Recyclable.
2. Sisal fibers are obtained from the outer leaf skin, removing the inner pulp.
3. It is available as plaid, herringbone and twill.
4. Sisal fibers are Anti static, does not attract or trap dust particles and does not absorb moisture or water easily.
5. The fine texture takes dyes easily and offers the largest range of dyed colours of all natural fibers.
6. It exhibits good sound and impact absorbing properties.

Its leaves can be treated with natural borax for fire resistance properties

Sisal Fiber Mat

COCONUT COIR FIBER

coconut fibre, is a natural fibre extracted from the husk of coconut[1] and used in products such as floor mats, doormats, brushes and mattresses. Coir is the fibrous material found between the hard, internal shell and the outer coat of a coconut. Other uses of brown coir (made from ripe coconut) are in upholstery padding, sacking and horticulture. White coir, harvested from unripe coconuts, is used for making finer brushes, string, rope and fishing nets.

Coir fibres are found between the hard, internal shell and the outer coat of a coconut. The individual fibre cells are narrow and hollow, with thick walls made of cellulose. They are pale when immature, but later become hardened and yellowed as a layer of lignin is deposited on their walls. Each cell is about 1 mm (0.04 in) long and 10 to 20 µm (0.0004 to 0.0008 in) in diameter.

The common name, scientific name and plant family of coconut fiber is Coir, Cocos nucifera and Arecaceae (Palm), respectively.

Chemical Composition of Coconut / Coir Fiber:

- Lignin…………….................…45.84%
- Cellulose………….............…43.44%
- Hemi-Cellulose……………................00.25%
- Pectin’s and related Compound…………03.00%
- Water soluble…………….........05.25%
- Ash…………………….............02.22%

Physical Properties of Coconut / Coir Fiber:

- Length in inches…………6-8
- Density (g/cc)………………….1.40
- Tenacity (g/Tex)………………10.0
- Breaking elongation%..............30%
- Diameter in mm…………0.1 to 1.5
- Rigidity of Modulus……….1.8924 dyne/cm2
- Swelling in water (diameter)…………5%
- Moisture at 65% RH…………10.50%

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Manufacturing Process of Coconut Fiber:

Harvesting and husking of coconut, retting of coconut fiber, Extraction of Fiber, Spinning, Weaving, Dyeing and Printing.

Coconut Fiber mat

GLASS FIBER

Glass fiber (or glass fibre) is a material consisting of numerous extremely fine fibers of glass.

Glassmakers throughout history have experimented with glass fibers, but mass manufacture of glass fiber was only made possible with the invention of finer machine tooling. In 1893, Edward Drummond Libbey exhibited a dress at the World's Columbian Exposition incorporating glass fibers with the diameter and texture of silk fibers. Glass fibers can also occur naturally, as Pele's hair.

EPOXY RESIN LY556

Epoxy is either any of the basic components or the cured end products of epoxy resins, as well as a colloquial name for the epoxide functional group.[1] Epoxy resins, also known as polyepoxides, are a class of reactive prepolymers and polymers which contain epoxide groups. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homopolymerisation, or with a wide range of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, alcohols and thiols. These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Reaction of polyepoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with favorable mechanical properties and high thermal and chemical resistance.

Epoxy Resin and Hardener

FABRICATION METHODS

There are numerous methods for fabricating composite components. Some methods have been borrowed (injection molding, for example), but many were developed to meet specific design or manufacturing challenges. Selection of a method for a particular part, therefore, will depend on the materials, the part design and end-use or application.

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The most basic fabrication method for thermoset composites is *hand layup*, which typically consists of laying dry fabric layers, or "plies," or prepreg plies, by hand onto a tool to form a laminate stack. Resin is applied to the dry plies after layup is complete (e.g., by means of resin infusion). In a variation known as wet layup, each ply is coated with resin and "debulked" or compacted after it is placed.

HAND LAYUP TECHNIQUE

Hand lay-up is an open molding method suitable for making a wide variety of composites products from very small to very large. Production volume per mold is low; however, it is feasible to produce substantial production quantities using multiple molds. Hand lay-up is the simplest composites molding method, offering low cost tooling, simple processing, and a wide range of part sizes. Design changes are readily made. There is a minimum investment in equipment. With skilled operators, good production rates and consistent quality are obtainable.

I. PROCESS:

Gel coat is first applied to the mold using a spray gun for a high quality surface. When the gel coat has cured sufficiently, roll stock fiberglass reinforcement is manually placed on the mold. The laminating resin is applied by pouring, brushing, spraying, or using a paint roller. FRP rollers, paint rollers, or squeegees are used to consolidate the laminate, thoroughly wetting the reinforcement and removing entrapped air. Subsequent layers of fiberglass reinforcement are added to build laminate thickness. Low density core materials such as end-grain balsa, foam, and honeycomb, are commonly used to stiffen the laminate. This is known as sandwich construction.

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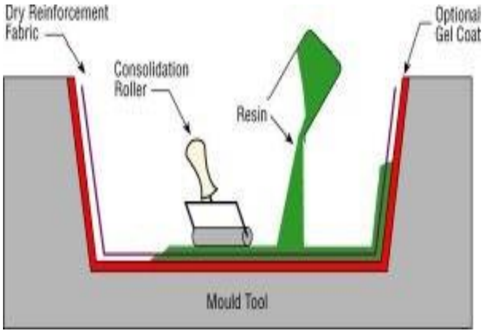

Hand Layup Technique

EXPERIMENTAL WORK

Materials for experimentation:

Sisal (Agave sisalana), coconut coir fiber and E-Glass fibre are the core materials based on which, the hybrid composites are prepared and tested. Coconut coir from COIR BOARD Ltd.., Thanjavur and Sisal fibre mat from GO GREEN PRODUCTS Chennai, and E-Glass fibre from GO GREEN PRODUCTS Chennai, are procured and suitable binders for these fibres are chosen which include Epoxy Resin of grade LY 556 and hardener of grade HY 906, which are procured from fibre manufacturers . Fabrication and Mechanical Testing of this specimen are carried out at Strength of materials, Laboratory, PITS Thanjavur, Tamil Nadu, India.

Hybrid Composite preparation

Hybrid composite specimen are sandwiched to form the resultant hybrid composite of 403mm * 250mm mm dimension with 10 mm thickness. Sandwich structured hybrid composite specimen incorporates an innermost layer of coir fibre covered by an intermediate double layered E-glass fibre, and Sisal fibre in the later. Epoxy resin of LY 556 grade is mixed with HY 906 grade hardener at the proportion of 10:1. On each layers of the hybrid composite, a required amount of epoxy resin is applied on both fibre surfaces and then reinforcement is done in compression moulding machine. For curing of specimen, 70ºC temperature for duration of 2 hours is maintained within the Electrical Oven machine. After the curing process, the specimen is taken out from the machine.

weight of sisal and glass fiber

weight of epoxy resin

Specimen preparation

The cured specimen taken from the machine is properly barbered to carry out mechanical property testing such as Tensile, Flexural and Impact as per ASTM standard. The images of the barbered specimen before and after testing are shown.

Fabrication of composites.

Our reason allows us to make predictions about the natural world. Scientists attempt to predict and perhaps control future events based on present and past knowledge. The ability to make accurate predictions hinges on the seven steps of the Scientific Method.

S no	Samples	Test	Ultimate break load(KN)	Displacement (mm)	Ultimate stress (N/mm^2)
1	Sample 1	Tension	2.322	2.9	33.23
2	Sample 2	Tension	2.115	4.0	35.01

Step 1. Make observations.

Step 2. Form a hypothesis.

Step 3. Make a prediction.

Step 4. Perform an experiment.

Step 5. Analyze the results of the experiment.

Step 6. Draw a conclusion.

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Step 7. Report your results.

VARIOUS TYPES OF TESTS

- ✓ Tensile test
- ✓ Impact test
- ✓ Flexural test

s.no	Test	Length(mm)	Breadth(mm)	Thickness(mm)
1	Tension	250	25	10
2	Compression	250	25	10
3	Izod impact	65	13	10
4	Charpy impact	65	13	10
5	Flexure	110	25	10

Results:

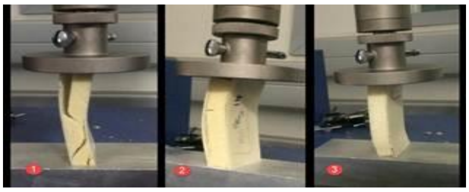
Table. Geometry of test specimen.

S no	Samples	Test	Ultimate break load(KN)	Displacement (mm)	Ultimate stress (N/mm^2)
1	Sample 1	Compression	2.322	3.1	38.23
2	Sample 2	Compression	2.115	2.6	36.01

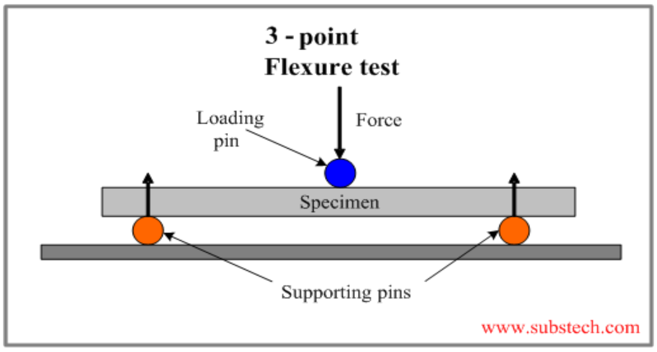
UTM MACHINE

Tensile Test Results on hybrid composites

COMPRESSION TEST



Compression Test Results on hybrid composites



Specimen loading on Flexure

Results:

S no	Samples	Test	Ultimate break load(KN)	Displacement (mm)	Ultimate tensile strength(Mpa)
1	Sample 1	Flexural	3.14	2.32	40.88
2	Sample 2	Flexural	2.89	1.39	38.72

Flexural Test Results of specimen

IMPACT TESTING

S no	**Samples**	**Test**	**Ultimate Impact load(KN)**	**Displacement (mm)**	**Impact Energy(J)**
1	Sample 1	Charpy impact	1.45	1.11	45.62
2	Sample 2	Charpy impact	1.36	0.78	47.87

Charpy Impact Test on Hybrid composites

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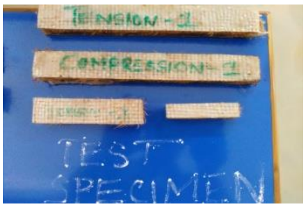
Izod Impact Test Results on Hybrid composites



(i) Test specimen (tension,compression and impact) (ii) Compression Test specimen (iii) Izod Impact (iv) Charpy Impact (v) Impact test specimens on breaking(izod and charpy) (vi) Flexural,Impact and tension testing specimens.

SOFTWARE ANALYSIS:
The Software analysis has been made on hybrid composites by comparing the values of aluminium.That is the structural properties of the aluminium is considered.
Here we can use a CATIA V5R21 Software to find out structural analysis of reinforced epoxy hybrid composites. Engineered Composites have actually been in use for thousands of years. Adobe bricks were made using a composite of mud and straw. It is the combination of the physical properties of each material that gives the composite material many of its physical characteristics. Today's advanced composites, like carbon fiber, bring together combined properties we've come to know – lightweight, strong, durable and heat-resistant. Today, the benefits of components and products designed and produced in composite materials – instead of metals, such as aluminum and steel – are well recognized by many industries.

ALUMINIUM FOR TURBOJET 172 LEARJET
II. TURBODIESEL CESSNA 172 JT-A USES ALUMINIUM 2024-T3 ALLOYS FOR ITS WING STRUCTURE.THEIR CHARACTERISTICS PROPERTIES ARE MENTIONED BELOW,

S no		Test	Ultimate Impact load(KN)	Displacement (mm)	Impact Energy(J)
	Sample 1	Izod impact	1.08	1.32	41.09
	Sample 2	Izod impact	0.93	1.24	38.75

ALUMINIUM 2024-T3

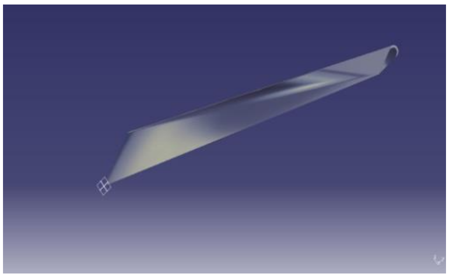
Ultimate tensile strength	483 Mpa
Tensile yield strength	345 Mpa
Young's modulus	73.1 Gpa
Poisson's ratio	0.33
Fatigue strength	138 mpa
Thermal conductivity	121 W/m-k

Table.6.2 Aluminium 2024-T3

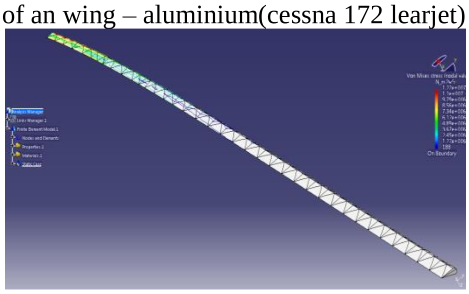
2024-T3 :

T3 temper 2024 sheet has an ultimate tensile strength of 400–430 MPa (58–62 ksi) and yield strength of at least 270–280 MPa (39–40 ksi). It has an elongation of 10-15%.

Results:



Structure of an wing – aluminium(cessna 172 learjet)



Wing von-mesis stress - aluminium(cessna 172 learjet)

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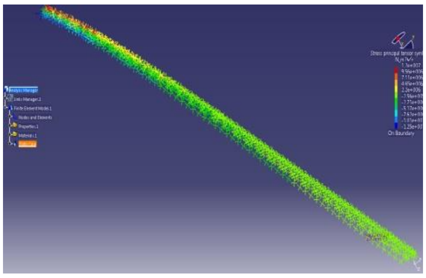
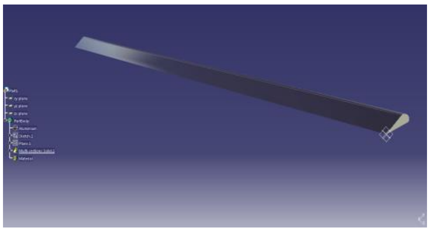
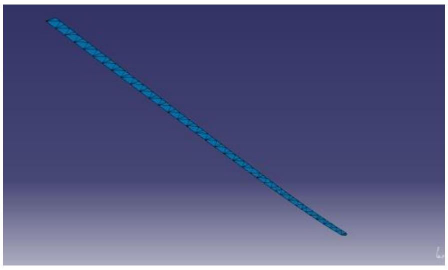


Wing principal stress - aluminium(cessna 172 learjet)

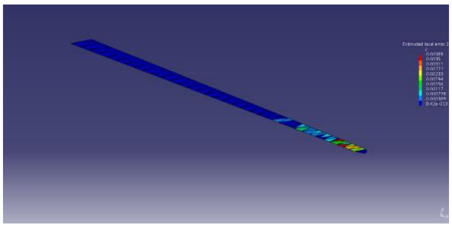
HYBRID COMPOSITES

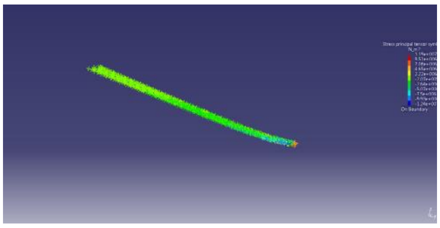


Structure of wing-hybrid composite material(Cessna 172 learjet)

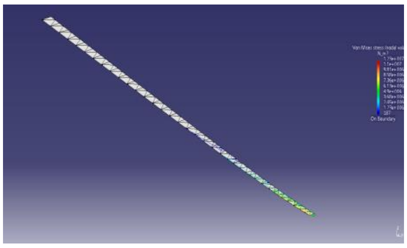


Wing deformation hybrid composites(Cessna 172 Learjet)

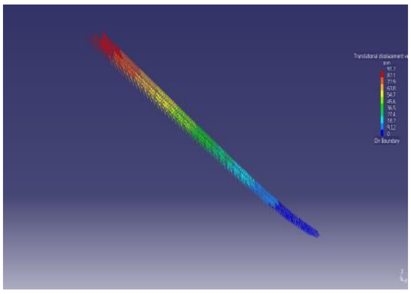




Wing structural analysis hybrid composites(Cessna 172 Learjet)



Wing von mises stress hybrid composites(Cessna 172 Learjet)



Wing translational displacement hybrid composites(Cessna 172 Learjet)

CONCLUSION:

Mechanical testing's such as Tensile, Flexural and Impact test on the hybrid composite are performed and their mean average values are correlated with each other, which are described in the Table which represents Sisal fibre + E-Glass fibre + Coconut coir fiber hybrid composite .

The result of software analysis shows that the structural properties for Cessna 172 learjet is better in terms of hybrid composites than the aluminium alloy.

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