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Design Fabrication and Analysis of Open and Closed Section Nano-Composite Beams

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Abstract—*The purpose of this reaearch paper is to determine the principal stresses for glass fiber composite tubes and nano particles infused glass fiber composite tubes due to combine loading, and also to determine the bending stresses obtained for both the glass fiber and nano particle infused composite angle sections. All the components made are four layered and constitute bi-directional S-glass fibres, with the matrix content comprising epoxy resin and a hardener compatible to it. The above mentioned are mixed in desired ratios as per our requirements. Aluminium nano particles are added too.*
Tests are conducted and loads like bending, torsion and axial loads are determined. Various mechanical properties like strain, tensile strength, shear strength etc are found. With the results obtained we make a comparison between these composites and conventional metal.
On further introspection it is experimentally proved that the composite components fabricated are far better than their metallic counterparts and we gradually can replace the metallic components with composite components as in the case of propeller shafts which which we find out with composite torque tubes that they would withstand much more loads without buckling and at lesser weights.

1. COMPOSITE OVERVIEW

A composite is defined as combination of two or more materials the results in better properties than when individual components are used alone. They consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phases which are harder than the continuous phase are called reinforcements. The continuous phase is termed as the matrix which is usually less hard. The reinforcements serve to strengthen the composites and improve the overall mechanical properties of the matrix. Apart from the nature of the constituents, the geometry of reinforcements influences the properties o a great extent.

2. MATERIALS USED IN FABRICATING COMPOSITE BEAMS

To fabricate a FRP composite material, we require fiber, resin and hardener.

- FIBER : Bi-directional S-glass fiber
- RESIN : Epoxy (Araldite LY 556)
- HARDENER : XY 54 & HY 951

Composition & Properties

S-Glass has a typical nominal composition of SiO_2 65wt%, Al_2O_3 25wt%, MgO 10wt%. Some other materials may also be present at impurity levels.

- Density: 2.49 g/cm^3
- Tensile Strength : 4750 MPa
- Young's Modulus: 89 GPa

The product name of the epoxy resin we used is **ARALDITE LY556.**

It is an unfilled non modified epoxy resin of low viscosity for the laying up of laminates which may be converted into solid. Two pack low viscosity, room temperature curing epoxy system for use in light, heavy industry, general bonding etc.

Advantages

No volatiles during cure. Low resin shrinkage during cure. Good chemical resistance, better than polyesters. Good heat resistance - certain formulations to 170°C (340°F). Excellent adhesion to various substrates and reinforcing fibres.

Disadvantages

Expensive. Certain catalysts (hardeners) can cause dermatitis. Require precise formulation and curing to achieve optimum properties.

Applications

Injection, transfer and compression mouldings mainly for electrical components. Laminates with carbon, glass and Kevlar fibres for aerospace applications. Coatings for chemical protection of pipes and structures, marine protection, car coatings. Used for tooling, encapsulation and as an adhesive.

3. ALUMINIUM NANO-PARTICLES

Nanoparticle research is an area of strong scientific interest due to the variety of potential applications in optical, biomedical, and electronic fields. In the last 10 years, aluminium nano-particles have been widely researched and used, primarily because of their increased reactivity as compared with conventional micron-sized particle.

Aluminium (Al) is a Block P, Group 13, Period 3 element. The morphology of these particles is spherical and they appear as black or grey-black powder.

Care must be taken when handling metal nanopowders, so as to avoid any strong vibration or friction. Aluminium nano-particles are highly reactive, so measures should also be taken to protect the material from moisture, heat, and sunlight. These particles should be sealed in vacuum and stored in a cool and dry room.

Chemical Properties

The chemical properties of aluminium nano-particles are outlined in the following table.

Chemical Data

Chemical Symbol	Al
CAS No.	7429-90-5
Group	13
Electronic configuration	[Ne] 3s2 3p1

Physical Properties

The physical properties of aluminium nano-particles are given in the following table.

Properties	Metric	Imperial
Density	2.70 g/cm3	0.0975 lb/in3
Molar mass	26.98 g/mol	-

Thermal Properties

The thermal properties of aluminium nano-particles are provided in the table below.

Properties	Metric	Imperial
Melting point	660.32 °C	1220.58 °F
Boiling point	2519 °C	4566.2 °F

FABRICATION OF COMPOSITE MATERIALS
CIRCULAR SECTION
MARKING & CUTTING

- Mark 4 plies of bi directional glass fibre mat for dimensions 16*60cm
- Now, cut the marked plies carefully using a cutter.

MIXTURE RATIO

- Weigh the layers and note it down.
- The ratio of resin to fibre should be 1:1.
- Pour equal amount of resin in the bowl.
- Add the hardener in such a way that the resin hardener ratio is 1:0.5
- Add aluminium nano-particles to the mixture such that it amounts to 5% of the total weight of the mixture.
- Now stir thoroughly so that the particles are fully wetted by the resin mixture.

APPLYING OVER MOULD

- Place the PVC pipe in a stand.
- The pipe is the mould
- Apply the resin mixture coating over it. Now place the first of the 4 layers on top of it.
- Apply the mixture again.
- Repeat the process until the last of the layers has been placed.
- Now neatly cover the fourth layer with the laminate sheet again.
- Allow it 24 hours to cure.

PROVIDING THE SMOOTH FINISH

- Remove the composite from the mould after the curing time.
- Now smoothen the surface by applying the metal paste over it.
- Apply a paint coat.

The nano-particle composite is ready now.

ANGLE SECTION

MARKING & CUTTING

- Mark 4 plies of bi directional glass fibre mat for dimensions 3.5*60cm
- Now, cut the marked plies carefully using a cutter.

MIXTURE RATIO

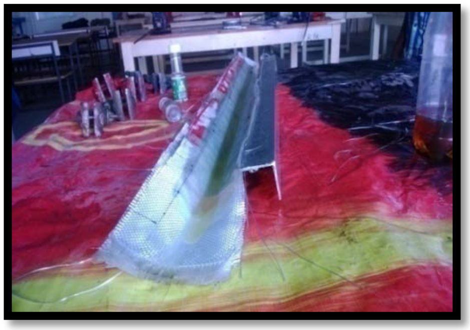
- Weigh the layers and note it down.
- The ratio of resin to fibre should be 1:1.
- Pour equal amount of resin in the bowl.
- Add the hardener in such a way that the resin hardener ratio is 1:0.5

- Add aluminium nano-particles to the mixture such that it amounts to 5% of the total weight of the mixture.
- Now stir thoroughly so that the particles are fully wetted by the resin mixture.

APPLYING OVER MOULD

- Place the aluminium angles in a stand.
- The aluminium angles are the mould
- Apply the resin mixture coating over it. Now place the first of the 4 layers on top of it.
- Apply the mixture again.
- Repeat the process until the last of the layers has been placed.
- Now neatly cover the fourth layer with the laminate sheet again.

Allow it 24 hours to cure.



PROVIDING THE SMOOTH FINISH

- Remove the composite from the mould after the curing time.
- Now smoothen the surface by applying the metal paste over it.
- Apply a paint coat.
- The nano-particle composite is ready now.

Closing the mould with clamps for angle section

Components after removing from mould and painting

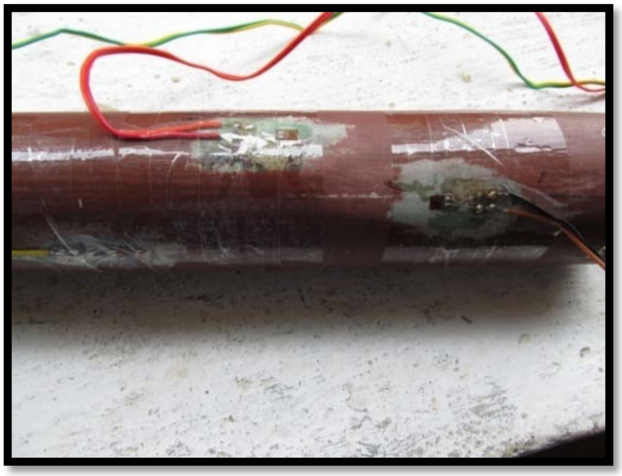
EXPERIMENT SETUP

Preparing the strain gauge

The composite components must be properly finished and ready to be fitted in the experiment set-up.
An important part is to ***fix the strain gauges*** in the components, which if not done precisely will result in improper measurements.
Proper care must be taken while fixing the strain gauges.

Attaching the strain gauge

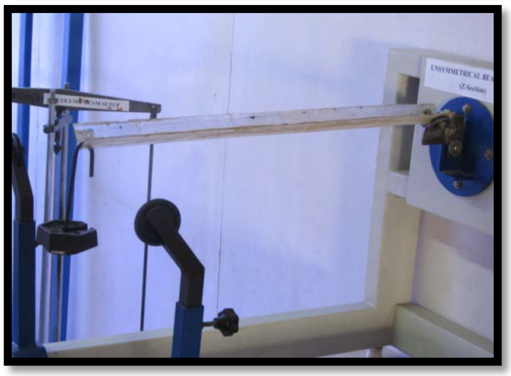
Once the soldering is done, the surface of the component must be cleaned and smoothened in the spot where the strain gauges are to be fixed.



Loading the specimen in the set-up

Loading must be done after ensuring that everything else is proper and the specimen is perfectly ready for testing.

Set up of the angle section



Set up of the circular specimen

CALCULATION

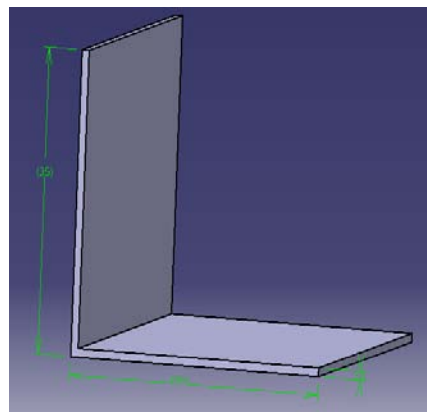
Determination of principal stress of nano composite circular tube due to combine loading:

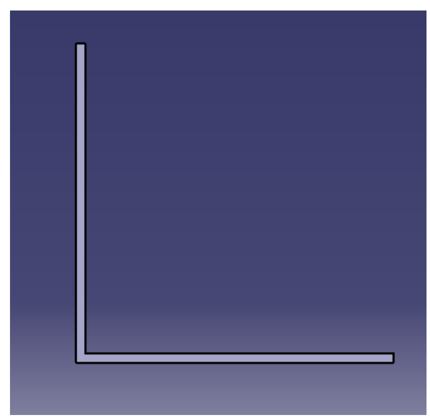
To find the bending stress acting on the above component is shown in below

$$\frac{M}{I} = \frac{\sigma}{Y}$$ Where,

M- Moment, I - moment of inertia, σ - stress & we know that moment is the product of force and distance

So, when the load is 200g and the distance is 52 cm then the moment is,





So, when the load is 200g and the distance is 52 cm then the moment is,

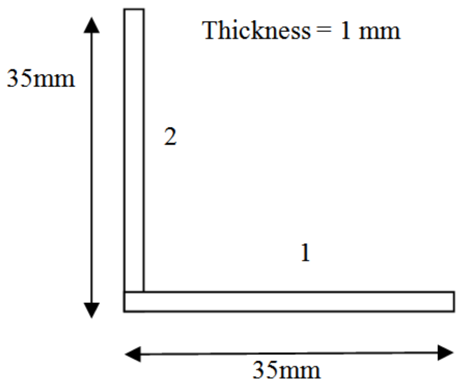
$$M= 200 * 9.81 * 52 * 10$$

$$M = 1020240 \text{ N} – \text{mm}$$

The moment of inertia is given by,

$$I_{xx}= \Sigma I_{cx}+ \Sigma Ay^2 – \Sigma \tilde{A}y^2$$

Here the component is symmetric about x axis so I_{yy} is zero



Element	Area (mm2)	X (mm)	Y (mm)	Ax (mm3)	Ay (mm3)
1	35	17.5	0.5	612.5	17.5
2	35	0.5	17.5	17.5	612.5

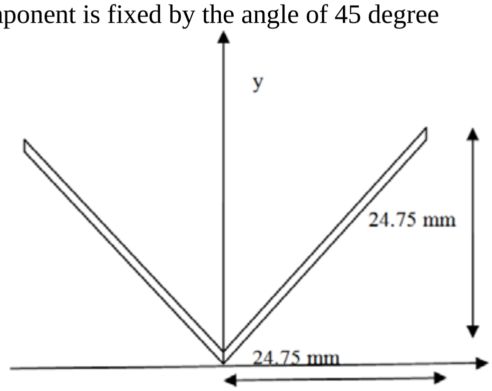
$\Sigma I_{cx} = \frac{bd^3}{12} + \frac{db^3}{12}$

$\Sigma I_{cx} = 3575.833$ mm

$X = \frac{\Sigma Ax}{\Sigma A} = 9$ mm

$Y = \frac{\Sigma Ay}{\Sigma A} = 9$ mm

The component is fixed by the angle of 45 degree



$I_{xx} = \Sigma I_{cx} + \Sigma Ay^2 - \Sigma \tilde{A}y^2$

$I_{xx} = \Sigma I_{cx} + \Sigma Ay^2 - \Sigma \tilde{A}y^2$
$I_{xx} = 35735.3642$ mm^4
$\sigma = \frac{M}{I} y$

Sub the above values then we get,

$\sigma = 353.3046$ N/ mm^2

the same way substitute the moment for the different values of load we get different values of stress,

S. no	Weight (g)	M(N – mm)	Ixx (mm4)	Y (mm)	σ (N/ mm2)
1	200	1020204	35735.3642	12.375	353.3046
2	400	2040480	35735.3642	12.375	706.609
3	600	3060720	35735.3642	12.375	1059.869

$E_c = E_f V_f + E_m V_m$

$G_{12} = \frac{G_f G_m}{G_f V_m + G_m V_f} = 17.5$ G Pa

For load 1 Kg

$\sigma_x = E_c \epsilon_a + E_c \epsilon_b = 2073.6$ KN/ m^2
$\tau_{xy} = G_{12} E_t = 560$ KN/m^2
$\sigma_1 = 2215.16$ KN/m^2, $\sigma_2 = -141.57$ KN/m^2

For load 2kg,

$\sigma_x = E_c \epsilon_a + E_c \epsilon_b = 4147.2$ KN/ m^2
$\tau_{xy} = G_{12} E_t = 1190$ KN/m^2
$\sigma_1 = 4464.39$ KN/m^2, $\sigma_2 = -317.19$ KN/m^2

For load 3kg,

$\sigma_x = E_c \epsilon_a + E_c \epsilon_b = 6220.8$ KN/ m^2
$\tau_{xy} = G_{12} E_t = 1610$ KN/m^2
$\sigma_1 = 6612.78$ KN/m^2, $\sigma_2 = -391.98$ KN/m^2

For composite circular tube without nano particles:

For load 1 Kg

$\sigma_x = E_c \epsilon_a + E_c \epsilon_b = 1612.8$ KN/ m^2
$\tau_{xy} = G_{12} E_t = 280$ KN/m^2
$\sigma_1 = 1660.03$ KN/m^2, $\sigma_2 = -472.28$ KN/m^2

For load 2kg,

$\sigma_x = E_c \epsilon_a + E_c \epsilon_b = 4147.2$ KN/ m^2
$\tau_{xy} = G_{12} E_t = 490$ KN/m^2
$\sigma_1 = 4204.31$ KN/m^2
$\sigma_2 = -571.08$ KN/m^2

For load 3kg,

$\sigma_x = E_c \epsilon_a + E_c \epsilon_b = 5990.04$ KN/ m^2
$\tau_{xy} = G_{12} E_t = 700$ KN/m^2
$\sigma_1 = 6070.11$ KN/m^2, $\sigma_2 = -807.10$ KN/m^2

4. COMPARISON TABLE

	Metal (Al)	Composite with nano particles	Composite without nano particles
Axial load	1	1	1
Bending load	1	1	1
Torsion load	1	1	1
ϵa	2	2	6
ϵb	3	5	6
ϵT	1	4	8
σx	1400	1612.8	2073.6
Ʈxy	108	280	560
σ1	1408.2	1660.3	2215.16
σ2	-8.28	-472.28	141.57

	Metal (Al)	Composite with nano particles	Composite without nano particles

Axial load	2	2	2
Bending load	2	2	2
Torsion load	2	2	2
ϵa	3	6	6
ϵb	7	12	17
ϵT	4	7	12
σx	2800	4147.2	4147.2
Ʈxy	432	450	1190
σ1	2865.1	4204.31	4464.31
σ2	-65.1	-571.08	-317.19

	Metal (Al)	**Composite with nano particles**	**Composite without nano particles**
Axial load	3	3	3
Bending load	3	3	3
Torsion load	3	3	3
ϵa	4	9	9
ϵb	11	17	18
ϵT	7	9	23
σx	4200	5990	6220.8
Ʈxy	756	700	1610
σ1	4331.9	6071.1	6612.7
σ2	-131.9	-807.10	-391.98

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