AE673 Fibre Reinforced Composites

Bio-Research Laboratory Door

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Objective:

To replace a conventional material such as metals, currently being used in laboratory doors, with lighter composite materials without any compromise in strength and chemical and biological resistance properties.

Materials

Some examples such as:

- GRPs
- CFRPs

Materials for additional protection:

- High impact PVC
- Stainless steel
- Ribbed rubber

Why?

These composites offer several advantages:

- Chemical Resistance
- Cleanliness
- Cost effective: long-term durability
- Design flexibility
- Non-porosity which helps in easier cleaning process

How?

The manufacturing process of CFRP composite doors involves several steps

- Material selection for the requirements
- Designing the door
- Molding
- Curing
- Finishing and assembly

Physical specifications of the Door and the materials used

Material Properties:

GFRP

E1	70 GPa
E2	10 GPa
G12	8 GPa
v12	0.33

CFRP

E1	250 GPa
E2	20 GPa
G12	30 GPa
v12	0.2

Door specifications:

- Thickness of protective material: 2-8 mm
- Stainless steel hinges
- Thickness of the door: 50 mm
- Non-porous gelcoat finish
- Height: 2000 mm
- Width: 3000 mm

Load specifications:

- Weight Reduction: ~40%
- Tensile Strength: 200 MPa
- Shear Strength: 20 MPa
- Temperature: 50°C

Method:

Classical Laminate Theory and Tsai-Wu Failure criterion will be used to analyze stresses and strains for different composite layer thickness.

Layup selected:

1. GFRP = [0, 45, -45, 90, 0]
2. CFRP = [0, 90, 45, -45, 0]
   unidirectional, ±45°, and 90°

Calculations:

Safety factor(SF)= 2

Max. allowable stress (Tm) = Tensile strength * SF
Tm = 100 Mpa

Thickness of each layer= 5 mm
Total layers= 10 (2 CFRP, 8 GFRP)

Weight calculation:

Weight of our composite door: 492 kg
Weight of a typical metallic lab door: 840 kg
% Reduction = 41%

Results:

Layer-wise stresses in the composite laminate:
Layer 1: 0.25 MPa
Layer 2: 0.18 MPa
Layer 3: 0.18 MPa
Layer 4: 0.00 MPa
Layer 5: 0.25 MPa
Layer 6: 0.50 MPa
Layer 7: 0.00 MPa
Layer 8: 0.35 MPa
Layer 9: 0.35 MPa
Layer 10: 0.50 MPa

Composite Laminate Parameters:
Maximum Stress: 0.50 MPa
Strain in GFRP: 0.001667
Strain in CFRP: 0.000167

Tsai-Wu Criterion

Tsai-Wu Failure Theory

$$\left(\frac{1}{x_t}-\frac{1}{x_c}\right)\sigma_1+\left(\frac{1}{y_t}-\frac{1}{y_c}\right)\sigma_2+\frac{\sigma_1^2}{x_t x_c}+\frac{\sigma_2^2}{y_t y_c}+\frac{\tau_{12}^2}{s^2}+2F_{12}\sigma_1\sigma_2=\text{F.I.}$$

- **Xt** tension limit, along fiber
- **Xc** compression limit, along fiber
- **Yt** tension limit, transverse fiber
- **Yc** compression limit, transverse fiber
- **S** shear limit
- **F12** interaction term

Layer	σ1 (MPa)	σ2 (MPa)	τ12 (MPa)	Failure Index
1	0.53	0.00	0.00	0.00
2	0.53	0.00	0.00	0.00
3	0.53	0.00	0.00	0.00
4	0.53	0.00	0.00	0.00
5	0.53	0.00	0.00	0.00
6	0.53	0.00	0.00	0.00
7	0.53	0.00	0.00	0.00
8	0.53	0.00	0.00	0.00
9	0.53	0.00	0.00	0.00
10	0.53	0.00	0.00	0.00

We have run the MATLAB code to calculate stresses in three directions for all 8 layers along with Tsai-Wu failure criteria:

Tsai-Wu failure criteria is defined as given in the above figure.

THANK YOU

IF OPPORTUNITY DOESN’T KNOCK,
BUILD A DOOR!