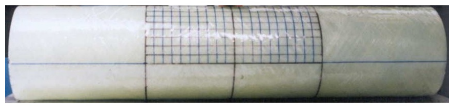
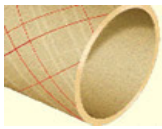
MANCHESTER 1824

Coursework Assignment

Design and Analysis of a Composite Tube

General Description

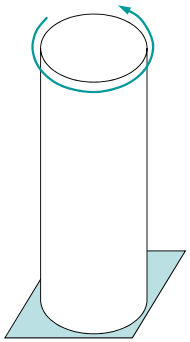




- Design a cylindrical composite tube
  - 4 layers, with a lay–up of $[\alpha/\beta/\alpha/\beta]$, angle to the axis of the tube
  - Winding tapes cut from a UD prepreg sheet onto a R=25mm mandrel
  - The thickness of the prepreg is 0.25mm → $X4 = 1mm$
  - The tube is 300mm long
- Design variable: fibre orientation angle α and β
  - $-75° \le \alpha \le -30°$ or $+30° \le \alpha \le +75°$, $-75° \le \beta \le -30°$ or $+30° \le \beta \le +75°$
- Tube sustains two loading conditions according to maximum stress criterion
  - Internal pressure of 3 MPa (ends closed)
  - Axial compression force of 25 kN

Special Requirement

- The tube should achieve a twist under axial compression in such a direction as shown below
- Aiming at achieving the maximum angle of twist without failure



NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC87-0182 Date: July 24, 1987 Photo by: NASA

X-29 in Banked Flight

Arrangement and Report

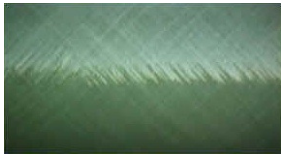
- A group project
  - Maximum 3 students to form one group among yourselves
  - Marks shared by group members
- Computer-based lab
  - Week 6
  - Please check your personal timetable for your session and venue
- Report
  - Group report (maximum 8 pages)
  - Design method and theory, analysis procedure

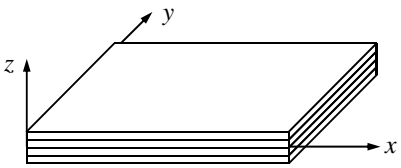
    All equations used, same format as in lecture notes, NOT as in the handout
  - Results & analysis to prove the success of the design
  - **Due two weeks after your lab session, Blackboard submission**

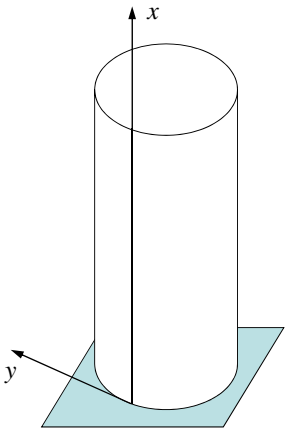
    One group one report with all names of group member

Tube Design Analysis

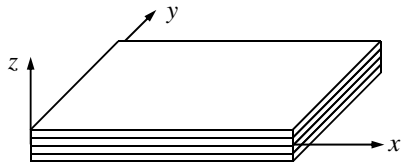
- Composite tube is a laminated structure
- A developed tube is a laminate
  - Lay up: $[\alpha/\beta/\alpha/\beta]$
- Laminate theory can be used for stress analysis

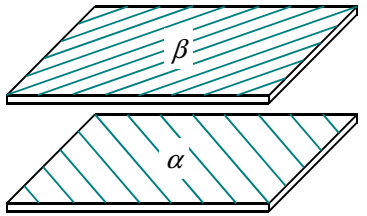






Laminate Analysis of the Tube





- Infinitesimal FBD from the tube
  - A laminate with lay-up $[\alpha/\beta/\alpha/\beta]$
  - Generalised stresses and strains

    $N_x,\ N_y,\ N_{xy},\ M_x,\ M_y,\ M_{xy}$

    $\varepsilon_x^0,\ \varepsilon_y^0,\ \gamma_{xy}^0,\ \kappa_x,\ \kappa_y,\ \kappa_{xy}$

$N_x,\ N_y,\ N_{xy},\ M_x,\ M_y,\ M_{xy}$

$N_x,\ N_y,\ N_{xy},\ \kappa_x,\ \kappa_y,\ \kappa_{xy}$

$M_x,\ M_y,\ M_{xy},\ \varepsilon_x^0,\ \varepsilon_y^0,\ \gamma_{xy}^0$

- Determination of the generalised stresses and strains
  - Loading condition and generalised stress-strain relationship

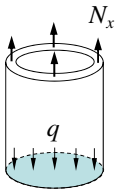
Generalised Stresses $\{N\}$

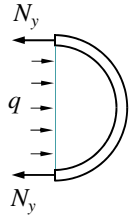
- Load case 1: Internal pressure with closed ends

$$N_x = \frac{1}{2}qR$$

$$N_y = qR$$

$$N_{xy} = 0$$

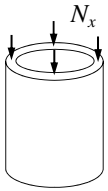




- Load case 2: Axial compression load P

$$N_x = \frac{P}{2\pi R}$$

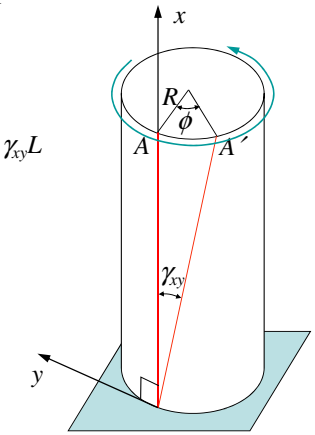
$$N_y = 0 \qquad N_{xy} = 0$$



Twist Angle

- Tube is fixed at the bottom end and axially compressed at the top
- Generator on the tube deforms by an angle γ_{xy}
- Point A at the top end moves to A' by a distance $\gamma_{xy}L$
- Twist angle of the tube

$$\phi = \frac{\gamma_{xy}L}{R}$$



MathCAD Sheet

- A MathCAD sheet will be provided to assist you to carry out the design analysis.
  - Demonstrators will be present to offer help.
- Students are free to use other tools, such as Matlab, to perform the analysis.
  - No need to attend computer lab session, as no help will be offered.

assume $K = 0$

$N = A\varepsilon^0 + BK$

$M = B\varepsilon^0 + DK$

$\varepsilon^0 = A^{-1}N$ $\quad \varepsilon' = \varepsilon^0 + zK$

$= \varepsilon^0 \rightarrow \gamma_{xy} \rightarrow q = \frac{LD_{xy}}{R}$

twist

$\varepsilon \rightarrow \sigma$

$\rightarrow$ failure Analysis