MAE 6070 Composites II
Fall 2013
UTAH STATE UNIVERSITY

Project 2C   Laminate Orthotropic Tube
Due: November 15, 2013

1.0 Documentation

Write a summary of the laminated tube solution which includes the following.

a) Draw a figure showing the geometry and coordinate system.
b) Describe the limitations of the solution and the possible the loads.
c) Summarize the boundary conditions on the tube and evaluate them so that they are in the form of coefficients of A^k_1, A^k_2, ε_x^o, γ^o (reference the single lamina tube report where needed).
d) Describe any problems where terms may be divided by zero when a transversely isotropic, 0° lamina is used.
e) Using the result from c) write the system of equations in matrix form following the pattern shown:

$$\begin{bmatrix} K_{11} & K_{12} & \cdots & K_{1,2N+2} \\ K_{21} & K_{22} & & K_{2,2N+2} \\ \vdots & & \ddots & \vdots \\ K_{2N+2,1} & K_{2N+2,2} & \cdots & K_{2N+2,2N+2} \end{bmatrix} \begin{Bmatrix} A_1^{(1)} \\ A_2^{(1)} \\ \vdots \\ A_1^{(k)} \\ A_1^{(k)} \\ \vdots \\ A_1^{(N)} \\ A_1^{(N)} \\ P_x \text{ or } \varepsilon_x^\circ \\ T_x \text{ or } \gamma_{x\theta}^\circ \end{Bmatrix} = \begin{Bmatrix} F_1 \\ \vdots \\ F_i \\ \vdots \\ F_{2N+2} \end{Bmatrix}$$

2.0 Write a computer program with following features.

2.1 Input

<u>Tube Geometry</u>

a) number of layers, b) number of materials, c) inside radius, d) the orientation angle, thickness, and material type of each material.

<u>Material Properties</u>

E_1, E_2, G_{12}, ν_{12}, ν_{23}, α_1, α_2 of each lamina

<u>Loading</u>

a)P_{in}, b) P_{out}, c) P_x or ε_x^o d) T_x or γ^o e) ΔT

2.2 Calculations

a) the 3D stiffness matrix for each material [C], b) the transformed stiffness matrix for each layer $[\bar{C}]$, c) the [K] matrix, d) the A_1^k, A_2^k for each lamina e) , ε_x^o or P_x, γ^o or T_x.

2.3 Post-Process

a) can find *u*,*v*, and *w* at a specified location.
b) finds strains and stresses at a specified location, *r* location.
c) finds the smeared tube properties E_x, $\nu_{x\theta}$, $G_{x\theta}$, α_x, α_r, $\zeta_{P\gamma}$, $\zeta_{T\varepsilon}$, $\zeta_{\Delta T}$, ζ_{PI}

3.0 Test Cases

3.1 Verification of Code

Recreate the table below. Each ply is assumed to be 0.025". Include the value of P_x and T_x for each laminate when the axial strain or the shear strain is given. r_i=30.0"

Loading		$[0_4]$	$[90_4]$	$[45_4]$	[0/90]s	[45/-45]s	[-45/45]s
Axial Epsx=.001	gamma	0	0	-2.08E-05	0	-1.37E-11	1.37E-11
	wi	-7.20E-03	-5.56E-04	-8.76E-03	-1.06E-03	-2.21E-02	-2.21E-02
	Px	3.63E+05	2.95E+04	4.00E+04	1.97E+04	5.38E+04	5.38E+04
Torque Gamma=.001	epsx	0	0	-1.23E-02	0	-2.19E-08	2.19E-08
	wi	0	0	-0.3710519	0	5.49E-09	-5.49E-09
	T	1.40E+07	1.40E+07	2.37E+07	1.40E+07	8.57E+07	8.57E+07
Internal Pressure pi=10 psi	gamma	0	0	-2.95E-05	0	1.21E-13	-1.21E-13
	wi	5.79E-02	4.70E-03	4.26E-02	8.67E-03	3.17E-02	3.17E-02
	epsx	-3.74E-05	-3.56E-05	-4.13E-04	-1.01E-05	-7.76E-04	-7.76E-04
Thermal delta T= 100 F	epsx	-4.30E-05	1.36E-03	6.58E-04	8.32E-05	8.32E-05	8.32E-05
	gamma	0	0	-4.67E-05	0	-3.64E-11	3.64E-11
	wi	4.08E-02	-1.36E-03	1.97E-02	2.40E-03	2.40E-03	2.40E-03

Recreate the following table also where the axial strain and twist angle are given and the axial load and torque are the results.

Layup	Px	Tx	epsx	Gamma	wi
[0/90]s	196650	13980700	0.001	0.001	-0.0010602
[45/-45]s	53770	85696800	0.001	0.001	-0.0221240
[-45/45]s	53767	85696800	0.001	0.001	-0.0221231

The material is T300/5208 with the following properties.

E_1= 19.2 Msi E_2=1.56 Msi G_{12}= 0.82 Msi ν_{12}=0.24 ν_{23}=0.59
α_1= -0.43E-06 /°F α_2= 13.6E-06 /°F

3.2 Strains & Displacements

Using the properties of T300/5208 and a ΔT=100°F plot the following curves
a) $w(r_i)$ as a function of θ for a $[\theta/-\theta_2/\theta]$ laminate
b) ε_x^o, as a function of θ for a $[\theta/-\theta_2/\theta]$ laminate

c) γ^o as a function of θ for a [θ/-θ_2/θ] laminate

r_i=5.0” Each ply is 0.025”

3.3 Stresses

Using the properties of T300/5208 and P_{in}=1 ksi plot the stresses (σ_x, σ_θ, σ_r, $\tau_{x\theta}$) through the thickness for a [26/-26_2/26] laminate. r_i=5.0” Each ply is 0.025”

3.4 Smeared Properties

Calculate, the smeared tube properties

E_x, $\nu_{x\theta}$, $G_{x\theta}$, α_x, α_r, $\zeta_{P\gamma}$, $\zeta_{T\varepsilon}$, $\zeta_{\Delta T}$, ζ_{PI}

For the following cases

a) [60_2/-60_2] R_I/h=30 Hyer Graphite

b) [60_2/-60_2] R_I/h=5 Hyer Graphite

c) [26/-26/Alum] R_I =5 cm Hyer Graphite & aluminum

Each lamina is 0.635 mm thick. *h* is the total wall thickness

Graphite-Epoxy Properties

E_1= 155.GPa E_2=12.GPa G_{12}= 4.40 GPa ν_{12}=0.2480 ν_{23}=0.4580

α_1= -0.018E-06 /°C α_2= 24.3E-06 /°C α_3= 24.3E-06 /°C

Aluminum Properties

E_1= 72.4 GPa E_2=72.4 GPa G_{12}= 27.846 GPa ν_{12}=0.3 ν_{23}=0.3

α_1= 22.5E-06 /°C α_2= 22.5E-06 /°C α_3= 22.5E-06 /°C