MATLAB Project (#3) - Analysis of Composite Laminates

SE-160A Aerospace Structural Analysis, University of California, San Diego (Copyright J.B. Kosmatka, 2020)

Version: Winter, 2020 (v2)

Project Title: 03-06-2020 Test Case - 8 ply carbon/epoxy laminate offering high extension and torsion stiffness/strength. Common in aircraft wing skins.

Variable	Description	Value	Units
iInput	Input Units	1	1 = US
iOutput	Output Units	1	1 = US, 2 = SI

	Units Reference	
	US	*SI*
F	10^3 *lb/in* ^{2}	*MPa*
E, G	10^6 *lb/in* ^{2}	*GPa*
ρ	*lb/in* ^{3}	*kg/m* ^{3}

X **Part 1: Weight Properties**

Fiber Properties

Variable	Description	Value	Units
	Material Name:	IM7	
E_{fL}	Young's Modulus (Longitudinal)	40.03	Msi
E_{fT}	Young's Modulus (Transverse)	2.76	Msi
G_{fLT}	Shear Modulus (L-T plane)	3.92	Msi
G_{fTT}	Shear Modulus (T-T plane)	1.02	Msi
ν_{fLT}	Poisson ratio (L-T plane)	0.2	
ν_{fTT}	Poisson ratio (T-T plane)	0.2	
ρ_f	Weight Density	0.0643	lb/in^3
F_{Ft}	Tension strength	751.3	Ksi
F_{Fc}	Compression strength	-464.1	Ksi

Resin Properties

Variable	Description	Value	Units
	Material Name:	3501-6	
E_m	Young's Modulus	0.631	Msi
G_m	Shear Modulus	0.232	Msi
ν_m	Poisson ratio	0.36	
ρ_m	Weight Density	0.0469	lb/in^3
F_{mt}	Tension strength	8.08	Ksi
F_{mc}	Compression strength	-17.18	Ksi
F_{ms}	Shear Strength	12.61	Ksi

X **Part 2: MicroMechanics**

Variable	Description	Value	Units
iAFW	Areal Fiber Weight Units:	2	1 = oz/yd^2, 2 = g/m^2
AFW	Areal Fiber Weight:	150	oz/yd^2 or g/m^2
RC	Resin Content (by weight)	30	%

X **Part 3: Lamina Behavior**

Variable	Description	Value	Units
θ_z	Orientation Angle	20	degrees

X **Part 4: Laminate Behavior***

note: the laminate is a 12-ply maximum where the lay-up MUST be symmetric

Variable	Description	Value	Units
n	Number of plies (12 max)	8	
t ply	ply thickness	0.03	inch
N_x	Inplane x-direction load	12000	lb/inch
N_y	Inplane y-direction load	0	lb/inch
N_{xy}	Inplane shear load	-1000	lb/inch
SF	Safety Factor:	1.5	

Laminate Definition		
(#)	θ_i (degree)	
12		
11		
10		
9		
8	0	
7	0	
6	45	
5	-45	
4	-45	
3	45	
2	0	
1	0	tool surface

0 **END OF FILE**

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Version: Winter, 2020 (v2) - Input: US, Output: US/SI

Student Name: John Kosmatka

Student ID: A0123456789

Project Title: 03-06-2020 Test Case - 8 ply carbon/epoxy laminate offering high extension and torsion stiffness/strength. Common in aircraft wing skins.

INPUT ECHO:

Variable	Description	Value	Units
iInput	Input Units	1	1 = US
iOutput	Output Units	1	1 = US, 2 = SI

Units Reference		
	US	*SI*
F	$10^3\ lb/in^2$	*MPa*
E, G	$10^6\ lb/in^2$	*GPa*
ρ	lb/in^3	kg/m^3

Fiber Properties

Variable	Description	Value	Units
	Material Name:	IM7	
E_{fL}	Young's Modulus (Longitudinal)	40.03	Msi
E_{fT}	Young's Modulus (Transverse)	2.76	Msi
G_{fLT}	Shear Modulus (L-T plane)	3.92	MSi
G_{fTT}	Shear Modulus (T-T plane)	1.02	Msi
v_{fLT}	Poisson ratio (L-T plane)	0.2	
v_{fTT}	Poisson ratio (T-T plane)	0.2	
ρ_f	Weight Density	0.0643	Ksi
F_{Ft}	Tension strength	751.3	Ksi
F_{Fc}	Compression strength	-464.1	Ksi

Resin Properties

Variable	Description	Value	Units
	Material Name:	3501-6	
E_m	Young's Modulus	0.631	Msi
G_m	Shear Modulus	0.232	Msi
v_m	Poisson ratio	0.36	
ρ_m	Weight Density	0.0469	lb/in^3
F_{mt}	Tension strength	8.08	Ksi
F_{mc}	Compression strength	-17.18	Ksi
F_{ms}	Shear Strength	12.61	Ksi

MicroMechanics

Variable	Description	Value	Units
iAFW	Areal Fiber Weight Units:	2	
AFW	Areal Fiber Weight:	150	g/m^2
RC	Resin Content (by weight)	30	

Lamina Behavior

Variable	Description	Value	Units
θ_z	Orientation Angle	20	degrees

Laminate Behavior

Variable	Description	Value	Units
n	Number of plies (12 max)	8	
t ply	ply thickness	0.03	inch
N_x	Inplane x-direction load	12000	lb/in
N_y	Inplane y-direction load	0	lb/in
N_{xy}	Inplane shear load	-1000	lb/in
SF	Safety Factor:	1.5	

Laminate Definition		
(#)	θ_i(degree)	
12		
11		
10		
9		
8	0	
7	0	
6	45	
5	-45	
4	-45	
3	45	
2	0	
1	0	tool surface

OUTPUT:

X **Part 1: Weight Properties**

Variable	Description	Value	Units
Vf	Volume Fraction (Fiber)	0.62989	
Vr	Volume Fraction (Resin)	0.37011	
Wf	Weight Fraction (Fiber)	0.70000	
Wr	Weight Fraction (Resin)	0.30000	
ρ_c	Composite density	0.05786	lb/in^3
t_{ply}	Cured ply thickness	0.00527	inch

X **Part 2: MicroMechanics**

Variable	Description	Value	Units
E_L	Young's Modulus (Longitudinal)	25.4481	Msi
E_T	Young's Modulus (Transverse)	1.2274	Msi
G_{LT}	Shear Modulus (L-T plane)	0.5695	Msi
G_{TT}	Shear Modulus (T-T plane)	0.4873	Msi
v_{LT}	Poisson ratio (L-T plane)	0.2592	
v_{TT}	Poisson ratio (T-T plane)	0.2592	
F_{1t}	Tension Strength (Longitudinal)	477.6214	Ksi
F_{2t}	Tension Strength (Transverse)	7.0593	Ksi

	F_{1c}	Compression Strength (Longitudinal)	-157.6250	Ksi									
		Compression Strength (Fiber Failure)	-292.3331	Ksi									
		Compression Strength (Micro-Buckling)	-569.4834	Ksi									
		Compression Strength (Delamination)	-157.6250	Ksi									
	F_{2c}	Compression Strength (Transverse)	-15.0097	Ksi									
	F_{s6}	Shear Strength (1-2 plane)	10.6671	Ksi									
X	**Part 3:**	**Lamina Behavior**											
	2-D material reduced stiffness [Q]:		2.55309E+01	3.19185E-01	0.00000E+00								
			3.19185E-01	1.23134E+00	0.00000E+00	Msi	units						
			0.00000E+00	0.00000E+00	5.69483E-01								
	2-D material reduced compliance [S]:		3.92956E-02	-1.01861E-02	0.00000E+00								
			-1.01861E-02	8.14763E-01	0.00000E+00	1/Msi	units						
			0.00000E+00	0.00000E+00	1.75598E+00								
	Orientation Angle (θ_z):		20	degrees									
	Transformation matrix [T_1']		8.83022E-01	1.16978E-01	6.42788E-01								
			1.16978E-01	8.83022E-01	-6.42788E-01								
			-3.21394E-01	3.21394E-01	7.66044E-01								
	Transformation matrix [T_2']		8.83022E-01	1.16978E-01	-6.42788E-01								
			1.16978E-01	8.83022E-01	6.42788E-01								
			3.21394E-01	-3.21394E-01	7.66044E-01								
	2-D material reduced stiffness [Q-bar]:		2.02252E+01	2.78232E+00	6.84031E+00								
			2.78232E+00	1.61071E+00	9.69405E-01	Msi	units						
			6.84031E+00	9.69405E-01	3.03262E+00								
	2-D material reduced compliance [S-bar]:		2.21067E-01	-1.01245E-01	-4.66269E-01								
			-1.01245E-01	8.15109E-01	-3.21919E-02	1/Msi	units						
			-4.66269E-01	-3.21919E-02	1.39174E+00								
	Variable	**Description**	**Value**	**Units**									
	E_x	Young's Modulus (*x*-direction)	4.5235	Msi									
	E_y	Young's Modulus (y-direction)	1.2268	Msi									
	G_{xy}	Shear Modulus (x-y plane)	0.7185	Msi									
	ν_{xy}	Poisson Ratio (x-y plane)	0.4580										
	$\eta_{x,xy}$	Extension-Shear coupling (x-direction, x-y plane)	-2.1092										
	$\eta_{y,xy}$	Extension-Shear coupling (y-direction, x-y plane)	-0.0395										
	F^*_{1T}	Allowable Fiber Direction Tension Strength	318.4143	Ksi									
	F^*_{1C}	Allowable Fiber Direction Compression Strength	-105.0833	Ksi									
	F^*_{2T}	Allowable Matrix Direction Tension Strength	4.7062	Ksi									
	F^*_{2C}	Allowable Matrix Direction Compression Strength	-10.0065	Ksi									
	F^*_{S}	Allowable Shear Strength	7.1114	Ksi									
X	**Part 4:**	**Laminate Behavior**											
	In-Plane Stiffness Relationship			[A]									
		N_x	3.95406E+06	7.91982E+05	0.00000E+00	ε_{xxo}	units						
		N_y =	7.91982E+05	1.03812E+06	0.00000E+00	ε_{yyo}	lb/in						
		N_{xy}	0.00000E+00	0.00000E+00	8.52053E+05	γ_{xyo}							
	Inverse In-Plane Stiffness Relationship												
				[A*]									
		ε_{xxo}	2.98520E-07	-2.27742E-07	0.00000E+00	N_x		3.58224E-03					
		ε_{yyo} =	-2.27742E-07	1.13703E-06	0.00000E+00	N_y	.=.	-2.73290E-03	inch/inch				
		γ_{xyo}	0.00000E+00	0.00000E+00	1.17364E-06	N_{xy}		-1.17364E-03					
	Equivalent Laminate Stiffness Properties (In-Plane Analysis)												
	Variable	**Description**	**Value**	**Units**									
	t_{lam}	Laminate Thickness	0.24	inch									
	E_x	Young's Modulus (x-direction)	13.9577	Msi									
	E_y	Young's Modulus (y-direction)	3.6645	Msi									
	G_{xy}	Shear Modulus (x-y plane)	3.5502	Msi									
	ν_{xy}	Poisson Ratio (applied x, measured y)	0.7629										
	$\eta_{x,xy}$	Extension-Shear Coupling (x, xy)	0.0000										
	$\eta_{y,xy}$	Extension-Shear Coupling (y, xy)	0.0000										
	Iso-Check	In-plane Isotropic Check (1.00)	0.703910829										
	Ply stresses		Ply Depth	inch	Global Stresses (x,y frame)		Ksi	Local Stresses (1,2 frame)		Ksi			
	Ply (#)	**Ply Angle (degree)**	Bottom	Top	σ_{xx}	σ_{yy}	τ_{xy}	σ_{11}	σ_{22}	τ_{12}			
	12												
	11												
	10												
	9												
	8	0	0.09	0.12	90.586	-2.222	-0.668	90.586	-2.222	-0.668			
	7	0	0.06	0.09	90.586	-2.222	-0.668	90.586	-2.222	-0.668			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
172			6	45	0.03	0.06	2.285	-4.908	-2.505	-3.817	1.194	-3.596		
173			5	-45	0	0.03	16.544	9.351	-12.825	25.772	0.123	3.596		
174			4	-45	-0.03	0	16.544	9.351	-12.825	25.772	0.123	3.596		
175			3	45	-0.06	-0.03	2.285	-4.908	-2.505	-3.817	1.194	-3.596		
176			2	0	-0.09	-0.06	90.586	-2.222	-0.668	90.586	-2.222	-0.668		
177			1	0	-0.12	-0.09	90.586	-2.222	-0.668	90.586	-2.222	-0.668		
178				tool surface										
179														
180														
181	**End of Output**													