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 - 6 ply extension-shear carbon/epoxy laminate subjected to Nx and Nxy. Common in propeller and wind turbines.

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)	6	
t ply	ply thickness	0.02	inch
N_x	Inplane x-direction load	5000	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	
7	
6	0
5	0
4	15
3	15
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 - 6 ply extension-shear carbon/epoxy laminate subjected to Nx and Nxy. Common in propeller and wind turbines.

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)	6	
t ply	ply thickness	0.02	inch
N_x	Inplane x-direction load	5000	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		
7		
6	0	
5	0	
4	15	
3	15	
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	2.93898E+06	9.79170E+04	2.24754E+05	ε_{xxo}	units
N_y =	9.79170E+04	1.53257E+05	1.82418E+04	ε_{yyo}	lb/in
N_{xy}	2.24754E+05	1.82418E+04	1.27953E+05	γ_{xyo}	

Inverse In-Plane Stiffness Relationship

[A*]

ε_{xxo}	3.97553E-07	-1.73831E-07	-6.73533E-07	N_x		2.66130E-03	
ε_{yyo} =	-1.73831E-07	6.71365E-06	-6.51805E-07	N_y	.=.	-2.17348E-04	inch/inch
γ_{xyo}	-6.73533E-07	-6.51805E-07	9.09139E-06	N_{xy}		-1.24591E-02	

Equivalent Laminate Stiffness Properties (In-Plane Analysis)

Variable	Description	Value	Units
t_{lam}	Laminate Thickness	0.12	inch
E_x	Young's Modulus (x-direction)	20.9616	Msi
E_y	Young's Modulus (y-direction)	1.2413	Msi
G_{xy}	Shear Modulus (x-y plane)	0.9166	Msi
ν_{xy}	Poisson Ratio (applied x, measured y)	0.4373	
$\eta_{x,xy}$	Extension-Shear Coupling (x, xy)	-1.6942	
$\eta_{y,xy}$	Extension-Shear Coupling (y, xy)	-0.0971	
Iso-Check	In-plane Isotropic Check (1.00)	4.213345395	

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									
7									

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
172			6	0	0.04	0.06	67.876	0.582	-7.095	67.876	0.582	-7.095		
173			5	0	0.02	0.04	67.876	0.582	-7.095	67.876	0.582	-7.095		
174			4	15	6.93889E-18	0.02	-10.752	-1.164	-10.810	-15.514	3.599	-6.964		
175			3	15	-0.02	6.93889E-18	-10.752	-1.164	-10.810	-15.514	3.599	-6.964		
176			2	0	-0.04	-0.02	67.876	0.582	-7.095	67.876	0.582	-7.095		
177			1	0	-0.06	-0.04	67.876	0.582	-7.095	67.876	0.582	-7.095		
178					tool surface									
179														
180														
181	**End of Output**													