MBARI

AUTODESK.

ISUS-APEX Composite PV

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Requested By:
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Report Contents

List of Symbols			
Symbol	**Description**	**English Units**	**SI Units**
A	[A] extensional stiffness matrix for CLT	lb/in	N/m
[A]	[A] inverse extensional stiffness matrix for CLT	in/lb	m/N
A Inverse	[B] coupling stiffness matrix for CLT	lb	N
B	[B] inverse coupling stiffness matrix for CLT	1/lb	1/N
B Inverse	b (subscript)		
C	Distance to extreme fiber from neutral axis	in	m
c (subscript)	Denotes "core" material		
CS Area	Cross sectional area	in^2	m^2
CTcr	Critical torque factor		
CTE	Coefficient of thermal expansion	in/in/ºF	m/m/ºC
CME	Coefficient of moisture expansion	in/in/%moisture	m/m/%moisture
dCell	Honeycomb core cell diameter	in	m
D	[D] bending stiffness matrix for CLT	lb-in	N-m
D Inverse	[D] inverse bending stiffness matrix for CLT	1/(lb-in)	1/(N-m)
DEN	Density	lb/in^3	g/m^3
DENc	Density of the core (not the density of the material the core is made from)	lb/in^3	g/m^3
+e, +eps	Tensile strain	in/in	m/m
-e, -eps	Compression strain	in/in	m/m
E	Young's modulus	lb/in^2	Pa
Ec	Compressive modulus of a core material	lb/in^2	Pa
End area	End area	in^2	m^2
f (subscript)	Denotes "fiber" or "face sheet" for sandwich plates		
G	Shear modulus	lb/in^2	Pa
gage	Honeycomb core cell wall thickness	in	m
gam	Shear strain	in/in	m/m
GcL	Core shear modulus in a sandwich plate, x-direction	lb/in^2	Pa
GcW	Core shear modulus in a sandwich plate, y-direction	lb/in^2	Pa
I	Area moment of inertia of a beam cross section	in^4	m^4
J	Polar moment of inertia of a beam/tube cross section		
K	Thermal Conductivity	Btu/(hr-ft-ºF)	W/(m-ºK)
k (subscript)	Denotes "curvature"		
L	Plate length in the X-direction, Beam length	in	m
m (subscript)	Denotes "matrix"		
%m	Percent moisture content	%	%
N	Resultant plate load	lb/in	N/m
NU	Poisson's ratio	lb/in	N/m
P	Concentrated point load	lb	N
p	Uniform distributed load	lb/in^2	Pa

+S	Tensile strength	lb/in²	Pa
-S	Compression strength	lb/in²	Pa
T	Thickness of face sheets or core material	in	m
W	Plate width in the Y-direction	in	m
W	Point load on a beam	lb	N
w	Distributed load on a beam	lb/in	N/m
X	X-direction of coordinate system		
x (subscript)	X-direction		
Y	Y-direction of coordinate system		
y (subscript)	Y-direction		
1 (subscript)	Lamina 1-direction (i.e. fiber direction)		
11 (subscript)	Lamina 11-direction (i.e. fiber direction)		
2 (subscript)	Lamina 2-direction (i.e. transverse to fiber direction)		
22 (subscript)	Lamina 22-direction (i.e. transverse to fiber direction)		
12 (subscript)	Lamina 12 shear direction (i.e. in plane direction), or for NU12 denotes deflection in 2-direction due to load in 1-direction		
21 (subscript)	For NU21 denotes deflection in 1-direction due to load in 2-direction		

Summary

DESCRIPTIO

12L_60x60 Tube

SOFTWARE INFORMATIO

Helius Composite Version	2017.0.82.0

ISUS-APEX-12L-60x60

Materials

Laminas

LM Graphite_Epoxy	
Name	**Value**
Composite Type	
Fiber Vf	0.00000E+00
Thickness (in)	1.22500E-02
E11 (psi)	2.10000E+07
E22 (psi)	1.40000E+06
E33 (psi)	1.40000E+06
G12 (psi)	8.50000E+05
G13 (psi)	8.50000E+05
G23 (psi)	5.02000E+05
NU12	2.50000E-01
NU13	2.50000E-01
NU23	4.06500E-01
CTE1 (in/in/F)	-4.40000E-08
CTE2 (in/in/F)	1.20000E-05
CTE3 (in/in/F)	1.20000E-05
CME1 (in/in/%m)	1.37000E-03
CME2 (in/in/%m)	4.89000E-03
CME3 (in/in/%m)	4.89000E-03
+S1 (psi)	3.15000E+05
+S2 (psi)	7.79800E+03
-S1 (psi)	-2.49900E+05
-S2 (psi)	-2.33800E+04
S12 (psi)	1.25800E+04
+e1 (in/in)	1.50000E-02
+e2 (in/in)	5.57000E-03
-e1 (in/in)	-1.19000E-02
-e2 (in/in)	-1.67000E-02
e12 (in/in)	1.48000E-02
K1 (Btu/hr/ft/F)	3.14100E+00
K2 (Btu/hr/ft/F)	3.78400E-01

K3 (Btu/hr/ft/F)	3.78400E-01
Density (lb/in3)	5.70000E-02

Laminates

Layup		
Lamina	**Thickness(in)**	**Angle(deg.)**
LM Graphite_Epoxy	1.22500E-02	60
LM Graphite_Epoxy	1.22500E-02	-60
LM Graphite_Epoxy	1.22500E-02	60
LM Graphite_Epoxy	1.22500E-02	-60
LM Graphite_Epoxy	1.22500E-02	60
LM Graphite_Epoxy	1.22500E-02	-60
LM Graphite_Epoxy	1.22500E-02	60
LM Graphite_Epoxy	1.22500E-02	-60
LM Graphite_Epoxy	1.22500E-02	60
LM Graphite_Epoxy	1.22500E-02	-60
LM Graphite_Epoxy	1.22500E-02	60
LM Graphite_Epoxy	1.22500E-02	-60

ABD

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ABD Matrices

[A](lb/in) Matrix
 4.23079E+05    5.58562E+05   -2.91038E-11
 5.58562E+05    1.86971E+06   -8.73115E-11
-2.91038E-11   -8.73115E-11    6.31846E+05

[B](lb) Matrix
0.00000E+00   0.00000E+00   0.00000E+00
0.00000E+00   0.00000E+00   0.00000E+00
0.00000E+00   0.00000E+00   0.00000E+00

[D](lb-in) Matrix
 7.61859E+02    1.00583E+03   -1.70530E-13
 1.00583E+03    3.36687E+03   -4.54747E-13
-1.70530E-13   -4.54747E-13    1.13780E+03
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ABD Inverse

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ABD Inverse Matrices

[A]Inverse(in/lb) Matrix
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 3.90301E-06   -1.16600E-06    1.86559E-23
-1.16600E-06    8.83177E-07    6.83339E-23
 1.86559E-23    6.83339E-23    1.58266E-06

[B]Inverse(1/lb) Matrix
0.00000E+00   0.00000E+00   0.00000E+00
0.00000E+00   0.00000E+00   0.00000E+00
0.00000E+00   0.00000E+00   0.00000E+00

[D]Inverse(1/lb-in) Matrix
 2.16744E-03   -6.47507E-04    6.60590E-20
-6.47507E-04    4.90450E-04    9.89729E-20
 6.60590E-20    9.89729E-20    8.78891E-04
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Q-Bars

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Q-Bar For Ply: 1       Angle(deg): 60.00
Material: LM Graphite_Epoxy

 2.87809E+06    3.79974E+06    2.27042E+06
 3.79974E+06    1.27191E+07    6.25214E+06
 2.27042E+06    6.25214E+06    4.29827E+06


Q-Bar For Ply: 2       Angle(deg): -60.00
Material: LM Graphite_Epoxy

 2.87809E+06    3.79974E+06   -2.27042E+06
 3.79974E+06    1.27191E+07   -6.25214E+06
-2.27042E+06   -6.25214E+06    4.29827E+06


Q-Bar For Ply: 3       Angle(deg): 60.00
Material: LM Graphite_Epoxy

 2.87809E+06    3.79974E+06    2.27042E+06
 3.79974E+06    1.27191E+07    6.25214E+06
 2.27042E+06    6.25214E+06    4.29827E+06


Q-Bar For Ply: 4       Angle(deg): -60.00
Material: LM Graphite_Epoxy

 2.87809E+06    3.79974E+06   -2.27042E+06
 3.79974E+06    1.27191E+07   -6.25214E+06
-2.27042E+06   -6.25214E+06    4.29827E+06


Q-Bar For Ply: 5       Angle(deg): 60.00
Material: LM Graphite_Epoxy

 2.87809E+06    3.79974E+06    2.27042E+06
 3.79974E+06    1.27191E+07    6.25214E+06
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 2.27042E+06    6.25214E+06    4.29827E+06


Q-Bar For Ply: 6       Angle(deg): -60.00
Material: LM Graphite_Epoxy

 2.87809E+06    3.79974E+06   -2.27042E+06
 3.79974E+06    1.27191E+07   -6.25214E+06
-2.27042E+06   -6.25214E+06    4.29827E+06


Q-Bar For Ply: 7       Angle(deg): 60.00
Material: LM Graphite_Epoxy

 2.87809E+06    3.79974E+06    2.27042E+06
 3.79974E+06    1.27191E+07    6.25214E+06
 2.27042E+06    6.25214E+06    4.29827E+06


Q-Bar For Ply: 8       Angle(deg): -60.00
Material: LM Graphite_Epoxy

 2.87809E+06    3.79974E+06   -2.27042E+06
 3.79974E+06    1.27191E+07   -6.25214E+06
-2.27042E+06   -6.25214E+06    4.29827E+06


Q-Bar For Ply: 9       Angle(deg): 60.00
Material: LM Graphite_Epoxy

 2.87809E+06    3.79974E+06    2.27042E+06
 3.79974E+06    1.27191E+07    6.25214E+06
 2.27042E+06    6.25214E+06    4.29827E+06


Q-Bar For Ply: 10      Angle(deg): -60.00
Material: LM Graphite_Epoxy

 2.87809E+06    3.79974E+06   -2.27042E+06
 3.79974E+06    1.27191E+07   -6.25214E+06
-2.27042E+06   -6.25214E+06    4.29827E+06


Q-Bar For Ply: 11      Angle(deg): 60.00
Material: LM Graphite_Epoxy

 2.87809E+06    3.79974E+06    2.27042E+06
 3.79974E+06    1.27191E+07    6.25214E+06
 2.27042E+06    6.25214E+06    4.29827E+06


Q-Bar For Ply: 12      Angle(deg): -60.00
Material: LM Graphite_Epoxy
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 2.87809E+06    3.79974E+06   -2.27042E+06
 3.79974E+06    1.27191E+07   -6.25214E+06
-2.27042E+06   -6.25214E+06    4.29827E+06
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Properties - 2D	
Title	**Value**
Ex (psi)	1.74294E+06
Ey (psi)	7.70256E+06
Gxy (psi)	4.29827E+06
NUxy	2.98743E-01
NUyx	1.32023E+00
Exb (psi)	1.74294E+06
Eyb (psi)	7.70256E+06
Gxyb (psi)	4.29827E+06
NUxyb	-2.98743E-01
NUyxb	-1.32023E+00
CTEx (in/in/F)	6.59291E-06
CTEy (in/in/F)	-1.41574E-06
CTExy (in/in/F)	2.41670E-22
CTExk (1/in/F)	-5.13690E-21
CTEyk (1/in/F)	2.83865E-21
CTExyk (1/in/F)	-5.13690E-21
CMEx (in/in/%m)	3.30971E-03
CMEy (in/in/%m)	9.69092E-04
CMExy (in/in/%m)	6.85516E-20
CMExk (1/in/F)	1.43646E-18
CMEyk (1/in/F)	4.99008E-19
CMEyk (1/in/F)	2.77325E-03
Density (lb/in3)	5.70000E-02
Thickness (in)	1.47000E-01

Properties - 3D	
Title	**Value**
Ex (psi)	1.74294E+06
Ey (psi)	7.70256E+06
Ez (psi)	1.54212E+06

Gxy (psi)	4.29939E+06
Gxz (psi)	5.89000E+05
Gyz (psi)	7.63000E+05
NUxy	2.98743E-01
NUyx	1.32023E+00
NUxz	2.87650E-01
NUzx	2.54507E-01
NUyz	-1.56956E-01
NUzy	-3.14240E-02
CTEx (in/in/F)	6.57948E-06
CTEy (in/in/F)	-1.44030E-06
CTEz (in/in/F)	1.48472E-05
CTEyz (in/in/F)	0.00000E+00
CTEzx (in/in/F)	0.00000E+00
CTExy (in/in/F)	2.41689E-22
CMEx (in/in/%m)	3.30579E-03
CMEy (in/in/%m)	9.61914E-04
CMEz (in/in/%m)	5.72214E-03
CMEyz (in/in/%m)	0.00000E+00
CMEzx (in/in/%m)	0.00000E+00
CMExy (in/in/%m)	7.65754E-20
Kx (Btu/hr/ft/F)	1.06905E+00
Ky (Btu/hr/ft/F)	2.45035E+00
Kz (Btu/hr/ft/F)	3.78400E-01
Kxy (Btu/hr/ft/F)	0.00000E+00
Density (lb/in3)	5.70000E-02
Thickness (in)	1.47000E-01

Tube/Beam Analysis

Tube Geometry

Cross Section : Circle

R - Radius (in) : 1.13500E+00

Section Properties

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Section Properties

Cross Section: Circle
Radius(in): 1.13500E+00
Ex(psi) = 1.74294E+06
Thickness(in) = 1.47000E-01
Ix(in^4) = 8.18108E-01
ExIx(lb-in^2)= 1.42591E+06
Iy(in^4) = 8.18108E-01
ExIy(lb-in^2)= 1.42591E+06
Cmin (in) = -1.28200E+00
Cmax (in) = 1.28200E+00
Gxy(psi) = 4.29827E+06
K(in^4) = 1.63622E+00
GxyJ(lb-in^2) = 7.03290E+06
Radius Gyration(in) = 8.56118E-01
Area(in^2) = 1.11620E+00
Weight/Length(lb/in) = 6.36237E-02
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Pressure Vessel

Axial Load (lb) : -1.51340E+04

P - Pressure (psi) : 0.00000E+00

Thick Wall : Yes

External Pressure (psi) : 2.93100E+03

Torque (lb-in) : 0.00000E+00

Temperature Change (F) : 0

Failure Criteria	
Name	**Parameters**
MaxStress	

Tabular Results					
Ply#-Loc	Radius	Delta Radius	Axial Strain	Hoop Strain	Radial Strain
1-B	1.135	-0.00131285	-0.00314136	-0.0011567	0.00167402
1-M	1.14113	-0.00130288	-0.00314136	-0.00114175	0.00158395
1-T	1.14725	-0.00129345	-0.00314136	-0.00112743	0.00149544
2-B	1.14725	-0.00129345	-0.00314136	-0.00112743	0.00149633
2-M	1.15338	-0.00128455	-0.00314136	-0.00111373	0.00141002
2-T	1.1595	-0.00127617	-0.00314136	-0.00110062	0.00132516
3-B	1.1595	-0.00127617	-0.00314136	-0.00110062	0.00132426
3-M	1.16563	-0.00126832	-0.00314136	-0.0010881	0.00124012
3-T	1.17175	-0.00126098	-0.00314136	-0.00107615	0.00115734
4-B	1.17175	-0.00126098	-0.00314136	-0.00107615	0.00115826
4-M	1.17788	-0.00125413	-0.00314136	-0.00106474	0.0010775
4-T	1.184	-0.00124778	-0.00314136	-0.00105387	0.000998012
5-B	1.184	-0.00124778	-0.00314136	-0.00105387	0.000997089
5-M	1.19013	-0.00124191	-0.00314136	-0.00104351	0.000918155
5-T	1.19625	-0.00123653	-0.00314136	-0.00103367	0.000840423
6-B	1.19625	-0.00123653	-0.00314136	-0.00103367	0.000841355
6-M	1.20238	-0.00123161	-0.00314136	-0.00102431	0.000765475
6-T	1.2085	-0.00122715	-0.00314136	-0.00101543	0.000690718
7-B	1.2085	-0.00122715	-0.00314136	-0.00101543	0.000689777
7-M	1.21463	-0.00122315	-0.00314136	-0.00100702	0.000615422
7-T	1.22075	-0.00121961	-0.00314136	-0.000999063	0.000542125
8-B	1.22075	-0.00121961	-0.00314136	-0.000999063	0.000543076
8-M	1.22688	-0.0012165	-0.00314136	-0.000991543	0.000471492
8-T	1.233	-0.00121383	-0.00314136	-0.000984451	0.000400898
9-B	1.233	-0.00121383	-0.00314136	-0.000984451	0.000399938
9-M	1.23913	-0.00121159	-0.00314136	-0.000977782	0.000329616
9-T	1.24525	-0.00120979	-0.00314136	-0.000971523	0.000260228
10-B	1.24525	-0.00120979	-0.00314136	-0.000971523	0.000261198
10-M	1.25138	-0.0012084	-0.00314136	-0.000965655	0.000193401
10-T	1.2575	-0.00120742	-0.00314136	-0.000960173	0.000126478
11-B	1.2575	-0.00120742	-0.00314136	-0.000960173	0.000125498
11-M	1.26363	-0.00120685	-0.00314136	-0.000955073	5.87341e-005
11-T	1.26975	-0.0012067	-0.00314136	-0.000950342	-7.2064e-006
12-B	1.26975	-0.0012067	-0.00314136	-0.000950342	-6.21706e-006
12-M	1.27588	-0.00120693	-0.00314136	-0.000945965	-7.06716e-005

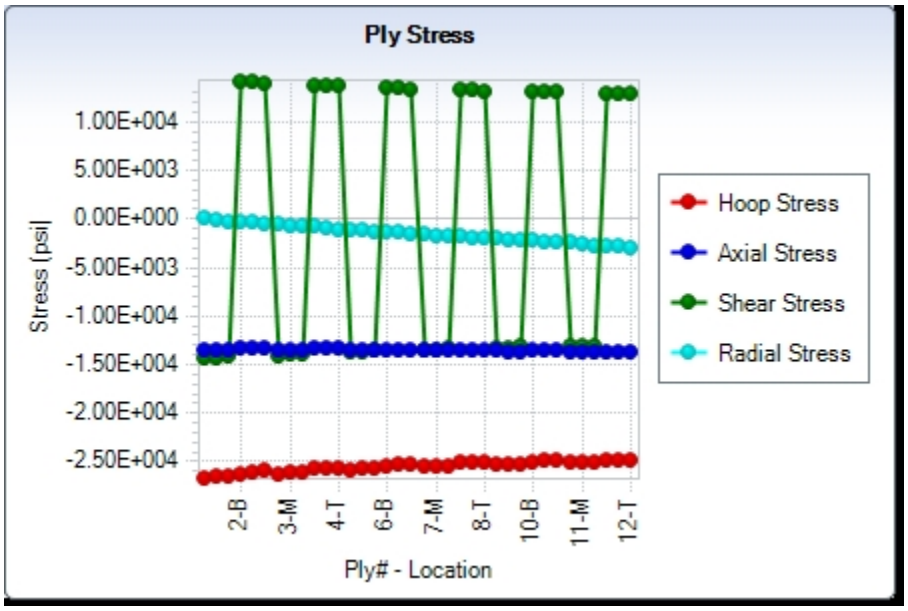
12-T	1.282	-0.00120756	-0.00314136	-0.000941935	-0.000134355

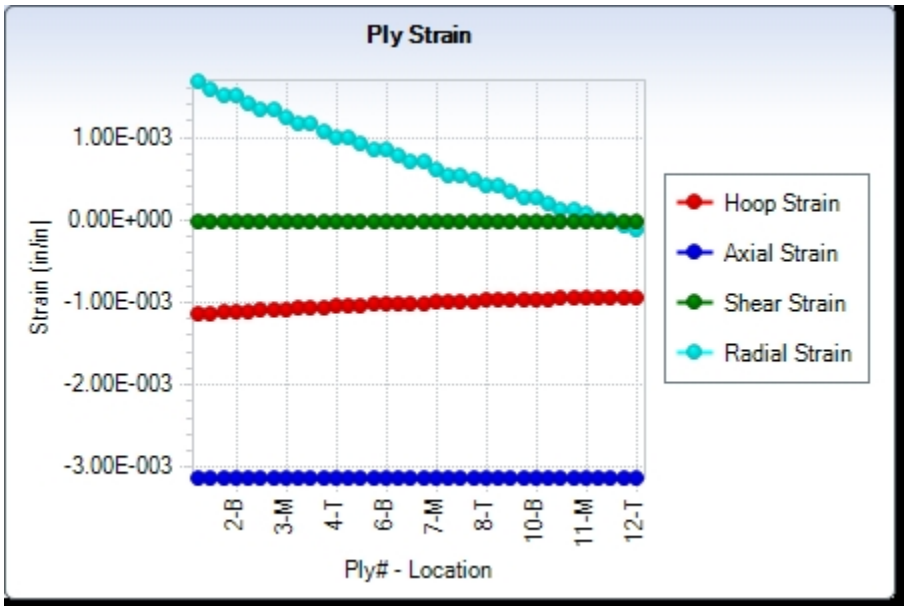
Tabular Results cont'd					
Ply#-Loc	Shear Strain	Axial Stress	Hoop Stress	Radial Stress	Shear Stress
1-B	-1.72235e-005	-13475.4	-26756.2	0	-14438.1
1-M	-1.73164e-005	-13475.7	-26619.3	-143.243	-14341.3
1-T	-1.74094e-005	-13477.6	-26489.7	-284.246	-14248.6
2-B	-1.74094e-005	-13398.5	-26272	-284.246	14098.9
2-M	-1.75023e-005	-13401	-26147.8	-421.921	14009.3
2-T	-1.75952e-005	-13404.9	-26030.4	-557.504	13923.5
3-B	-1.75952e-005	-13484.8	-26250.4	-557.504	-14074.8
3-M	-1.76882e-005	-13491	-26141.3	-692.222	-13993.4
3-T	-1.77811e-005	-13498.5	-26038.7	-824.979	-13915.7
4-B	-1.77811e-005	-13417.8	-25816.3	-824.979	13762.8
4-M	-1.78741e-005	-13425.8	-25718.4	-954.678	13687.8
4-T	-1.7967e-005	-13435.1	-25626.5	-1082.54	13616.1
5-B	-1.7967e-005	-13516.7	-25851.2	-1082.54	-13770.5
5-M	-1.806e-005	-13528.1	-25766.9	-1209.8	-13703
5-T	-1.81529e-005	-13540.9	-25688.5	-1335.33	-13638.6
6-B	-1.81529e-005	-13458.4	-25461.5	-1335.33	13482.5
6-M	-1.82459e-005	-13471.4	-25387	-1458.04	13420.5
6-T	-1.83388e-005	-13485.6	-25318	-1579.14	13361.4
7-B	-1.83388e-005	-13568.9	-25547.3	-1579.14	-13519.1
7-M	-1.84318e-005	-13585.1	-25485.3	-1699.85	-13463.8
7-T	-1.85247e-005	-13602.5	-25428.6	-1819.04	-13411.4
8-B	-1.85247e-005	-13518.4	-25196.9	-1819.04	13252.2
8-M	-1.86177e-005	-13536	-25143.6	-1935.62	13201.7
8-T	-1.87106e-005	-13554.6	-25095.2	-2050.78	13154
9-B	-1.87106e-005	-13639.5	-25329.2	-2050.78	-13314.9
9-M	-1.88035e-005	-13660.1	-25287.2	-2165.74	-13270.6
9-T	-1.88965e-005	-13681.7	-25250	-2279.38	-13229
10-B	-1.88965e-005	-13595.9	-25013.7	-2279.38	13066.5
10-M	-1.89894e-005	-13617.6	-24979.4	-2390.57	13026.6
10-T	-1.90824e-005	-13640.3	-24949.5	-2500.52	12989.1
11-B	-1.90824e-005	-13726.9	-25188.2	-2500.52	-13153.2
11-M	-1.91753e-005	-13751.5	-25164.3	-2610.43	-13118.8
11-T	-1.92683e-005	-13776.9	-25144.7	-2719.17	-13086.9

12-B	-1.92683e-005	-13689.4	-24903.8	-2719.17	12921.2
12-M	-1.93612e-005	-13714.9	-24886.7	-2825.63	12890.7
12-T	-1.94542e-005	-13741.3	-24873.6	-2931	12862.4

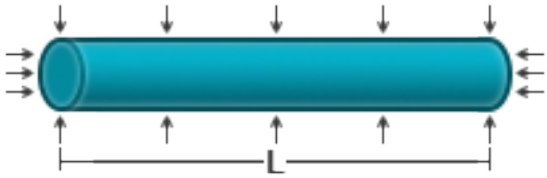
Tabular Results cont'd			
Ply#-Loc	**Failure Index**	**Safety Factor**	**Failure Mode**
1-B	0.183568	5.44757	0
1-M	0.183173	5.45932	0
1-T	0.182795	5.47062	0
2-B	0.183475	5.45035	0
2-M	0.183116	5.46102	0
2-T	0.182773	5.47127	0
3-B	0.182086	5.49192	0
3-M	0.181754	5.50193	0
3-T	0.181438	5.51152	0
4-B	0.182133	5.4905	0
4-M	0.181834	5.49951	0
4-T	0.18155	5.50812	0
5-B	0.180848	5.5295	0
5-M	0.180574	5.53789	0
5-T	0.180313	5.5459	0
6-B	0.181022	5.52418	0
6-M	0.180778	5.53165	0
6-T	0.180546	5.53875	0
7-B	0.17983	5.56081	0
7-M	0.179607	5.56772	0
7-T	0.179396	5.57427	0
8-B	0.180119	5.55188	0
8-M	0.179923	5.55793	0
8-T	0.179738	5.56364	0
9-B	0.179008	5.58635	0
9-M	0.17883	5.59189	0
9-T	0.178664	5.5971	0
10-B	0.179402	5.57407	0
10-M	0.179249	5.57882	0
10-T	0.179107	5.58325	0
11-B	0.178362	5.60658	0

11-M	0.178226	5.61086	0
11-T	0.1781	5.61484	0
12-B	0.178852	5.59121	0
12-M	0.178739	5.59476	0
12-T	0.178635	5.59802	0





Cylinder Stability



Torsion Load (lb-in) : 2.93100E+03

Load Type : Axial Compression + External Pressure

Compression Load (lb) : 1.51340E+04

Axial Compression Layup Type : Special, Mid Plane Symmetry [B]=0

Length (in) : 1.57500E+01

Max. Longitudinal Buckle Half Waves (in) : 50

Max. Circumferential Buckle Waves (in) : 50

Results

```
Axial Compression + External Pressure

Valid for laminates which are:
Symmetric [Bij] = [0]
Balanced All ()16 and ()26 terms = 0
Length(in) = 15.75
Applied Compression(lb) = 15134
Applied External Pressure(psi) = 2931
Critical Compression(lb) = 7.52258E+05
n = 5   m = 30
Rc = 2.01181E-02
Critical Lateral Pressure(psi) = 5.89353E+03
n = 2   m = 1
Rlp = -4.97325E-01
Rc + Rlp = -4.77207E-01 must be <1
Critical Hydrostatic Pressure(psi) = 5.85103E+03
n = 2   m = 1
Rhp = -5.00938E-01
Rc + Rhp = -4.80819E-01 must be <1
```