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SE 160A: Project 3 Write Up

1. A QUASI-ISOTROPIC LAMINATES. Consider carbon/epoxy laminates fabricated with (IM7) carbon fibers and (3501-6) epoxy with an areal fiber weight of (150 g/m2) and (RC=30%).

a. Compare (A11, A12, A66) and (Ex, Gxy, vxy) for the following:

Laminate Type	**A11 (lb/in)**	**A12 (lb/in)**	**A66 (lb/in)**	**Ex (Msi)**	**Gxy (Msi)**	**vxy (unitless)**
0.050 inch ply [0/60/-60]2s	6.24022E+06	1.97995E+06	2.13013E+06	9.3533	3.5502	0.3173
0.050 inch ply [0/120/30/90/60/-30]s	6.24022E+06	1.97995E+06	2.13013E+06	9.3533	3.5502	0.3173
0.075 inch ply [0/45/-45/90]s	6.24022E+06	1.97995E+06	2.13013E+06	9.3533	3.5502	0.3173
0.075 inch ply [20/65/-25/110]s	6.24022E+06	1.97995E+06	2.13013E+06	9.3533	3.5502	0.3173

From these values, all laminates have the same properties.

b. Applying an in-plane load (Nx = 5,000 lb/in, Ny = Nxy = 0 lb/in) to the four laminates of part(a.), calculate the strain (exx, eyy, exy) in the four laminates. Calculate the stress (Sxx) in each ply. Calculate the fiber stress (S11) in each ply. Is there a best laminate? Which one, why?

Strain Table

Laminate Type	**strain xx (in/in)**	**strain yy (in/in)**	**strain xy (in/in)**
0.050 inch ply [0/60/-60]2s	8.90947E-04	-2.82688E-04	0.00000E+00
0.050 inch ply [0/120/30/90/60/-30]s	8.90947E-04	-2.82688E-04	-1.16090E-20
0.075 inch ply [0/45/-45/90]s	8.90947E-04	-2.82688E-04	0.00000E+00
0.075 inch ply [20/65/-25/110]s	8.90947E-04	-2.82688E-04	-1.22339E-19

Stress Table

Laminate Type	Sxx of each ply (Ksi)		S11 fiber stress in each ply (Ksi)	
0.050 inch ply [0/60/-60]2s	Angle (deg	σ_{xx}	Angle (deg	σ_{11}
	0	22.65643788	0	22.6564379
	60	1.171781059	60	0.46443947
	-60	1.171781059	-60	0.46443947
	-60	1.171781059	-60	0.46443947
	60	1.171781059	60	0.46443947
	0	22.65643788	0	22.6564379
	0	22.65643788	0	22.6564379
	60	1.171781059	60	0.46443947
	-60	1.171781059	-60	0.46443947
	-60	1.171781059	-60	0.46443947
	60	1.171781059	60	0.46443947
	0	22.65643788	0	22.6564379
0.050 inch ply [0/120/30/90/60/-30]s	Ply Angle (degree)	σ_{xx}	Ply Angle (degree)	σ_{11}
	0	22.65643788	0	22.6564379
	120	1.171781059	120	0.46443947
	30	11.99658474	30	15.2591051
	90	1.006830518	90	-6.93289333
	60	1.171781059	60	0.46443947
	-30	11.99658474	-30	15.2591051
	-30	11.99658474	-30	15.2591051
	60	1.171781059	60	0.46443947
	90	1.006830518	90	-6.93289333
	30	11.99658474	30	15.2591051
	120	1.171781059	120	0.46443947
	0	22.65643788	0	22.6564379
0.075 inch ply [0/45/-45/90]s	Ply Angle (degree)	σ_{xx}	Ply Angle (degree)	σ_{11}
	0	22.65643788	0	22.6564379
	45	4.835032467	45	7.86177228
	-45	4.835032467	-45	7.86177228
	90	1.006830518	90	-6.93289333
	90	1.006830518	90	-6.93289333
	-45	4.835032467	-45	7.86177228
	45	4.835032467	45	7.86177228
	0	22.65643788	0	22.6564379

Laminate	Ply Angle (degree)	σ_{xx}	Ply Angle (degree)	σ_{11}
0.075 inch ply [20/65/-25/110]s				
	20	17.23308761	20	19.1951437
	65	0.767810079	65	-1.64805546
	-25	14.68390945	-25	17.3716
	110	0.648526195	110	-3.4715991
	110	0.648526195	110	-3.4715991
	-25	14.68390945	-25	17.3716
	65	0.767810079	65	-1.64805546
	20	17.23308761	20	19.1951437

Based off these results, it appears that all laminate layups have the same deformation (exx, eyy, exy). However, the 4th layup [20/65/-25/110]s has a better distributed load on the fibers for each ply. Its max fiber stress (per ply) only reaches 19Ksi, while other laminates have 22Ksi on a ply. This low stress value increases the margin of safety for the laminate. Thus, the 4th layup is best.

c. Applying an in-plane shear load (Nx = Ny = 0 lb/in, Nxy = 5,000 lb/in) to the four laminates of part (a.), calculate the strain (□xx, □yy, □xy) in the four laminates. Calculate the shear stress (□xy) in each ply. Calculate the fiber stress (□11) and the matrix shear stress (□12) in each ply. Is there a best laminate? Which one, why?

Strain Table

Laminate Type	strain xx	strain yy	strain xy
0.050 inch ply [0/60/-60]2s	0.00000E+00	0.00000E+00	2.34727E-03
0.050 inch ply [0/120/30/90/60/-30]s	-1.16090E-20	3.68342E-21	2.34727E-03
0.075 inch ply [0/45/-45/90]s	0.00000E+00	0.00000E+00	2.34727E-03
0.075 inch ply [20/65/-25/110]s	-1.22339E-19	1.22339E-19	2.34727E-03

Stress Table

Laminate Type	Shear Txy each ply (Ksi)		Fiber Stress S11 each ply (Ksi)		Local Shear T12 each ply (Ksi)	
0.050 inch ply [0/60/-60]2s	Angle (degr	τ_{xy}	Angle (degr	σ_{11}	Angle (degr	τ_{12}
	0	1.3367316	0	0	0	1.3367316
	60	11.8316342	60	25.6251125	60	-0.6683658
	-60	11.8316342	-60	-25.6251125	-60	-0.6683658
	-60	11.8316342	-60	-25.6251125	-60	-0.6683658
	60	11.8316342	60	25.6251125	60	-0.6683658
	0	1.3367316	0	0	0	1.3367316
	0	1.3367316	0	0	0	1.3367316
	60	11.8316342	60	25.6251125	60	-0.6683658
	-60	11.8316342	-60	-25.6251125	-60	-0.6683658
	-60	11.8316342	-60	-25.6251125	-60	-0.6683658
	60	11.8316342	60	25.6251125	60	-0.6683658
	0	1.3367316	0	0	0	1.3367316
0.050 inch ply [0/120/30/90/60/-30]s	Ply Angle (degree	τ_{xy}	Ply Angle (degree	σ_{11}	Angle (degr	τ_{12}
	0	1.3367316	0	-2.9521E-16	0	1.3367316
	120	11.8316342	120	-25.6251125	120	-0.6683658
	30	11.8316342	30	25.6251125	30	0.6683658
	90	1.3367316	90	9.0335E-17	90	-1.3367316
	60	11.8316342	60	25.6251125	60	-0.6683658
	-30	11.8316342	-30	-25.6251125	-30	0.6683658
	-30	11.8316342	-30	-25.6251125	-30	0.6683658
	60	11.8316342	60	25.6251125	60	-0.6683658
	90	1.3367316	90	9.0335E-17	90	-1.3367316
	30	11.8316342	30	25.6251125	30	0.6683658
	120	11.8316342	120	-25.6251125	120	-0.6683658
	0	1.3367316	0	-2.9521E-16	0	1.3367316
0.075 inch ply [0/45/-45/90]s	y Angle (degre	τ_{xy}	y Angle (degre	σ_{11}	Angle (deg	τ_{12}
	0	1.3367316	0	0	0	1.3367316
	45	15.3299351	45	29.5893312	45	-1.932E-16
	-45	15.3299351	-45	-29.5893312	-45	-1.932E-16
	90	1.3367316	90	0	90	-1.3367316
	90	1.3367316	90	0	90	-1.3367316
	-45	15.3299351	-45	-29.5893312	-45	-1.932E-16
	45	15.3299351	45	29.5893312	45	-1.932E-16
	0	1.3367316	0	0	0	1.3367316

Laminate	Ply Angle (degree	τ_{xy}	Ply Angle (degree	σ_{11}	Angle (deg	τ_{12}
0.075 inch ply [20/65/-25/110]s						
	20	7.11838619	20	19.0196555	20	1.02399581
	65	9.54828047	65	22.6667427	65	-0.8592345
	-25	9.54828047	-25	-22.6667427	-25	0.85923451
	110	7.11838619	110	-19.0196555	110	-1.0239958
	110	7.11838619	110	-19.0196555	110	-1.0239958
	-25	9.54828047	-25	-22.6667427	-25	0.85923451
	65	9.54828047	65	22.6667427	65	-0.8592345
	20	7.11838619	20	19.0196555	20	1.02399581

Based off these results, it appears that all laminate layups have the same deformation (exx, eyy, exy). Again, the 4th layup [20/65/-25/110]s has a better distributed load on the fibers for each ply. Its max fiber stress (per ply) only reaches 22Ksi, while other laminates have 25Ksi on a ply. In addition, the local shear stress on each ply is maximum 1Ksi versus the other laminates having minimums of 1.3Ksi This low stress value increases the margin of safety for the laminate. Thus, the 4th layup is best.

2. OFF-ANGLE SYMMETRIC LAMINATES. An aerospace structures engineer has developed an invention. The design will only work with a material having a large negative extension-shear coupling (□x,xy). The engineer considers using a thick (tply = 0.10 inch) single ply of carbon/epoxy laminate that is fabricated with (IM7) carbon fibers and (3501-6) epoxy with an areal fiber weight of (150 g/m2) and (RC=30%). If the engineer can only cut material in 5-degree increments, what orientation angle (□) between (0) and (90) degrees, will provide the largest negative (□x,xy).

With the following alteration to my code, I can find that of all angles from 0:5:90, the most ideal angle for the engineer to cut will be at 30 degrees, which produces -13.402203230209718 extension shear coupling

“”” this section of code has been inserted and commented out from lines 112-124 in my code”””

```
% Question 2 in writeup
results = zeros(19,2);
results(:,1) = [0:5:90];
index=1;
for Testang = 0:5:90
    Sbar = (T1(Testang)')*Smat*T1(Testang);
    nxxya = Sbar(1,3)*Exa;
    results(index,2) = nxxya;
    index=index+1;
end
results
return
```

```
>> results

results =

                   0                  0
   5.000000000000000  -3.631600260576560
  10.000000000000000  -6.979776836607272
  15.000000000000000  -9.790593652566834
  20.000000000000000 -11.865675940388074
  25.000000000000000 -13.081863547947391
  30.000000000000000 -13.402203230209718
  35.000000000000000 -12.877071454879674
  40.000000000000000 -11.635393606677336
  45.000000000000000  -9.867100863222740
  50.000000000000000  -7.799001253033061
  55.000000000000000  -5.667012284561664
  60.000000000000000  -3.688116788298787
  65.000000000000000  -2.035412023985105
  70.000000000000000  -0.819224416425789
  75.000000000000000  -0.076507210655901
  80.000000000000000   0.230282333710734
  85.000000000000000   0.204792093067713
  90.000000000000000                  0
```