**MECH530 – Assignment 6**

**Philip Becker**

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**DESIGN #1**

*Note: The angle was chosen using something learned in my first year (Prof Higgins), where we learned that this type of stress is resisted in braided hoses, and the optimal angle is around 55 degrees. Upon trying this angle and then cycling through other angles, I found that indeed this was the strongest ply orientation.*

CHOSEN MATERIAL: graphite\_epoxy\_1

================= GEOMETRY PARAMETERS =================

Layer Number Type Thickness (mm) Orientation (degrees)

-----------------------------------------------------------------

1 ply 0.125 55

2 ply 0.125 -55

3 ply 0.125 55

4 ply 0.125 -55

5 ply 0.125 55

6 ply 0.125 -55

7 ply 0.125 55

8 ply 0.125 -55

9 ply 0.125 55

10 ply 0.125 -55

11 ply 0.125 55

12 ply 0.125 -55

- core 10.000 N/A

13 ply 0.125 -55

14 ply 0.125 55

15 ply 0.125 -55

16 ply 0.125 55

17 ply 0.125 -55

18 ply 0.125 55

19 ply 0.125 -55

20 ply 0.125 55

21 ply 0.125 -55

22 ply 0.125 55

23 ply 0.125 -55

24 ply 0.125 55

================= MATRICES =================

[A] Matrix (in N/m):

9.584e+07 1.131e+08 0.000e+00

1.131e+08 2.718e+08 0.000e+00

0.000e+00 0.000e+00 1.259e+08

[a] Matrix (in m/N):

2.051e-08 -8.537e-09 0.000e+00

-8.537e-09 7.233e-09 0.000e+00

0.000e+00 0.000e+00 7.940e-09

[D] Matrix (in Nm):

3.187e+03 3.761e+03 5.954e+01

3.761e+03 9.036e+03 1.142e+02

5.954e+01 1.142e+02 4.187e+03

[d] Matrix (in (Nm)^-1):

6.168e-04 -2.567e-04 -1.770e-06

-2.567e-04 2.175e-04 -2.282e-06

-1.770e-06 -2.282e-06 2.389e-04

================= CURVATURES AND OFF-AXIS STRAIN =================

N\_vector (N) = [150000.000; 300000.000; 0.000]

M\_vector (Nm) = [0.000; 0.000; 0.000]

epsilon\_o\_vector = [

5.155e-04

8.893e-04

0.000e+00

]

k\_vector (m^-1) = [

0.000e+00

0.000e+00

0.000e+00

]

================= PER-LAYER STRESSES AND STRAINS =================

Ply Angle (deg) z\_height (m) Surface Epsilon\_x epsilon\_vector on\_axis\_strain on\_axis\_stress

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1 55 0.0065 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

1 55 0.006375 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

2 -55 0.006375 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

2 -55 0.00625 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

3 55 0.00625 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

3 55 0.006125 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

4 -55 0.006125 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

4 -55 0.006 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

5 55 0.006 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

5 55 0.005875 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

6 -55 0.005875 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

6 -55 0.00575 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

7 55 0.00575 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

7 55 0.005625 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

8 -55 0.005625 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

8 -55 0.0055 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

9 55 0.0055 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

9 55 0.005375 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

10 -55 0.005375 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

10 -55 0.00525 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

11 55 0.00525 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

11 55 0.005125 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

12 -55 0.005125 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

12 -55 0.005 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

13 -55 -0.005 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

13 -55 -0.005125 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

14 55 -0.005125 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

14 55 -0.00525 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

15 -55 -0.00525 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

15 -55 -0.005375 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

16 55 -0.005375 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

16 55 -0.0055 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

17 -55 -0.0055 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

17 -55 -0.005625 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

18 55 -0.005625 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

18 55 -0.00575 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

19 -55 -0.00575 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

19 -55 -0.005875 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

20 55 -0.005875 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

20 55 -0.006 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

21 -55 -0.006 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

21 -55 -0.006125 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

22 55 -0.006125 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

22 55 -0.00625 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

23 -55 -0.00625 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

23 -55 -0.006375 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, -3.513e-04]'} {'[1.412e+02, 8.825e+00, -2.519e+00]'}

24 55 -0.006375 {'Top' } 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

24 55 -0.0065 {'Bottom'} 0.00076632 {'[5.155e-04, 8.893e-04, 0.000e+00]'} {'[7.663e-04, 6.385e-04, 3.513e-04]' } {'[1.412e+02, 8.825e+00, 2.519e+00]' }

================= QUADRATIC FAILURE CRITERIA COEFFICIENTS =================

F\_xx: 4.444e-07

F\_x: 0.000e+00

F\_yy: 1.016e-04

F\_y: 2.093e-02

F\_s: 1.113e-02

F\_xy: -3.360e-06

================= FAILURE CRITERIA =================

Ply Angle (deg) Surface R\_1 R\_2 R\_3 R\_4 R\_5

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_

1 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

1 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

2 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

2 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

3 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

3 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

4 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

4 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

5 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

5 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

6 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

6 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

7 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

7 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

8 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

8 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

9 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

9 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

10 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

10 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

11 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

11 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

12 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

12 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

13 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

13 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

14 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

14 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

15 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

15 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

16 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

16 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

17 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

17 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

18 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

18 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

19 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

19 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

20 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

20 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

21 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

21 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

22 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

22 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

23 -55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

23 -55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

24 55 {'Top' } 10.625 10.625 4.5323 27.874 3.7636

24 55 {'Bottom'} 10.625 10.625 4.5323 27.874 3.7636

Ply Angle (deg) Surface R\_quadratic\_1 R\_quadratic\_2

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_

1 55 {'Top' } 2.5757 -4.9145

1 55 {'Bottom'} 2.5757 -4.9145

2 -55 {'Top' } 2.5757 -4.9145

2 -55 {'Bottom'} 2.5757 -4.9145

3 55 {'Top' } 2.5757 -4.9145

3 55 {'Bottom'} 2.5757 -4.9145

4 -55 {'Top' } 2.5757 -4.9145

4 -55 {'Bottom'} 2.5757 -4.9145

5 55 {'Top' } 2.5757 -4.9145

5 55 {'Bottom'} 2.5757 -4.9145

6 -55 {'Top' } 2.5757 -4.9145

6 -55 {'Bottom'} 2.5757 -4.9145

7 55 {'Top' } 2.5757 -4.9145

7 55 {'Bottom'} 2.5757 -4.9145

8 -55 {'Top' } 2.5757 -4.9145

8 -55 {'Bottom'} 2.5757 -4.9145

9 55 {'Top' } 2.5757 -4.9145

9 55 {'Bottom'} 2.5757 -4.9145

10 -55 {'Top' } 2.5757 -4.9145

10 -55 {'Bottom'} 2.5757 -4.9145

11 55 {'Top' } 2.5757 -4.9145

11 55 {'Bottom'} 2.5757 -4.9145

12 -55 {'Top' } 2.5757 -4.9145

12 -55 {'Bottom'} 2.5757 -4.9145

13 -55 {'Top' } 2.5757 -4.9145

13 -55 {'Bottom'} 2.5757 -4.9145

14 55 {'Top' } 2.5757 -4.9145

14 55 {'Bottom'} 2.5757 -4.9145

15 -55 {'Top' } 2.5757 -4.9145

15 -55 {'Bottom'} 2.5757 -4.9145

16 55 {'Top' } 2.5757 -4.9145

16 55 {'Bottom'} 2.5757 -4.9145

17 -55 {'Top' } 2.5757 -4.9145

17 -55 {'Bottom'} 2.5757 -4.9145

18 55 {'Top' } 2.5757 -4.9145

18 55 {'Bottom'} 2.5757 -4.9145

19 -55 {'Top' } 2.5757 -4.9145

19 -55 {'Bottom'} 2.5757 -4.9145

20 55 {'Top' } 2.5757 -4.9145

20 55 {'Bottom'} 2.5757 -4.9145

21 -55 {'Top' } 2.5757 -4.9145

21 -55 {'Bottom'} 2.5757 -4.9145

22 55 {'Top' } 2.5757 -4.9145

22 55 {'Bottom'} 2.5757 -4.9145

23 -55 {'Top' } 2.5757 -4.9145

23 -55 {'Bottom'} 2.5757 -4.9145

24 55 {'Top' } 2.5757 -4.9145

24 55 {'Bottom'} 2.5757 -4.9145

Ply Angle (deg) Surface R\_hashin\_1 R\_hashin\_2 R\_hashin\_3 R\_hashin\_4

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_

1 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

1 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

2 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

2 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

3 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

3 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

4 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

4 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

5 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

5 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

6 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

6 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

7 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

7 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

8 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

8 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

9 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

9 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

10 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

10 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

11 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

11 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

12 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

12 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

13 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

13 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

14 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

14 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

15 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

15 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

16 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

16 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

17 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

17 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

18 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

18 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

19 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

19 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

20 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

20 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

21 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

21 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

22 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

22 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

23 -55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

23 -55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

24 55 {'Top' } 3.5476 "N/A" 2.8955 "N/A"

24 55 {'Bottom'} 3.5476 "N/A" 2.8955 "N/A"

================= MAX STRESS CRITERION CONCLUSIONS =================

First failure occurs in Ply 1 at 55.000 degrees on the Top surface.

Smallest R value (failure): R = 3.764

Failure Mode: Shear

M\_i \* R = [0.000; 0.000; 0.000] Nm

N\_i \* R = [564534.873; 1129069.746; 0.000] N

================= QUADRATIC CRITERION CONCLUSIONS =================

First failure occurs in Ply 1 at 55.000 degrees on the Top surface.

Smallest R value (failure): R = 2.576

M\_i \* R = [0.000; 0.000; 0.000] Nm

N\_i \* R = [386357.817; 772715.633; 0.000] N

================= HASHIN CRITERION CONCLUSIONS =================

First failure occurs in Ply 1 at 55.000 degrees on the Top surface.

Smallest R value (failure): R = 2.895

Failure Mode: Matrix Tension

M\_i \* R = [0.000; 0.000; 0.000] Nm

N\_i \* R = [434317.525; 868635.049; 0.000] N

**DESIGN #2**

Note: A “brute-force” method was used to get all permutations of laminates up to 100 plies thick. Below is the program output for the top 10 best laminates and their attributed K ratio.

My “official” result to submit is the following, with K = 4.0000318.  
  
Schedule Plies D11 D22 K (D11/D22)

[5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5] 88 3.023e+05 7.558e+04 4.0000318

Below is the top 10 results from this sweep:  
  
Top 10 Results Closest to K = 4:

Schedule Plies D11 D22 K (D11/D22)

[5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 30 5 -20 20 -30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5 30 -30 20 -20 5] 88 3.023e+05 7.558e+04 4.0000318

[5 -20 20 30 -30 5 -20 20 30 -30 5 -20 20 30 -30 5 -20 20 30 -30 5 -20 20 30 -30 5 -20 20 30 -30 5 -20 20 30 -30 5 -20 20 30 -30 5 -20 20 30 30 20 -20 5 -30 30 20 -20 5 -30 30 20 -20 5 -30 30 20 -20 5 -30 30 20 -20 5 -30 30 20 -20 5 -30 30 20 -20 5 -30 30 20 -20 5 -30 30 20 -20 5] 88 3.023e+05 7.558e+04 4.0000318

[5 20 -20 -30 30 5 20 -20 -30 30 5 20 -20 -30 30 5 20 -20 -30 30 5 20 -20 -30 30 5 20 -20 -30 30 5 20 -20 -30 30 5 20 -20 -30 30 5 20 -20 -30 -30 -20 20 5 30 -30 -20 20 5 30 -30 -20 20 5 30 -30 -20 20 5 30 -30 -20 20 5 30 -30 -20 20 5 30 -30 -20 20 5 30 -30 -20 20 5 30 -30 -20 20 5] 88 3.023e+05 7.558e+04 4.0000318

[5 20 -20 30 -30 5 20 -20 30 -30 5 20 -20 30 -30 5 20 -20 30 -30 5 20 -20 30 -30 5 20 -20 30 -30 5 20 -20 30 -30 5 20 -20 30 -30 5 20 -20 30 30 -20 20 5 -30 30 -20 20 5 -30 30 -20 20 5 -30 30 -20 20 5 -30 30 -20 20 5 -30 30 -20 20 5 -30 30 -20 20 5 -30 30 -20 20 5 -30 30 -20 20 5] 88 3.023e+05 7.558e+04 4.0000318

[-5 -20 20 -30 30 -5 -20 20 -30 30 -5 -20 20 -30 30 -5 -20 20 -30 30 -5 -20 20 -30 30 -5 -20 20 -30 30 -5 -20 20 -30 30 -5 -20 20 -30 30 -5 -20 20 -30 -30 20 -20 -5 30 -30 20 -20 -5 30 -30 20 -20 -5 30 -30 20 -20 -5 30 -30 20 -20 -5 30 -30 20 -20 -5 30 -30 20 -20 -5 30 -30 20 -20 -5 30 -30 20 -20 -5] 88 3.023e+05 7.558e+04 4.0000318

[-5 -20 20 30 -30 -5 -20 20 30 -30 -5 -20 20 30 -30 -5 -20 20 30 -30 -5 -20 20 30 -30 -5 -20 20 30 -30 -5 -20 20 30 -30 -5 -20 20 30 -30 -5 -20 20 30 30 20 -20 -5 -30 30 20 -20 -5 -30 30 20 -20 -5 -30 30 20 -20 -5 -30 30 20 -20 -5 -30 30 20 -20 -5 -30 30 20 -20 -5 -30 30 20 -20 -5 -30 30 20 -20 -5] 88 3.023e+05 7.558e+04 4.0000318

[-5 20 -20 -30 30 -5 20 -20 -30 30 -5 20 -20 -30 30 -5 20 -20 -30 30 -5 20 -20 -30 30 -5 20 -20 -30 30 -5 20 -20 -30 30 -5 20 -20 -30 30 -5 20 -20 -30 -30 -20 20 -5 30 -30 -20 20 -5 30 -30 -20 20 -5 30 -30 -20 20 -5 30 -30 -20 20 -5 30 -30 -20 20 -5 30 -30 -20 20 -5 30 -30 -20 20 -5 30 -30 -20 20 -5] 88 3.023e+05 7.558e+04 4.0000318

[-5 20 -20 30 -30 -5 20 -20 30 -30 -5 20 -20 30 -30 -5 20 -20 30 -30 -5 20 -20 30 -30 -5 20 -20 30 -30 -5 20 -20 30 -30 -5 20 -20 30 -30 -5 20 -20 30 30 -20 20 -5 -30 30 -20 20 -5 -30 30 -20 20 -5 -30 30 -20 20 -5 -30 30 -20 20 -5 -30 30 -20 20 -5 -30 30 -20 20 -5 -30 30 -20 20 -5 -30 30 -20 20 -5] 88 3.023e+05 7.558e+04 4.0000318

[-5 20 50 0 5 -5 20 50 0 5 -5 -5 5 0 50 20 -5 5 0 50 20 -5] 22 4.854e+03 1.214e+03 3.9999647

[5 20 50 0 -5 5 20 50 0 -5 5 5 -5 0 50 20 5 -5 0 50 20 5] 22 4.854e+03 1.214e+03 3.9999647

**Design #3**

Presented :

* Safety factor results
* Short summary of
* (1) number of layers
* (2) material chosen
* (3) ply orientation
* (4) mass of your design
* (5) Minimum safety factor results for load cases I and II.

Program output for Load 1 :

Ply Angle (deg) z\_height (m) Surface Epsilon\_x epsilon\_vector on\_axis\_strain on\_axis\_stress

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1 0 0.002125 {'Top' } -0.0041577 {'[-4.158e-03, 2.044e-03, -8.760e-04]'} {'[-4.158e-03, 2.044e-03, -8.760e-04]' } {'[-7.500e+02, 9.104e+00, -6.281e+00]' }

1 0 0.002 {'Bottom'} -0.0039208 {'[-3.921e-03, 1.928e-03, -8.258e-04]'} {'[-3.921e-03, 1.928e-03, -8.258e-04]' } {'[-7.073e+02, 8.593e+00, -5.921e+00]' }

2 30 0.002 {'Top' } -0.0028161 {'[-3.921e-03, 1.928e-03, -8.258e-04]'} {'[-2.816e-03, 8.236e-04, 4.653e-03]' } {'[-5.096e+02, 3.634e-01, 3.336e+01]' }

2 30 0.001875 {'Bottom'} -0.0026456 {'[-3.684e-03, 1.813e-03, -7.756e-04]'} {'[-2.646e-03, 7.743e-04, 4.372e-03]' } {'[-4.788e+02, 3.465e-01, 3.135e+01]' }

3 -30 0.001875 {'Top' } -0.001974 {'[-3.684e-03, 1.813e-03, -7.756e-04]'} {'[-1.974e-03, 1.026e-04, -5.148e-03]' } {'[-3.586e+02, -4.657e+00, -3.691e+01]'}

3 -30 0.00175 {'Bottom'} -0.001847 {'[-3.447e-03, 1.697e-03, -7.254e-04]'} {'[-1.847e-03, 9.671e-05, -4.817e-03]' } {'[-3.355e+02, -4.350e+00, -3.454e+01]'}

4 45 0.00175 {'Top' } -0.0012378 {'[-3.447e-03, 1.697e-03, -7.254e-04]'} {'[-1.238e-03, -5.124e-04, 5.144e-03]' } {'[-2.265e+02, -8.888e+00, 3.688e+01]' }

4 45 0.001625 {'Bottom'} -0.0011522 {'[-3.210e-03, 1.581e-03, -6.752e-04]'} {'[-1.152e-03, -4.770e-04, 4.791e-03]' } {'[-2.109e+02, -8.273e+00, 3.435e+01]' }

5 -45 0.001625 {'Top' } -0.00047701 {'[-3.210e-03, 1.581e-03, -6.752e-04]'} {'[-4.770e-04, -1.152e-03, -4.791e-03]'} {'[-9.006e+01, -1.330e+01, -3.435e+01]'}

5 -45 0.0015 {'Bottom'} -0.00044156 {'[-2.973e-03, 1.465e-03, -6.250e-04]'} {'[-4.416e-04, -1.067e-03, -4.438e-03]'} {'[-8.337e+01, -1.231e+01, -3.182e+01]'}

6 30 0.0015 {'Top' } -0.0021343 {'[-2.973e-03, 1.465e-03, -6.250e-04]'} {'[-2.134e-03, 6.262e-04, 3.531e-03]' } {'[-3.862e+02, 2.958e-01, 2.532e+01]' }

6 30 0.001375 {'Bottom'} -0.0019638 {'[-2.736e-03, 1.349e-03, -5.748e-04]'} {'[-1.964e-03, 5.768e-04, 3.251e-03]' } {'[-3.554e+02, 2.789e-01, 2.331e+01]' }

7 -30 0.001375 {'Top' } -0.0014661 {'[-2.736e-03, 1.349e-03, -5.748e-04]'} {'[-1.466e-03, 7.906e-05, -3.826e-03]' } {'[-2.663e+02, -3.429e+00, -2.743e+01]'}

7 -30 0.00125 {'Bottom'} -0.0013391 {'[-2.500e-03, 1.234e-03, -5.246e-04]'} {'[-1.339e-03, 7.318e-05, -3.495e-03]' } {'[-2.433e+02, -3.122e+00, -2.506e+01]'}

8 45 0.00125 {'Top' } -0.00089525 {'[-2.500e-03, 1.234e-03, -5.246e-04]'} {'[-8.952e-04, -3.707e-04, 3.733e-03]' } {'[-1.638e+02, -6.429e+00, 2.677e+01]' }

8 45 0.001125 {'Bottom'} -0.0008096 {'[-2.263e-03, 1.118e-03, -4.744e-04]'} {'[-8.096e-04, -3.352e-04, 3.380e-03]' } {'[-1.482e+02, -5.814e+00, 2.424e+01]' }

9 -45 0.001125 {'Top' } -0.00033523 {'[-2.263e-03, 1.118e-03, -4.744e-04]'} {'[-3.352e-04, -8.096e-04, -3.380e-03]'} {'[-6.329e+01, -9.347e+00, -2.424e+01]'}

9 -45 0.001 {'Bottom'} -0.00029979 {'[-2.026e-03, 1.002e-03, -4.242e-04]'} {'[-2.998e-04, -7.240e-04, -3.028e-03]'} {'[-5.660e+01, -8.359e+00, -2.171e+01]'}

10 90 0.001 {'Top' } 0.001002 {'[-2.026e-03, 1.002e-03, -4.242e-04]'} {'[1.002e-03, -2.026e-03, 4.242e-04]' } {'[1.763e+02, -1.806e+01, 3.041e+00]' }

10 90 0.000875 {'Bottom'} 0.00088625 {'[-1.789e-03, 8.862e-04, -3.740e-04]'} {'[8.862e-04, -1.789e-03, 3.740e-04]' } {'[1.559e+02, -1.594e+01, 2.681e+00]' }

11 90 0.000875 {'Top' } 0.00088625 {'[-1.789e-03, 8.862e-04, -3.740e-04]'} {'[8.862e-04, -1.789e-03, 3.740e-04]' } {'[1.559e+02, -1.594e+01, 2.681e+00]' }

11 90 0.00075 {'Bottom'} 0.00077046 {'[-1.552e-03, 7.705e-04, -3.238e-04]'} {'[7.705e-04, -1.552e-03, 3.238e-04]' } {'[1.356e+02, -1.383e+01, 2.321e+00]' }

12 90 -0.00075 {'Top' } -0.000619 {'[1.291e-03, -6.190e-04, 2.787e-04]' } {'[-6.190e-04, 1.291e-03, -2.787e-04]' } {'[-1.088e+02, 1.156e+01, -1.998e+00]' }

12 90 -0.000875 {'Bottom'} -0.00073479 {'[1.527e-03, -7.348e-04, 3.289e-04]' } {'[-7.348e-04, 1.527e-03, -3.289e-04]' } {'[-1.292e+02, 1.367e+01, -2.358e+00]' }

13 90 -0.000875 {'Top' } -0.00073479 {'[1.527e-03, -7.348e-04, 3.289e-04]' } {'[-7.348e-04, 1.527e-03, -3.289e-04]' } {'[-1.292e+02, 1.367e+01, -2.358e+00]' }

13 90 -0.001 {'Bottom'} -0.00085058 {'[1.764e-03, -8.506e-04, 3.791e-04]' } {'[-8.506e-04, 1.764e-03, -3.791e-04]' } {'[-1.495e+02, 1.579e+01, -2.718e+00]' }

14 -45 -0.001 {'Top' } 0.00026732 {'[1.764e-03, -8.506e-04, 3.791e-04]' } {'[2.673e-04, 6.464e-04, 2.615e-03]' } {'[5.047e+01, 7.462e+00, 1.875e+01]' }

14 -45 -0.001125 {'Bottom'} 0.00030276 {'[2.001e-03, -9.664e-04, 4.293e-04]' } {'[3.028e-04, 7.320e-04, 2.968e-03]' } {'[5.717e+01, 8.451e+00, 2.128e+01]' }

15 45 -0.001125 {'Top' } 0.00073204 {'[2.001e-03, -9.664e-04, 4.293e-04]' } {'[7.320e-04, 3.028e-04, -2.968e-03]' } {'[1.340e+02, 5.253e+00, -2.128e+01]' }

15 45 -0.00125 {'Bottom'} 0.00081768 {'[2.238e-03, -1.082e-03, 4.795e-04]' } {'[8.177e-04, 3.382e-04, -3.320e-03]' } {'[1.496e+02, 5.868e+00, -2.381e+01]' }

16 -30 -0.00125 {'Top' } 0.0012004 {'[2.238e-03, -1.082e-03, 4.795e-04]' } {'[1.200e-03, -4.449e-05, 3.115e-03]' } {'[2.181e+02, 3.017e+00, 2.234e+01]' }

16 -30 -0.001375 {'Bottom'} 0.0013273 {'[2.475e-03, -1.198e-03, 5.297e-04]' } {'[1.327e-03, -5.037e-05, 3.446e-03]' } {'[2.412e+02, 3.324e+00, 2.471e+01]' }

17 30 -0.001375 {'Top' } 0.0017861 {'[2.475e-03, -1.198e-03, 5.297e-04]' } {'[1.786e-03, -5.091e-04, -2.916e-03]' } {'[3.233e+02, -9.301e-02, -2.091e+01]' }

17 30 -0.0015 {'Bottom'} 0.0019565 {'[2.712e-03, -1.314e-03, 5.799e-04]' } {'[1.957e-03, -5.584e-04, -3.196e-03]' } {'[3.541e+02, -1.099e-01, -2.292e+01]' }

18 -45 -0.0015 {'Top' } 0.00040909 {'[2.712e-03, -1.314e-03, 5.799e-04]' } {'[4.091e-04, 9.890e-04, 4.026e-03]' } {'[7.724e+01, 1.142e+01, 2.886e+01]' }

18 -45 -0.001625 {'Bottom'} 0.00044453 {'[2.949e-03, -1.430e-03, 6.301e-04]' } {'[4.445e-04, 1.075e-03, 4.378e-03]' } {'[8.393e+01, 1.241e+01, 3.139e+01]' }

19 45 -0.001625 {'Top' } 0.0010746 {'[2.949e-03, -1.430e-03, 6.301e-04]' } {'[1.075e-03, 4.445e-04, -4.378e-03]' } {'[1.967e+02, 7.712e+00, -3.139e+01]' }

19 45 -0.00175 {'Bottom'} 0.0011603 {'[3.186e-03, -1.545e-03, 6.803e-04]' } {'[1.160e-03, 4.800e-04, -4.731e-03]' } {'[2.123e+02, 8.327e+00, -3.392e+01]' }

20 -30 -0.00175 {'Top' } 0.0017083 {'[3.186e-03, -1.545e-03, 6.803e-04]' } {'[1.708e-03, -6.802e-05, 4.437e-03]' } {'[3.104e+02, 4.245e+00, 3.181e+01]' }

20 -30 -0.001875 {'Bottom'} 0.0018352 {'[3.422e-03, -1.661e-03, 7.305e-04]' } {'[1.835e-03, -7.390e-05, 4.768e-03]' } {'[3.335e+02, 4.552e+00, 3.418e+01]' }

21 30 -0.001875 {'Top' } 0.0024679 {'[3.422e-03, -1.661e-03, 7.305e-04]' } {'[2.468e-03, -7.065e-04, -4.037e-03]' } {'[4.466e+02, -1.606e-01, -2.895e+01]' }

21 30 -0.002 {'Bottom'} 0.0026383 {'[3.659e-03, -1.777e-03, 7.807e-04]' } {'[2.638e-03, -7.559e-04, -4.318e-03]' } {'[4.775e+02, -1.775e-01, -3.096e+01]' }

22 0 -0.002 {'Top' } 0.0036593 {'[3.659e-03, -1.777e-03, 7.807e-04]' } {'[3.659e-03, -1.777e-03, 7.807e-04]' } {'[6.602e+02, -7.783e+00, 5.598e+00]' }

22 0 -0.002125 {'Bottom'} 0.0038962 {'[3.896e-03, -1.893e-03, 8.309e-04]' } {'[3.896e-03, -1.893e-03, 8.309e-04]' } {'[7.029e+02, -8.295e+00, 5.958e+00]' }

F\_xx: 4.444e-07

F\_x: 0.000e+00

F\_yy: 1.016e-04

F\_y: 2.093e-02

F\_s: 1.113e-02

F\_xy: -3.360e-06

Ply Angle (deg) z\_height (m) Surface Sigma\_x Sigma\_y Sigma\_s

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_

1 0 0.002125 {'Top' } -749.99 9.1044 -6.2809

1 0 0.002 {'Bottom'} -707.26 8.5927 -5.9209

2 30 0.002 {'Top' } -509.61 0.36342 33.359

2 30 0.001875 {'Bottom'} -478.76 0.34652 31.349

3 -30 0.001875 {'Top' } -358.59 -4.657 -36.91

3 -30 0.00175 {'Bottom'} -335.52 -4.35 -34.541

4 45 0.00175 {'Top' } -226.54 -8.8878 36.881

4 45 0.001625 {'Bottom'} -210.86 -8.273 34.353

5 -45 0.001625 {'Top' } -90.063 -13.303 -34.353

5 -45 0.0015 {'Bottom'} -83.37 -12.314 -31.824

6 30 0.0015 {'Top' } -386.22 0.2958 25.32

6 30 0.001375 {'Bottom'} -355.38 0.2789 23.31

7 -30 0.001375 {'Top' } -266.32 -3.4291 -27.431

7 -30 0.00125 {'Bottom'} -243.25 -3.1222 -25.061

8 45 0.00125 {'Top' } -163.84 -6.4285 26.767

8 45 0.001125 {'Bottom'} -148.17 -5.8137 24.238

9 -45 0.001125 {'Top' } -63.294 -9.3474 -24.238

9 -45 0.001 {'Bottom'} -56.602 -8.3586 -21.709

10 90 0.001 {'Top' } 176.31 -18.056 3.0413

10 90 0.000875 {'Bottom'} 155.95 -15.941 2.6813

11 90 0.000875 {'Top' } 155.95 -15.941 2.6813

11 90 0.00075 {'Bottom'} 135.58 -13.825 2.3214

12 90 -0.00075 {'Top' } -108.8 11.559 -1.9981

12 90 -0.000875 {'Bottom'} -129.17 13.674 -2.358

13 90 -0.000875 {'Top' } -129.17 13.674 -2.358

13 90 -0.001 {'Bottom'} -149.53 15.79 -2.718

14 -45 -0.001 {'Top' } 50.474 7.4621 18.749

14 -45 -0.001125 {'Bottom'} 57.166 8.4508 21.277

15 45 -0.001125 {'Top' } 133.97 5.2531 -21.277

15 45 -0.00125 {'Bottom'} 149.64 5.8679 -23.806

16 -30 -0.00125 {'Top' } 218.11 3.0171 22.335

16 -30 -0.001375 {'Bottom'} 241.18 3.3241 24.705

17 30 -0.001375 {'Top' } 323.25 -0.093008 -20.907

17 30 -0.0015 {'Bottom'} 354.1 -0.10991 -22.917

18 -45 -0.0015 {'Top' } 77.242 11.417 28.863

18 -45 -0.001625 {'Bottom'} 83.935 12.406 31.392

19 45 -0.001625 {'Top' } 196.67 7.7123 -31.392

19 45 -0.00175 {'Bottom'} 212.34 8.3272 -33.92

20 -30 -0.00175 {'Top' } 310.38 4.245 31.815

20 -30 -0.001875 {'Bottom'} 333.45 4.5519 34.185

21 30 -0.001875 {'Top' } 446.64 -0.16063 -28.947

21 30 -0.002 {'Bottom'} 477.49 -0.17753 -30.957

22 0 -0.002 {'Top' } 660.16 -7.7832 5.5976

22 0 -0.002125 {'Bottom'} 702.89 -8.2949 5.9575

Ply Angle (deg) Surface R\_1 R\_2 R\_3 R\_4 R\_5

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_\_\_

1 0 {'Top' } "N/A" 2 "4.3935" 27.02 "1.5093"

1 0 {'Bottom'} "N/A" 2.1209 "4.6551" 28.629 "1.6011"

2 30 {'Top' } "N/A" 2.9434 "110.0648" 676.9 "N/A"

2 30 {'Bottom'} "N/A" 3.1331 "115.4343" 709.92 "N/A"

3 -30 {'Top' } "N/A" 4.183 "N/A" 52.824 "N/A"

3 -30 {'Bottom'} "N/A" 4.4706 "N/A" 56.552 "N/A"

4 45 {'Top' } "N/A" 6.6215 "N/A" 27.678 "N/A"

4 45 {'Bottom'} "N/A" 7.1136 "N/A" 29.735 "N/A"

5 -45 {'Top' } "N/A" 16.655 "N/A" 18.493 "N/A"

5 -45 {'Bottom'} "N/A" 17.992 "N/A" 19.978 "N/A"

6 30 {'Top' } "N/A" 3.8838 "135.2251" 831.63 "N/A"

6 30 {'Bottom'} "N/A" 4.2209 "143.4215" 882.04 "N/A"

7 -30 {'Top' } "N/A" 5.6323 "N/A" 71.739 "N/A"

7 -30 {'Bottom'} "N/A" 6.1665 "N/A" 78.792 "N/A"

8 45 {'Top' } "N/A" 9.1553 "N/A" 38.267 "N/A"

8 45 {'Bottom'} "N/A" 10.124 "N/A" 42.314 "N/A"

9 -45 {'Top' } "N/A" 23.699 "N/A" 26.318 "N/A"

9 -45 {'Bottom'} "N/A" 26.501 "N/A" 29.431 "N/A"

10 90 {'Top' } "8.5076" 8.5076 "N/A" 13.624 "3.1171"

10 90 {'Bottom'} "9.6186" 9.6186 "N/A" 15.432 "3.5356"

11 90 {'Top' } "9.6186" 9.6186 "N/A" 15.432 "3.5356"

11 90 {'Bottom'} "11.0634" 11.063 "N/A" 17.793 "4.0838"

12 90 {'Top' } "N/A" 13.786 "3.4606" 21.282 "4.7446"

12 90 {'Bottom'} "N/A" 11.613 "2.9252" 17.99 "4.0203"

13 90 {'Top' } "N/A" 11.613 "2.9252" 17.99 "4.0203"

13 90 {'Bottom'} "N/A" 10.031 "2.5333" 15.58 "3.4879"

14 -45 {'Top' } "29.7185" 29.719 "5.3605" 32.967 "N/A"

14 -45 {'Bottom'} "26.2395" 26.239 "4.7333" 29.11 "N/A"

15 45 {'Top' } "11.1966" 11.197 "7.6146" 46.83 "N/A"

15 45 {'Bottom'} "10.0238" 10.024 "6.8168" 41.923 "N/A"

16 -30 {'Top' } "6.8772" 6.8772 "13.2576" 81.534 "N/A"

16 -30 {'Bottom'} "6.2194" 6.2194 "12.0334" 74.005 "N/A"

17 30 {'Top' } "4.6403" 4.6403 "N/A" 2644.9 "N/A"

17 30 {'Bottom'} "4.2361" 4.2361 "N/A" 2238.1 "N/A"

18 -45 {'Top' } "19.4194" 19.419 "3.5035" 21.546 "N/A"

18 -45 {'Bottom'} "17.8711" 17.871 "3.2242" 19.829 "N/A"

19 45 {'Top' } "7.6271" 7.6271 "5.1865" 31.897 "N/A"

19 45 {'Bottom'} "7.0641" 7.0641 "4.8036" 29.542 "N/A"

20 -30 {'Top' } "4.8327" 4.8327 "9.4229" 57.951 "N/A"

20 -30 {'Bottom'} "4.4984" 4.4984 "8.7874" 54.043 "N/A"

21 30 {'Top' } "3.3584" 3.3584 "N/A" 1531.5 "N/A"

21 30 {'Bottom'} "3.1415" 3.1415 "N/A" 1385.7 "N/A"

22 0 {'Top' } "2.2722" 2.2722 "N/A" 31.607 "1.6936"

22 0 {'Bottom'} "2.134" 2.134 "N/A" 29.657 "1.5913"

Ply Angle (deg) Surface R\_quadratic\_1 R\_quadratic\_2

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_

1 0 {'Top' } 1.0388 -1.2952

1 0 {'Bottom'} 1.1016 -1.3738

2 30 {'Top' } 0.28255 -0.28315

2 30 {'Bottom'} 0.30066 -0.30131

3 -30 {'Top' } 0.25966 -0.25325

3 -30 {'Bottom'} 0.27747 -0.27063

4 45 {'Top' } 0.26311 -0.25083

4 45 {'Bottom'} 0.28247 -0.2693

5 -45 {'Top' } 0.28662 -0.26543

5 -45 {'Bottom'} 0.30938 -0.28653

6 30 {'Top' } 0.37223 -0.37309

6 30 {'Bottom'} 0.40432 -0.40528

7 -30 {'Top' } 0.34935 -0.3408

7 -30 {'Bottom'} 0.38237 -0.37304

8 45 {'Top' } 0.3625 -0.34564

8 45 {'Bottom'} 0.40031 -0.38171

9 -45 {'Top' } 0.40616 -0.37625

9 -45 {'Bottom'} 0.45344 -0.42011

10 90 {'Top' } 3.76 -1.5529

10 90 {'Bottom'} 4.2623 -1.7595

11 90 {'Top' } 4.2623 -1.7595

11 90 {'Bottom'} 4.9195 -2.0296

12 90 {'Top' } 2.4105 -5.7848

12 90 {'Bottom'} 2.0388 -4.897

13 90 {'Top' } 2.0388 -4.897

13 90 {'Bottom'} 1.7665 -4.2455

14 -45 {'Top' } 0.48581 -0.5257

14 -45 {'Bottom'} 0.42811 -0.46319

15 45 {'Top' } 0.43451 -0.45632

15 45 {'Bottom'} 0.38837 -0.40783

16 -30 {'Top' } 0.41813 -0.42947

16 -30 {'Bottom'} 0.37804 -0.38826

17 30 {'Top' } 0.45147 -0.45107

17 30 {'Bottom'} 0.41189 -0.4115

18 -45 {'Top' } 0.31564 -0.3414

18 -45 {'Bottom'} 0.29023 -0.31389

19 45 {'Top' } 0.29455 -0.30925

19 45 {'Bottom'} 0.2726 -0.2862

20 -30 {'Top' } 0.2936 -0.30146

20 -30 {'Bottom'} 0.27325 -0.28056

21 30 {'Top' } 0.32612 -0.32576

21 30 {'Bottom'} 0.30495 -0.30461

22 0 {'Top' } 1.4568 -1.1773

22 0 {'Bottom'} 1.3687 -1.1059

Ply Angle (deg) Surface R\_hashin\_1 R\_hashin\_2 R\_hashin\_3 R\_hashin\_4

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_

1 0 {'Top' } "N/A" "2" "1.4275" "N/A"

1 0 {'Bottom'} "N/A" "2.1209" "1.5141" "N/A"

2 30 {'Top' } "N/A" "2.9434" "0.28418" "N/A"

2 30 {'Bottom'} "N/A" "3.1331" "0.3024" "N/A"

3 -30 {'Top' } "N/A" "4.183" "N/A" "0.28806"

3 -30 {'Bottom'} "N/A" "4.4706" "N/A" "0.31055"

4 45 {'Top' } "N/A" "6.6215" "N/A" "0.32775"

4 45 {'Bottom'} "N/A" "7.1136" "N/A" "0.36052"

5 -45 {'Top' } "N/A" "16.6551" "N/A" "0.46756"

5 -45 {'Bottom'} "N/A" "17.992" "N/A" "0.54928"

6 30 {'Top' } "N/A" "3.8838" "0.37441" "N/A"

6 30 {'Bottom'} "N/A" "4.2209" "0.40669" "N/A"

7 -30 {'Top' } "N/A" "5.6323" "N/A" "0.40579"

7 -30 {'Bottom'} "N/A" "6.1665" "N/A" "0.45213"

8 45 {'Top' } "N/A" "9.1553" "N/A" "0.51889"

8 45 {'Bottom'} "N/A" "10.1238" "N/A" "0.61128"

9 -45 {'Top' } "N/A" "23.699" "N/A" "1.5404"

9 -45 {'Bottom'} "N/A" "26.501" "N/A" "0-2.0104i"

10 90 {'Top' } "2.9268" "N/A" "N/A" "0-0.29784i"

10 90 {'Bottom'} "3.3185" "N/A" "N/A" "0-0.31533i"

11 90 {'Top' } "3.3185" "N/A" "N/A" "0-0.31533i"

11 90 {'Bottom'} "3.8311" "N/A" "N/A" "0-0.33685i"

12 90 {'Top' } "N/A" "13.7864" "2.7959" "N/A"

12 90 {'Bottom'} "N/A" "11.6127" "2.3654" "N/A"

13 90 {'Top' } "N/A" "11.6127" "2.3654" "N/A"

13 90 {'Bottom'} "N/A" "10.0312" "2.0497" "N/A"

14 -45 {'Top' } "0.50556" "N/A" "0.5034" "N/A"

14 -45 {'Bottom'} "0.44548" "N/A" "0.44359" "N/A"

15 45 {'Top' } "0.44519" "N/A" "0.44479" "N/A"

15 45 {'Bottom'} "0.39791" "N/A" "0.39754" "N/A"

16 -30 {'Top' } "0.42363" "N/A" "0.42422" "N/A"

16 -30 {'Bottom'} "0.383" "N/A" "0.38353" "N/A"

17 30 {'Top' } "0.45128" "N/A" "N/A" "0.4564"

17 30 {'Bottom'} "0.4117" "N/A" "N/A" "0.41633"

18 -45 {'Top' } "0.3284" "N/A" "0.32701" "N/A"

18 -45 {'Bottom'} "0.30195" "N/A" "0.30067" "N/A"

19 45 {'Top' } "0.30175" "N/A" "0.30148" "N/A"

19 45 {'Bottom'} "0.27926" "N/A" "0.27901" "N/A"

20 -30 {'Top' } "0.29741" "N/A" "0.29783" "N/A"

20 -30 {'Bottom'} "0.27679" "N/A" "0.27718" "N/A"

21 30 {'Top' } "0.32595" "N/A" "N/A" "0.32943"

21 30 {'Bottom'} "0.30479" "N/A" "N/A" "0.30798"

22 0 {'Top' } "1.3579" "N/A" "N/A" "0-0.45751i"

22 0 {'Bottom'} "1.2757" "N/A" "N/A" "0-0.44472i"

First failure occurs in Ply 1 at 0.000 degrees on the Top surface.

Smallest R value (failure): R = 2.000

Failure Mode: Fiber Compression

M\_i \* R = [-1982.022; -198.002; -210.002] Nm

N\_i \* R = [-45000.498; 6200.069; -4000.044] N

================= QUADRATIC CRITERION CONCLUSIONS =================

First failure occurs in Ply 3 at -30.000 degrees on the Top surface.

Smallest R value (failure): R = 0.260

M\_i \* R = [-257.320; -25.706; -27.264] Nm

N\_i \* R = [-5842.289; 804.938; -519.315] N

================= HASHIN CRITERION CONCLUSIONS =================

First failure occurs in Ply 20 at -30.000 degrees on the Bottom surface.

Smallest R value (failure): R = 0.277

Failure Mode: Fiber Tension

M\_i \* R = [-274.299; -27.402; -29.063] Nm

N\_i \* R = [-6227.775; 858.049; -553.580] N

Results of evaluateLaminate:

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Maximum Stress Reserve Minimum: 2.0000

Quadratic Reserve Minimum: 0.2597

Hashin Reserve Minimum: 0.2768

Mass of Laminate: 88.0000 g

Program Output for Load 2:

Ply Angle (deg) z\_height (m) Surface Epsilon\_x epsilon\_vector on\_axis\_strain on\_axis\_stress

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1 0 0.002125 {'Top' } -0.0039636 {'[-3.964e-03, 1.921e-03, -9.956e-04]'} {'[-3.964e-03, 1.921e-03, -9.956e-04]' } {'[-7.151e+02, 8.394e+00, -7.138e+00]' }

1 0 0.002 {'Bottom'} -0.0037368 {'[-3.737e-03, 1.810e-03, -9.385e-04]'} {'[-3.737e-03, 1.810e-03, -9.385e-04]' } {'[-6.741e+02, 7.901e+00, -6.729e+00]' }

2 30 0.002 {'Top' } -0.0027565 {'[-3.737e-03, 1.810e-03, -9.385e-04]'} {'[-2.756e-03, 8.297e-04, 4.334e-03]' } {'[-4.988e+02, 5.985e-01, 3.108e+01]' }

2 30 0.001875 {'Bottom'} -0.0025894 {'[-3.510e-03, 1.699e-03, -8.814e-04]'} {'[-2.589e-03, 7.783e-04, 4.070e-03]' } {'[-4.685e+02, 5.506e-01, 2.918e+01]' }

3 -30 0.001875 {'Top' } -0.0018261 {'[-3.510e-03, 1.699e-03, -8.814e-04]'} {'[-1.826e-03, 1.490e-05, -4.952e-03]' } {'[-3.320e+02, -5.136e+00, -3.550e+01]'}

3 -30 0.00175 {'Bottom'} -0.0017084 {'[-3.283e-03, 1.588e-03, -8.244e-04]'} {'[-1.708e-03, 1.293e-05, -4.630e-03]' } {'[-3.106e+02, -4.815e+00, -3.320e+01]'}

4 45 0.00175 {'Top' } -0.0012599 {'[-3.283e-03, 1.588e-03, -8.244e-04]'} {'[-1.260e-03, -4.356e-04, 4.871e-03]' } {'[-2.303e+02, -8.156e+00, 3.492e+01]' }

4 45 0.001625 {'Bottom'} -0.0011736 {'[-3.056e-03, 1.476e-03, -7.673e-04]'} {'[-1.174e-03, -4.063e-04, 4.532e-03]' } {'[-2.145e+02, -7.603e+00, 3.250e+01]' }

5 -45 0.001625 {'Top' } -0.00040627 {'[-3.056e-03, 1.476e-03, -7.673e-04]'} {'[-4.063e-04, -1.174e-03, -4.532e-03]'} {'[-7.726e+01, -1.332e+01, -3.250e+01]'}

5 -45 0.0015 {'Bottom'} -0.00037697 {'[-2.829e-03, 1.365e-03, -7.102e-04]'} {'[-3.770e-04, -1.087e-03, -4.194e-03]'} {'[-7.169e+01, -1.234e+01, -3.007e+01]'}

6 30 0.0015 {'Top' } -0.0020882 {'[-2.829e-03, 1.365e-03, -7.102e-04]'} {'[-2.088e-03, 6.241e-04, 3.277e-03]' } {'[-3.779e+02, 4.071e-01, 2.350e+01]' }

6 30 0.001375 {'Bottom'} -0.0019212 {'[-2.602e-03, 1.254e-03, -6.532e-04]'} {'[-1.921e-03, 5.727e-04, 3.013e-03]' } {'[-3.476e+02, 3.593e-01, 2.160e+01]' }

7 -30 0.001375 {'Top' } -0.0013555 {'[-2.602e-03, 1.254e-03, -6.532e-04]'} {'[-1.356e-03, 7.002e-06, -3.666e-03]' } {'[-2.464e+02, -3.854e+00, -2.629e+01]'}

7 -30 0.00125 {'Bottom'} -0.0012379 {'[-2.376e-03, 1.143e-03, -5.961e-04]'} {'[-1.238e-03, 5.027e-06, -3.345e-03]' } {'[-2.250e+02, -3.534e+00, -2.398e+01]'}

8 45 0.00125 {'Top' } -0.00091447 {'[-2.376e-03, 1.143e-03, -5.961e-04]'} {'[-9.145e-04, -3.184e-04, 3.518e-03]' } {'[-1.672e+02, -5.943e+00, 2.523e+01]' }

8 45 0.001125 {'Bottom'} -0.0008281 {'[-2.149e-03, 1.031e-03, -5.390e-04]'} {'[-8.281e-04, -2.891e-04, 3.180e-03]' } {'[-1.514e+02, -5.390e+00, 2.280e+01]' }

9 -45 0.001125 {'Top' } -0.00028909 {'[-2.149e-03, 1.031e-03, -5.390e-04]'} {'[-2.891e-04, -8.281e-04, -3.180e-03]'} {'[-5.496e+01, -9.405e+00, -2.280e+01]'}

9 -45 0.001 {'Bottom'} -0.00025979 {'[-1.922e-03, 9.203e-04, -4.819e-04]'} {'[-2.598e-04, -7.417e-04, -2.842e-03]'} {'[-4.938e+01, -8.427e+00, -2.038e+01]'}

10 90 0.001 {'Top' } 0.00092029 {'[-1.922e-03, 9.203e-04, -4.819e-04]'} {'[9.203e-04, -1.922e-03, 4.819e-04]' } {'[1.618e+02, -1.722e+01, 3.456e+00]' }

10 90 0.000875 {'Bottom'} 0.00080908 {'[-1.695e-03, 8.091e-04, -4.249e-04]'} {'[8.091e-04, -1.695e-03, 4.249e-04]' } {'[1.422e+02, -1.519e+01, 3.046e+00]' }

11 90 0.000875 {'Top' } 0.00080908 {'[-1.695e-03, 8.091e-04, -4.249e-04]'} {'[8.091e-04, -1.695e-03, 4.249e-04]' } {'[1.422e+02, -1.519e+01, 3.046e+00]' }

11 90 0.00075 {'Bottom'} 0.00069788 {'[-1.468e-03, 6.979e-04, -3.678e-04]'} {'[6.979e-04, -1.468e-03, 3.678e-04]' } {'[1.226e+02, -1.317e+01, 2.637e+00]' }

12 90 -0.00075 {'Top' } -0.0006366 {'[1.254e-03, -6.366e-04, 3.171e-04]' } {'[-6.366e-04, 1.254e-03, -3.171e-04]' } {'[-1.121e+02, 1.113e+01, -2.273e+00]' }

12 90 -0.000875 {'Bottom'} -0.0007478 {'[1.481e-03, -7.478e-04, 3.741e-04]' } {'[-7.478e-04, 1.481e-03, -3.741e-04]' } {'[-1.317e+02, 1.316e+01, -2.683e+00]' }

13 90 -0.000875 {'Top' } -0.0007478 {'[1.481e-03, -7.478e-04, 3.741e-04]' } {'[-7.478e-04, 1.481e-03, -3.741e-04]' } {'[-1.317e+02, 1.316e+01, -2.683e+00]' }

13 90 -0.001 {'Bottom'} -0.00085901 {'[1.708e-03, -8.590e-04, 4.312e-04]' } {'[-8.590e-04, 1.708e-03, -4.312e-04]' } {'[-1.512e+02, 1.518e+01, -3.092e+00]' }

14 -45 -0.001 {'Top' } 0.00020892 {'[1.708e-03, -8.590e-04, 4.312e-04]' } {'[2.089e-04, 6.401e-04, 2.567e-03]' } {'[3.984e+01, 7.228e+00, 1.841e+01]' }

14 -45 -0.001125 {'Bottom'} 0.00023821 {'[1.935e-03, -9.702e-04, 4.883e-04]' } {'[2.382e-04, 7.265e-04, 2.905e-03]' } {'[4.541e+01, 8.206e+00, 2.083e+01]' }

15 45 -0.001125 {'Top' } 0.00072649 {'[1.935e-03, -9.702e-04, 4.883e-04]' } {'[7.265e-04, 2.382e-04, -2.905e-03]' } {'[1.328e+02, 4.569e+00, -2.083e+01]' }

15 45 -0.00125 {'Bottom'} 0.00081286 {'[2.162e-03, -1.081e-03, 5.454e-04]' } {'[8.129e-04, 2.675e-04, -3.243e-03]' } {'[1.486e+02, 5.122e+00, -2.325e+01]' }

16 -30 -0.00125 {'Top' } 0.0011148 {'[2.162e-03, -1.081e-03, 5.454e-04]' } {'[1.115e-03, -3.448e-05, 3.081e-03]' } {'[2.026e+02, 2.873e+00, 2.209e+01]' }

16 -30 -0.001375 {'Bottom'} 0.0012325 {'[2.389e-03, -1.193e-03, 6.024e-04]' } {'[1.232e-03, -3.645e-05, 3.403e-03]' } {'[2.240e+02, 3.193e+00, 2.440e+01]' }

17 30 -0.001375 {'Top' } 0.0017542 {'[2.389e-03, -1.193e-03, 6.024e-04]' } {'[1.754e-03, -5.582e-04, -2.800e-03]' } {'[3.173e+02, -6.931e-01, -2.008e+01]' }

17 30 -0.0015 {'Bottom'} 0.0019213 {'[2.616e-03, -1.304e-03, 6.595e-04]' } {'[1.921e-03, -6.096e-04, -3.065e-03]' } {'[3.475e+02, -7.410e-01, -2.197e+01]' }

18 -45 -0.0015 {'Top' } 0.00032609 {'[2.616e-03, -1.304e-03, 6.595e-04]' } {'[3.261e-04, 9.856e-04, 3.919e-03]' } {'[6.214e+01, 1.114e+01, 2.810e+01]' }

18 -45 -0.001625 {'Bottom'} 0.00035539 {'[2.842e-03, -1.415e-03, 7.166e-04]' } {'[3.554e-04, 1.072e-03, 4.257e-03]' } {'[6.772e+01, 1.212e+01, 3.053e+01]' }

19 45 -0.001625 {'Top' } 0.001072 {'[2.842e-03, -1.415e-03, 7.166e-04]' } {'[1.072e-03, 3.554e-04, -4.257e-03]' } {'[1.959e+02, 6.782e+00, -3.053e+01]' }

19 45 -0.00175 {'Bottom'} 0.0011583 {'[3.069e-03, -1.526e-03, 7.736e-04]' } {'[1.158e-03, 3.847e-04, -4.596e-03]' } {'[2.117e+02, 7.336e+00, -3.295e+01]' }

20 -30 -0.00175 {'Top' } 0.0015854 {'[3.069e-03, -1.526e-03, 7.736e-04]' } {'[1.585e-03, -4.238e-05, 4.367e-03]' } {'[2.881e+02, 4.154e+00, 3.131e+01]' }

20 -30 -0.001875 {'Bottom'} 0.001703 {'[3.296e-03, -1.637e-03, 8.307e-04]' } {'[1.703e-03, -4.435e-05, 4.688e-03]' } {'[3.095e+02, 4.475e+00, 3.361e+01]' }

21 30 -0.001875 {'Top' } 0.0024224 {'[3.296e-03, -1.637e-03, 8.307e-04]' } {'[2.422e-03, -7.638e-04, -3.857e-03]' } {'[4.382e+02, -8.845e-01, -2.766e+01]' }

21 30 -0.002 {'Bottom'} 0.0025895 {'[3.523e-03, -1.749e-03, 8.878e-04]' } {'[2.589e-03, -8.152e-04, -4.121e-03]' } {'[4.684e+02, -9.323e-01, -2.955e+01]' }

22 0 -0.002 {'Top' } 0.003523 {'[3.523e-03, -1.749e-03, 8.878e-04]' } {'[3.523e-03, -1.749e-03, 8.878e-04]' } {'[6.355e+02, -7.886e+00, 6.365e+00]' }

22 0 -0.002125 {'Bottom'} 0.0037499 {'[3.750e-03, -1.860e-03, 9.449e-04]' } {'[3.750e-03, -1.860e-03, 9.449e-04]' } {'[6.764e+02, -8.379e+00, 6.775e+00]' }

F\_xx: 4.444e-07

F\_x: 0.000e+00

F\_yy: 1.016e-04

F\_y: 2.093e-02

F\_s: 1.113e-02

F\_xy: -3.360e-06

Ply Angle (deg) z\_height (m) Surface Sigma\_x Sigma\_y Sigma\_s

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_

1 0 0.002125 {'Top' } -715.07 8.3942 -7.1384

1 0 0.002 {'Bottom'} -674.14 7.9008 -6.7291

2 30 0.002 {'Top' } -498.75 0.59846 31.077

2 30 0.001875 {'Bottom'} -468.53 0.55062 29.182

3 -30 0.001875 {'Top' } -331.95 -5.1358 -35.502

3 -30 0.00175 {'Bottom'} -310.57 -4.8154 -33.199

4 45 0.00175 {'Top' } -230.33 -8.1563 34.922

4 45 0.001625 {'Bottom'} -214.54 -7.603 32.498

5 -45 0.001625 {'Top' } -77.264 -13.319 -32.498

5 -45 0.0015 {'Bottom'} -71.687 -12.34 -30.074

6 30 0.0015 {'Top' } -377.85 0.40711 23.499

6 30 0.001375 {'Bottom'} -347.63 0.35928 21.604

7 -30 0.001375 {'Top' } -246.43 -3.8544 -26.287

7 -30 0.00125 {'Bottom'} -225.05 -3.534 -23.983

8 45 0.00125 {'Top' } -167.18 -5.9432 25.226

8 45 0.001125 {'Bottom'} -151.4 -5.3899 22.802

9 -45 0.001125 {'Top' } -54.959 -9.4051 -22.802

9 -45 0.001 {'Bottom'} -49.382 -8.4267 -20.378

10 90 0.001 {'Top' } 161.75 -17.217 3.4555

10 90 0.000875 {'Bottom'} 142.19 -15.192 3.0463

11 90 0.000875 {'Top' } 142.19 -15.192 3.0463

11 90 0.00075 {'Bottom'} 122.63 -13.167 2.6371

12 90 -0.00075 {'Top' } -112.11 11.133 -2.2734

12 90 -0.000875 {'Bottom'} -131.67 13.158 -2.6826

13 90 -0.000875 {'Top' } -131.67 13.158 -2.6826

13 90 -0.001 {'Bottom'} -151.23 15.183 -3.0918

14 -45 -0.001 {'Top' } 39.838 7.228 18.406

14 -45 -0.001125 {'Bottom'} 45.414 8.2065 20.83

15 45 -0.001125 {'Top' } 132.77 4.5692 -20.83

15 45 -0.00125 {'Bottom'} 148.56 5.1224 -23.254

16 -30 -0.00125 {'Top' } 202.59 2.8729 22.093

16 -30 -0.001375 {'Bottom'} 223.97 3.1933 24.397

17 30 -0.001375 {'Top' } 317.31 -0.69313 -20.078

17 30 -0.0015 {'Bottom'} 347.54 -0.74096 -21.973

18 -45 -0.0015 {'Top' } 62.143 11.142 28.102

18 -45 -0.001625 {'Bottom'} 67.719 12.12 30.526

19 45 -0.001625 {'Top' } 195.92 6.7823 -30.526

19 45 -0.00175 {'Bottom'} 211.71 7.3356 -32.95

20 -30 -0.00175 {'Top' } 288.12 4.1543 31.309

20 -30 -0.001875 {'Bottom'} 309.5 4.4746 33.613

21 30 -0.001875 {'Top' } 438.21 -0.88447 -27.656

21 30 -0.002 {'Bottom'} 468.44 -0.93231 -29.551

22 0 -0.002 {'Top' } 635.45 -7.8861 6.3654

22 0 -0.002125 {'Bottom'} 676.38 -8.3794 6.7746

Ply Angle (deg) Surface R\_1 R\_2 R\_3 R\_4 R\_5

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_\_\_

1 0 {'Top' } "N/A" 2.0977 "4.7652" 29.306 "1.328"

1 0 {'Bottom'} "N/A" 2.2251 "5.0628" 31.136 "1.4088"

2 30 {'Top' } "N/A" 3.0075 "66.8384" 411.06 "N/A"

2 30 {'Bottom'} "N/A" 3.2015 "72.6451" 446.77 "N/A"

3 -30 {'Top' } "N/A" 4.5187 "N/A" 47.899 "N/A"

3 -30 {'Bottom'} "N/A" 4.8298 "N/A" 51.086 "N/A"

4 45 {'Top' } "N/A" 6.5124 "N/A" 30.161 "N/A"

4 45 {'Bottom'} "N/A" 6.9916 "N/A" 32.355 "N/A"

5 -45 {'Top' } "N/A" 19.414 "N/A" 18.47 "N/A"

5 -45 {'Bottom'} "N/A" 20.924 "N/A" 19.935 "N/A"

6 30 {'Top' } "N/A" 3.9698 "98.253" 604.26 "N/A"

6 30 {'Bottom'} "N/A" 4.3149 "111.3351" 684.71 "N/A"

7 -30 {'Top' } "N/A" 6.087 "N/A" 63.824 "N/A"

7 -30 {'Bottom'} "N/A" 6.6653 "N/A" 69.609 "N/A"

8 45 {'Top' } "N/A" 8.9722 "N/A" 41.392 "N/A"

8 45 {'Bottom'} "N/A" 9.9078 "N/A" 45.641 "N/A"

9 -45 {'Top' } "N/A" 27.293 "N/A" 26.156 "N/A"

9 -45 {'Bottom'} "N/A" 30.375 "N/A" 29.193 "N/A"

10 90 {'Top' } "9.2735" 9.2735 "N/A" 14.288 "2.7434"

10 90 {'Bottom'} "10.5492" 10.549 "N/A" 16.192 "3.112"

11 90 {'Top' } "10.5492" 10.549 "N/A" 16.192 "3.112"

11 90 {'Bottom'} "12.232" 12.232 "N/A" 18.683 "3.5949"

12 90 {'Top' } "N/A" 13.38 "3.5929" 22.096 "4.17"

12 90 {'Bottom'} "N/A" 11.392 "3.0399" 18.696 "3.5339"

13 90 {'Top' } "N/A" 11.392 "3.0399" 18.696 "3.5339"

13 90 {'Bottom'} "N/A" 9.9187 "2.6345" 16.202 "3.0662"

14 -45 {'Top' } "37.6529" 37.653 "5.534" 34.034 "N/A"

14 -45 {'Bottom'} "33.0296" 33.03 "4.8742" 29.976 "N/A"

15 45 {'Top' } "11.2974" 11.297 "8.7544" 53.839 "N/A"

15 45 {'Bottom'} "10.0968" 10.097 "7.8088" 48.024 "N/A"

16 -30 {'Top' } "7.4041" 7.4041 "13.9232" 85.628 "N/A"

16 -30 {'Bottom'} "6.6973" 6.6973 "12.5264" 77.037 "N/A"

17 30 {'Top' } "4.7272" 4.7272 "N/A" 354.91 "N/A"

17 30 {'Bottom'} "4.3161" 4.3161 "N/A" 332 "N/A"

18 -45 {'Top' } "24.138" 24.138 "3.5901" 22.079 "N/A"

18 -45 {'Bottom'} "22.1504" 22.15 "3.3003" 20.297 "N/A"

19 45 {'Top' } "7.6561" 7.6561 "5.8977" 36.271 "N/A"

19 45 {'Bottom'} "7.0852" 7.0852 "5.4529" 33.535 "N/A"

20 -30 {'Top' } "5.2062" 5.2062 "9.6286" 59.216 "N/A"

20 -30 {'Bottom'} "4.8465" 4.8465 "8.9393" 54.977 "N/A"

21 30 {'Top' } "3.423" 3.423 "N/A" 278.13 "N/A"

21 30 {'Bottom'} "3.2021" 3.2021 "N/A" 263.86 "N/A"

22 0 {'Top' } "2.3605" 2.3605 "N/A" 31.194 "1.4893"

22 0 {'Bottom'} "2.2177" 2.2177 "N/A" 29.358 "1.3993"

Ply Angle (deg) Surface R\_quadratic\_1 R\_quadratic\_2

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_

1 0 {'Top' } 0.99056 -1.1993

1 0 {'Bottom'} 1.051 -1.2721

2 30 {'Top' } 0.30289 -0.30404

2 30 {'Bottom'} 0.32256 -0.32377

3 -30 {'Top' } 0.27049 -0.26285

3 -30 {'Bottom'} 0.28927 -0.28108

4 45 {'Top' } 0.27764 -0.26508

4 45 {'Bottom'} 0.29836 -0.28484

5 -45 {'Top' } 0.30363 -0.27993

5 -45 {'Bottom'} 0.32812 -0.30248

6 30 {'Top' } 0.40064 -0.40201

6 30 {'Bottom'} 0.43581 -0.43724

7 -30 {'Top' } 0.36539 -0.35492

7 -30 {'Bottom'} 0.40051 -0.38899

8 45 {'Top' } 0.38443 -0.36688

8 45 {'Bottom'} 0.42533 -0.40585

9 -45 {'Top' } 0.43285 -0.39886

9 -45 {'Bottom'} 0.48439 -0.44626

10 90 {'Top' } 3.3901 -1.5257

10 90 {'Bottom'} 3.8475 -1.7302

11 90 {'Top' } 3.8475 -1.7302

11 90 {'Bottom'} 4.4475 -1.998

12 90 {'Top' } 2.3308 -5.1029

12 90 {'Bottom'} 1.9743 -4.3284

13 90 {'Top' } 1.9743 -4.3284

13 90 {'Bottom'} 1.7125 -3.758

14 -45 {'Top' } 0.49512 -0.53521

14 -45 {'Bottom'} 0.43744 -0.47299

15 45 {'Top' } 0.44505 -0.46484

15 45 {'Bottom'} 0.39862 -0.41642

16 -30 {'Top' } 0.423 -0.43404

16 -30 {'Bottom'} 0.38303 -0.39309

17 30 {'Top' } 0.47135 -0.46815

17 30 {'Bottom'} 0.43067 -0.42781

18 -45 {'Top' } 0.32416 -0.35068

18 -45 {'Bottom'} 0.2984 -0.32285

19 45 {'Top' } 0.3036 -0.31728

19 45 {'Bottom'} 0.28125 -0.29395

20 -30 {'Top' } 0.29842 -0.30637

20 -30 {'Bottom'} 0.27795 -0.28538

21 30 {'Top' } 0.3421 -0.33994

21 30 {'Bottom'} 0.32015 -0.31816

22 0 {'Top' } 1.3507 -1.1044

22 0 {'Bottom'} 1.269 -1.0379

Ply Angle (deg) Surface R\_hashin\_1 R\_hashin\_2 R\_hashin\_3 R\_hashin\_4

\_\_\_ \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_

1 0 {'Top' } "N/A" "2.0977" "1.2793" "N/A"

1 0 {'Bottom'} "N/A" "2.2251" "1.3572" "N/A"

2 30 {'Top' } "N/A" "3.0075" "0.30504" "N/A"

2 30 {'Bottom'} "N/A" "3.2015" "0.32485" "N/A"

3 -30 {'Top' } "N/A" "4.5187" "N/A" "0.30708"

3 -30 {'Bottom'} "N/A" "4.8298" "N/A" "0.33237"

4 45 {'Top' } "N/A" "6.5124" "N/A" "0.34907"

4 45 {'Bottom'} "N/A" "6.9916" "N/A" "0.38518"

5 -45 {'Top' } "N/A" "19.4141" "N/A" "0.56035"

5 -45 {'Bottom'} "N/A" "20.9242" "N/A" "0.69125"

6 30 {'Top' } "N/A" "3.9698" "0.40343" "N/A"

6 30 {'Bottom'} "N/A" "4.3149" "0.43881" "N/A"

7 -30 {'Top' } "N/A" "6.087" "N/A" "0.44245"

7 -30 {'Bottom'} "N/A" "6.6653" "N/A" "0.49807"

8 45 {'Top' } "N/A" "8.9722" "N/A" "0.56468"

8 45 {'Bottom'} "N/A" "9.9078" "N/A" "0.67426"

9 -45 {'Top' } "N/A" "27.2933" "N/A" "0-1.6518i"

9 -45 {'Bottom'} "N/A" "30.3752" "N/A" "0-1.0459i"

10 90 {'Top' } "2.6307" "N/A" "N/A" "0-0.30493i"

10 90 {'Bottom'} "2.9848" "N/A" "N/A" "0-0.32293i"

11 90 {'Top' } "2.9848" "N/A" "N/A" "0-0.32293i"

11 90 {'Bottom'} "3.449" "N/A" "N/A" "0-0.34509i"

12 90 {'Top' } "N/A" "13.3801" "2.7219" "N/A"

12 90 {'Bottom'} "N/A" "11.3923" "2.3046" "N/A"

13 90 {'Top' } "N/A" "11.3923" "2.3046" "N/A"

13 90 {'Bottom'} "N/A" "9.9187" "1.9982" "N/A"

14 -45 {'Top' } "0.51501" "N/A" "0.51284" "N/A"

14 -45 {'Bottom'} "0.45507" "N/A" "0.45315" "N/A"

15 45 {'Top' } "0.45475" "N/A" "0.4545" "N/A"

15 45 {'Bottom'} "0.40734" "N/A" "0.40712" "N/A"

16 -30 {'Top' } "0.42837" "N/A" "0.42888" "N/A"

16 -30 {'Bottom'} "0.38791" "N/A" "0.38838" "N/A"

17 30 {'Top' } "0.46982" "N/A" "N/A" "0.49904"

17 30 {'Bottom'} "0.42931" "N/A" "N/A" "0.45316"

18 -45 {'Top' } "0.33731" "N/A" "0.33587" "N/A"

18 -45 {'Bottom'} "0.31053" "N/A" "0.30919" "N/A"

19 45 {'Top' } "0.3103" "N/A" "0.31013" "N/A"

19 45 {'Bottom'} "0.28747" "N/A" "0.28731" "N/A"

20 -30 {'Top' } "0.30228" "N/A" "0.30264" "N/A"

20 -30 {'Bottom'} "0.28156" "N/A" "0.2819" "N/A"

21 30 {'Top' } "0.34107" "N/A" "N/A" "0.35553"

21 30 {'Bottom'} "0.3192" "N/A" "N/A" "0.33177"

22 0 {'Top' } "1.2596" "N/A" "N/A" "0-0.45928i"

22 0 {'Bottom'} "1.1834" "N/A" "N/A" "0-0.44748i"

First failure occurs in Ply 1 at 0.000 degrees on the Top surface.

Smallest R value (failure): R = 2.098

Failure Mode: Fiber Compression

M\_i \* R = [-1992.825; -199.282; -241.237] Nm

N\_i \* R = [-43632.374; -6083.360; -4719.848] N

================= QUADRATIC CRITERION CONCLUSIONS =================

First failure occurs in Ply 3 at -30.000 degrees on the Top surface.

Smallest R value (failure): R = 0.270

M\_i \* R = [-256.967; -25.697; -31.107] Nm

N\_i \* R = [-5626.230; -784.426; -608.607] N

================= HASHIN CRITERION CONCLUSIONS =================

First failure occurs in Ply 20 at -30.000 degrees on the Bottom surface.

Smallest R value (failure): R = 0.282

Failure Mode: Fiber Tension

M\_i \* R = [-267.482; -26.748; -32.379] Nm

N\_i \* R = [-5856.448; -816.524; -633.510] N

Results of evaluateLaminate:

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Maximum Stress Reserve Minimum: 2.0977

Quadratic Reserve Minimum: 0.2705

Hashin Reserve Minimum: 0.2816

Mass of Laminate: 88.0000 g

**Summary:**

Number of layers: 22

Material Chosen: Graphite Epoxy (AS/H3501)

Ply orientation: [0, 30, -30, 45, -45, 30, -30, 45, -45, 90, 90]S

Mass: 88g

Min FoS: 2.000

Explanation:

Note that I believe that my Hashin and Poly safety criteria are incorrectly implemented from last assignment, and the FoS’s presented are abnormally low. I am only going off of max stress for this assignment, which I understand is likely incorrect.

To design my laminate, I used Siemens NX Pre/Post FEA to apply the loads to an arbitrary material just to get the loadpaths. Here is the result from Load 1:

A screenshot of a computer

Description automatically generated

I measured two main load direction: ~30deg and ~45 deg. So, I decided to make an angle ply laminate containing -30, 30, -45-, 45-, 0- and 90-degree ply orientations. I tried to distribute these uniformally through the laminate, and also used some trial and error (for ply count and direction distribution) until my minimum FoS was 2 or greater.

This yields a mass of 88g, and FoS of 2.000 for Load 1 and 2.098 for Load 2.