**MECH530 – Assignment 5**

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CHOSEN MATERIAL: graphite\_epoxy\_1

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

Layer Number Type Thickness (mm) Orientation (degrees)

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

1 ply 0.125 0

2 ply 0.125 0

3 ply 0.125 20

4 ply 0.125 -20

5 ply 0.125 0

6 ply 0.125 90

- core 10.000 N/A

7 ply 0.125 90

8 ply 0.125 0

9 ply 0.125 -20

10 ply 0.125 20

11 ply 0.125 0

12 ply 0.125 0

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

[A] Matrix (in N/m):

2.117e+08 1.249e+07 1.055e-10

1.249e+07 6.027e+07 2.519e-09

1.055e-10 2.519e-09 1.890e+07

[a] Matrix (in m/N):

4.783e-09 -9.911e-10 1.054e-25

-9.911e-10 1.680e-08 -2.234e-24

1.054e-25 -2.234e-24 5.291e-08

[D] Matrix (in Nm):

6.268e+03 3.611e+02 1.578e+01

3.611e+02 1.602e+03 2.736e+00

1.578e+01 2.736e+00 5.465e+02

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

1.617e-04 -3.642e-05 -4.484e-06

-3.642e-05 6.323e-04 -2.114e-06

-4.484e-06 -2.114e-06 1.830e-03

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

N\_vector (N) = [5000.000; 0.000; 0.000]

M\_vector (Nm) = [-1250.000; 0.000; 0.000]

epsilon\_o\_vector = [

2.391e-05

-4.955e-06

5.271e-22

]

k\_vector (m^-1) = [

-2.021e-01

4.553e-02

5.605e-03

]

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

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

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

1 0 0.00575 {'Top' } -0.001138 {'[-1.138e-03, 2.568e-04, 3.223e-05]' } {'[-1.138e-03, 2.568e-04, 3.223e-05]' } {'[-2.061e+02, -6.394e-01, 2.311e-01]' }

1 0 0.005625 {'Bottom'} -0.0011127 {'[-1.113e-03, 2.511e-04, 3.153e-05]' } {'[-1.113e-03, 2.511e-04, 3.153e-05]' } {'[-2.016e+02, -6.252e-01, 2.261e-01]' }

2 0 0.005625 {'Top' } -0.0011127 {'[-1.113e-03, 2.511e-04, 3.153e-05]' } {'[-1.113e-03, 2.511e-04, 3.153e-05]' } {'[-2.016e+02, -6.252e-01, 2.261e-01]' }

2 0 0.0055 {'Bottom'} -0.0010874 {'[-1.087e-03, 2.454e-04, 3.083e-05]' } {'[-1.087e-03, 2.454e-04, 3.083e-05]' } {'[-1.970e+02, -6.109e-01, 2.210e-01]' }

3 20 0.0055 {'Top' } -0.00092161 {'[-1.087e-03, 2.454e-04, 3.083e-05]' } {'[-9.216e-04, 7.961e-05, 8.804e-04]' } {'[-1.673e+02, -1.846e+00, 6.312e+00]' }

3 20 0.005375 {'Bottom'} -0.0009002 {'[-1.062e-03, 2.397e-04, 3.013e-05]' } {'[-9.002e-04, 7.777e-05, 8.599e-04]' } {'[-1.634e+02, -1.803e+00, 6.166e+00]' }

4 -20 0.005375 {'Top' } -0.00091957 {'[-1.062e-03, 2.397e-04, 3.013e-05]' } {'[-9.196e-04, 9.714e-05, -8.138e-04]'} {'[-1.669e+02, -1.659e+00, -5.835e+00]'}

4 -20 0.00525 {'Bottom'} -0.0008977 {'[-1.037e-03, 2.341e-04, 2.943e-05]' } {'[-8.977e-04, 9.484e-05, -7.944e-04]'} {'[-1.629e+02, -1.619e+00, -5.696e+00]'}

5 0 0.00525 {'Top' } -0.0010369 {'[-1.037e-03, 2.341e-04, 2.943e-05]' } {'[-1.037e-03, 2.341e-04, 2.943e-05]' } {'[-1.878e+02, -5.823e-01, 2.110e-01]' }

5 0 0.005125 {'Bottom'} -0.0010117 {'[-1.012e-03, 2.284e-04, 2.873e-05]' } {'[-1.012e-03, 2.284e-04, 2.873e-05]' } {'[-1.833e+02, -5.680e-01, 2.060e-01]' }

6 90 0.005125 {'Top' } 0.00022837 {'[-1.012e-03, 2.284e-04, 2.873e-05]' } {'[2.284e-04, -1.012e-03, -2.873e-05]'} {'[3.859e+01, -9.805e+00, -2.060e-01]' }

6 90 0.005 {'Bottom'} 0.00022268 {'[-9.864e-04, 2.227e-04, 2.803e-05]' } {'[2.227e-04, -9.864e-04, -2.803e-05]'} {'[3.763e+01, -9.560e+00, -2.009e-01]' }

7 90 -0.005 {'Top' } -0.00023259 {'[1.034e-03, -2.326e-04, -2.803e-05]'} {'[-2.326e-04, 1.034e-03, 2.803e-05]' } {'[-3.929e+01, 1.003e+01, 2.009e-01]' }

7 90 -0.005125 {'Bottom'} -0.00023828 {'[1.059e-03, -2.383e-04, -2.873e-05]'} {'[-2.383e-04, 1.059e-03, 2.873e-05]' } {'[-4.025e+01, 1.027e+01, 2.060e-01]' }

8 0 -0.005125 {'Top' } 0.0010595 {'[1.059e-03, -2.383e-04, -2.873e-05]'} {'[1.059e-03, -2.383e-04, -2.873e-05]'} {'[1.919e+02, 6.040e-01, -2.060e-01]' }

8 0 -0.00525 {'Bottom'} 0.0010847 {'[1.085e-03, -2.440e-04, -2.943e-05]'} {'[1.085e-03, -2.440e-04, -2.943e-05]'} {'[1.965e+02, 6.183e-01, -2.110e-01]' }

9 -20 -0.00525 {'Top' } 0.00093878 {'[1.085e-03, -2.440e-04, -2.943e-05]'} {'[9.388e-04, -9.800e-05, 8.315e-04]' } {'[1.704e+02, 1.706e+00, 5.962e+00]' }

9 -20 -0.005375 {'Bottom'} 0.00096064 {'[1.110e-03, -2.497e-04, -3.013e-05]'} {'[9.606e-04, -1.003e-04, 8.509e-04]' } {'[1.744e+02, 1.745e+00, 6.101e+00]' }

10 20 -0.005375 {'Top' } 0.00094127 {'[1.110e-03, -2.497e-04, -3.013e-05]'} {'[9.413e-04, -8.093e-05, -8.971e-04]'} {'[1.709e+02, 1.890e+00, -6.432e+00]' }

10 20 -0.0055 {'Bottom'} 0.00096268 {'[1.135e-03, -2.554e-04, -3.083e-05]'} {'[9.627e-04, -8.277e-05, -9.175e-04]'} {'[1.748e+02, 1.932e+00, -6.578e+00]' }

11 0 -0.0055 {'Top' } 0.0011353 {'[1.135e-03, -2.554e-04, -3.083e-05]'} {'[1.135e-03, -2.554e-04, -3.083e-05]'} {'[2.057e+02, 6.469e-01, -2.210e-01]' }

11 0 -0.005625 {'Bottom'} 0.0011605 {'[1.161e-03, -2.610e-04, -3.153e-05]'} {'[1.161e-03, -2.610e-04, -3.153e-05]'} {'[2.102e+02, 6.612e-01, -2.261e-01]' }

12 0 -0.005625 {'Top' } 0.0011605 {'[1.161e-03, -2.610e-04, -3.153e-05]'} {'[1.161e-03, -2.610e-04, -3.153e-05]'} {'[2.102e+02, 6.612e-01, -2.261e-01]' }

12 0 -0.00575 {'Bottom'} 0.0011858 {'[1.186e-03, -2.667e-04, -3.223e-05]'} {'[1.186e-03, -2.667e-04, -3.223e-05]'} {'[2.148e+02, 6.755e-01, -2.311e-01]' }

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

First failure occurs in Ply 10 (20.000 degrees) on the Bottom surface.

Smallest R value (failure): R = 1.441

Failure Mode: Shear

M\_i \* R = [-1801.357; 0.000; 0.000] Nm

N\_i \* R = [7205.430; 0.000; 0.000] N

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

First failure occurs in Ply 10 (20.000 degrees) on the Bottom surface.

Smallest R value (failure): R = 1.383

M\_i \* R = [-1729.359; 0.000; 0.000] Nm

N\_i \* R = [6917.436; 0.000; 0.000] N

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

First failure occurs in Ply 10 (20.000 degrees) on the Bottom surface.

Smallest R value (failure): R = 1.421

Failure Mode: Fiber Tension

M\_i \* R = [-1776.500; 0.000; 0.000] Nm

N\_i \* R = [7106.000; 0.000; 0.000] N

All results are summarized (All R values) are summarized below. Note that invalid values of R (i.e., smaller than 1 for Max & Hash, or complex-valued) have been replaced with N/A.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Max** | | | | | **Quad** | | **Hash** | | | |
| **Ply** | **Angle (deg)** | **FT** | **FC** | **MT** | **MC** | **S** | **(+)** | **(-)** | **FT** | **FC** | **MT** | **MC** |
| 1 | 0 | N/A | 7.2763 | N/A | 384.71 | 41.024 | 7.6929 | -6.9746 | N/A | 7.2763 | N/A | N/A |
| 1 | 0 | N/A | 7.4415 | N/A | 393.5 | 41.935 | 7.8673 | -7.1329 | N/A | 7.4415 | N/A | N/A |
| 2 | 0 | N/A | 7.4415 | N/A | 393.5 | 41.935 | 7.8673 | -7.1329 | N/A | 7.4415 | N/A | N/A |
| 2 | 0 | N/A | 7.6143 | N/A | 402.71 | 42.888 | 8.0498 | -7.2985 | N/A | 7.6143 | N/A | N/A |
| 3 | 20 | N/A | 8.9644 | N/A | 133.25 | 1.5018 | 1.5272 | -1.4421 | N/A | 8.9644 | N/A | N/A |
| 3 | 20 | N/A | 9.1776 | N/A | 136.42 | 1.5375 | 1.5635 | -1.4763 | N/A | 9.1776 | N/A | N/A |
| 4 | -20 | N/A | 8.9871 | N/A | 148.29 | 1.6247 | 1.6472 | -1.5581 | N/A | 8.9871 | N/A | N/A |
| 4 | -20 | N/A | 9.206 | N/A | 151.91 | 1.6643 | 1.6874 | -1.5961 | N/A | 9.206 | N/A | N/A |
| 5 | 0 | N/A | 7.9853 | N/A | 422.48 | 44.931 | 8.4415 | -7.6539 | N/A | 7.9853 | N/A | N/A |
| 5 | 0 | N/A | 8.1846 | N/A | 433.11 | 46.027 | 8.652 | -7.8449 | N/A | 8.1846 | N/A | N/A |
| 6 | 90 | 38.8711 | 38.871 | N/A | 25.089 | 46.027 | 19.148 | -3.8835 | 29.6973 | N/A | N/A | N/A |
| 6 | 90 | 39.8644 | 39.864 | N/A | 25.731 | 47.177 | 19.638 | -3.983 | 30.4493 | N/A | N/A | N/A |
| 7 | 90 | 38.177 | 38.177 | 3.9894 | 24.535 | 47.177 | 3.8006 | -18.794 | 38.1768 | 38.1768 | 3.9752 | N/A |
| 7 | 90 | 37.265 | 37.265 | 3.8943 | 23.95 | 46.027 | 3.71 | -18.345 | 37.2649 | 37.2649 | 3.8805 | N/A |
| 8 | 0 | 7.8151 | 7.8151 | 66.2253 | 407.29 | 46.027 | 7.4975 | -8.2827 | 7.7048 | 7.7048 | 37.795 | N/A |
| 8 | 0 | 7.6331 | 7.6331 | 64.6944 | 397.87 | 44.931 | 7.3228 | -8.0896 | 7.5253 | 7.5253 | 36.9036 | N/A |
| 9 | -20 | 8.803 | 8.803 | 23.4511 | 144.22 | 1.59 | 1.5246 | -1.6124 | 1.5647 | 1.5647 | 1.5864 | N/A |
| 9 | -20 | 8.6027 | 8.6027 | 22.9192 | 140.95 | 1.5539 | 1.4899 | -1.5757 | 1.5291 | 1.5291 | 1.5503 | N/A |
| 10 | 20 | 8.7771 | 8.7771 | 21.1694 | 130.19 | 1.4739 | 1.415 | -1.4998 | 1.4536 | 1.4536 | 1.4703 | N/A |
| 10 | 20 | 8.5819 | 8.5819 | 20.6991 | 127.3 | 1.4411 | 1.3835 | -1.4655 | 1.4212 | 1.4212 | 1.4376 | N/A |
| 11 | 0 | 7.2935 | 7.2935 | 61.8356 | 380.29 | 42.888 | 6.9969 | -7.7292 | 7.1902 | 7.1902 | 35.2414 | N/A |
| 11 | 0 | 7.1347 | 7.1347 | 60.4989 | 372.07 | 41.935 | 6.8445 | -7.5608 | 7.0336 | 7.0336 | 34.2521 | N/A |
| 12 | 0 | 7.1347 | 6.9827 | 59.2188 | 364.2 | 41.024 | 6.8445 | -7.5608 | 7.0336 | 6.8837 | 34.4652 | N/A |
| 12 | 0 | 7.1347 | 6.9827 | 59.2188 | 364.2 | 41.024 | 6.6987 | -7.3996 | 6.8837 | 6.8837 | 33.7224 | N/A |