TERM PROJECT

MECH-530

Progress Report 4

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Overview: This progress report features calculating the resultant stress and strain at the top and bottom of each ply in a laminate skateboard to determine if the design criterion are met. New modules include calculating the matrices D, d, the radius of curvature K, as well as developing an input interface for an applied resultant moment M.

1 Preliminary Calculations and Design Criterion

Based on the following given values, M_1 is determined to be 2869.425 N downwards while $M_2 = M_3 = 0$ N

- L = 52 cm (length of skateboard)
- b = 10 cm (width of skateboard)
- m = 225 kg (worst case concentrated mass)
- W = $225 \cdot 9.81 = 2207.25$ N downwards (worst case concentrated weight)

$$\begin{aligned} M_1 &= \frac{M}{b} \\ &= \frac{P \cdot b}{4 \cdot b} \\ &= \frac{-225 \cdot 9.81 \cdot 0.52}{4 \cdot 0.1} \\ &= -2869.425N \end{aligned}$$

Refer to the end of Section 2 for the deflection and the midpoint along with the max strain along the fibers. Note that neither of the following design criterions are met.

- Max deflection at the skateboard's midpoint: $\delta < 5.0$ mm
- Max strain along the fibers: $\epsilon_x < 0.002$

2 Program Output

Program output to follow...

In [1]:
```
run MECH530_main.py
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PLYBOOK (READ FROM EXCEL FILE AND SUMMARIZED HERE)

The laminate is given by the following plybook where the highest ply number '13
' indicates the top layer, while the first ply number '1' indicates the bottom
layer.

Unique Ply #, Fiber/Matrix, Orientation, Thickness
                              (degrees)      (mm)
    13           AS4/PEEK          0         0.125
    12           AS4/PEEK          0         0.125
    11           AS4/PEEK         25         0.125
    10           AS4/PEEK        -25         0.125
     9           AS4/PEEK          0         0.125
     8           AS4/PEEK          0         0.125
     7               CORE          0        10.000
     6           AS4/PEEK          0         0.125
     5           AS4/PEEK          0         0.125
     4           AS4/PEEK        -25         0.125
     3           AS4/PEEK         25         0.125
     2           AS4/PEEK          0         0.125
     1           AS4/PEEK          0         0.125

PLIES AND THICKNESSES
-Total number of plies in the laminate: 13
-Total thickness of laminate is: 11.500 mm
-The core thickness is 2 Zc = 10.000 mm
-Laminate contains 1 Fiber/Matrix combination. The material properties for this
 combination shall be listed below.

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MATERIALS AND MATERIAL PROPERTIES

RESIN/MATRIX 1 of 1: For AS4/PEEK, the given material properties are:

-Stiffness and Strength:

Ex = 134.0000 GPa, Ey =   8.9000 GPa, Es =   5.1000 GPa and nu_x =   0.2800

Xt = 2130.0000 MPa, Xc = 1100.0000 MPa, Yt =  80.0000f MPa, Yc = 200.0000 MPa a
nd Sc = 160.0000 MPa.

-The 'on-axis' matrices are given by the following:
S_on =
[[   0.0075   -0.0021       0.0]
 [  -0.0021    0.1124       0.0]
 [      0.0       0.0    0.1961]] [1/GPa]

Q_on =
[[ 134.7014    2.5050       0.0]
 [   2.5050    8.9466       0.0]
 [      0.0       0.0    5.1000]] [GPa]
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-The linear combinations of the modulus, independent of ply angle are the follo
wing:
Us_1 =    0.0689 [1/GPa]
Us_2 =   -0.0524 [1/GPa]
Us_3 =   -0.0090 [1/GPa]
Us_4 =   -0.0111 [1/GPa]
Us_5 =    0.1600 [1/GPa]

-The linear combinations of the modulus, dependent on ply angle are the followi
ng:
Uq_1 =   57.0443 GPa
Uq_2 =   62.8774 GPa
Uq_3 =   14.7797 GPa
Uq_4 =   17.2848 GPa
Uq_5 =   19.8797 GPa

-The 'Stiffness' [A] and 'Compliance' [a] matrices are given by the following:
A =
[[   0.1821    0.0124       0.0]
 [   0.0124    0.0160       0.0]
 [      0.0       0.0    0.0163]] [GN/m]

a =
[[   5.7979   -4.5109      -0.0]
 [  -4.5109   66.0994      -0.0]
 [      0.0       0.0   61.2628]] [m/GN]

-The 'In-Plane Flexural Modulus' [D] and 'In-Plane Flexural Compliance' [d] mat
rices are given by the following:
D =
[[   5.2718    0.3594    0.0130]
 [   0.3594    0.4622    0.0032]
 [   0.0130    0.0032    0.4720]] [kNm]

d =
[[ 200.3143 -155.6995   -4.4529]
 [-155.6995 2284.5488  -11.2113]
 [  -4.4529  -11.2113 2118.8941]] [1/MNm]

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INPUTS:

Would you like to input a resultant applied stress? ON/OFF/NO
NO
Would you like to input a resultant applied moment? ON/OFF/NO
OFF
Enter the applied moment resultant vector [M1, M2, M6] [N].
M1 = -2869.245
M2 = 0
M6 = 0

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Curvature K =
[[  -0.5748    0.4467    0.0128]] [m]

OFF-AXIS APPLIED RESULTANTS:
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(INPUT) Off-axis Applied stress resultant N =
[[      0.0       0.0       0.0]] [GN/m]

(INPUT) Off-axis Applied moment resultant M =
[[-2869.2450       0.0       0.0]] [N]

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STRESSES AND STRAINS PER PLY:
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PLY: 13
ORIENTATION: 0 degrees

TOP

Off-axis strain =
[[  -0.0033    0.0026    0.0001]] [unitless]

On-axis strain =
[[  -0.0033    0.0026    0.0001]] [unitless]

On-axis stress =
[[  -0.4387    0.0147    0.0004]] [GPa]

BOTTOM

Off-axis strain =
[[  -0.0032    0.0025    0.0001]] [unitless]

On-axis strain =
[[  -0.0032    0.0025    0.0001]] [unitless]

On-axis stress =
[[  -0.4292    0.0144    0.0004]] [GPa]

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PLY: 12
ORIENTATION: 0 degrees

TOP

Off-axis strain =
[[  -0.0032    0.0025    0.0001]] [unitless]

On-axis strain =
[[  -0.0032    0.0025    0.0001]] [unitless]

On-axis stress =
[[  -0.4292    0.0144    0.0004]] [GPa]

BOTTOM

Off-axis strain =
[[  -0.0032    0.0025    0.0001]] [unitless]

On-axis strain =
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[[  -0.0032    0.0025    0.0001]] [unitless]

On-axis stress =
[[  -0.4197    0.0141    0.0004]] [GPa]

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PLY: 11
ORIENTATION: 25 degrees

TOP

Off-axis strain =
[[  -0.0032    0.0025    0.0001]] [unitless]

On-axis strain =
[[  -0.0021    0.0014    0.0043]] [unitless]

On-axis stress =
[[  -0.2834    0.0074    0.0222]] [GPa]

BOTTOM

Off-axis strain =
[[  -0.0031    0.0024    0.0001]] [unitless]

On-axis strain =
[[  -0.0021    0.0014    0.0043]] [unitless]

On-axis stress =
[[  -0.2770    0.0073    0.0217]] [GPa]

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PLY: 10
ORIENTATION: -25 degrees

TOP

Off-axis strain =
[[  -0.0031    0.0024    0.0001]] [unitless]

On-axis strain =
[[  -0.0021    0.0014   -0.0042]] [unitless]

On-axis stress =
[[  -0.2840    0.0076   -0.0212]] [GPa]

BOTTOM

Off-axis strain =
[[  -0.0030    0.0023    0.0001]] [unitless]

On-axis strain =
[[  -0.0021    0.0014   -0.0041]] [unitless]

On-axis stress =
[[  -0.2774    0.0074   -0.0207]] [GPa]
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PLY: 9
ORIENTATION: 0 degrees

TOP

Off-axis strain =
[[  -0.0030    0.0023    0.0001]] [unitless]

On-axis strain =
[[  -0.0030    0.0023    0.0001]] [unitless]

On-axis stress =
[[  -0.4006    0.0134    0.0003]] [GPa]

BOTTOM

Off-axis strain =
[[  -0.0029    0.0023    0.0001]] [unitless]

On-axis strain =
[[  -0.0029    0.0023    0.0001]] [unitless]

On-axis stress =
[[  -0.3910    0.0131    0.0003]] [GPa]

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PLY: 8
ORIENTATION: 0 degrees

TOP

Off-axis strain =
[[  -0.0029    0.0023    0.0001]] [unitless]

On-axis strain =
[[  -0.0029    0.0023    0.0001]] [unitless]

On-axis stress =
[[  -0.3910    0.0131    0.0003]] [GPa]

BOTTOM

Off-axis strain =
[[  -0.0029    0.0022    0.0001]] [unitless]

On-axis strain =
[[  -0.0029    0.0022    0.0001]] [unitless]

On-axis stress =
[[  -0.3815    0.0128    0.0003]] [GPa]

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PLY: 7, CORE!
ORIENTATION: N/A
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PLY: 6
ORIENTATION: 0 degrees

TOP

Off-axis strain =
[[   0.0029   -0.0022   -0.0001]] [unitless]

On-axis strain =
[[   0.0029   -0.0022   -0.0001]] [unitless]

On-axis stress =
[[   0.3815   -0.0128   -0.0003]] [GPa]

BOTTOM

Off-axis strain =
[[   0.0029   -0.0023   -0.0001]] [unitless]

On-axis strain =
[[   0.0029   -0.0023   -0.0001]] [unitless]

On-axis stress =
[[   0.3910   -0.0131   -0.0003]] [GPa]

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PLY: 5
ORIENTATION: 0 degrees

TOP

Off-axis strain =
[[   0.0029   -0.0023   -0.0001]] [unitless]

On-axis strain =
[[   0.0029   -0.0023   -0.0001]] [unitless]

On-axis stress =
[[   0.3910   -0.0131   -0.0003]] [GPa]

BOTTOM

Off-axis strain =
[[   0.0030   -0.0023   -0.0001]] [unitless]

On-axis strain =
[[   0.0030   -0.0023   -0.0001]] [unitless]

On-axis stress =
[[   0.4006   -0.0134   -0.0003]] [GPa]

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PLY: 4
ORIENTATION: -25 degrees
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TOP

Off-axis strain =
[[   0.0030   -0.0023   -0.0001]] [unitless]

On-axis strain =
[[   0.0021   -0.0014    0.0041]] [unitless]

On-axis stress =
[[   0.2774   -0.0074    0.0207]] [GPa]

BOTTOM

Off-axis strain =
[[   0.0031   -0.0024   -0.0001]] [unitless]

On-axis strain =
[[   0.0021   -0.0014    0.0042]] [unitless]

On-axis stress =
[[   0.2840   -0.0076    0.0212]] [GPa]

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PLY: 3
ORIENTATION: 25 degrees

TOP

Off-axis strain =
[[   0.0031   -0.0024   -0.0001]] [unitless]

On-axis strain =
[[   0.0021   -0.0014   -0.0043]] [unitless]

On-axis stress =
[[   0.2770   -0.0073   -0.0217]] [GPa]

BOTTOM

Off-axis strain =
[[   0.0032   -0.0025   -0.0001]] [unitless]

On-axis strain =
[[   0.0021   -0.0014   -0.0043]] [unitless]

On-axis stress =
[[   0.2834   -0.0074   -0.0222]] [GPa]

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PLY: 2
ORIENTATION: 0 degrees

TOP

Off-axis strain =
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[[   0.0032   -0.0025   -0.0001]] [unitless]

On-axis strain =
[[   0.0032   -0.0025   -0.0001]] [unitless]

On-axis stress =
[[   0.4197   -0.0141   -0.0004]] [GPa]

BOTTOM

Off-axis strain =
[[   0.0032   -0.0025   -0.0001]] [unitless]

On-axis strain =
[[   0.0032   -0.0025   -0.0001]] [unitless]

On-axis stress =
[[   0.4292   -0.0144   -0.0004]] [GPa]

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PLY: 1
ORIENTATION: 0 degrees

TOP

Off-axis strain =
[[   0.0032   -0.0025   -0.0001]] [unitless]

On-axis strain =
[[   0.0032   -0.0025   -0.0001]] [unitless]

On-axis stress =
[[   0.4292   -0.0144   -0.0004]] [GPa]

BOTTOM

Off-axis strain =
[[   0.0033   -0.0026   -0.0001]] [unitless]

On-axis strain =
[[   0.0033   -0.0026   -0.0001]] [unitless]

On-axis stress =
[[   0.4387   -0.0147   -0.0004]] [GPa]

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CHECK DESIGN CRITERION:

The deflection at the midpoint is: -12.9519 mm
The maximum strain along the fibers is: 0.0033

Therefore the design will NOT meet the requirements!

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