TERM PROJECT

MECH-530

Progress Report 5

Elaine Craigie

(260476434)

November 3, 2014

Overview: This progress report features the addition of a module to analyze various failure criterion, notably Maximum Stress, Quadratic Polynomial and Hashin Criterion. The purpose of this analysis is to determine how close the laminate is to failure as well as the mode of the eventual failure, where applicable.

1 Preliminary Calculations and Design Criterion

Based on the following given parameters, the applied load vectors were obtained. Thus, M_1 = -1159.09 N while $M_2 = M_6 = 0$ N, and $N_1 = 4545.45$ N/m (tensile load) while $N_2 = N_6 = 0$ N/m.

- L = 51 cm (length of skateboard)
- b = 11 cm (width of skateboard)
- P_1 = 1000 N downwards (arbitrary load)

$$\begin{aligned} M_1 &= \frac{M}{b} \\ &= \frac{P_1 \cdot L}{4 \cdot b} \\ &= \frac{-1000 \cdot 0.51}{4 \cdot 0.11} \\ &= -1159.0909 \text{ N} \end{aligned}$$

$$\begin{aligned} N_1 &= \frac{0.5 \cdot |P_1|}{b} \\ &= \frac{1000}{2 \cdot 0.11} \\ &= 4545.4545 \text{ N/m} \end{aligned}$$

Refer to the tables in Sections A and B for the stresses, strains and failure R values per top and bottom of each ply.

2 Program Output

Program output to follow...

In [1]:
```
run -i MECH530_main.py
```

```
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
-Note that the CORE will be ommitted in the following stress and safety factor
tables
-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 =
[[      0.0   -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]

-The linear combinations of the modulus, independent of ply angle are the follo
wing:
Us_1 =    0.0661 [1/GPa]
Us_2 =   -0.0562 [1/GPa]
Us_3 =   -0.0099 [1/GPa]
Us_4 =   -0.0120 [1/GPa]
Us_5 =    0.1563 [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]

--------------------------------------------------------------------------------
INPUTS:

Would you like to input a resultant applied stress? ON/OFF/NO
OFF
Enter the applied stress resultant vector [N1, N2, N6] [N/m].
N1 = 4545.4545
N2 = 0
N6 = 0
Would you like to input a resultant applied moment? ON/OFF/NO
OFF
Enter the applied moment resultant vector [M1, M2, M6] [N].
M1 = -1159.0909
M2 = 0
M6 = 0
```

```
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Curvature K =
[[  -0.2322    0.1805    0.0052]] [1/m]

OFF-AXIS APPLIED RESULTANTS:

(INPUT) Off-axis Applied stress resultant N =
[[4545.4545       0.0       0.0]] [N/m]

(INPUT) Off-axis Applied moment resultant M =
[[-1159.0909       0.0       0.0]] [N]

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FAILURE CRITERION AND ANALYSIS

MAXIMUM STRESS:
-Minimum R = 6.331 and laminate fails in Fiber Compression at TOP of ply 13
-The load vectors which cause the failure are:
R*N =
[[  28.7795       0.0       0.0]] [kN/m]
R*M =
[[  -7.3388       0.0       0.0]] [kN]

QUADRATIC POLYNOMIAL:
-Minimum R = 4.664 and laminate fails at TOP of ply 13
-The load vectors which cause the failure are:
R*N =
[[  21.2022       0.0       0.0]] [kN/m]
R*M =
[[  -5.4066       0.0       0.0]] [kN]

HASHIN CRITERION:
-Minimum R = 6.331 and laminate fails in Fiber Compression at TOP of ply 13
-The load vectors which cause the failure are:
R*N =
[[  28.7795       0.0       0.0]] [kN/m]
R*M =
[[  -7.3388       0.0       0.0]] [kN]
--------------------------------------------------------------------------------
```

In [2]:
```
# stress_df
```

In [3]:
```
# failure_df
```

In [11]:
```
# print stress_df.to_latex()
```

In [12]:
```
# print failure_df.to_latex(float_format=lambda x:"%.3f" % x)
```

Position	Ply	Angle	ϵ_1	ϵ_2	ϵ_6	ϵ_x	ϵ_y	ϵ_s	σ_x	σ_y	σ_s
		(^{o})							(GPa)	(GPa)	(GPa)
TOP	13	0	-0.001309	0.001017	0.000030	-0.001309	0.001017	0.000030	-0.173735	0.005822	0.000151
BOT	13	0	-0.001280	0.000995	0.000029	-0.001280	0.000995	0.000029	-0.169882	0.005693	0.000148
TOP	12	0	-0.001280	0.000995	0.000029	-0.001280	0.000995	0.000029	-0.169882	0.005693	0.000148
BOT	12	0	-0.001251	0.000972	0.000028	-0.001251	0.000972	0.000028	-0.166029	0.005564	0.000145
TOP	11	25	-0.001251	0.000972	0.000028	-0.000843	0.000564	0.001721	-0.112111	0.002937	0.008777
BOT	11	25	-0.001222	0.000950	0.000028	-0.000823	0.000551	0.001681	-0.109508	0.002868	0.008573
TOP	10	-25	-0.001222	0.000950	0.000028	-0.000844	0.000572	-0.001645	-0.112318	0.003005	-0.008391
BOT	10	-25	-0.001193	0.000927	0.000027	-0.000824	0.000559	-0.001606	-0.109650	0.002934	-0.008192
TOP	9	0	-0.001193	0.000927	0.000027	-0.001193	0.000927	0.000027	-0.158323	0.005306	0.000138
BOT	9	0	-0.001164	0.000904	0.000026	-0.001164	0.000904	0.000026	-0.154470	0.005177	0.000135
TOP	8	0	-0.001164	0.000904	0.000026	-0.001164	0.000904	0.000026	-0.154470	0.005177	0.000135
BOT	8	0	-0.001135	0.000882	0.000026	-0.001135	0.000882	0.000026	-0.150618	0.005047	0.000132
TOP	6	0	0.001187	-0.000923	-0.000026	0.001187	-0.000923	-0.000026	0.157615	-0.005282	-0.000132
BOT	6	0	0.001216	-0.000945	-0.000026	0.001216	-0.000945	-0.000026	0.161468	-0.005411	-0.000135
TOP	5	0	0.001216	-0.000945	-0.000026	0.001216	-0.000945	-0.000026	0.161468	-0.005411	-0.000135
BOT	5	0	0.001245	-0.000968	-0.000027	0.001245	-0.000968	-0.000027	0.165320	-0.005540	-0.000138
TOP	4	-25	0.001245	-0.000968	-0.000027	0.000860	-0.000583	0.001678	0.114435	-0.003061	0.008558
BOT	4	-25	0.001274	-0.000991	-0.000028	0.000880	-0.000597	0.001717	0.117102	-0.003132	0.008757
TOP	3	25	0.001274	-0.000991	-0.000028	0.000859	-0.000575	-0.001753	0.114293	-0.002995	-0.008939
BOT	3	25	0.001303	-0.001013	-0.000028	0.000879	-0.000588	-0.001793	0.116895	-0.003064	-0.009143
TOP	2	0	0.001303	-0.001013	-0.000028	0.001303	-0.001013	-0.000028	0.173026	-0.005799	-0.000145
BOT	2	0	0.001332	-0.001036	-0.000029	0.001332	-0.001036	-0.000029	0.176879	-0.005928	-0.000148
TOP	1	0	0.001332	-0.001036	-0.000029	0.001332	-0.001036	-0.000029	0.176879	-0.005928	-0.000148
BOT	1	0	0.001361	-0.001058	-0.000030	0.001361	-0.001058	-0.000030	0.180732	-0.006057	-0.000151

			Maximum Stress					Quad Poly		Hashin Criterion			
Position	Ply	Angle	FT	FC	MT	MC	S	(+)	(-)	FT	FC	MT	MC
		(^{o})											
TOP	13	0	0.000	6.331	13.741	0.000	1057.104	4.664	-10.599	0.000	6.331	13.740	0.000
BOT	13	0	0.000	6.475	14.052	0.000	1080.595	4.770	-10.840	0.000	6.475	14.051	0.000
TOP	12	0	0.000	6.475	14.052	0.000	1080.595	4.770	-10.840	0.000	6.475	14.051	0.000
BOT	12	0	0.000	6.625	14.378	0.000	1105.154	4.881	-11.091	0.000	6.625	14.377	0.000
TOP	11	25	0.000	9.812	27.243	0.000	18.230	6.912	-13.631	0.000	9.812	15.151	0.000
BOT	11	25	0.000	10.045	27.890	0.000	18.663	7.077	-13.955	0.000	10.045	15.511	0.000
TOP	10	-25	0.000	9.794	26.620	0.000	19.067	6.931	-13.817	0.000	9.794	15.501	0.000
BOT	10	-25	0.000	10.032	27.267	0.000	19.531	7.099	-14.153	0.000	10.032	15.878	0.000
TOP	9	0	0.000	6.948	15.078	0.000	1157.780	5.119	-11.631	0.000	6.948	15.077	0.000
BOT	9	0	0.000	7.121	15.454	0.000	1186.019	5.246	-11.921	0.000	7.121	15.453	0.000
TOP	8	0	0.000	7.121	15.454	0.000	1186.019	5.246	-11.921	0.000	7.121	15.453	0.000
BOT	8	0	0.000	7.303	15.850	0.000	1215.669	5.380	-12.226	0.000	7.303	15.848	0.000
TOP	6	0	13.514	0.000	0.000	37.863	1215.669	11.683	-5.141	13.513	0.000	0.000	37.836
BOT	6	0	13.192	0.000	0.000	36.959	1186.019	11.405	-5.019	13.191	0.000	0.000	36.934
TOP	5	0	13.192	0.000	0.000	36.959	1186.019	11.405	-5.019	13.191	0.000	0.000	36.934
BOT	5	0	12.884	0.000	0.000	36.098	1157.780	11.139	-4.902	12.883	0.000	0.000	36.073
TOP	4	-25	18.613	0.000	0.000	65.339	18.696	13.557	-6.802	13.191	0.000	0.000	16.892
BOT	4	-25	18.189	0.000	0.000	63.851	18.270	13.248	-6.647	12.890	0.000	0.000	16.507
TOP	3	25	18.636	0.000	0.000	66.769	17.898	13.375	-6.781	12.909	0.000	0.000	16.288
BOT	3	25	18.221	0.000	0.000	65.283	17.500	13.078	-6.630	12.622	0.000	0.000	15.925
TOP	2	0	12.310	0.000	0.000	34.490	1105.154	10.643	-4.684	12.310	0.000	0.000	34.466
BOT	2	0	12.042	0.000	0.000	33.739	1080.595	10.411	-4.581	12.041	0.000	0.000	33.716
TOP	1	0	12.042	0.000	0.000	33.739	1080.595	10.411	-4.581	12.041	0.000	0.000	33.716
BOT	1	0	11.785	0.000	0.000	33.020	1057.104	10.189	-4.484	11.785	0.000	0.000	32.997