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SE 160A: Project 5 Write Up

1. Perform a structural analysis of a single-cell aluminum wing for cruise and the four corners of the V-n diagram. The input data file is given at the end of this project statement. During this preliminary study, ignore stringer section properties (Iyy, Izz, Iyz). Using your results from the five analysis cases, fill out the following table and calculate the wing weight.

W = pL(4As + St), given that p is 0.1 lb/in^3, L is 250 inches, S is 98.49 inches, the other values are acquired by my code. The resultant wing weight is placed in the table below

		Cruise	PHAA	PLAA	NHAA	NLAA
MS stringer		-0.86272112	-0.96398191	-0.96540003	-0.90926488	-0.91715385
MS skin		2.859587386	-0.06934560	-0.08829493	1.276101557	0.485847175
Vertical Tip Displacement	(inch)	unable to complete				
Tip Twist	(degree)	-0.003695321	-0.7624224	0.0287223	0.390424229	1.181569014
Wing Weight	(lb)	143.10808589201				

2. Perform a structural analysis of a single-cell carbon/epoxy wing for cruise and the four corners of the V-n diagram. The input data file is given at the end of this project statement. Neglect stringer section properties. Using your results from the five analysis cases, fill out the following table and calculate the wing weight assuming the density of carbon/epoxy is (p = 0.056 lb/in3).

		Cruise	PHAA	PLAA	NHAA	NLAA
MS stringer		-0.16800924	-0.78040296	-0.78837694	-0.44503871	-0.49328984
MS skin		11.13013178	1.924913803	1.865358772	6.153462036	3.669805407
Vertical Tip Displacement	(inch)	unable to complete				
Tip Twist	(degree)	-0.00230957	-0.47651401	0.0179514	0.24401514	0.738480634
Wing Weight	(lb)	80.140528099				

3. Using the results from the table in Step 1, determine the minimum stringer area (As) and minimum skin thickness (ts) so that all the margins are safety for all five analysis cases are greater than or equal to zero. Rerun the five analysis cases from step (1) with the new section properties and fill out the table. (Hint: All MS > 0)

Stringer Area minimum (inch^2)	5.78035219468244
Skin Thickness minimum (inch)	0.0548422971229736

** Work for this calculation is shown on the attached pages at the end

		Cruise	PHAA	PLAA	NHAA	NLAA
MS stringer		2.931474791	0.037680032	-3.3680E-08	1.622404500	1.394399435
MS skin		3.233372986	0.020784547	5.24599E-08	1.496532888	0.629745530
Vertical Tip Displacement	(inch)	unable to complete				
Tip Twist	(degree)	-0.00336904	-0.69510434	0.026186321	0.35595172	1.077242397
Wing Weight	(lb)	713.0658115				

4. Using the results from the table in Step 2, determine the minimum composite stringer area (As) and minimum composite skin thickness (ts) so that all the margins are safety for all five load cases are greater than or equal to zero. Rerun the five analysis cases from step 2 with the new section properties and fill out the table.

Stringer Area minimum (inch^2)	0.945076594567852
Skin Thickness minimum (inch)	0.0174498218118552

** Work for this calculation is shown on the attached pages at the end

		Cruise	PHAA	PLAA	NHAA	NLAA
MS stringer		2.931474946	0.037680073	5.74783E-09	1.622404603	1.3943995
MS skin		3.233372324	0.020784387	-1.0383E-07	1.496532498	0.6297452
Vertical Tip Displacement	(inch)	unable to complete				
Tip Twist	(degree)	-0.00661776	-1.36538375	0.051437425	0.699191003	2.11601218
Wing Weight	(lb)	76.98428572				

5. Comment on the weight savings between the aluminum wing and the composite wing.

In order to withstand the loadings, the Aluminum wing needed to weigh 713.1 pounds, while the carbon epoxy wing only required 77.0 pounds of weight (which is actually lighter than the original sizing). Thus, the carbon epoxy wing has the same performance for just 10.80% of the weight. Essential for aircraft who need to be lightweight.

Find minimum Stringer Area for Aluminum Wing

Worst case scenario found to be

P4AA
stringer #2 } MS = -0.964

$\sigma_{xx} = 798.43$ klb/in^2

$\sigma^*_{xx\,tension} = 28.66\bar{6}$ ksi

$MS = 0 = \frac{\sigma^*_{xx\,tension}}{\sigma_{xx}} - 1$

find
$\sigma_{xx} = 28.66\bar{6}$ ksi

(1) $\sigma_{xx} = \frac{(M_y)E(z)}{EI_{yy}} - \frac{(M_z)(E)(y - EY_c)}{EI_{zz}}$

$EI_{yy} = \cancel{4} \cdot E \cdot (0 + \text{Area } z^2)$

2 only 2 stringers contribute to I_{yy}

(2) $EI_{yy} = 2E(A)z^2$

$EI_{zz} = 4 \cdot E \cdot (0 + \text{Area}(y_{st} - EY_c)^2)$

$EI_{zz} = \sum^{4} EA(y_{st} - EY_c)^2$

$EY_c = 20$ inch $\quad Y_{st} = [0 \ 16 \ 48 \ 16]$

$EI_{zz} = EA(20^2 + 4^2 + 28^2 + 4^2)$

(3) $EI_{zz} = 1216\,EA$

Combining (2) and (3) into (1)

$\sigma_{xx} = \frac{M_y \cancel{E} z_2}{2\cancel{E} A z^2} - \frac{M_z E(y_2 - EY_c)}{1216 \cancel{E} A}$ $\quad \times \frac{[A]}{\sigma_{xx}}$ both side

$A = \frac{M_y}{2z\,\sigma_{xx}} - \frac{M_z(y_2 - EY_c)}{1216\,\sigma_{xx}}$

~~substitute~~
~~$M_y = -114791.6$ lb/in~~
~~$M_z = 77083.3$ lb/in~~
~~$\sigma_{xx} = \sigma^*_{xx} = 28{,}666.\bar{6}$ lb/in^2~~
~~$z_2 = -3.6$ in~~
~~$y_2 = 16$ in~~
~~$EY_c = 20$ in~~

~~$A = \frac{(-114796)}{2(-3.6)(28.666)} - \frac{(77083)(-4)}{1216(28.666)}$~~

using matlab values & matlab to calculate

$\boxed{\cancel{A_{min} = 5.5105 \text{ in}^2}}$

Aluminum stringers

* Correction

$$A = \frac{M_y}{2z\,\sigma_{xx}^*} - \frac{M_z(y_2 - EY_c)}{1216\,\sigma_{xx}^*}$$

substitute

$M_y = -1147916$ lb/in
$M_z = 1906250$ lb/in
$\sigma_{xx}^* = 28,666$ lb/in^2
$z = -3.6$ in
$y = 16$ in
$EY_c = 20$ in

$$A = \frac{-1147916}{2(-3.6)(28,666)} - \frac{1906250(-4)}{1216(28,666)}$$

using matlab

$\boxed{A_{min} \approx 5.780 \text{ in}^2 \text{ aluminum stringers}}$

For Carbon-Epoxy Wing

Geometry is the same so same derivation

$$A = \frac{M_y}{2z\,\sigma_{xx}^*} - \frac{M_z(y_2 - EY_c)}{1216\,\sigma_{xx}^*}$$

$$MS = 0 = \frac{\sigma_{xx}^*}{\sigma_{xx}} - 1$$

$\sigma_{xx}^* = 175,333$ lb/in^2

Worst-case scenario
RLAA
Stringer #2 } $MS = -0.788$

$S_{xx} = 828.51$

substitute

$M_y = -1147916$ lb/in
$M_z = 1906250$ lb/in
$y = 16$ in
$z = -3.6$ in
$EY_c = 20$ in

$$A = \frac{-1147916}{2(-3.6)(175,333)} - \frac{1906250(-4)}{1216(175,333)}$$

using matlab

$\boxed{A_{min} \approx 0.945 \text{ in}^2 \text{ carbon Epoxy stringers}}$

Find minimum skin thickness for Aluminum Wing

Worst case scenario found to be

PLAA
skin #4→1 } MS = −0.06935

$\tau_{sk} = -20.058$ ksi

$\tau^*_{sk} = 18.66\bar{6}$ ksi

$MS = 0 = \frac{|\tau_{sk}|}{\tau^*_{sk}} - 1$

find: $\tau_{sk} = -18.66\bar{6}$ ksi

$\tau_{sk} = \frac{q}{t}$

$t = \frac{q}{\tau_{sk}}$

q is influenced by: Area enclosed, P_z, P_y, EI_{yy}, EI_{zz}, y-coordinates, z-coordinates, M_x } not a function of thickness ✓

$q(4) = \cancel{-1002.879}$ #b/in

$\tau^*_{sk}(4) = -18.665$ klb/in²

$\cancel{t_{min} \approx \frac{-1002.879}{-18.666}}$

using matlab values to be exact

$\boxed{\cancel{t_{min} \approx 0.0538 \text{ inch}}}$

aluminum skin

* Correction

$q(4) = -1023.723$

$t_{min} = \frac{-1023.723}{-18.666}$

using matlab

$\boxed{t_{min} \approx 0.0548 \text{ inch aluminum}}$

For Carbon Fiber Epoxy skin

Worst case scenario is actually a positive MS!

weight savings

PLAA
skin #4→1 } MS = 1.865

$$MS = 0 = \frac{|\tau_{sk}|}{\tau_{sk}^*} - 1$$

$$\tau_{sk} = 58.66\bar{6}$$

$$\tau = \frac{q}{t}$$

$$t = \frac{q(4)}{\tau_{sk}^*} = \frac{-1022.723}{-58.66\bar{6}}$$

$$\boxed{t_{min} \approx \underline{0.01745} \text{ in} \quad \text{carbon fib skin}}$$