Step 1: Preliminary structural analysis and design of an aluminum wing spar

Perform a structural design study of a single-cell aluminum wing spar for stall, cruise, and the four corners of the *V-n* diagram. The input loads data are given in Table 2 and the material properties are given in Table 3. It is recommended that you start with a nominal wall thickness of (t = 0.150 inch) and perform the analysis for all six flight conditions. Identify which flight condition produces the lowest margin of safety. If the lowest MS is positive then reduce the wall thickness and rerun the six load cases. If the lowest MS is less than zero, then increase the wall thickness and rerun the six load cases. Repeat this iterative design approach until the wall thickness has converged to at least three significant figures. Using your final converged results from the six analysis cases, fill out the following table and calculate the aluminum spar weight. Also calculate the spar "unloaded self-weight" tip deflection. Include the spar weight in your calculations.

Aluminum Spar	*units*	*Stall*	*Cruise*	*PHAA*	*PLAA*	*NHAA*	*NLAA*
MS – spar (minimum)		1.019	1.019	0.0099	0.0099	1.018	1.0177
Tip vertical displacement	(inch)	69.56	69.56	139.111	139.11	-69.56	-69.56
Tip twist	(degree)	0.274	0.104	0.208	0.401	-0.621	-0.943
Spar weight	(lb)	65.52					
Spar self-weight tip deflection	(inch)	118.55					

$\boxed{t = 0.079 \text{ in}}$

Step 2: Preliminary structural analysis and design of a carbon/epoxy wing spar

Repeat step one using the carbon/epoxy material properties

Carbon / Epoxy Spar	*units*	*Stall*	*Cruise*	*PHAA*	*PLAA*	*NHAA*	*NLAA*
MS – spar (minimum)		1.046	1.046	0.0232	0.0232	1.046	1046
Tip vertical displacement	(inch)	189.87	189.87	379.73	379.73	-189.87	-189.87
Tip twist	(degree)	0.46	0.177	0.35	0.683	-1.06	-1.606
Spar weight	(lb)	13.47					
Spar self-weight tip deflection	(inch)	28.26					

$\boxed{t = 0.029 \text{ in}}$

Step 3:

a) The weight of the carbon/epoxy spar is less than the weight of the aluminum spar. As both spars carry about same loads, this shows the effectiveness of the composite materials. Carbon/epoxy is very strong and much lighter than aluminum hence an ideal application to lower the total weight of the aircraft.

b) To reduce the tip displacement, one can increase the length of the spar, the Young's modulus, or increase the area.

c) The deflection of the aluminum is greater than the deflection of the carbon/epoxy spar. This is related to the weight of the spar as the composite spar is lighter.

d) After a careful design and material selection, a mold must be created for a composite spar. Then the fiber layers of the composite must be laid and mixed to be cured. After the composite cures, it must be inspected and trimmed. Finally, it can be assembled.
An aluminum should first go through raw material preparation to eliminate imperfections. Then after machining, it must be formed in to the correct shape before assembling.The spar can also be heat treated to enhance its properties. Finally it must be inspected before/after assembly.