MEMORANDUM

4/16/2026

TO: Eric Ocegueda, Assistant Professor, Mechanical Engineering
FROM: Apolonio Ordaz, ME 328 – 02
SUBJECT: Lab 2: Intro to FEA

Overview

In this lab we were tasked with designing and evaluating the geometry and materials for an airplane wing spar, using SolidWorks Simulations. The design of the wing spar was fixed at 70 ft (840 inches), and a maximum cross section of 12 in in height, and 10 in in width. The design target was having a max tip deflection between 9-10 inches under specified loading conditions.

Two cross sections were evaluated, and I beam and hollow rectangular cross section as well as two materials, 7075-T6 Aluminum Alloy and AISI 4130 steel normalized at 870 degrees Celsius. These options produced 4 combinations. For each combination, the geometric dimensions were iterated until the target deflection was met.

Methods

Each wing spar was modeled as a cantilever beam that was fully fixed on one end and free at the tip. Beam Elements were used for all models with an element size of 1 inch. Beam elements were selected as extremely accurate when length of part is large compared to the cross-sectional dimensions, much like in this scenario.

In order to set up the simulation and confirm its accuracy, three different loading conditions were used on an I-Beam cross section made of 7075-T6 Aluminum Alloy. The dimensions, as seen in Figure one, were arbitrary and just used to confirm the simulation.

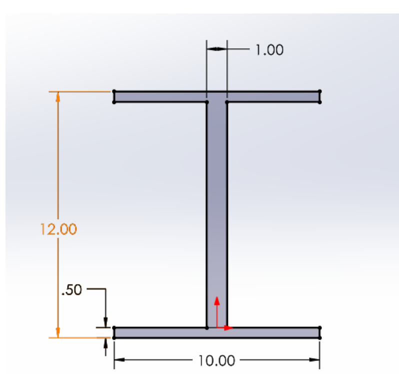


Figure 1. FEA Simulation arbitrary Configuration, I beam, 7075-T6 Aluminum Geometry

In order to validate the model, the first loading condition utilized was an evenly disturbed load acting upwards on the beam in order to simulate the effects of lift as seen in Figure 2. This was done utilizing the "per unit length," option found in SolidWorks and setting it to 3lbf/ in. The results obtained from the simulation were validated against hand calculations present in Appendix A.

<u>FEA Simulation Max Deflection</u>: 40.50 inches   <u>Hand Calculations Max Deflection</u>: 40.47 inches

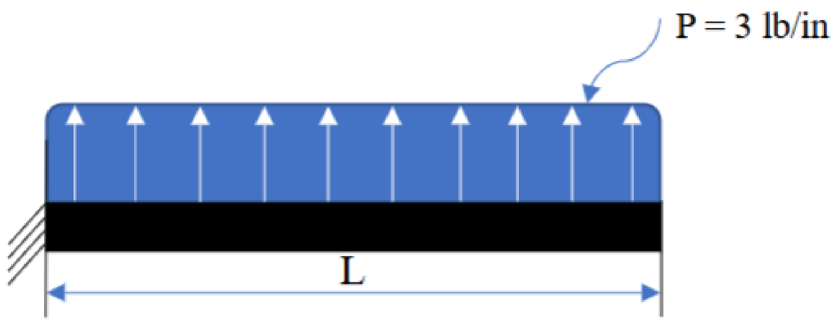


Figure 2. Evenly Distributed Loading Condition

Once the simulation was confirmed, a new triangular loading configuration was used as seen in Figure 3. This was done by selecting a nonuniform distributed and using the table-driven load distribution. This configuration provides a better analysis of the loading conditions experienced by an aircraft as further away from the body the wing diameter thins out and experiences less lift force. The maximum deflection provided by this simulation was 10.8 inches, which tracks with the reasoning stated.

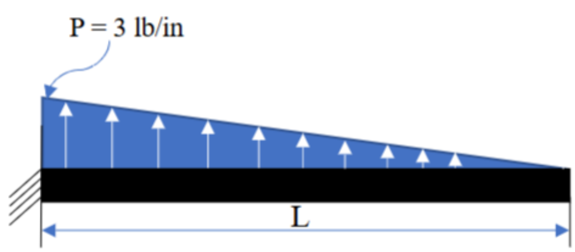


Figure 3. Triangular Distributed Loading Condition

This distributed load is a better model but still misses a major component which is the engine. In order to simulate this, a point load was utilized with the help of a point reference geometry and set at a distance of 240 inches or L/3 away from the fixed end of the wing. The mix of point load and distributed load is showcased in Figure 4. The maximum deflection after running this new loading conditions was 13.17 inches. This number makes sense as it is higher than just the triangular loading condition.

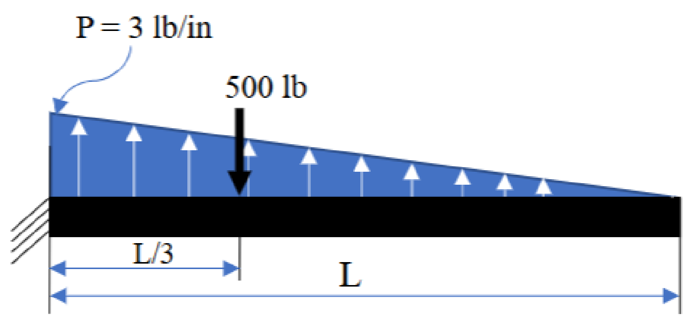


Figure 4. Triangular Distributed Loading and Fixed Loading Condition

The following table summarizes the maximum tip deflection for each load case applied for each beam with 7075-T6 aluminum and I beam cross section with the fixed arbitrary geometry seen in Figure 1.

Table 1.

Load Case	Max Deflection
Uniform (3lb/in)	40.5
Triangular (3lb/in peak)	10.8
Triangular +500 lb. point load	13.17

Optimizing Cross Section

From here, load case 3 (Triangular +500 lb. point load) seen in figure 4, was kept. There were 4 combinations that were produced that included two different cross sections and two different materials. These were I beam and Box beam, for the cross section, and 7075-T6 aluminum and 4130 steels. The geometry sizes were iterated for all 4 combinations until they reached the target range between 9 and 10 inches. During iteration, the general idea increased the inertia of the cross section in order to minimize the deflection. This relationship of increase inertia having lower deflection could be seen in the equation for max deflection for a fixed cantilever beam.

The combinations along with Deflection, weight, and cost were tabulated in table 2 seen below. Figures 5-8 also demonstrate the geometry that was obtained, in respect to each combination, to receive the maximum deflections and Von mises stresses.

Table 2.

Combo	Cross Section	Material	Max Deflection (in)	Max Stress (psi)	Weight (lbs.)	Est Cost (USD)
1	I-Beam	7075-T6 Al	9.78	4760	1969	$13,783.00
2	I-Beam	4130 Steel	9.544	13325	2596	$25,960.00
3	Box Beam	7075-T6 Al	9.378	3259	1705	$11,935.00
4	Box Beam	4130 Steel	9.3	6694	3335	$33,350.00

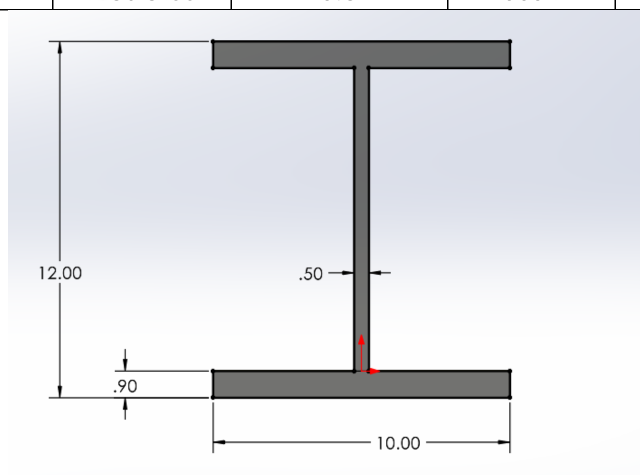


Figure 5. Combination 1: 7075-T6 Aluminum, I-beam Geometry

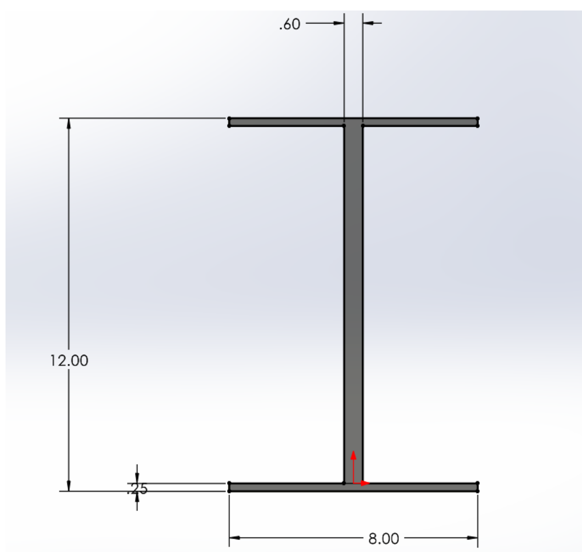


Figure 6. Combination 2: 4130 Steel, I-beam Geometry

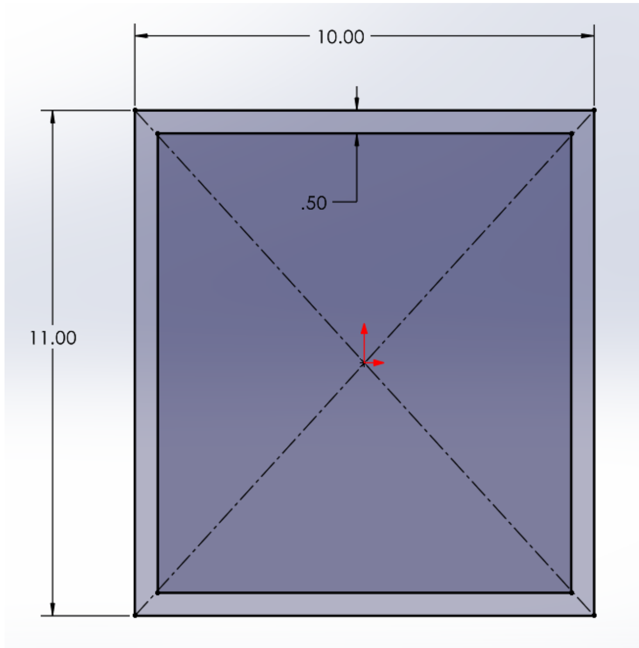


Figure 7. Combination 3: 7075-T6 Aluminum, Box-beam Geometry

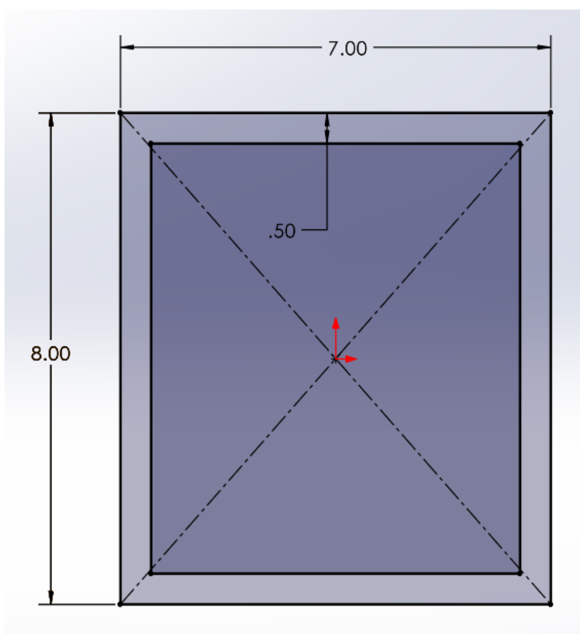


Figure 8. Combination 4: 4130 Steel, Box-beam Geometry

Final Recommendations

Based on the simulation results and the cost, combination 3, the box beam made of 7075-T6 aluminum, would be the recommendation for the wing spar design.

This combination achieved a maximum deflection of 9.378 inches, which is within the acceptable target range, while also remaining the lowest in weight among the other combinations, at 1705 lbs. In aerospace applications, the mass of the plane directly impacts the fuel efficiency and payload capacity that the aircraft can achieve. This is especially useful when price of fuel is on the rise and can spike due to unforeseen world events. Compared to combination one which had a weight of 1969 lbs., this has a weight difference of over 260 lbs.

Combination 3 also provides the lowest estimate material cost at $11,935 USD, making it the most economical choice in addition to its weight advantages. Although combination 1 is similar, the slightly higher cost and higher weight do not make it the ideal option. This same reasoning is applied to combination 2 and 4, which are both made of 4130 Steel. These two combinations are much heavier, and cost significantly more compared to combination 1.

Lastly, combination 3 also experiences the Von misses Stress, which is lower compared to the yield strength of 7075-T6 aluminum, which is around 73,000 psi. This produces a factor of safety of around 22.4 which far exceeds the risk of yielding under the applied loads.

It is for these reasons that combination 3, the box beam made of 7075-T6 Aluminum, is the optimal choice as it provides the best balance of structural performance, weight, and cost effectiveness, making it the design that is recommended.

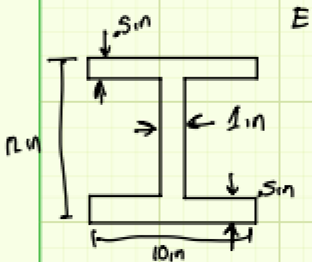
Appendix A

Hand Calculations

ORIGINAL HAND Calculations

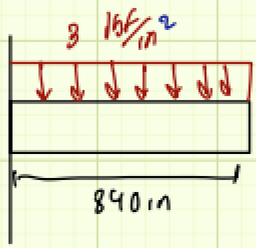
Material → 7075-T6 Aluminum Alloy

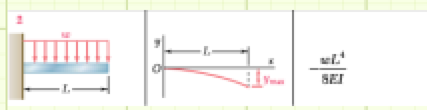
$E = 10{,}442{,}717.11$ Psi



$$I = \frac{1}{12}(10)(12)^3 - 2\left[\frac{1}{12}(4.5)(11)^3\right]$$

$$I = 441.75 \text{ in}^4$$



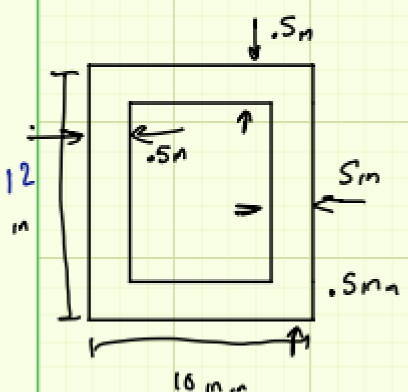


Max Deflection

$$y = \frac{3 \frac{\text{lbf}}{\text{in}} (840\text{in})^4}{8(10{,}442{,}717.11 \frac{\text{lbf}}{\text{in}^2})(441.75\text{in}^4)}$$

$y = 40.47$ inches

Calculated $= 40.50$ Inches

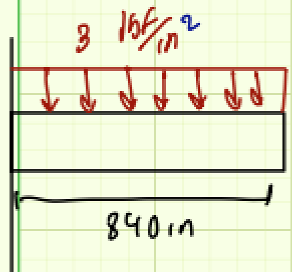


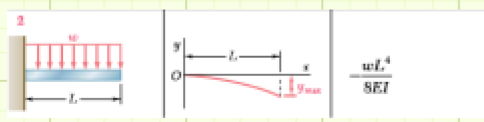
7075-T6 Aluminum Alloy

$E = 10{,}442{,}717.11$ Psi

$$I = \frac{1}{12}\left[(10)(12)^3 - ((9)(11)^3)\right]$$

$I = 441.75$ in^4





Max Deflection

$$y = \frac{3\ \frac{lbf}{in}\,(840in)^4}{8\left(10{,}442{,}717.11\ \frac{lbf}{in^2}\right)(441.75\ in^4)}$$

$y = 40.47$ inches

✓

FEA = 40.50 Inches