MAE 154B Wing Design Project - Preliminary Design Report

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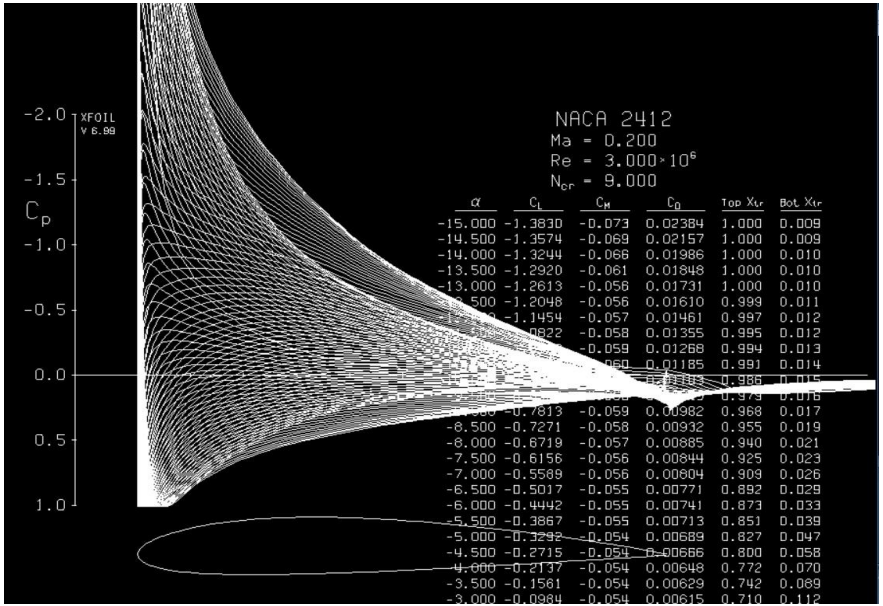
Contents

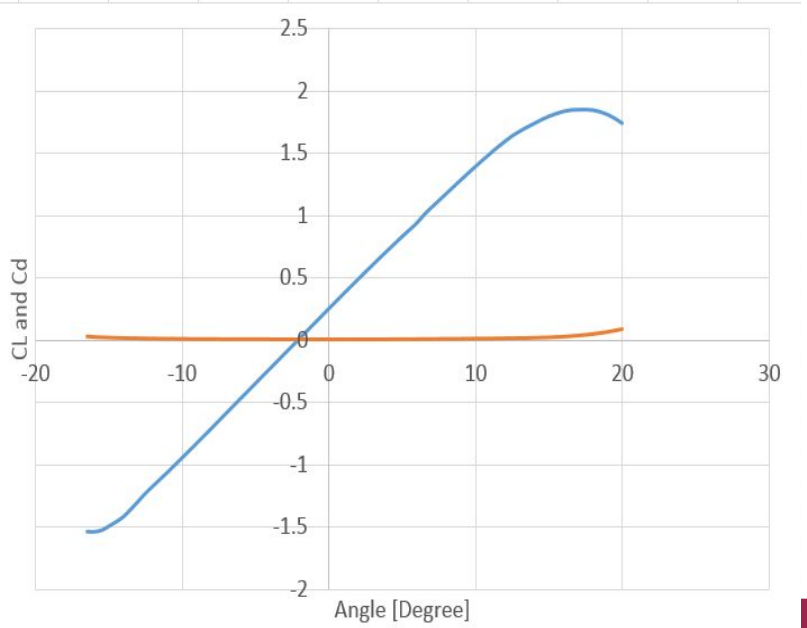
Project Requirements

- Wing structure design for utility aircraft.
- Efficient characteristics: low drag, low weight, high lift, and reliable structure.
- Satisfy Federal Aviation Regulations (FAR) Part 23
- Initial Estimation:
  - Airfoil: NACA-2412
  - MTOW: 2000 lb
  - Chord: 4’5”
  - Semi-span: 18.5’
  - Cruising speed: 87.5 m/s
  - Dive speed: 131.2 m/s
  - Load factor: from -1.76 to 4.4

Aerodynamic Calculations

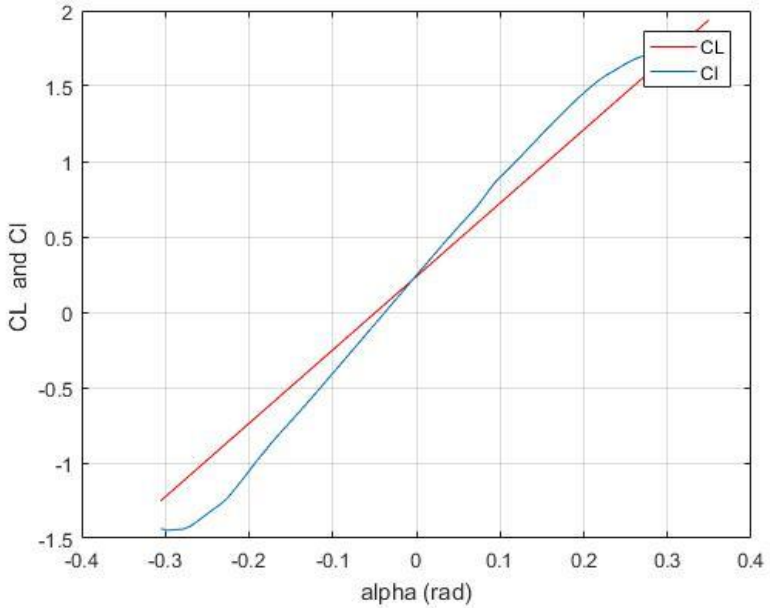


α	C_L	C_M	C_D	Top X_{tr}	Bot X_{tr}
-15.000	-1.3830	-0.073	0.02384	1.000	0.009
-14.500	-1.3574	-0.069	0.02157	1.000	0.009
-14.000	-1.3244	-0.066	0.01986	1.000	0.010
-13.500	-1.2920	-0.061	0.01848	1.000	0.010
-13.000	-1.2613	-0.058	0.01731	1.000	0.010
[illegible]	-1.2048	-0.056	0.01610	0.999	0.011
[illegible]	-1.1454	-0.057	0.01461	0.997	0.012
[illegible]	[illegible]822	-0.058	0.01355	0.995	0.012
[illegible]	[illegible]	-0.059	0.01268	0.994	0.013
[illegible]	[illegible]069	[illegible]	0.01185	0.991	0.014
[illegible]	[illegible]	[illegible]	[illegible]	0.986	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	-0.7813	-0.059	0.00982	0.968	0.017
-8.500	-0.7271	-0.058	0.00932	0.955	0.019
-8.000	-0.6719	-0.057	0.00885	0.940	0.021
-7.500	-0.6156	-0.056	0.00844	0.925	0.023
-7.000	-0.5589	-0.056	0.00804	0.909	0.026
-6.500	-0.5017	-0.055	0.00771	0.892	0.029
-6.000	-0.4442	-0.055	0.00741	0.873	0.033
-5.500	-0.3867	-0.055	0.00713	0.851	0.039
-5.000	-0.3292	-0.054	0.00689	0.827	0.047
-4.500	-0.2715	-0.054	0.00666	0.800	0.058
-4.000	-0.2137	-0.054	0.00648	0.772	0.070
-3.500	-0.1561	-0.054	0.00629	0.742	0.089
-3.000	-0.0984	-0.054	0.00615	0.710	0.112

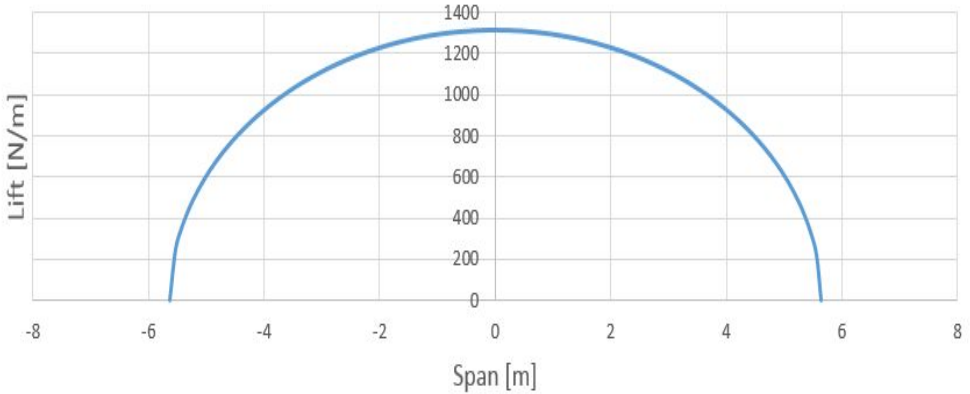


CL and Cd data of NACA-2412 are collect from X-foil and plotted by MS Excel. Then, the best value of lift and drag performance is at 0.5 degree AoA

Aerodynamic Calculations



2D and 3D CL values versus AoA in radians at 12000 ft Alt



Lift Distribution through the wingspan at 12000 ft Alt

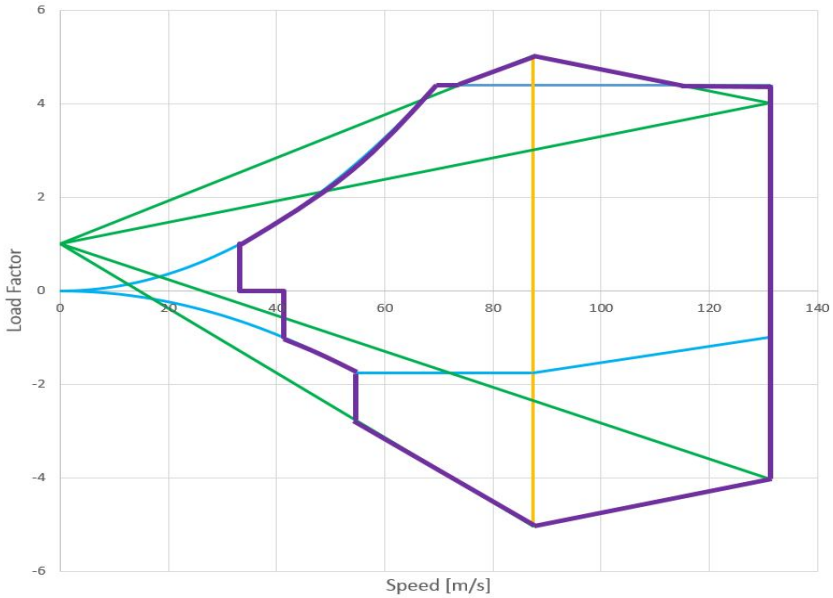
V-n Diagram

The Values of Speed and Load Factor in Critical Conditions

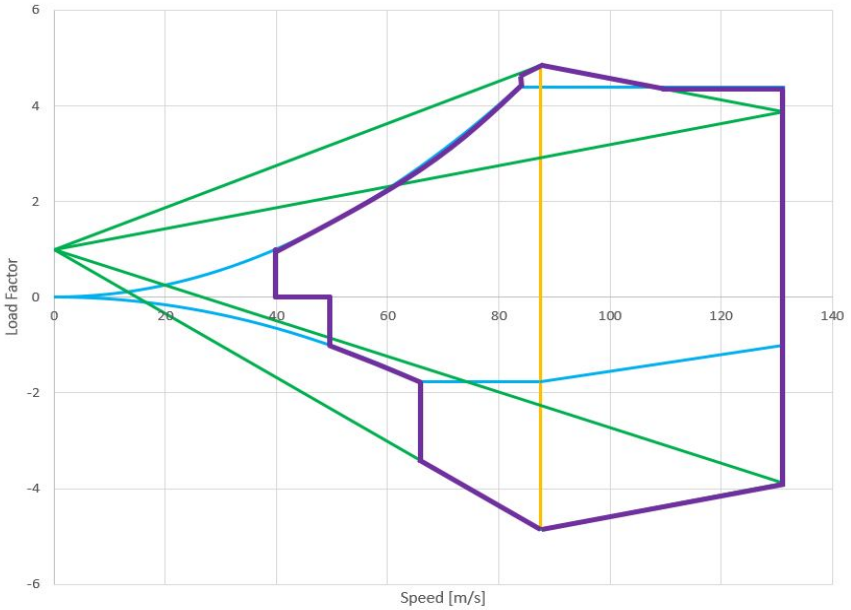
Conditions	Velocity [m/s]	Load Factor
Positive Stall	39.84	1
Negative Stall	49.61	-1
PHAA	83.57	4.4
PLAA	87.50	4.4
NLAA	87.50	-1.76
NHAA	65.81	-1.76

The values of the critical conditions are calculated for boundaries of the V-n diagram. All the conditions are based on FAR Part 23 for utility aircraft.

V-n Diagram

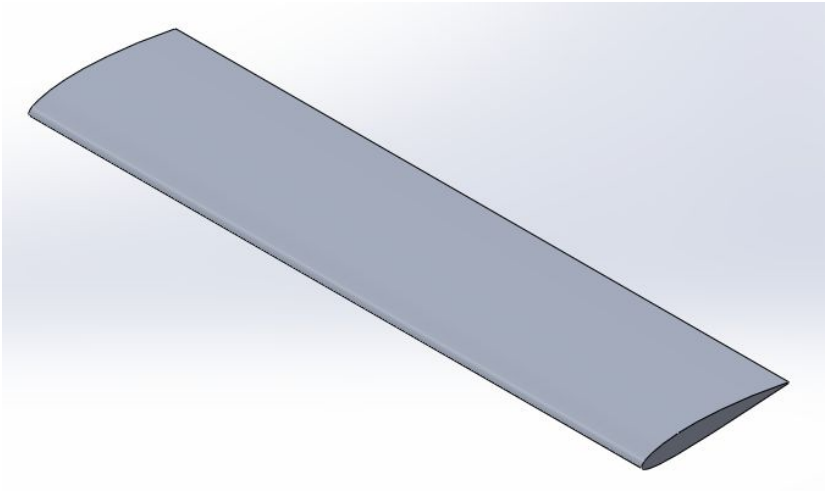


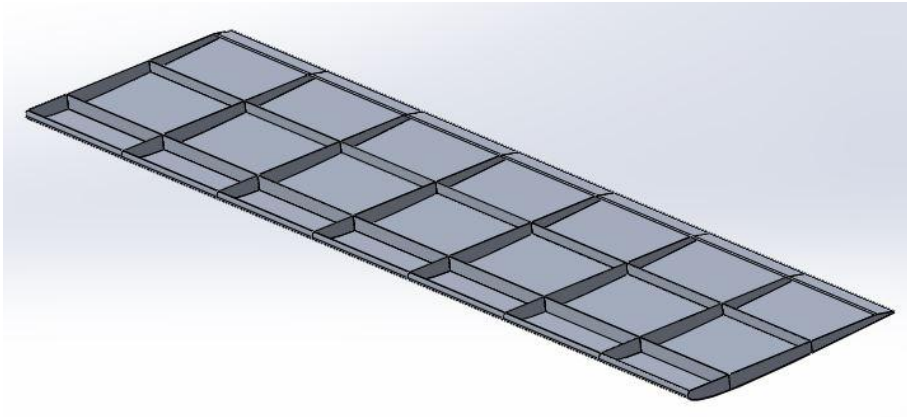
V-n diagram at Sea Level



V-n diagram at 12000 ft Alt

Preliminary Structural Design

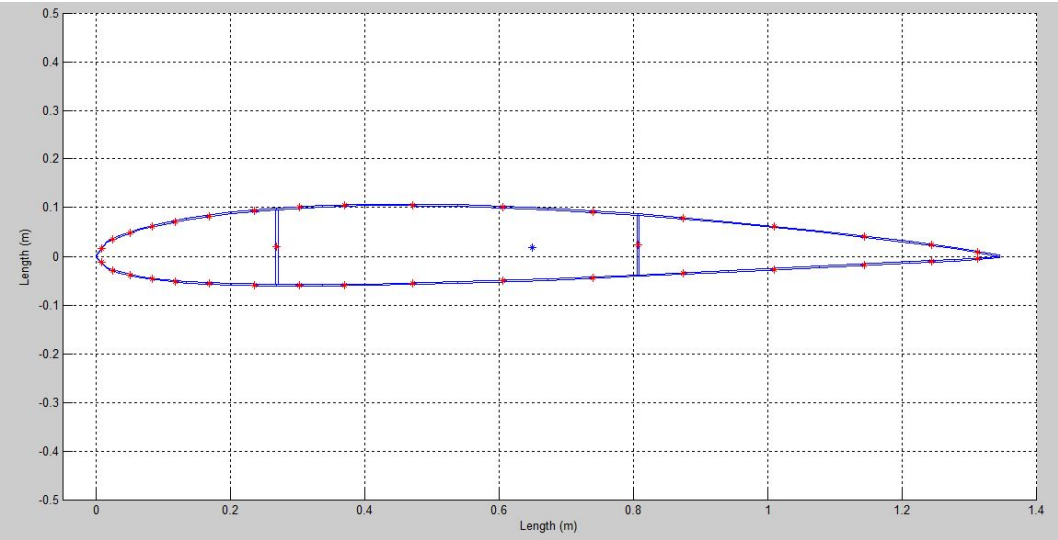


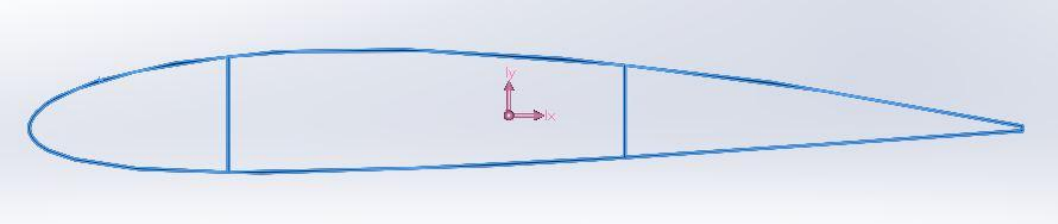


CAD model created in Solidworks

- 2 spars with 8 ribs
- Everything 3 mm thick

Preliminary Structural Analysis - Centroid/Inertia





Based on preliminary design shape, calculated centroid location and area moment of inertia:

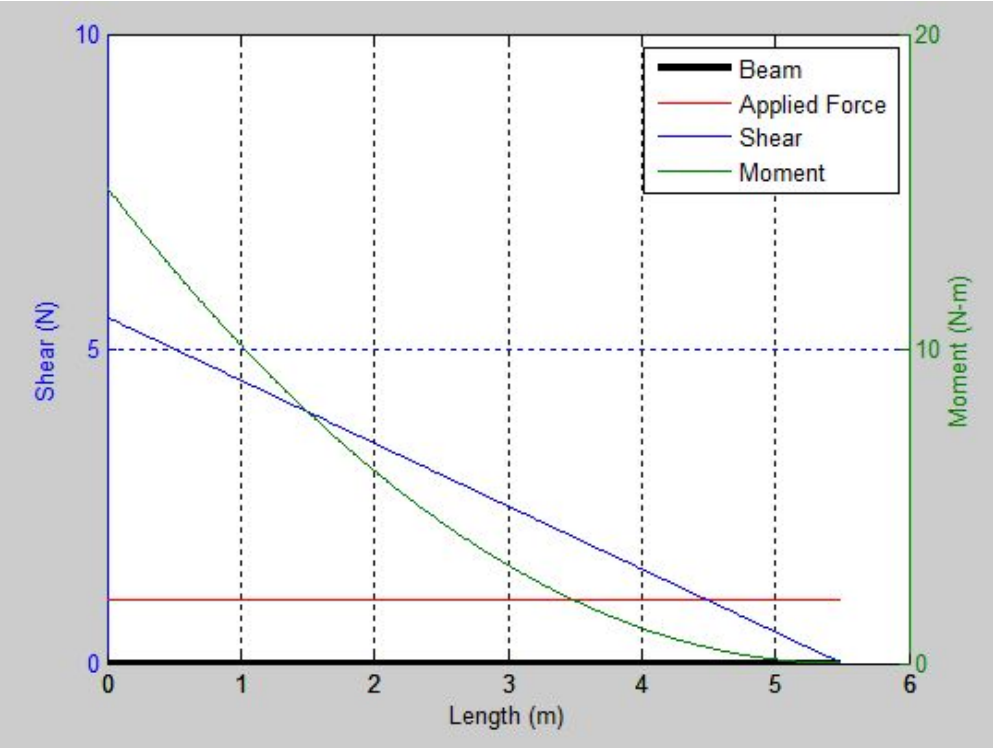
- Numerical Method (Matlab)
- Measurement from CAD model

Preliminary Structural Analysis - Centroid/Inertia

Compared calculated and measured result in the following table to valid the code in numerical analysis.

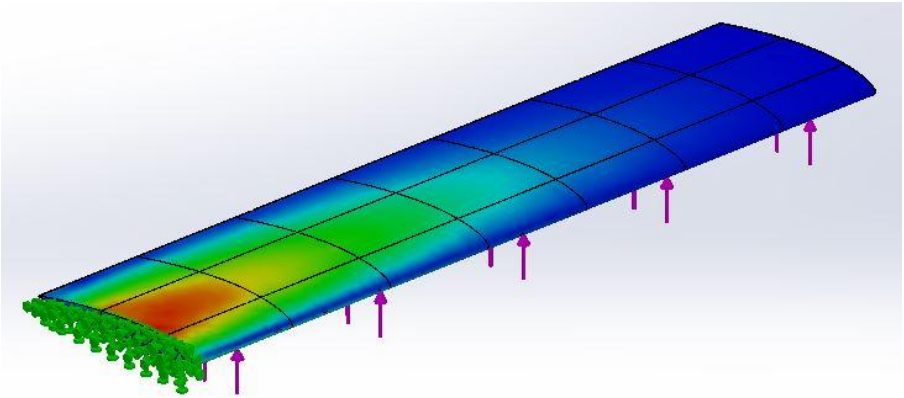
	Cx (m)	Cy (m)	Ixx (m4)	Iyy (m4)	Ixy (m4)
Numerical Method	6.498*10-1	1.742*10-2	3.207*10-5	1.357*10-3	-3.963*10-6
Measured from CAD	6.503*10-1	1.758*10-2	3.45*10-5	1.461*10-3	-3.42*10-4
Percent Error	0.077%	0.91%	7.0%	7.1%	15.9%

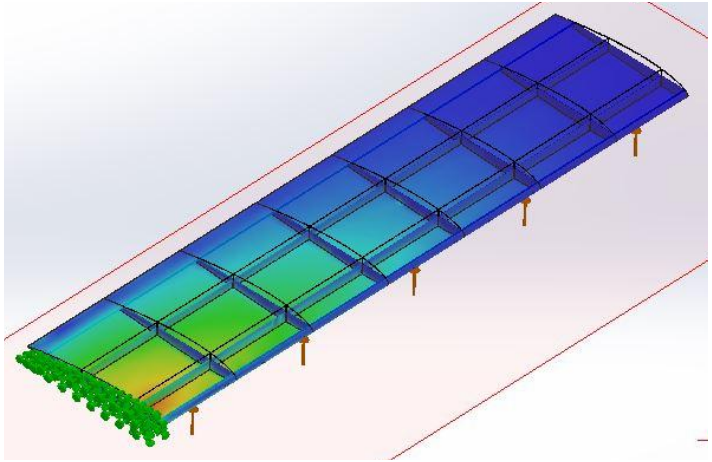
Preliminary Structural Analysis - Shear/Moment



Using a simple cantilever beam under uniform distributed load to valid numerical analysis code for calculation shear and moment along the wingspan.

Preliminary Structural Analysis - FEA





Preliminary FEA was done in CAD model to find high stress area and the general trend to help refine design in the next step.

Future Work

- Add spar caps, stringers in the structure
- Remove wing flaps and aileron from structure calculation
- Update centroid and moment of inertia
- Calculate shear and moment along wingspan based on loading conditions in numerical analysis
- Calculate rotation and deflection of the wing under load
  - Check numerical result with FEA simulation
- Refine design by adding or reduce number ribs, length spars etc.

Thank You!

Q&A