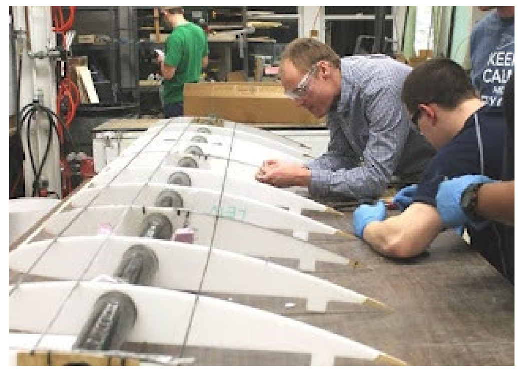
DESIGN STUDY



Now let's use your MATLAB code to perform a preliminary structural analysis of the main wing of a human-powered aircraft having a wing span of 110 feet and a wing chord of 3 feet. An engineering drawing of the MIT-built world record holder human powered aircraft is presented in Figure 1. Their aircraft had an empty weight of 70 lbs and a maximum vehicle weight of 230 lbs that included a 160 lb pilot. All of the structural performance of the wing comes from a single structural wing spar having a thin-wall circular cross-section. In the current study, the spar length for one-half of the wing span is 55 feet and the mean radius of the thin-wall circular cross-section is 2.0 inch. These two parameters can not be changed in this study. The aircraft flight speed and angle of attack for six different flight conditions are given in Table 1. Note the Table 1 data is not needed for your study, it is only presented to provide background information for the needed flight load data provided in Table 2.

The goal of this project is to (1) determine the minimum aluminum wall thickness that satisfies all six flight load conditions (i.e. MS >0, for every point on the spar for all six flight conditions), and (2) the minimum carbon/epoxy wall thickness that satisfies all six flight load conditions, and (3) compare the spar weight of the two different material options. The aluminum and graphite/epoxy material properties are given in Table 3.

Table 1: Flight speeds and wing angle of attack for stall, cruise, and the four corners of the V-n diagram

		Load Cases						
Variable	**Description**	***Stall***	***Cruise***	***PHAA***	***PLAA***	***NHAA***	***NLAA***	**Units**
V	Flight Speed	***13.50***	***19.00***	***19.09***	***22.80***	***13.50***	***22.80***	mph
V	Flight Speed	***19.80***	***27.87***	***28.00***	***33.44***	***19.80***	***33.44***	ft/sec
α	Wing Angle of Attack	***12.87***	***5.51***	***12.87***	***8.43***	***-16.87***	***-7.21***	degree

Table 2: Load case parameters for stall, cruise, and the four corners of the V-n diagram

		Load Cases						
Variable	**Description**	***Stall***	***Cruise***	***PHAA***	***PLAA***	***NHAA***	***NLAA***	**Units**
n	Aircraft Load factor	***1***	***1***	***2***	***2***	***-1***	***-1***	1
p_{yo}	Drag distribution (constant)	***0.00226***	***0.00226***	***0.00453***	***0.00428***	***0.00226***	***0.00269***	lb/in
p_{yr}	Drag distribution (rth order)	***0.00151***	***0.00151***	***0.00302***	***0.00285***	***0.00151***	***0.00180***	lb/in
r	Drag distribution (polynomial order)	***5***	***10***	***5***	***5***	***8***	***8***	1
p_{zo}	Lift distribution (constant)	***0.19451***	***0.19451***	***0.38902***	***0.38902***	***-0.19451***	***-0.19451***	lb/in
p_{z2}	Lift distribution (2nd order)	***-0.05447***	***-0.05447***	***-0.10895***	***-0.10895***	***0.05447***	***0.05447***	lb/in
p_{z4}	Lift distribution (4th order)	***-0.01362***	***-0.01362***	***-0.02724***	***-0.02724***	***0.01362***	***0.01362***	lb/in
m_{xo}	Twist moment distribution (constant)	***0.32773***	***0.12453***	***0.24906***	***0.47887***	***-0.74208***	***-1.12584***	lb-in/in
m_{x1}	Twist moment distribution (1st order)	***0***	***0***	***0***	***0***	***0***	***0***	lb-in/in

Table 3: Aluminum and Graphite/Epoxy Properties

Property	*Al 7075-T6*	*Carbon/epoxy*	*Units*
ρ	0.10	0.056	lb./in^3
E	10	23.5	Msi
G	3.75	6	Msi
σ_{Ty}	37	263	Ksi
σ_{Tu}	43	263	Ksi
σ_{Cy}	-37	-263	Ksi
σ_{Cu}	-43	-263	Ksi
τ_y	24	88	Ksi
τ_u	28	88	Ksi

<u>Step 1: Preliminary structural analysis and design of an aluminum wing spar</u>

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)							
Tip vertical displacement	(inch)						
Tip twist	(degree)						
Spar weight	(lb)						
Spar self-weight tip deflection	(inch)						

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

Repeat step one using the carbon/epoxy material properties

Carbon / Epoxy Spar	*units*	*Stall*	*Cruise*	*PHAA*	*PLAA*	*NHAA*	*NLAA*
MS – spar (minimum)							
Tip vertical displacement	(inch)						
Tip twist	(degree)						
Spar weight	(lb)						
Spar self-weight tip deflection	(inch)						

<u>Step 3: Comment on the following:</u>

a) Compare the weight of the aluminum wing spar and the composite wing spar having a (min MS > 0).
b) If the in-flight maximum tip displacement is excessive, recommend ideas for reducing the tip displacement.
c) Compare the self-deflection tip displacement of the aluminum wing spar and the composite wing spar.
d) Perform a 5 to 10 minute Google search, how would you manufacture the aluminum spar and the carbon/epoxy spar.

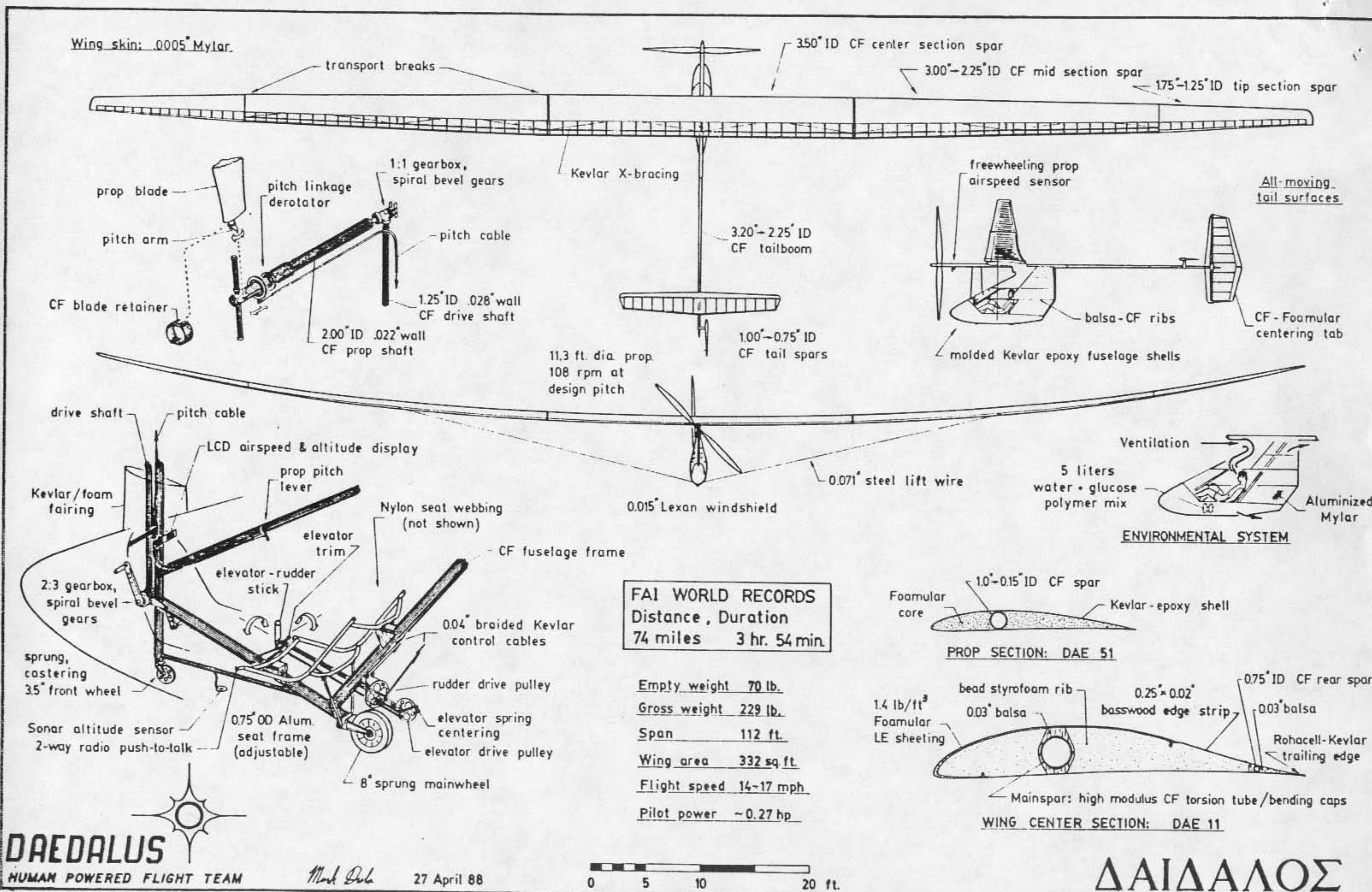


FIGURE 1

DAEDALUS HUMAN POWERED AIRCRAFT