LIFTLINE Manual

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1 Introduction

LIFTLINE is a collection of MATLAB scripts and functions that implement lifting-line theory. It solves the monoplane equation to estimate aerodynamic characteristics of a finite wing. It also provides capabilities to analyze shear force and bending moment along the wing spar.

1.1 Theory

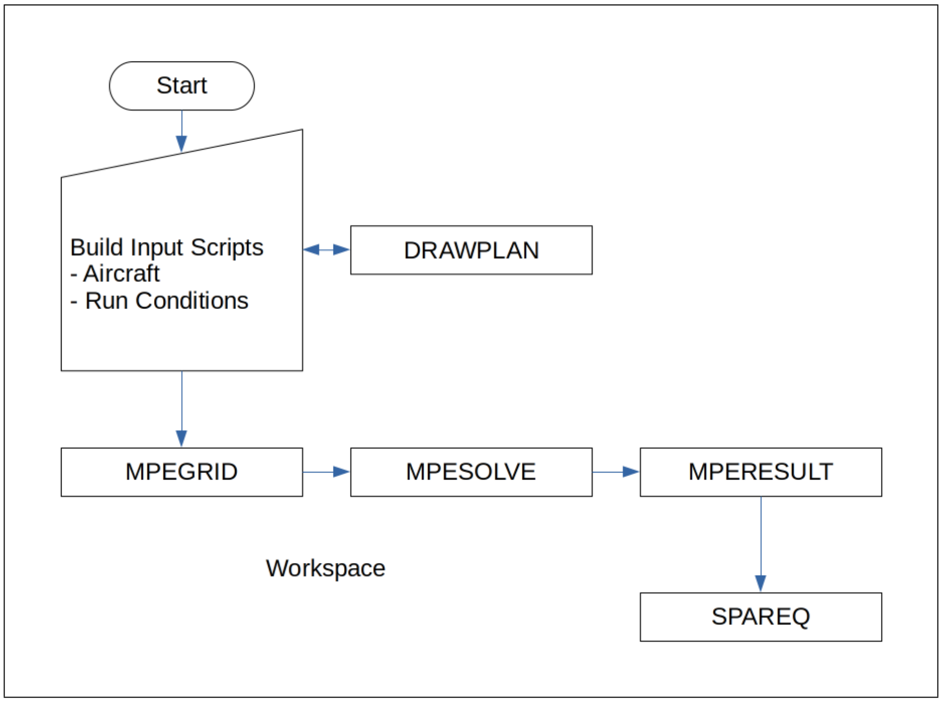
LIFTLINE implements lifting-line theory as described in [1] and [2]. The program estimates the spanwise circulation of a finite wing. Following from this result, the program can compute the lift and vortex-induced drag coefficients. The program can also estimate structural characteristics, such as shear and bending moment along the wing.

Classical lifting-line theory assumes incompressible flow, no wing sweep, and linear airfoil section lift-curve slopes. Currently, LIFTLINE assumes:

1. Incompressible flow
2. No wing sweep (input required to properly draw planform)
3. Linear airfoil section lift-curve slopes
4. Symmetrical loading.

Future versions of LIFTLINE will implement a modified lifting-line theory and relax these assumptions.

1.2 Graphical Workflow



1.3 LIFTLINEUI

The function LIFTLINEUI provides an interactive interface that guides the user through common analyses. These analyses are described below.

1. Grid Convergence Analysis. Find the number of Fourier sine series coefficients required to meet specified error requirements.

2. Find AoA for L = W. Find the angle of attack that generates lift equal to the weight of the aircraft specified in the aircraft script.

3. Run Case. Run MPEGRID, MPESOLVE, and MPERESULT.

4. AoA Range. Find CL and CDv over a range of angle of attack.

5. Spar Shear and Bending Moment. Compute and plot shear and bending moment along the wing.

When building a new aircraft script, it's generally recommended to run a grid convergence analysis at a small, positive angle of attack (e.g., 4 deg). Update the run configuration script as necessary. Then, if considering an aircraft in steady flight, find the angle of attack for L = W. Again, update the run configuration script as necessary.

2 Definition of Inputs and Outputs

2.1 Basic Configuration Geometry Inputs

N panels compose the semi-span. For each row of clalp, alpzl, and clmax, the inboard value applies immediately outboard of the panel's inboard breakpoint.

Variable Name	**Dimension**	**Description**	**Units**
ybp	1 x (N+1)	Spanwise coordinates of breakpoints [0, y_1, y_2, ..., $b/2$]	m
cbp	1 x (N+1)	Chord at breakpoints [c_r, c_1, c_2, ..., c_t]	m
sweepa	1 x N	Sweep angle (c/4) of each panel	deg
twista	1 x N	Twist angle at tip of each panel	deg
clalp	N x 2	Airfoil section lift-curve slope, C_{l_α}. Each row corresponds to a panel. Column 1 is the inboard value. Column 2 is the outboard value.	1/deg
alpzl	N x 2	Airfoil section zero lift angle of attack, α_{0l}. Each row corresponds to a panel. Column 1 is the inboard value. Column 2 is the outboard value.	deg
clmax	N x 2	Airfoil section maximum lift coefficient, $C_{l_{max}}$. Each row corresponds to a panel. Column 1 is the inboard value. Column 2 is the outboard value.	-
b	Scalar	Span	m
S	Scalar	Reference wing area	mˆ2
W	Scalar	Weight	N

2.2 MPEGRID, MPESOLVE, and MPERESULT

In addition to subsets of the basic configuration geometry inputs, the functions MPEGRID, MPESOLVE, and MPERESULT use inputs/outputs as defined below. N is the number of Fourier sine series coefficients.

Variable Name	Dimension	Description	Units
alpha_r	Scalar	Angle of attack (root)	deg
ncoef	Scalar	Number of Fourier sine series coefficients	-
theta	1 x N	Transformed spanwise coordinate	rad
y	1 x N	Spanwise coordinate	m
c	1 x N	Chord	m
a0	1 x N	Section lift-curve slope	1/rad
alpha	1 x N	Section angle of attack	rad
alpha_zl	1 x N	Section zero lift angle of attack	rad
clmax_vec	1 x N	Section maximum lift coefficient	-
An	1 x N	Fourier coefficients $[A_1, A_3, ..., A_{2N-1}]$	-
U	Scalar	Free-stream velocity	m/s
Gamma	1 x N	Circulation	m^2/s
CL	Scalar	Wing lift coefficient	-
CDv	Scalar	Wing vortex-induced drag coefficient	-
cl	1 x N	Section lift coefficient	-

2.3 SPAREQ

The function SPAREQ (Spar Equilibrium Shear and Bending Moment) optionally uses the inputs ploads and uloads, as defined below. Other inputs/outputs are also defined below.

Variable Name	Dimension	Description	Units
ploads	R x 2	Point loads applied along the wing. Each row specifies a point load. Column 1, y-values (meters). Column 2, loads. Negative loads values apply in the downward direction. For example, a store would be input as a negative load. Example: $\begin{bmatrix} 1.2 & -50 \\ 2.1 & -25 \end{bmatrix}$	N
uloads	R x 3	Uniform distributed loads applied along the wing. Column 1, inboard y-values (meters). Column 2, outboard y-values (meters). Column 3, load per unit span. Negative loads values apply in the downward direction. For example, a fuel tank would be input as a negative load. Example: $\begin{bmatrix} 1.1 & 2.2 & -10 \\ 2.0 & 4.0 & -20 \end{bmatrix}$	N/m
rho	Scalar	Density	kg/m^3
V	1 X N	Shear	N
M	1 X N	Bending Moment	N*m
M_root	1 X N	Root Bending Moment	N*m

References

[1] John J. Bertin and Russell M. Cummings. *Aerodynamics for Engineers.* 5th ed. Upper Saddle River, NJ: Pearson Prentice-Hall, 2009.

[2] John D. Anderson. *Fundamentals of Aerodynamcs.* 5th ed. New York: McGraw-Hill, 2011.