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

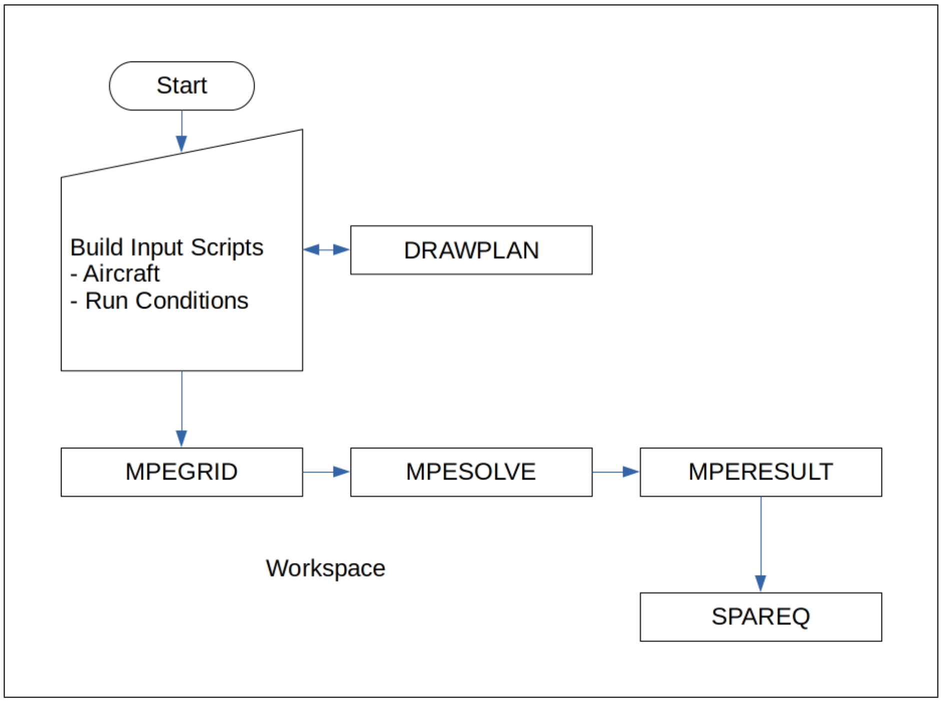
LIFTLINE implements lifting-line theory as described in [1] and [2]. The program estimates the spanwise circulation of a finite wing. Following from this result, the program can compute the lift and vortex-induced drag coefficients. The program can also estimate structural characteristics, such as shear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



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	mˆ2/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.