Lab 2 – Wind Tunnel Testing a 3-D Wings
Unified Engineering
Due Friday, 24 Feb 06, 5PM

Learning Objectives

- Measure lift, drag, moment from load cell data, using reference-axis conversions
- Perform lift and drag predictions for a 3-D wing, and compare to measurements

Secondary Objectives, for Flight Competition Project

- Get familiar with performance parameters for 3-D wings

Experimental Rig

- Test Articles: *Dragonfly* wing and *Aegea* RC glider wing in WBWT
- Instrumentation:

    – Tunnel's pitot-static probe

    – Wing load cell

- Wing parameters:

Dragonfly wing	Aegea wing
$S = 448\,\text{in}^2$ area	$S = 490\,\text{in}^2$ area
$b = 47\,\text{in}$ span	$b = 78.5\,\text{in}$ span
$c_{\text{ref}} = 10\,\text{in}$ reference chord	$c_{\text{ref}} = 7.5\,\text{in}$ reference chord
$c_{\text{avg}} = 9.5\,\text{in}$ average chord	$c_{\text{avg}} = 6.25\,\text{in}$ average chord
$e = 0.95$ span efficiency, estimated	$e = 0.97$ span efficiency, estimated
$x_o = 4.0\,\text{in}$ load cell location	$x_o = 2.7\,\text{in}$ load cell location
$y_o = -2.0\,\text{in}$ load cell location	$y_o = -2.5\,\text{in}$ load cell location

Test Conditions

- Nominal tunnel speed: $V = 15$ mph
- Nominal angles of attack from low lift to near-stall.
  Dragonfly: $\alpha = -2° \ldots 22°$,   in increments of $\sim 4°$.
  Aegea: $\alpha = -2° \ldots 12°$,   in increments of $\sim 2°$.

Data Recording

- All data are sampled continuously at about 1 Hz, and stored to an Excel file
- Each of the two Excel files will contain all α points for one wing, plus the tare data.
- Follow data recording instructions as given by staff or TA present at the test.

Raw Data Acquired for each model, each V

- $q_\infty, p_\infty, T_\infty$ for each α point, from tunnel's pitot-static probe
- Load-cell voltages for each α point, sampled for about 20–30 seconds.
- Load-cell voltages at zero wind (tare readings) at smallest α. Input artificial $\alpha = 91$.
- Load-cell voltages at zero wind (tare readings) at largest α. Input artificial $\alpha = 92$.

Data processing

- We will provide a spreadsheet program for reducing the raw load cell data.
  - Paste your raw spreadsheet data into the spreadsheet program in the same columns.
  - Enter the wing parameters and your test α values in column **X**
  - Spreadsheet outputs will be C_x, C_y, and C_{Mo} versus α, in highlighted box.
- You must perform the necessary rotation to get C_L and C_D. (Anderson 1.5).
- The C_{Mo} is about the (x_o, y_o) load-cell location. You must translate it to the $(c_{\text{ref}}/4, 0)$ quarter-chord point to get $C_M \equiv C_{M,c/4}$. See figure below.
- Determine the average-chord Reynolds numbers. Two or three significant digits is adequate here, e.g. $Re = 84000$, not $Re = 83862.17$

Prediction calculations

- Compute c_d, c_ℓ, c_m polars with XFOIL for test Reynolds numbers. Using small α steps of 0.5° or less will make XFOIL converge more reliably. Computed polars can be written to text save files, for importing into Excel or Matlab and plotting together with experimental data. Airfoil coordinate files:

      /mit/drela/Public/dfly.dat
      /mit/drela/Public/aegea.dat

- Assume $C_L = c_\ell$
- Compute $C_D = c_d + C_{Di}$ for each polar point
- Assume $C_M = c_m$
- Compute $\alpha_{3D} = \alpha + \alpha_i = \alpha + C_L/(\pi\, AR\, e)$ for each polar point.

Lab Report Contents

- Name of author, and members of the lab group
- Abstract
- Sketch of experimental setup, showing key dimensions
- Plots for each model and Reynolds number:
  - $C_D(C_L)$, for measurements and predictions,
  - $C_L(\alpha)$, for measurements and predictions, the latter being $C_L(\alpha_{3D})$
  - $C_M(\alpha)$, for measurements and predictions, the latter being $C_M(\alpha_{3D})$
- Estimates of uncertainty and errors in results.
- Discussion of data and comparison with predictions