Lab 2 – Wind Tunnel Testing a 3-D Wing
Unified Engineering

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 Article: *Aegea* 2-meter RC glider wing, with and without wingtips

- WBWT Instrumentation:
  - Tunnel's pitot-static probe
  - Wing load cell

- Wing parameters:

parameter	whole wing	without tips	units	definition
$S =$	490	257	in^2	area ($= \int c\, dy$)
$b =$	78.5	36	in	span ($= \int dy$)
$c_{\text{avg}} =$	6.25	7.15	in	average chord ($= \int c\, dy / \int dy = S/b$)
$c_{\text{ref}} =$	6.45	7.16	in	reference chord (r.m.s. chord $= \int c^2\, dy/S$)
$x_{\text{ref}} =$	2.29	2.29	in	moment-reference location
$x_o =$	2.7	2.7	in	load cell location
$y_o =$	−2.5	−2.5	in	load cell location
$e =$	0.97	0.92	–	span efficiency, estimated

Test Conditions

- Nominal tunnel speed: $V = 25$ mph (11 m/s)
- Nominal angles of attack from near-zero lift to near-stall, in increments of $\sim 2°$.

Set $\alpha = -4° \ldots 16°$, or until stall.

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_∞, p_∞, T_∞ 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 $\alpha = 81$.
- Load-cell voltages at zero wind (tare readings) at largest α. Input artificial $\alpha = 82$.
- While α is being changed, the data is invalid. Input artificial $\alpha = 99$ when wing is in α-motion to make spreadsheet ignore this data.

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 axis 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 $(x_{\text{ref}}, 0)$ reference point to get $C_M \equiv C_{M,\text{ref}}$. See figure below.
- Determine the average-chord Reynolds number. Two or three significant digits is adequate here, e.g. $Re = 110000$, not $Re = 111362.17$

Prediction calculations

- Compute viscous c_d, c_ℓ, c_m vs α_{2D} polars with XFOIL for the test Reynolds number. Using small α steps of 0.5° or less will make XFOIL converge more reliably. Save computed polars to text files, and import into Excel or Matlab and plotting together with experimental data. Airfoil coordinate file:

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/mit/drela/Public/aegea_4.dat
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XFOIL's c_d, c_ℓ, c_m α_{2D} output must be converted to corresponding 3D numbers for plotting:

- Assume $C_L = c_\ell$, $C_M = c_m$
- Compute $C_D = c_d + C_{Di} = c_d + C_L^2/(\pi\, AR\, e)$ for each polar point
- Compute $\alpha_{3D} = \alpha_{2D} + \alpha_i = \alpha + C_L/(\pi\, AR\, e)$ 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 flap position:
  - $C_D(C_L)$, 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

Note: Each student submits a report. Within your test group, you will share data and may collaborate in the spreadsheet data reduction work