10 Configuration Development and Flying Qualities

Tutorial: Under construction.
Exercises and Projects – software here VLM, SU2

Review questions to consider before doing calculations

1. Explain why the CG must be ahead of the *aerodynamic center* for *longitudinal stick-fixed stability*. Give the definitions of the italicized terms.

2. What is tip stall? Why is it to be avoided, especially on swept wings?

3. The TCR computed below has, like the Concorde and many other high-speed craft, a highly swept inner wing leading edge. Thinking of low speed flight, what does it contribute? Can VLM model that?

Configuration computations

4. A balsa glider model. Proper flight simulation needs mass, CG location, and mass moments of inertia. The file `glider.BMP` shows the scan of a balsa glider toy made from balsa sheet. `balsa.txt` holds the 3D coordinates of the outlines of the body and lifting surfaces in assembled form. The script `read_plot_balsa.m` reads the file and plots the outline of the polygons. The body is 3 mm and the lifting surfaces 1.5 mm thick. The units are m and the density of the balsawood is assumed to be 160 kg/m^3. Your job is to compute the mass, CG and mass moments of inertia of the assembled model. The function

       `[iner,area,cg] = weibalpoly(xyz)`

   computes inertia tensor `iner` around its CG, area `area`, and CG `cg` of a constant thickness plane surface bounded by the vertices in `xyz`. Add up the contributions *Vol$_j$*, *CG$_j$*, and *I$_j$* from the fuselages and wings:

   Vol = sum(*Vol$_j$*);

   CG = sum(*Vol$_j$ CG$_j$*)/*Vol*

   I   = sum {I$_j$ + *Vol$_j$* [|*CG$_j$ - CG*|^2 – (*CG$_j$-CG*)(*CG$_j$-CG*)^T]} ... (3)

   ((3) is the "parallel axis theorem" of rigid body mechanics, look it up if unsure). Vectors are column vectors. There is a lead weight at the nose. What must it weigh to give pitch static margin 10% of main wing chord? You may assume that AC is at wing quarterchord.

5. Compute the longitudinal stability margin at *M* 0.5 on the TCR by VLM. A sumo file `TCR15.smx` and a VLM geometry definition file `TCR15.geo` produced from it are provided. An octave script `geo2table.m` uses the `VLM_e.m` function to write a table (see Ch 3 exercises) of flight state parameters (Mach, alpha, beta, ...) and force and moment coefficients.

6. `HALEbook.smx` and `HALEbook.geo` describe a typical High Altitude, Long Endurance configuration with no details of propulsion, fig. 1 below. Google the Airbus Zephyr to see an

IRL example. Use the volume coefficient (see Ch. 10) to size the existing placeholder horizontal tail. The horizontal tail is all-moving around its quarter-chord line. The wing span is 30 (!) m,
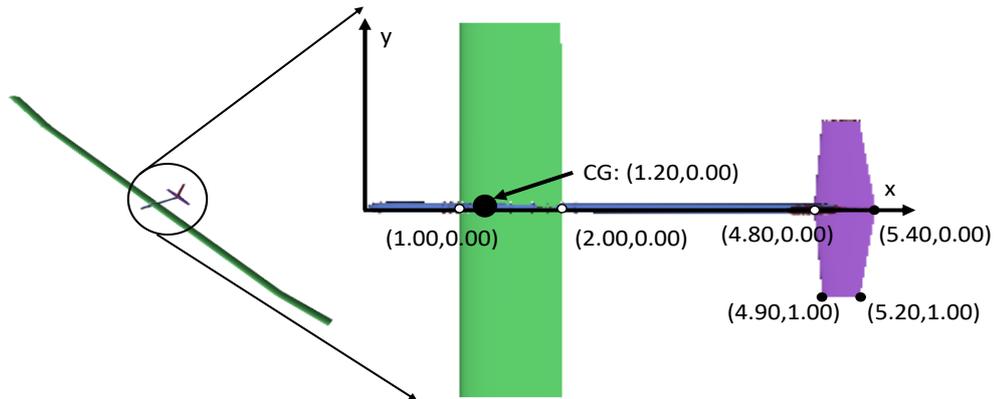

Figure 1. Typical HALE configuration

Compute $dC_m/dele$ from $C_{L,\alpha} = 2\pi/(1+2/AR)$, flat plate $AC = 1/4c$, the tail arm to CG, and other data given in the figure. Compare with $dC_m/dele$ obtained from VLM computations. Suggest aerodynamic reasons for the differences.

7. Use the HALE model and an alpha-sweep to compute the longitudinal stability margin. What alpha is required to stay aloft at M 0.1 at alt. 20000 m if the mass is 80 kg? Run a beta-sweep at that alpha, suggest a stability requirement for sideslip and define and compute a quantity for sideslip analogous to the longitudinal static margin.

8. Run `ModelIA` swept wing (see Ch 6 Exercises) with SU2 in inviscid mode with an M sweep from 0.5 to 1.1. Neglect the necessary elevator deflection to balance the moment, choose $\alpha(M)$ to give constant lift (not lift coefficient) across the M-range. Explain why αM^2 is expected to be approx. constant and select $\alpha = 2$ deg at M 0.5. Check that the computation bears out the expectation.

9. Vortex lift on highly swept wings at high angle of attack is not modeled by our VLM code. The leading edge suction analogy empiricism by E.Polhamus was incorporated in e.g. the VORSTAB NASA VLM code from the eighties. We recommend instead to go up the fidelity scale and use SU2 Euler. To this end, `delta60.smx` and `delta60.geo` are provided, modeling a 60° swept delta wing with quite sharp leading edge. Run an alpha-sweep up to 15° with SU2 and VLM and plot the lift curves so obtained. The sharpness of the leading edge is essential for make the inviscid flow separate on the leading edge. But the exact separation pattern can be obtained only by RANS.