Aeroelasticity Course – Exercise $n^o 4$ – Academic Year 2015–2016

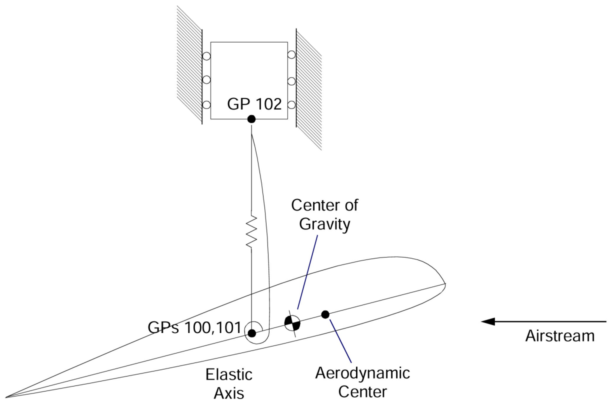

Figure 1: Three degree of freedom airfoil and fuselage system.

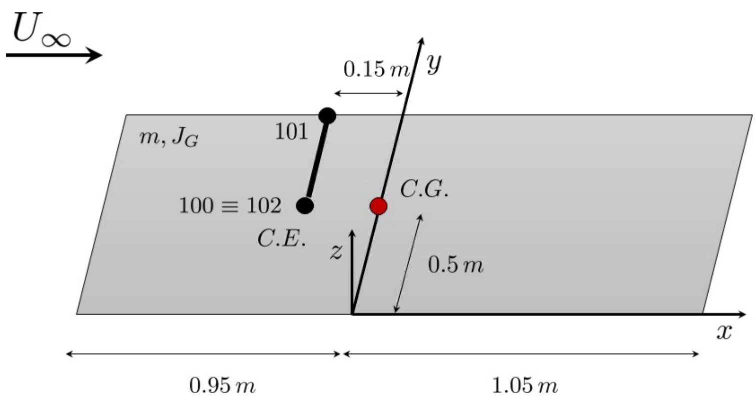

Figure 2: NASTRAN model of the system in Fig. 1.

Consider the three degree of freedom system shown in Fig. 1. The degrees of freedom are the airfoil plunge and pitch, and fuselage plunge only.

A simple structural model is illustrated in Fig. 2 and can be built in NASTRAN as follows:

- **GRIDs:** GRID 100 is on the airfoil centerline at the elastic axis, GRID 102 is coincident with GRID 100 and represents the fuselage, and GRID 101 is connected to GRID 100 by means of a rigid bar RBAR 101. The fuselage is only able to plunge (T3), whereas the airfoil is able to plunge (T3) and pitch (R2).

- **Concentrated springs:** CELAS2 is used to define a bending spring that connects GRID 100 (airfoil) to GRID 102 (fuselage) and a torsional spring that connects GRID 100 (airfoil) to the ground (or to the fuselage, which cannot pitch).

- **Concentrated mass and moment of inertia:** CONM2 is used to define the mass m of the structure and center of mass coordinates, together with the elements of the inertia tensor (all but $I_{22} = J_G$ are trivial). A CMASS2 is also used to introduce a (large) fuselage mass.

The input data for the structural model can be completely determined once a set of non-dimensional data $a, \xi_G, \xi_E, r_\alpha^2, \Omega$ for the typical section is assumed, as well as two arbitrary dimensional data (*e.g.*, the chord b and the uncoupled torsional natural frequency ω_α). Then, the dimensional properties of the system are computed as follows:

$$
\begin{array}{lll}
m = a\rho\pi b^2 & J_\alpha = m(br_\alpha)^2 & J_G = J_\alpha - mb^2(\xi_G - \xi_E)^2 \\
k_h = m(\Omega\omega_\alpha)^2 & k_\alpha = J_\alpha\omega_\alpha^2 &
\end{array}
$$

The aerodynamic model consists of:

- **Reference data:** AERO is used to define the reference free-stream velocity, chord, and density of air.
- **Aerodynamic surface:** CAERO4 and PAERO4 are used to define an aerodynamic surface associated with the structure. The aerodynamic model is based on Strip theory.
- **Interpolation:** SPLINE2 and SET1 are used to define an interpolation between the structure (airfoil, GRIDs 100 and 101) and the aerodynamic surface defined above.

The flutter analysis is carried out by first generating the GAF matrix for a set of reduced frequencies and Mach numbers (MKAERO1). Then, the methods for extracting the eigenvalues of the structure in vacuum (EIGRL) and perfoming flutter analysis (FLUTTER) are specified. FLUTTER entry refers to three FLFACT entries that specify the ranges for fluid density, Mach number, and free-stream velocity to be considered for studying the aeroelastic stability.

Assumed the typical section non-dimensional parameters used in Exercises 2 and 3, together with an airfoil chord $b = 2\,m$ and an uncoupled torsional natural frequency $\omega_\alpha = 100\,rad/s$:

- Compute the dimensional quantities to be inserted in the NASTRAN input file;
- Study the aeroelastic stability of the typical section with respect to the free-stream velocity and present the obtained results in the complex plane (root locus);
- Identify the flutter and diverge dimensional velocities and compare the results with what obtained in Exercise 3.