ADVANCED AEROELASTICITY

Aeroelastic analysis of wing

The goal of this project is to perform an aeroelastic analysis of the wing design proposed in Project 1. The following is asked:

1. Find divergence conditions.
2. Study the risk of flutter.
3. Analyze the wing response to a turbulent gust encounter with the following one-sided PSD:

$$\Phi_{gg}(k) = \begin{cases} \sigma_g^2 10^{8/3} & \text{for } 0 \leq k < k_0 \\ \sigma_g^2 10^{-8/3} k^{-12/7} & \text{for } k \geq k_0 \end{cases} \quad [(\mathrm{m/s})^2]$$

with $\sigma_g = 1$ m/s, and $k_0 = 10^{-28/9}$ and $k = \omega c_0 / 2U_\infty$ is the reduced frequency ($c_0 = 0.85$ m is the chord at the root section).

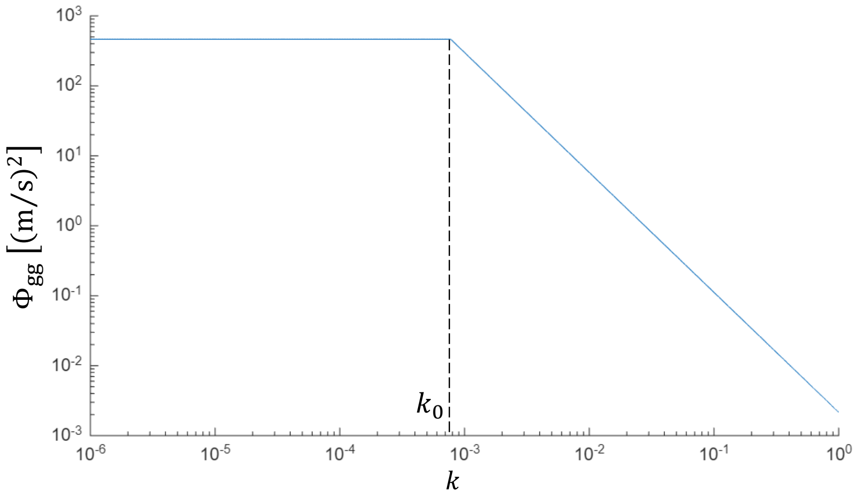

Figure 1. PSD of the turbulent gust encounter.

In your report, the following must be included:

1. Wing structure design (the same as in Project 1):
   a. Overall sizes.
   b. Cross-section design(s), detailing how properties change along the span.
   c. Specifications: mass ratio, lift-to-mass ratio, stress-to-mass ratio

$$\mu = \frac{M_{\text{tot}}}{\pi \rho_\infty c_0 S} \qquad \frac{C_L}{\mu} \quad \text{with} \quad C_L = \frac{L}{\frac{1}{2}\rho_\infty U_\infty^2 S \alpha} \qquad \frac{C_\sigma}{\mu} \quad \text{with} \quad C_\sigma = \frac{\sigma_{\max}}{\frac{1}{2}\rho_\infty U_\infty^2 \alpha}$$

2. Summary of the aeroelastic properties:
   a. Divergence speed U_D.
   b. Flutter speed U_F.
   c. For different values of U_∞ in the range $[0, U_D]$, PSD curves and RMS values of:
      - Maximum stress: $\sigma_{\max}$.
      - Acceleration at the shear center of the wing tip: $\ddot{\eta}(b)$.

Recall that $\sigma_{\max}$ can be obtained from the stress at each (x,y) point in the wing's planform can be obtained from the rates of change of the bending and twist angles along the span, $\zeta(y)$ and $\theta(y)$, according to:

$$\sigma(x,y) = \sqrt{E^2\big(h(x,y)\big)^2\left(\frac{\partial\zeta(y)}{\partial y}\right)^2 + 3G^2\big(r_{sc}(x,y)\big)^2\left(\frac{\partial\theta(y)}{\partial y}\right)^2}$$

where $h(x,y)$ and $r_{sc}(x,y)$ are the distances depicted in Figure 2.

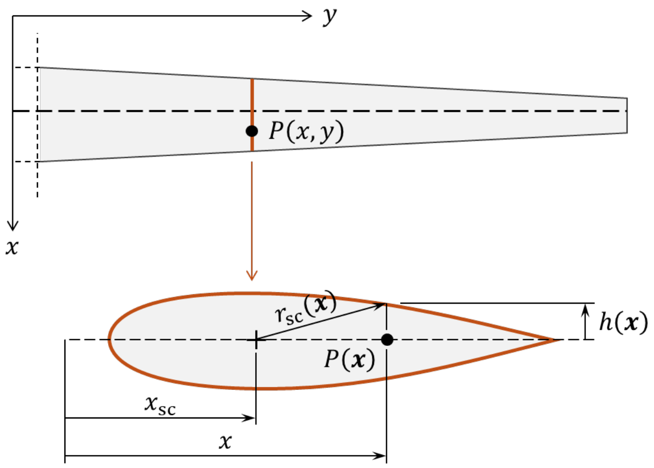

Figure 2. Distances within the cross-section.

Bonus. Doing these additional tasks will contribute to the "Excellence" grade:

- Propose and justify a new design including a control surface to improve the aeroelastic response of the wing.
- Assess the risk of control reversal.
- Design a control loop to mitigate vibrations.