HOMEWORK 2

Problem 1

Write a computer code for analyzing trapezoidal wings using the horseshoe vortex method. The program input parameters should be:

- Wing planform. Use a minimum set of parameters to define the wing, for example: **aspect ratio** (A), **taper ratio** (λ) and **quarter chord sweep angle** (Δ_{25}). Consider all the lengths non-dimensional with the wing span, i.e **b=1**.
- Wing geometric and aerodynamic twist. The additional parameters required are the **wing tip twist** (ε_t), the **angles of zero-lift** (α_{l0}) for the root and tip sections and the initial and final **flap y-position** along the span. Consider a linear variation of $\varepsilon_t(y)$ and $\alpha_{l0}(y)$ between the root and tip sections. $\boldsymbol{\Delta\alpha_{l0}}$ should be provided for the sections in the flap. This value can be obtained for the required flap deflection η using the results of the thin-airfoil theory, but corrected with experimental data to improve the accuracy of the results (see slides M2_4 pp. 37-38).
- Geometric angle of attack.

The code should compute the lift distribution along the span $C_l(2y/b)$, the wing lift coefficient C_L, the moment coefficient about the leading edge C_{Mle} (of the root chord) and the induced drag coefficient C_{Di}. Once the code is written, perform the following analyses (do not forget to check grid convergence of your numerical results).

1. Consider a rectangular unswept wing with constant airfoil along the span and no twist and study the variation of the lift-slope ($C_{L,\alpha}$) for increasing aspect ratios A≥6. Compare the results obtained for A=6 with those presented in the book *Low-speed aerodynamics* by Katz and Plotkin (Figure 12.16). Only one comparative plot must be presented including both, the calculated results and those from Katz and Plotkin.

2. Analyze the variation of $C_{L,\alpha}$ and the position of the wing aerodynamic centre (x_{ac}) with the sweep angle Λ_{LE}. Consider a sweptback wing with λ=1 and A=6. Compare

your results for $C_{L,\alpha}$ with those presented in Katz and Plotkin. Similar as before, only one comparative plot must be presented.

3. For a wing having A=10 and $\Lambda_{c/4}$=0º, study the variation of the non-dimensional spanwise lift distribution as a function of the taper ratio for a wing C_L=0.25. Only one plot showing the different lift distributions must be presented.
4. Compute the variation of the Oswald's efficiency factor as a function of the taper ratio for three wings having $\Lambda_{c/4}$=0º with A = 4, 8 and 10. Perform a similar analysis with the wing sweep, use A=8 with $\Lambda_{c/4}$ = 0, 30 and 60º. Extract some conclusion on the effects of aspect ratio, taper ratio and sweep on the wing's efficiency factor. Present only two plots.
5. Consider a trapezoidal wing with A=8, λ=0.5, ε_t=0 and Δ_{50}=0 with airfoil NACA 2412 constant along the span. Calculate the basic and additional lift distributions, the C_{M0} and the position of the wing's aerodynamic center. Present one plot showing the basic and additional lift distributions. Also estimate the maximum C_L (and α_{max}) of the wing for flap deflections η = 0º and 10º. This analysis must be presented in a separate plot containing the two flap positions.

Results discussion

From the point of view of the wing structure, do you consider that sweep and taper ratio have positive or negative effects? Concerning aerodynamics, what are the advantages and disadvantages of sweep and taper ratio? Justify (briefly) your answers using the numerical results presented above.

Submission

This homework must be performed in **groups of 4-5 students**. **Hardcopy report submissions are required**. The computer code must be included in an appendix, and the entire document (i.e. points 1-5 above, discussion and appendix) cannot exceed 8 pages (**4 sheets printed on both sides**). The deadline for submission is **11 January 2017** (final exam date). Late submissions will be penalized (-20% of the full grade).