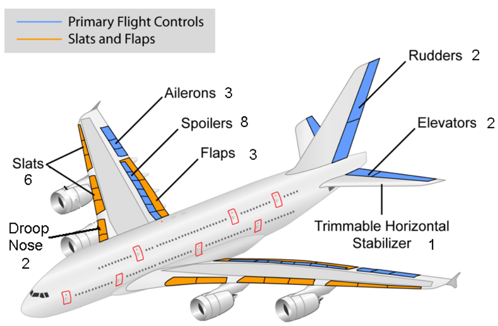
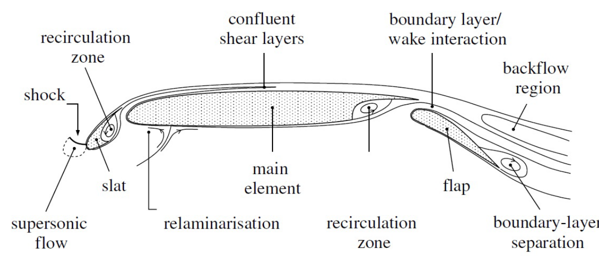
Assignment 3 High lift system analysis in 2D flow

Requirements

- Personal or group task: personal
- Minimum / Maximum number of pages: 8 / 15 (excluding Title page)
- Font size: 10 – 12





Background

Multi-element airfoils play a crucial role in achieving optimal performance during aircraft take-off and landing. The design complexity arises from the intricate interactions among various elements, such as leading edge and trailing edge devices, as detailed in references 1 and 2 in Handout #3. The challenges in designing a high-lift system are evident in the literature, with several factors contributing to the difficulty:

- Limited accuracy in predicting flow separation using modern CFD codes.
- Possible wake bursting occurrences.
- The impact of compressibility on the flow field across different elements.
- The potential bursting of laminar separation bubbles and the resulting detrimental hysteresis effects.

Given these complexities, defining a satisfactory high-lift system becomes a non-trivial and labor-intensive task. Due to limited time available, this assignment focuses solely on a low-fidelity analysis of an airfoil equipped with a trailing edge flap to estimate its fundamental effects and discuss key phenomena.

Tasks

To get further insight in the interaction effects between elements in a high lift system perform the following tasks:

1. Explain the key difference in working principle between a leading-edge slat and a trailing-edge flap. Add clarifying figures.

2. Read the paper from reference [1] (also available from Handout#3 in BrightSpace) and describe in your own words the 5 main effects that occur in multi-element flows:

    a. Slat effect
    b. Circulation effect
    c. Dumping effect
    d. Off-the-surface pressure recovery
    e. Fresh boundary layer effect

    Please add your **own** clear **hand-drawn** sketches that support the discussion. Please note the following: Without the **hand-drawn sketches** this assignment will not be accepted. It is **mandatory** to add your **signature** and **date** on the lower right corner of the drawings.

3. Find a relevant 2D-case in open literature of a main element with a trailing-edge flap. A very good reference case is the the so-called NLR 7301 airfoil with flap [4], but you are free to select an alternative model. Provide bibliographical details of all references used.

4. Provide a drawing of the model as well as the lift polar for one or more flap settings as found from the particular reference.

5. Use this model to construct a "like-wise" high lift system that consists of a main element and a separate flap based on 2 airfoils in close proximity. This means that the cove area is smoothed (see fig. 1) to enable calculations with the selected low fidelity code that will used below. This high-lift system is to be used in subsequent analyses.

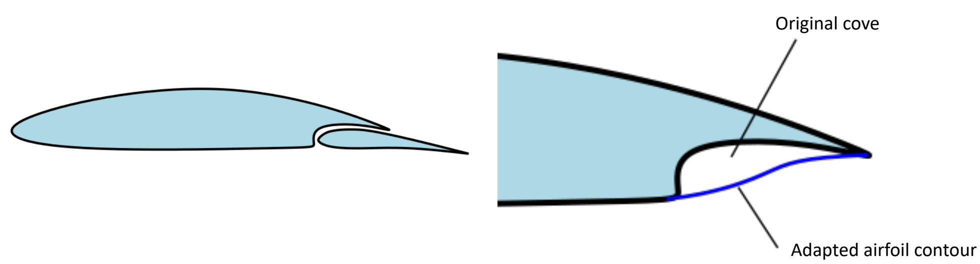


Fig. 1 Adaptation of the cove area to prevent computational problems.

6. Use the constructed model to:
    a. Simulate the high lift condition that was found in literature (task 3) and compare to experimental results by plotting the lift polars (C_l versus α) in the same graph. For this 2D simulation you may use the "*JavaFoil*" application (available on the internet, [3]) or any other 2D code of your preference that is capable of calculating 2D multi-element airfoils. Make sure that you have mainly turbulent flow by fixing the location of transition close to the leading edge of all elements.
    b. Check the effect of the Reynolds number. For this, use the Re number that was found in the reference and a significant lower value.
    c. The main airfoil with the flap retracted (flap removed and no gap left).

7. Discuss possible differences between the experimental data (from the literature in task 3) and the predicted data, based on the simulations and shortly discuss its limitations. Compare to the result with the flap retracted.

8. Provide at least one plot (one combination of angle of attack and flap angle) that shows the pressure field (if possible combined with the streamlines). Shortly discuss whether this flow field is according to your expectations for multi-element airfoils.

9. Describe shortly the flow phenomenon that is referred to as "*wake bursting*". What is the effect of the Reynolds number on the potential occurrence of wake bursting? Add a **hand-drawn sketch** (add date and signature) to support your descriptive text.

10. **Optional Task.** For the airfoil-flap model that was analyzed in task 7:
    a. For one or more conditions (airfoil angle of attack plus flap deflection angle) provide a plot with the pressure distribution in "canonical" form.
    b. Check in how far your model is prone to the earlier discussed wake bursting effect by considering Gartshore's condition (see lecture slides):

       Wake growth when: $\frac{1}{1-\overline{C_p}}\frac{d\overline{C_p}}{dx} > \frac{0.007}{\delta^*}$

References

1. A.M.O. Smith. "High-Lift Aerodynamics", Journal of Aircraft, Vol. 12, No. 6 (1975), pp. 501-530.
2. C.P. van Dam, "The aerodynamic design of multi-element high-lift systems for transport airplanes", Progress in Aerospace Sciences 38, 101–144, 2002
3. M. Hepperle, Javafoil, http://www.mh-aerotools.de/airfoils/javafoil.htm.

4. NLR 7703 data: https://www.grc.nasa.gov/www/wind/valid/nlrflap/nlrflap01/nlrflap01.html