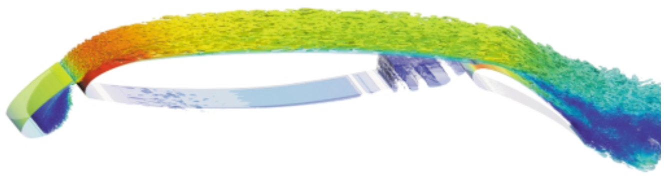
Assignment 3: High-lift system analysis in 2D flow

Academic year: 2024-2025

Full Name:	
Student Number:	
Date:	



Requirements

- Personal / group task: personal
- Handwritten drawings must contain a visible signature to its side
- Be as complete as necessary, as succinct as possible

Introduction

Multi-element airfoils play a key role in attaining high performance in take-off and landing conditions of aircraft. The design of systems with leading edge and trailing edge devices is complicated due to the strong interaction effects between the different elements (see ref. 1 and ref. 2 in Handout # 3).

As is evinced by results from literature several factors make the design of a high lift system very difficult:

- The limited accuracy with which flow separation can be predicted with modern CFD codes
- The possible occurrence of wake bursting
- The effects of compressibility on the flow field over the different elements
- Potential bursting of laminar separation bubbles and associated detrimental hysteresis effects

The task of defining an acceptable high lift system becomes a non- trivial and laborious task. In this assignment, we will only concentrate on a low fidelity analysis of an airfoil equipped with a trailing edge flap and estimate the basic effects.

Preparation

Task 2 of this assignment requires you to simulate the flow over a multi-element airfoil. You are free to choose your own method. A suggestion for an easy access tool is "JavaFoil", based on an applet that is available on the internet. Please ensure to force turbulent flow over the entire airfoil so comparisons can be drawn regardless of transition location.

After having defined your means of simulation, you are asked to find a relevant 2D-case in open literature of an airfoil main element with a trailing-edge flap. A very good reference case is the so-called NLR 7301 airfoil with flap [4]. You are free to select an alternative model. Please bear in mind that you will be asked to compare your results with the results from open literature, so it is preferable to select a case for which the lift polar is available.

Along with the main element + flap geometry, reconstruct a "like-wise" single element airfoil that consists of the main element and flap in close proximity (example below), representing the retracted condition.

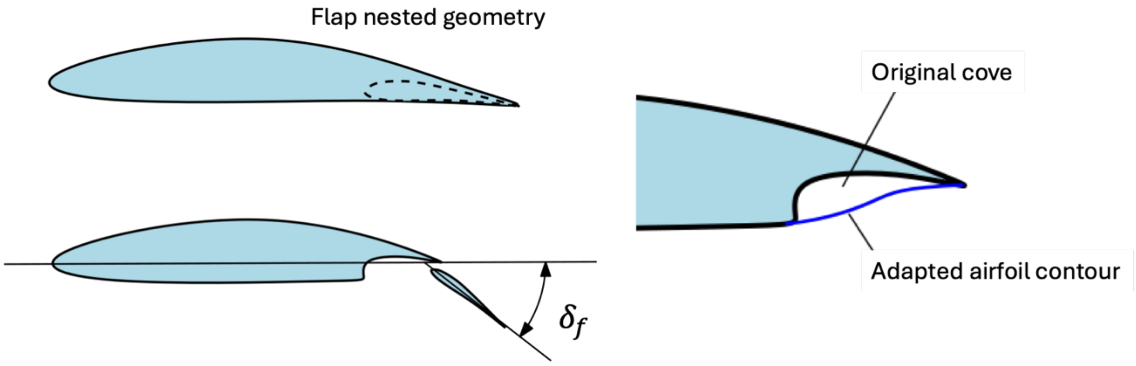


Figure 1 - Geometry of the flap nested case (left) and adaptation of the cove area to prevent computational problems (right)

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 7301 data: https://www.grc.nasa.gov/www/wind/valid/nlrflap/nlrflap01/nlrflap01.html

Task 1 – Theoretical background

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

1. **Difference in working principle between a leading-edge slat and a trailing-edge flap**
    a. In the box below, succinctly describe the main differences in the working principle between a leading-edge slat and a trailing-edge flap.

    b. Insert a drawing showing how the lift coefficient polar, C_l vs. α , of an airfoil is modified by the inclusion of a leading-edge slat and a trailing-edge flap.

2. Read the paper from reference [1] (also available from a handout in BrightSpace) and describe in your own words the following effects that determine the behaviour of a high lift system. Please add your **own** clear **hand-drawn** sketches that support the discussion on the top row and a succinct description on the bottom one.
    a. Slat Effect

    b. Circulation Effect

    c. Dumping Effect

    d. Off-the-surface Pressure Recovery

e. Fresh Boundary Layer Effect

3. Select an aircraft and describe the high-lift system used. Feel free to add drawings and schematics in the box at the bottom row and your description in the top one. Mention the type of high-lift system used, the number of elements, and the integration in the wing. In a succinct form try to highlight the advantages and disadvantages of each choice and possible reasons for opting for such a system.

Task 2 – Numerical assignment

Find a relevant 2D-case in open literature of a main element with a trailing-edge flap. A very good reference case is the so-called NLR 7301 airfoil with flap [4], but you are free to select an alternative model. Along with the main element and flap geometry, reconstruct a "like-wise" single element airfoil that consists of the main element and flap in close proximity.

1. Provide bibliographical details of all references used and the airfoil chosen.

2. Add a figure of the high-lift airfoil and your single element airfoil

3. Use the selected flow solver (for example JavaFoil) to simulate the high-lift condition of your model and compare to experimental results:
    a. Add a plot where the experimental lift polar obtained from open literature is compared against your simulation results.

b. Comment on the discrepancies between the 2 data sets and possible causes, e.g. limitations in the methodologies, experimental uncertainties, etc.

c. Add a plot of the lift polar for the retracted versus extended flap.

d. Comment if the differences match the expected effect of the flap. If not, what could be happening?

e. Add two plots of the pressure field (C_p-distribution) at a fixed value of the lift coefficient. One shows the pressure field of the airfoil with flap and the other shows the one of its retracted version.

f. Shortly discuss whether the flow fields are according to your expectations for multi-element airfoils.

Task 3 – Wake-bursting effect

The so called 'Wake-bursting' effect can drastically affect the performance of a high-lift system.

1. Describe in your own words wake bursting and its influence on the drag and lift of the high-lift system

2. Add a hand-drawing of a wing-flap system showing the phenomenon. Use clear annotation describing the flow field. Moreover, add the Gartshore's condition for wake bursting.