GUIDE TO AERO2 LABS

Aerodynamics 2
AENG21100
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Outline

- **You spoke…we listened…to help reduce your workload, we have replaced the two 1500 word lab reports with 2 lab assessment tests (approx. 1-1.25hr). Learning objectives/content are unchanged**
- This term you will be carrying out the chordwise pressure distribution (A1) lab exercise
- Next term you will carry out the supersonic (A2) lab
- Due to timetabling the A1 lab starts early in the term for many of you
- This gives you an overview of what to expect

Timings (approx.)

- A1 (Dr Rendall) and matlab (Dr Gaitonde) assessment test – before Christmas
- A2 (Dr Rendall) assessment test – shortly before Easter
- Please note that these two online tests are separate to the three progress tests - there are 5 tests in total for this course

Learning and assessment

1. Read the lab document
2. Attend the lab and make sure to complete the learning prompts and discuss anything you do not understand with the demonstrator
3. Complete the learning exercises in your own time
4. Attend the lab help session (to be timetabled in one of the course lecture slots)
5. Complete the online progress test (when notified of availability). The dates given on SAFE are what we expect, +/- a week. We will let you know when tests go live and they will be available for 1 week

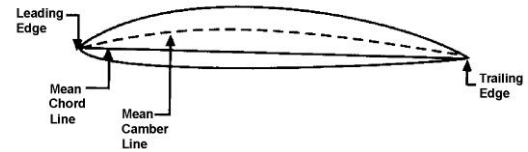
Introduction

- Although we will develop a simple mathematical models for aerofoils later in this course, the A1 lab only links partially to the theory in the Aero 2 lectures. However, the lab is a fundamental one that all aerospace engineers should undertake at some point in their training. It will demonstrate many points regarding 2D incompressible viscous flow around aerofoils
- This lab consists of looking at the effect of angle of attack and flap angle on the
  - Lift, drag and moment coefficients
  - Surface pressure

of an aerofoil section.

- You'll also have a wool tuft. This will be an excellent opportunity to satisfy any curiosity you may have about aerofoils!

Review of terminology

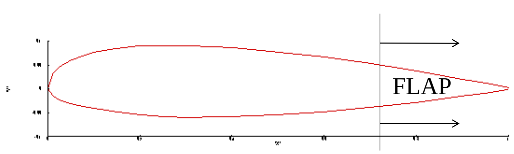


- The mean camber line is the line that is equidistant at all points between the upper and lower surfaces of the aerofoil
- Chord is line joining leading edge to trailing edge (leading edge is where the camber line meets surface at the front)

For symmetric aerofoils the mean camber line and the chord line are identical-the aerofoil is therefore uncambered

Aerofoil

- In the A1 lab the size of the trailing edge flap is 30% chord and the theoretical aerofoil shape with the flap undeflected is a NACA23015 profile.



Aerofoil

- The numbering of the NACA 5 digit series aerofoil gives information about its shape.
  - Find out what the designation 23015 means
  - 23015 has seen plenty of use outside of this experiment!







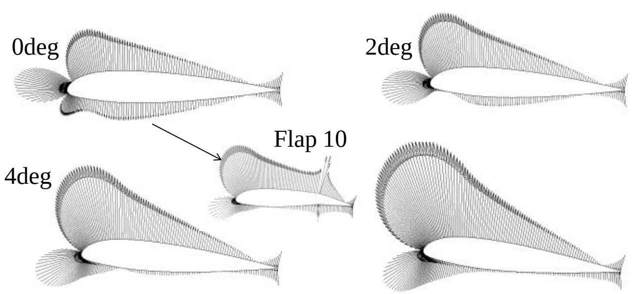
Process

- For a number of different flap angles, the aerofoil incidence is changed first up, then down. At each step, the incidence is held fixed and the flow about the aerofoil is allowed to settle down. This is thus a *static* (steady) process rather than a *dynamic* (moving) process.

Objectives

- The main thing to focus on in the lab is the effect of flap deflection and incidence on lift, drag, moments and lift to drag ratio. Note that deflecting a flap ‘changes the camber’.
- You will also see the effects of separation and stall on the above mentioned characteristics. These are viscous phenomena and are not modelled by the thin aerofoil theory presented in Aero2.
- Do not be distracted by hysteresis. You will see this, but it is a slight distraction from the main focus of the lab. What you need to understand about hysteresis is included in these notes.

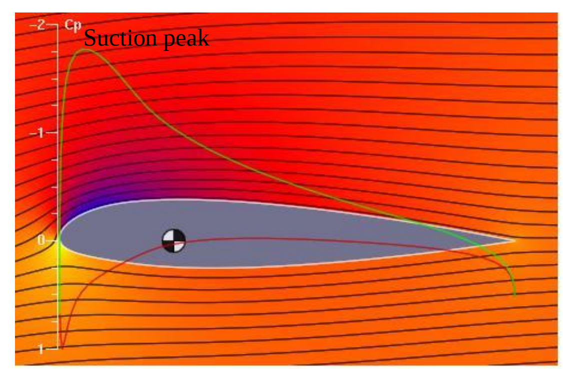
Pressure distributions



These are `inviscid’ pressures = ignoring viscosity forces

Arrows point away from surface if pressure < p_inf
and towards if pressure > p_inf … $C_p = \dfrac{p - p_\infty}{\frac{1}{2}\rho v_\infty^{\;2}}$

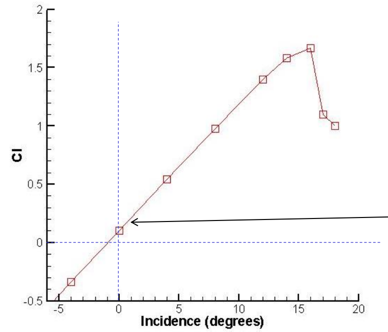
Streamlines



‘streamlines turn away from high pressure’

Cl vs. alpha

- The *static* (steady) force coefficient plots for the NACA23015 aerofoil typically shown in texts will look similar to this. Exact shape depends on similarity parameters (Re, M).



Note the approximately linear section where the flow is attached and the sharp decrease in lift as the flow separates and the aerofoil stalls.

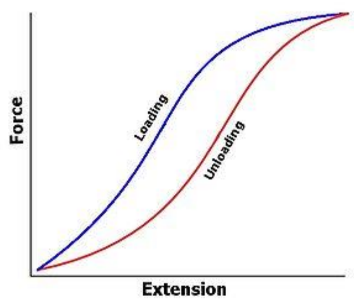
Note also the lift coefficient at zero incidence is non-zero as it is a cambered aerofoil

Cl

- For the previous plot all measurements are taken whilst increasing incidence. If you *also* take similar measurements whilst decreasing incidence things get more complicated.

Hysteresis will be observed.

Rubber bands



This kind of behaviour should be familiar – it is associated with failure/lag in recovering the input energy

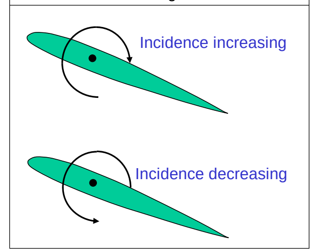
It is also a consequence of **nonlinearity**

Aerodynamics is not excluded from this behaviour

Hysteresis

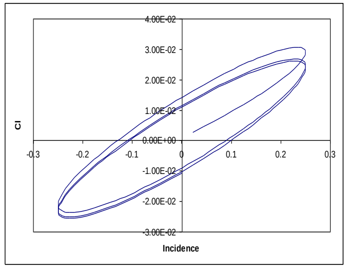
- Consider what happens when the incidence of an aerofoil is increased and decreased by a periodic *dynamic* rotation.

Aerofoil at same angle of incidence



Clarification

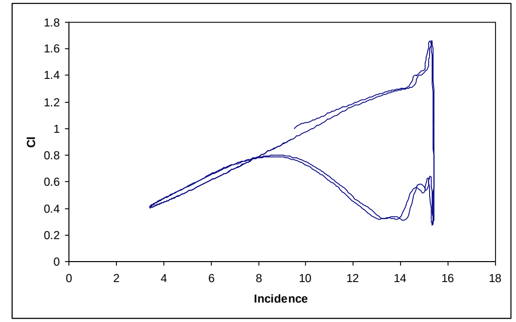
- Then there will be a difference between the flow fields at a particular incidence α_0 depending on whether the aerofoil has increasing incidence or decreasing incidence, because the speed and acceleration of the aerofoil surface will differ. This leads to loops in the Cl vs Incidence plots.



- The loop observed in the *dynamic* lift coefficient plot shown, disappears as the speed of the motion tends to zero i.e. *static* conditions are approached, because the flow stays attached and the flow is **approximately linear**.

What is hysteresis?

- Consider the situation if during the motion of the aerofoil the incidence goes above that required for stall.



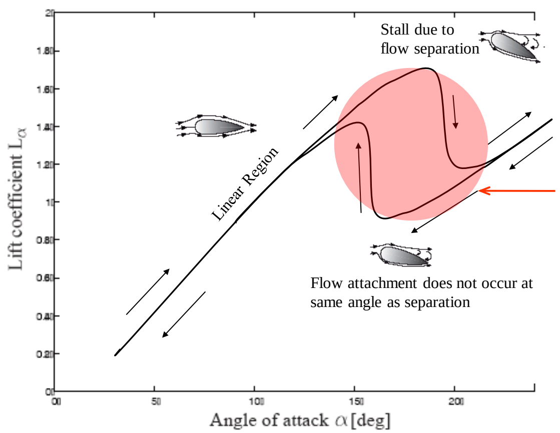
Hysteresis

- The loops observed in the *dynamic* lift coefficient plot shown on the previous slide are found to remain as the speed of the motion tends to zero i.e. *static* conditions are approached. This means the system is *hysteretic*.
- Note only non-linear systems can be hysteretic. Linear systems are never hysteretic – a set of linear equations is either indeterminate or has a single solution
- Thus hysteresis is the dependency of the system on its previous state, in this case the direction of the change in the angle of attack and exists even in the *static* measurement situation.

Static Hysteresis

- There is a region at higher incidences where there are two possible solutions per incidence and the solution branch followed depends on the history, much the same as there were two possible extensions of the rubber band for a given load
- So in this case on the way up to approach the stall angle, the flow field history follows the solution branch that remains attached until a high incidence.
- And on the way down from this same angle, the flow field history is of a more grossly separated flow. The flow therefore follows the other solution branch
- They do join up again

Static Hysteresis



Not standard practice to fly here – inefficient, unpredictable and unnecessary, except for testing and training

Experimental Issues

This document gives a summary of the theoretical issues behind the A1 lab, but what other issues affect the experiment?

- Flow unsteadiness (purpose of meshes on wind tunnel intake is to help give uniform inflow)
- Wind tunnel corrections (5% blockage rule – how does this change with angle of attack?). What effect do the wind tunnel walls have?
- Similarity parameters (Re and M - these influence how applicable the results would be to a full size aircraft)
- Manufacturing accuracy
- Freeplay in the hinge

Review

<u>You should now be able to:</u>

- Understand the basic principles behind the A1 lab.
- Be prepared for the A1 lab progress tests (note that Dr Gaitonde will cover the matlab part of this test)

Next week we will begin the compressible flow course!