Fall 2025

ME-445 AERODYNAMICS

10 - Group project info

K. Mulleners

Group project on airfoil/wing characterisation (30 % of grade)

Group project

The task of the group project is to extract airfoil performance data from a journal paper and compare the results with your own calculations using at least 2 out of 3 theories that we cover in the class (potential flow theory, thin airfoil theory, Prandtl lifting line theory)

Intended learning outcomes:

- Apply the theoretical concepts learned (potential flow, thin airfoil profile, Prandtl's lifting line theory) in practice
- Critically assess the results
- Understand the limitations of the theories learned

Transversal skills:

- Project management: set objectives and design a plan to reach those objectives
- Work in group
- Summarize an article or a technical report
- Present your results

Tasks

- Select one of the six papers we preselected
- Read and summarise the paper
- Select two figures from the paper with different quantities to reproduce using potential flow, thin airfoil, or Prandtl's lifting line theory.
- For each figure:
  - extract the necessary data from the paper
  - select a theory to calculate the data presented in the figure
  - calculate the data using the chosen theory - to do this you will have to make certain choices or simplifications
  - challenge one of the simplifications/choices made by testing the sensitivity of results on the simplification/choice made
- Summarise and present the results in an oral presentation at the end of the semester

Tasks

How to select the figures to reproduce?

What to pay attention to?

- Does the theory allow you to compute the quantities presented in the figures?
- Are different quantities presented in the two figures?
- Do you have data for relevant parameter variations? (e.g. variations in Reynolds numbers can not be reproduced)
- Is the task sufficiently challenging?
- Does the task fit the theory? (e.g. thin airfoil theory best suited to compare pressure distributions)

⚠ Potential flow, thin airfoil theory, and Prandtl's lifting line theory predict pressure based forces, comparisons of frictional drag will not be feasible.

Tasks

Compare data

For each figure:

- select a theory to reproduce the data presented in the figure
- extract the necessary data from the paper
- calculate the airfoil performance data using the chosen theory
- challenge one of the simplifications/choices made by testing the sensitivity of results on the simplification/choice made

Tasks

Compare data

For each figure:

- select a theory to reproduce the data presented in the figure
- extract the necessary data from the paper
- calculate the airfoil performance data using the chosen theory
- challenge one of the simplifications/choices made by testing the sensitivity of results on the simplification/choice made

What do we mean by simplification/choice made?
To apply the theories seen in class to the situations described in the paper, you will have to make certain approximations and choices. E.g. You will probably not be able to exactly replicate the airfoil geometry for the potential flow estimation of the lift, and you might decide to match the thickness and not the camber.

❗ The angle of attack is not an assumption, it is a parameter.
❗ Incompressibility is an assumption but not one that you can challenge in the scope of the class.

Tasks

Present results

- Each group presents their results at the end of the semester
- All group members have to be present at the presentation
- The presentation and code has to be submitted on Moodle by 8pm the day before the presentation
- Read and follow the instructions on the notion page

Organisation

Important dates:

- **October 28** Group project info session
- **November 04** Submit form to indicate paper preference
- **November 05** Papers attributed

- **December 09** Project presentations (groups tbc)
- **December 16** Project presentations (groups tbc)

Link to the form on **https://go.epfl.ch/ME445_groupproject**

Evaluation

The group project will count for 30 % of your final grade

Check the grading rubric on **https://go.epfl.ch/ME445_groupproject**

The rubric covers:

- amount of work done
- critical analysis
- creativity and level of difficulty
- code quality
- quality of the presentation

Example

PRL **117,** 234501 (2016) PHYSICAL REVIEW LETTERS week ending 2 DECEMBER 2016

Sharp Transition in the Lift Force of a Fluid Flowing Past Nonsymmetrical Obstacles: Evidence for a Lift Crisis in the Drag Crisis Regime

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(Received 3 February 2016; revised manuscript received 6 October 2016; published 29 November 2016)

Bluff bodies moving in a fluid experience a drag force which usually increases with velocity. However in a particular velocity range a *drag crisis* is observed, i.e., a sharp and strong decrease of the drag force. This counterintuitive result is well characterized for a sphere or a cylinder. Here we show that, for an object breaking the up-down symmetry, a *lift crisis* is observed simultaneously to the drag crisis. The term lift crisis refers to the fact that at constant incidence the time-averaged transverse force, which remains small or even negative at low velocity, transitions abruptly to large positive values above a critical flow velocity. This transition is characterized from direct force measurements as well as from change in the velocity field around the obstacle.

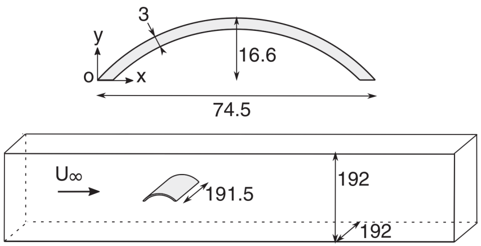
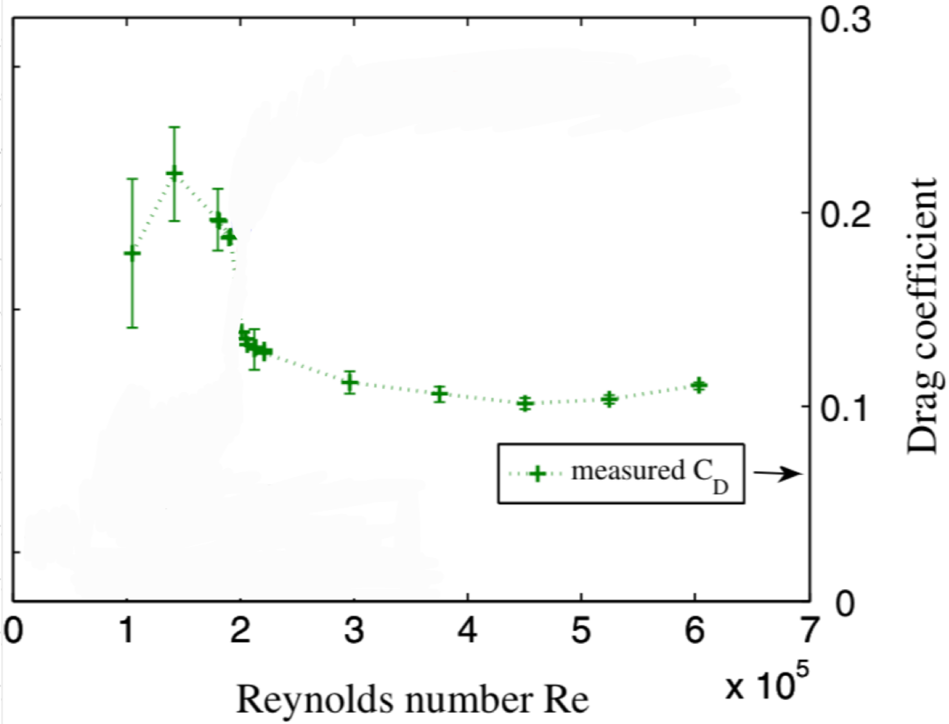
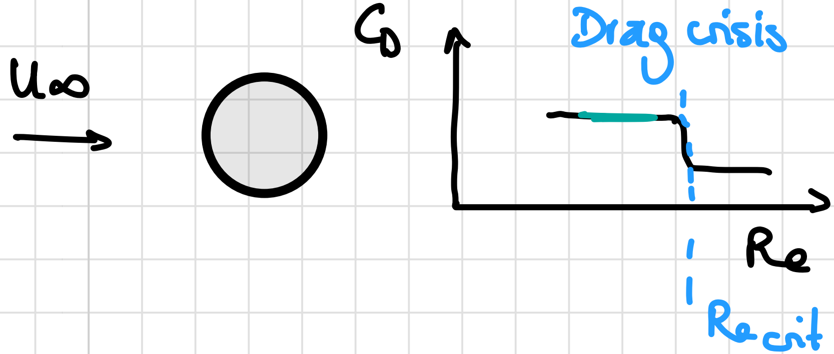
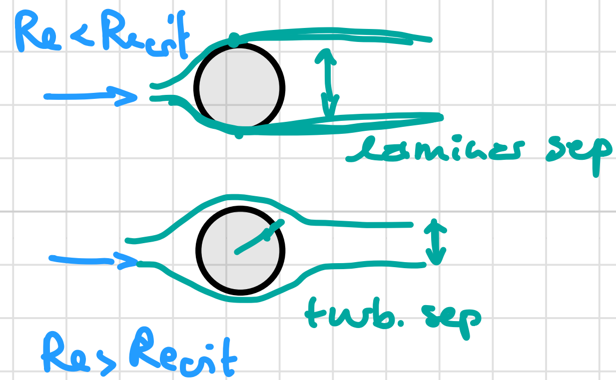


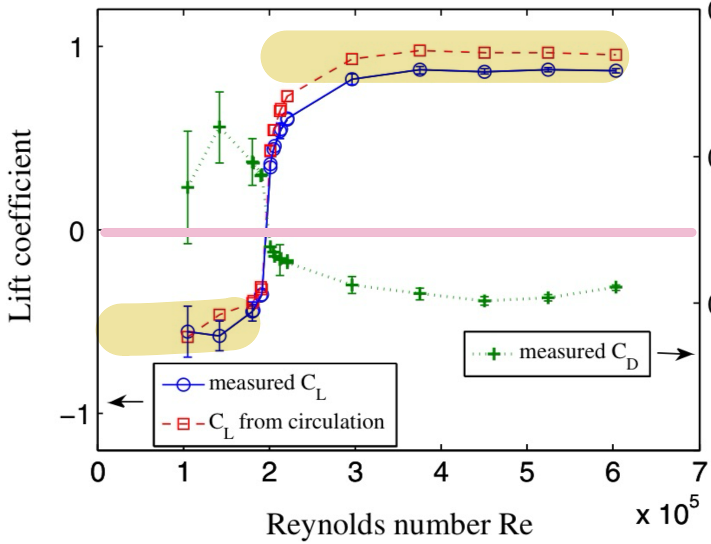
FIG. 1. Curved plate section: chord length $c = 74.5$ mm and camber $t = 16.6$ mm (top) and tunnel test setup (bottom). All dimensions are in mm.



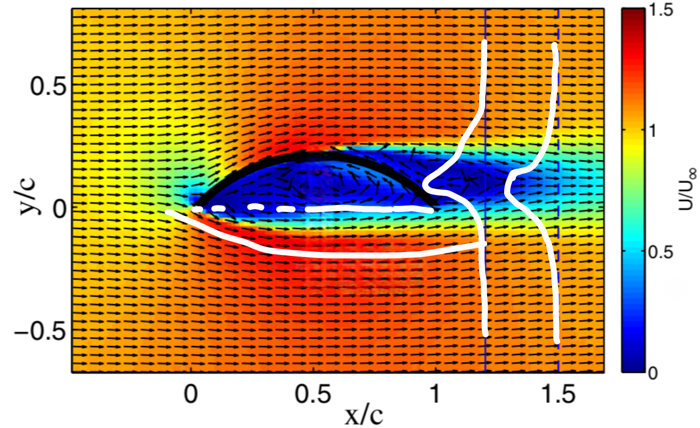


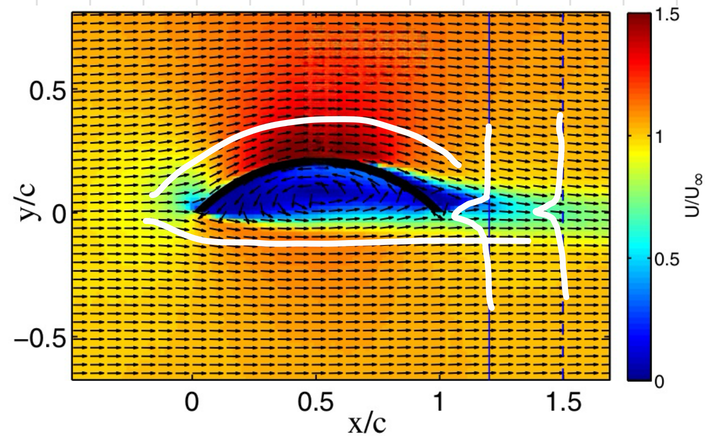


$$Re = \frac{UL}{\nu}$$


Lift coefficient
Drag coefficient
Reynolds number Re
x 10^5
0
1
2
3
4
5
6
7
−1
0.1
0.2
0.3
measured C_L
C_L from circulation
measured C_D

$C_L < 0$


y/c
x/c
0.5
0
−0.5
1
1.5
U/U∞


y/c
x/c
0.5
0
−0.5
1
1.5
U/U∞

$C_L > 0$

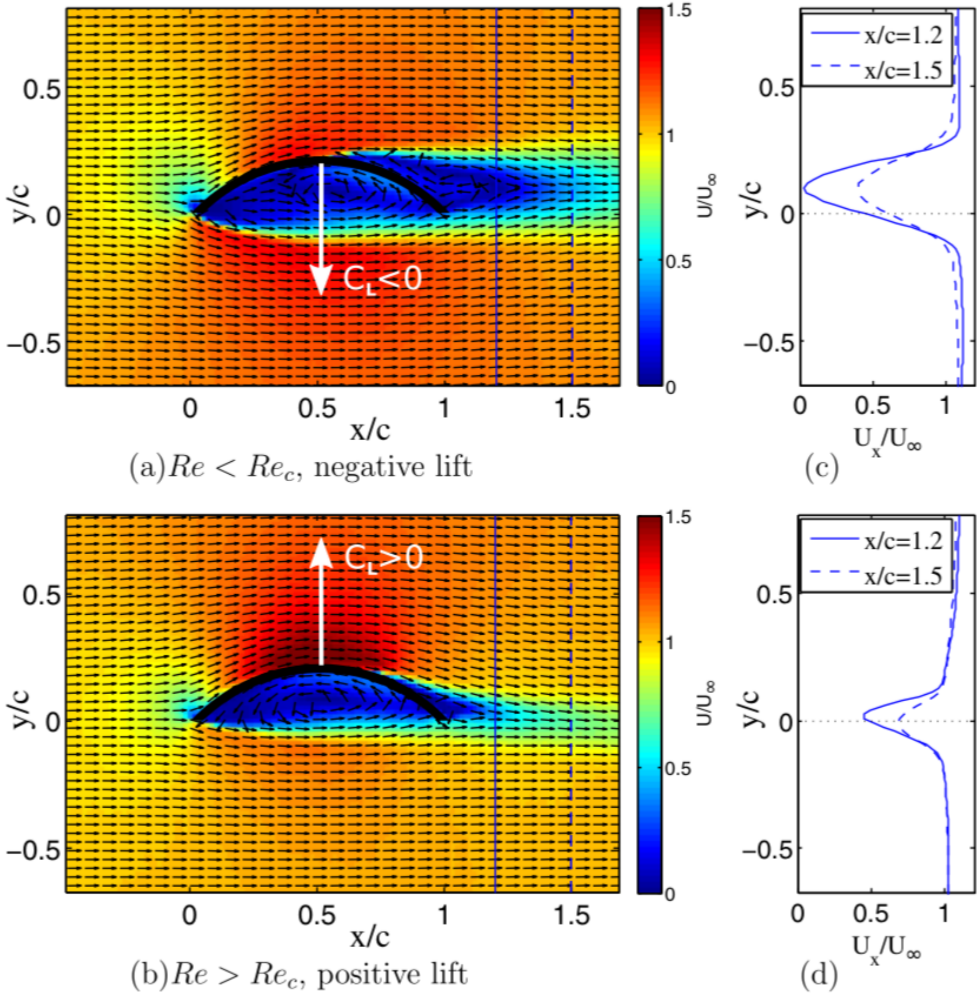
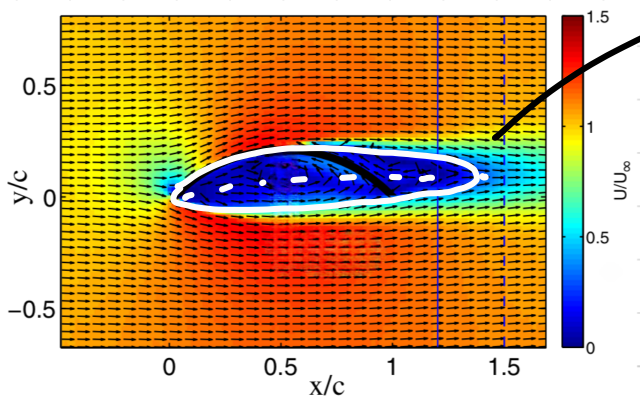


FIG. 4. Mean PIV velocity field (a),(b) and streamwise velocity profile $U_x(y)$ in the wake (c),(d) below and above the critical Reynolds number: (a),(c) Re $= 1.91\ 10^5$ and negative lift, and (b),(d) Re $= 2.05\ 10^5$ and positive lift. Color code in (a),(b) represents the normalized velocity magnitude from $U/U_\infty = 0$ (blue) to $U/U_\infty = 1.5$ (red).

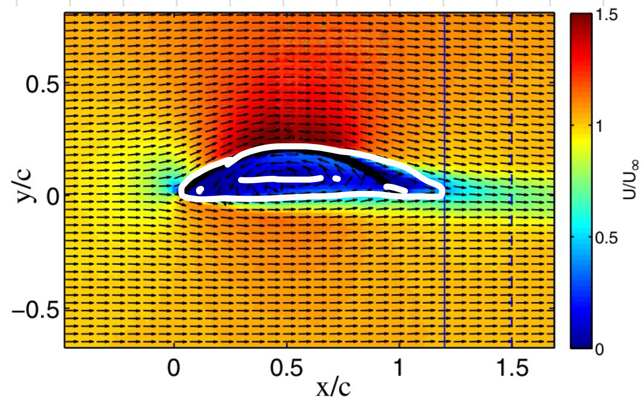
So what can we do here with our simple theories?



extract virtual airfoil contour

Pot. flow → challenges:

- find appropriate mapping
- set TE stagnation point



Thin airfoil theory: ↗

(k)