

ME-445 AERODYNAMICS

10 - Group project info



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 (or an excellent conference) 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

- Find and select a paper
- Select 2 out of 3: potential flow, thin airfoil, Prandtl's lifting line theory
- For each theory:
 - select a figure to reproduce using the chosen theory
 - extract the necessary data from the paper
 - calculate the airfoil performance data using the chosen theory
 - challenge one of the assumptions/choices made by testing the sensitivity of results on the assumption/choice made
- Summarise and present the results in an oral presentation at the end of the semester

Tasks

How to find and select a paper?

What to pay attention to?

- Does the paper include sufficient information about the airfoil geometry?
→ select non-symmetric airfoils
- Does the paper include sufficient information available about the flow conditions (Reynolds number, flow velocity, ...)?
- Are multiple quantities presented in the paper?
- Are the figures of good quality?
- Are the experimental set-up or simulation description of good quality?
- Is the journal of reliable quality?
(Stay away from predatory journals including MDPI, Frontiers)

Tasks

Select 2 out of 3

- Potential flow theory
→ airfoil geometry needs to be approximated
- Thin airfoil profile
→ only apply to non-symmetric airfoils, preferably select pressure data
- Prandtl's lifting line theory
→ finite wing data / 3D wing geometry required

⚠ These theories predict pressure based forces, comparisons of frictional drag will not be feasible.

Tasks

Compare data

For each theory:

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

Tasks

Compare data

For each theory:

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

What do we mean by assumption/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.

Example

Multi-element airfoil

Experimental Data

All of the experimental data used in the present work have been obtained in the Low Turbulence Pressure Tunnel (LTPT) located at the NASA Langley Research Center.¹⁵ The tunnel is a single-return, closed-throat wind tunnel that obtains high Reynolds numbers by operating at pressures up to 10 atm. The test section is 3 ft wide by 7.5 ft high by 7 ft long. Side-wall boundary-layer suction is applied to promote two-dimensional flow.¹⁶

Lift and moment measurements are obtained by using both a force balance and an integration of surface pressures; drag is obtained from a wake survey using three five-hole probes. The uncertainty of the lift coefficient from the balance measurement is ± 0.074 at $Re = 9 \times 10^6$, but increases to ± 0.13 at $Re = 5 \times 10^6$. The pitching moment uncertainty, as measured by the balance, is ± 0.03 at $Re = 9 \times 10^6$, and ± 0.05 at $Re = 5 \times 10^6$. The lift coefficient is estimated to be within ± 0.02 when obtained from pressure integration for $Re = 5$ and 9×10^6 . The drag coefficient is estimated to be accurate to within ± 0.001 for attached flows.¹⁷ Pressure coefficient



Fig. 1 Geometry for three-element airfoil 30P-30AG.

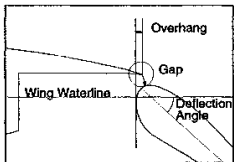


Fig. 2 Definition of gap and overhang for flap.

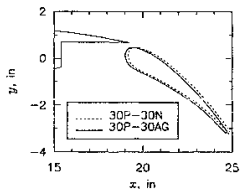


Fig. 3 Differences in flap rigging for the 30P-30N and 30P-30AG configurations.

Navier–Stokes Computations and Experimental Comparisons for Multielement Airfoil Configurations

W. Kyle Anderson,* Daryl L. Bonhaus,* Robert J. McGhee,† and Betty S. Walker*
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■ Potential flow theory



challenge to approximate the airfoil shape



high angles of attack

■ Thin airfoil theory



applicable to multi-element airfoils



airfoil thickness and gaps



high angles of attack

Example

Multi-element airfoil

Potential flow theory (+ thin airfoil theory)

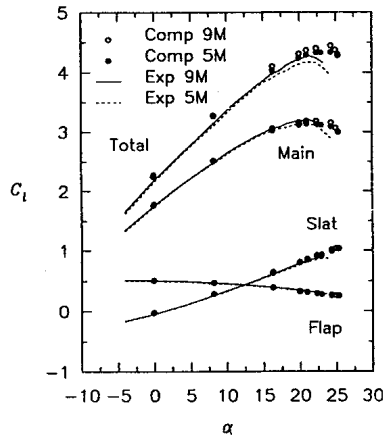


Fig. 12 Experimental and computational lift vs angle of attack for $Re = 5 \times 10^6$ and 9×10^6 for 30P-30N with $M_\infty = 0.2$.

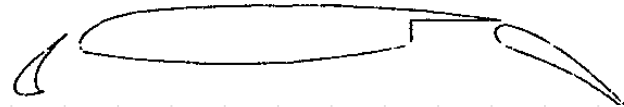
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Important challenge will be to approximate the airfoil profile.

Option 1: treat as one airfoil and test the sensitivity of the results on the different approximations of the airfoil shape

Option 2: treat as different airfoils and test the sensitivity of the results on the gaps between the airfoil parts



Example

Multi-element airfoil

Thin airfoil theory

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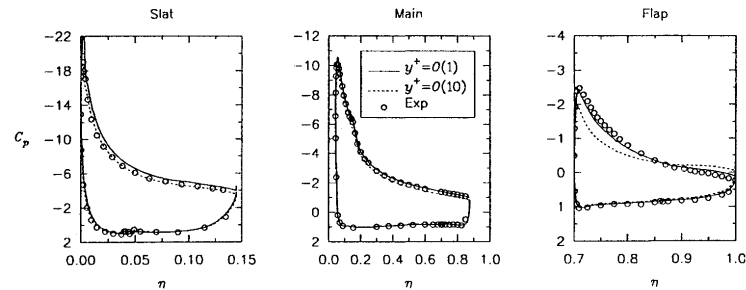
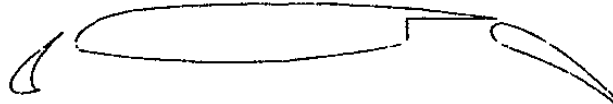


Fig. 11 Comparison of pressure distributions on grids with $y^+ \approx 1$ and $y^+ \approx 10$ for 30P–30N with $M_\infty = 0.2$, $Re = 9 \times 10^6$, $\alpha = 22.36$ deg.

Here, we will treat the airfoil as thin with the slat and the flap rotating about a hinge, ignoring the gaps.

Option 1: vary the hinge locations for the slat and flap and test the sensitivity of the results on the different locations

Option 2: vary the slat and flap angles and test the sensitivity of the results on the different angles



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
- A template for the presentation will be provided with a given structure
- Read and follow the instructions in the template

Organisation



Important dates:

- **October 15** Group project info session during the exercise session
- **October 30** Submit form to validate selected paper
- **November 08** Submit form with summary of progress & open challenges
- **November 11** Meeting schedule available
- **November 12** Mandatory group project progress meeting with teaching team
- **December 10** Project presentations (groups 1-13 tbc)
- **December 17** Project presentations (groups 14-26 tbc)

Links to the forms will be shared on https://go.epfl.ch/ME445_groupproject