Engineering Tripos Part IIB, 4A7: Aerodynamics, 2024-25

Module Leader

Dr JP Jarrett [1]

Lecturers

Dr JP Jarrett and Prof CA Hall

Lab Leader

Dr JP Jarrett

Timing and Structure

Michaelmas term. 12 lectures + coursework. Assessment: 100% coursework.

Prerequisites

3A1 and 3A3 assumed

Aims

The aims of the course are to:

- develop the basic ideas necessary to understand some advanced concepts in aerodynamics.
- cover the aerodynamic effects that constrain an aircraft design.

Objectives

As specific objectives, by the end of the course students should be able to:

- have an appreciation of the aerodynamic factors likely to feature in the designs of new aircraft.
- have an understanding of the behaviour of boundary layers over swept wings in compressible flow.
- estimate the position of laminar-turbulent transition.
- estimate wing drag, and to be familiar with techniques for avoiding turbulent flow.
- have sufficient knowledge to be able to predict the different supersonic zones on a wing.
- understand how the basic physics can be integrated into the design of an aircraft.
- understand how to make design trade-offs.
- have a basic appreciation of the impact of aviation on the environment and possible responses.

Content

This course aims to develop the basic ideas necessary to enable the student to understand some advanced concepts in aerodynamics. In particular the course will cover the aerodynamic effects that constrain an aircraft design. The course will highlight those factors determining the configuration of aircraft for different duties relating them to the effect of compressibility at transonic speeds, the control of boundary layers to benefit from laminar flows and the estimation of aerodynamic loads on the aircraft structure. Coursework will illustrate basic physics, via transonic airfoil design and the integration of these basics via a study of the trade-offs made in producing a design for a given specification. The course will end by reviewing the environmental impact of aviation and show how aircraft design might change to reduce this impact.

Introduction to transonic wings (3L, Dr J P Jarrett)

- Review of 3A3 material: boundary layers and drag estimation;
- Transonic flow about two-dimensional aerofoils;
- Shock-boundary layer interaction;
- Supercritical aerofoils with delayed shock-induced drag rise.

Transonic aerofoil design (4h coursework, Dr J P Jarrett)

This coursework section will allow the interactive design of a transonic aerofoil profile on a workstation in the DPO. The aim is to consolidate the lecture material and illustrate how the various design constraints compete in practice.

Advanced aerodynamics (3L, Dr J P Jarrett)

- Aerodynamic challenges of high-speed flight
- Airframe/Intake integration
- Stability of swept wing aircraft
- Practical swept wing design
- Delta and slender ogival wings
- Vertical / short take-off and landing

Aviation and the environment (6L, Prof CA Hall)

The impact of air transport on the environment; the relationship between technology, operational practice, regulation and economics.

- Basic modelling
- The environment - overview of atmospheric chemistry, fluid dynamics & mixing; the greenhouse effect; radiative forcing.
- Airframe - aircraft range & endurance, the Breguet equation; ML/D payload, fuel and structure weight; choice of fuel. Why do airplanes fly at the altitude they do? Payload and fuel efficiency.
- Engine - simple modelling of a high-bypass ratio turbofan engine. Cycle efficiency and propulsive efficiency, trading production of NOx and CO2.
- What would an airplane look like if optimised to reduce environmental impact?

Greener by Design (Coursework, Prof CA Hall)

The coursework consists of a choice of one from three case studies, based on the simple modelling above to study from the perspective of environmental impact the trade-offs associated with (A) design range;(B) cruise altitude;and (C) engine overall pressure ratio. It is intended that the case studies will be spreadsheet based.

Coursework

- Aerofoil design/Report/Michaelmas term/50%
- Transonic Aircraft Design/Report/Michaelmas Term/50%

Coursework	Format	Due date & marks
[Coursework activity #1 title / Interim] Coursework 1 brief description Learning objective: • •	Individual Report anonymously marked	day during te Thu week 6 [30/60]
[Coursework activity #2 title / Final] Coursework 2 brief description Learning objective: • •	Individual Report anonymously marked	Wed week 9 [30/60]

Booklists

Please see the Booklist for Group A Courses [2] for references for this module.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

IA2

Demonstrate creative and innovative ability in the synthesis of solutions and in formulating designs.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

D1

Wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations.

S1

The ability to make general evaluations of commercial risks through some understanding of the basis of such risks.

S3

Understanding of the requirement for engineering activities to promote sustainable development.

S4

Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk (including environmental risk) issues.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

US4

An awareness of developing technologies related to own specialisation.

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