Engineering Tripos Part IIB, 4A13: Combustion & IC Engines, 2017-18

Module Leader

Prof S Hochgreb [1]

Lecturers

Prof E Mastorakos and Prof S Hochgreb

Timing and Structure

Lent term. 16 lectures, including 2 examples classes. Assessment: 100% exam

Prerequisites

3A5, 3A6 useful

Aims

The aims of the course are to:

- introduce students to fundamental combustion concepts, and their influence on internal combustion engine preformance and emissions.

Objectives

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

- Understand fundamental concepts in combustion
- Understand combustion issues particularly relvant to gas turbines
- Understand the performance and efficiency characteristics of IC engines
- Understand the formation and aftertreatment of pollutants in IC engines, and tradeoffs with performance

Content

Chemical thermodynamics and equilibrium (1L)

- Mass, energy and atomic species conservation
- Multispecies equilibrium and calculation method

Chemical kinetics (1L)

- Principles of chemical kinetics: law of mass action and activation energy
- Hydrocarbon reaction chains
- Pollutant formation
- Multistep reactions and explosions
- Steady state and partial equilibrium approximations
- Characteristic time and space scales

Applications of chemical kinetics: limit reators (1L)

- Common approximations in combustion analysis:
    - Static reactor
    - Perfectly stirred reactor
    - Plug flow reactor
- Thermal explosions
- Autoignition

Laminar premixed flames (1L)

- Laminar premixed flames: concepts and measurements
- Conservation equations for combustion in one and multiple dimensions
- Characteristic time and space scales, Zeldovich number
- One-dimensional conservation equation and simplified solutions
- Effects of mixture composition, stretch and curvature

Laminar non-premixed flames (1L)

- Laminar diffusion flames: concept and measurement methods
- Characteristic time and space scales
- Conserved scalars and mixture fraction
- One-dimensional conservation equations: co-flow and opposed flow

Kinetics of pollution formation (NOx,CO, particles) (1L)

- Zel'dovich and extended NOx formation chemistry
- Time scales for CO and HC chemistry
- Particle formation and oxidation mechanisms

Flames and Turbulence (1L)

- Characteristic time and space scales
- Regimes of turbulent combustion
- Measurement methods and results
- Approaches to modeling turbulent combustion

Gas turbine combustion - performance and emissions (1L)

- Gas turbine combustion principles
- Emissions and stability in industrial gas turbines and aeroengines

Fundamental concepts in IC engines (2L)

- Overview of energy use in transportation
- IC and reciprocating engine evolution
- Basic concepts and definitions
- Ideal constant volume and constant pressure cycles
- Efficiency, indicated mean effective pressure and torque

Spark ignition engines (1L)

- Basic concepts and definitions
- Valve timing and volumetric efficiency
- Residual gases
- Intake and fuel injection systems
- Combustion in SI engines
- Autoignition and limits to combustion
- Spark timing and optimisation

- Effects of speed and load
- SI engine maps
- Emissions

CI engines - enhancing performance and emissions (1L)

- Compression ignition process parameters
- Combustion under autoignition
- Fuel injection timing, torque and emissions
- Controlling NOx and soot
- CI engine maps
- Principles of turbocharging and relevant physics
- Turbocharger matching

SI engine emissions and aftertreatment (1L)

- Combustion and engine out emissions
- Three way catalysts
- Air-fuel ratio control
- Exhaust gas recirculation

SI engine emissions and aftertreatment (1L)

- Combustion and engine out emissions
- Methods of in-cylinder control of NOx and soot
- Air-fuel ratio control
- Exhaust gas recirculation
- Selective catalytic reduction
- Particulate matter removal

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.

E1

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

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.

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