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

Module Leader
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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 performance 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 relevant 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 reactors (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

The UK Standard for Professional Engineering Competence (UK-SPEC) [4] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the ‘Accreditation of Higher Education Programmes’ (AHEP) document [5] which sets out the standard for degree accreditation.

The Output Standards Matrices [6] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.
Links
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