Combustion

ECTS: 6 ECTS

COORDINATOR: César Huete Ruiz de Lira (chuete@ing.uc3m.es)

UNIVERSITY WHERE THE COORDINATOR IS: UC3M

HAVE YOU GIVEN PERMISSION TO RECORD YOUR CLASSES? No

LECTURER 1: César Huete Ruiz de Lira (chuete@ing.uc3m.es)

LECTURER 2: Mario Sánchez Sanz (mssanz@ing.uc3m.es)

LECTURER 3: Daniel Fernández Galisteo (d.galisteo@ciemat.es o galisteo@ing.uc3m.es)

LECTURER 4: Alberto Cuadra Lara (acuadra@ing.uc3m.es)

UNIVERSITY WHERE THE LECTURERS 1, 2, 3 AND 4 ARE: UC3M

HAVE YOU GIVEN PERMISSION TO RECORD YOUR CLASSES? No

SUBJECT CONTENTS

1. Introduction

- Historical Perspective

- The science of combustion

- Future Developments

2. Conservation equations for reactive flows

- Multicomponent mixtures

    * Mass fractions

    * Molar fractions

  * Molar concentrations

- Equations of state for ideal gas mixtures

  * Thermal equation of state

  * Caloric equation of state

- Molecular transport in multicomponent mixtures

  * Diffusion velocities

  * Multicomponent transport

  * Usual simplifications in combustion problems

- Conservation equations

  * Mass

  * Linear momentum

  * Species

  * Energy

- Characteristic scales and dimensionless numbers

3. Thermochemistry

- The assumption of complete combustion

  * Stoichiometric mixture

  * Equivalence ratio

  * Composition of the product mixture in complete combustion

    + Lean combustion

    + Rich combustion

- Adiabatic flame temperature

  * Definition

  * Heat of combustion

  * Calculation of the adiabatic flame temperature

    + Variable cp

    + Constant cp

- Complete combustion vs. incomplete combustion

  * Major and minor species

- Chemical equilibrium in reactive mixtures

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* The equilibrium constant
* Dissociation of the major species
* Effect of temperature and pressure

4. Combustion kinetics

- Chemical kinetics
  * Types of elementary reactions
  * Detailed and reduced mechanisms
  * One-step mechanism
  * The limit of high activation energy
- Rate of heat release by chemical reaction
- Steady state assumption
- Partial equilibrium assumption
- Examples
  * Hydrogen combustion
  * Hydrocarbon combustion
  * Zeldovich analysis for the production of NOx

5. Combustion in systems with homogeneous composition

- Conservation equations for systems with homogeneous composition
- Adiabatic combustion in a well-stirred reactor. Steady solutions
  * The number of Damköhler
  * Ignition and extinction: The S-shaped curve
- Frank-Kamenetskii theory of thermal explosions
- Chain-branching explosions
  * Explosion limits in H2-O2 mixtures
  * Explosion limits in HC-O2 mixtures
- Spontaneous ignition in a combustion chamber with variable volume
- Other ignition processes

6. Fronts reagents: Detonation and deflagration

- Rankine-Hugoniot relations
- Detonation

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  * ZND Structure

  * Galloping "detonations"

  * Actual structure of detonations

- Deflagrations or premixed flames

  * Internal structure

  * Laminar flame speed

    + Variation with pressure and equivalence ratio

  * Minimum Ignition Energy

  * Quenching distance

  * Flammability limits

7. Diffusion Flames

- non-premixed combustion

- Relevant thermochemical parameters

- The limit of infinitely fast reaction

- Finite-rate effects

  * Counterflow diffusion flames

  * Ignition and extinction: The S-shaped curve

- Examples

  * Jet diffusion flames

  * Non-premixed flame-vortex interactions

8. Evaporation and combustion of droplets and sprays

- Droplet evaporation

- Droplet combustion

- Homogenised description of spray combustion

9. Combustion instabilities

- Flame stretch and curvature

- Thermo-diffusive instability

- Hydrodynamic instability

- Thermoacoustic instability

10. Turbulent combustion

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- Premixed turbulent combustion
  * Characteritis scales
  * Diagram of regimes
  * Turbulent flame speed
- Non-premixed turbulent combustion
  * Characteritis scales
  * Diagram of regimes
  * Turbulent jet diffusion flames

METHODOLOGY

Use of board for discussion of theoretical concepts and illustrative examples.

LANGUAGE USED IN CLASS: It will be adapted according to the audience.

IS IT COMPULSORY TO ATTEND CLASS? Students can attend via conference system

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BIBLIOGRAPHY

-Transport Processes in Chemically Reacting Flow Systems. D. E. Rosner. Dover. 2000.

-Diffusion and Heat Transfer in Chemical Kinetics. D. A. Frank-Kamenetskii. Plenum Press. 1969.

-Fundamental Aspects of Combustion. A. Liñán & F. A. Williams. Oxford University Press. 1993

-Combustion Theory. F. A. Williams. Benjamin-Cummings. 1985. 2 ed.

-Turbulent Combustion. N. Peters. Cambridge University Press. 2000

SKILLS

Basic:

CG1: To have knowledge that provide a basis or opportunity for originality in developing and / or applying ideas, often within a research context, knowing how to translate industrial needs in terms of R & D in the field of mathematics Industrial.

CG2: To be able to apply the acquired knowledge and abilities to solve problems in new or unfamiliar environments within broader contexts, including the ability to integrate multidisciplinary R & D in the business environment.

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CG4: To have the ability to communicate the findings to specialist and non-specialist audiences in a clear and unambiguous way.

CG5: To have the appropriate learning skills to enable them to continue studying in a way that will be largely self-directed or autonomous, and also to be able to successfully undertake doctoral studies.

Specific:

CE1: To acquire a basic knowledge in an area of Engineering / Applied Science, as a starting point for an adequate mathematical modelling, using well-established contexts or in new or unfamiliar environments within broader and multidisciplinary contexts.

CE2: To model specific ingredients and make appropriate simplifications in the model to facilitate their numerical treatment, maintaining the degree of accuracy, according to previous requirements.

CE5: To be able to validate and interpret the results, comparing them with visualizations, experimental measurements and functional requirements of the physical engineering system.

Modelling specialization:

CM2: To know how to model elements and complex systems leading to well-posed formulated problems.

WILL YOU BE USING A VIRTUAL PLATFORM? No.

WILL YOU BE USING ANY SPECIFIC SOFTWARE? No.

CRITERIA FOR THE 1ST ASSESSMENT OPPORTUNITY

Students must demonstrate that they understand and know how to apply the concepts learned by solving the homework problems proposed during the classes. Specifically, throughout the semester, the students must complete and submit 4 homeworks on the topics covered in the subject (75% of the grade). Class attendance will be positively assessed (10% of the grade) and a multiple choice quizz exam will be taken at the end of the semester (15% of the grade).

These criteria will be used to evaluate the skills CG1, CG2, CG4, CG5, CE1, CE2, CE5 and CM2.

CRITERIA FOR THE 2ND ASSESSMENT OPPORTUNITY

The same criteria as in the 1st opportunity.

REMARKS FOR THE ACADEMIC YEAR 2020-2021. CONTINGENCY PLAN:

No changes regarding the above.