Course guide
220305 - 220305 - Rockets Combustion and Propulsion

Last modified: 05/07/2024

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 724 - MMT - Department of Heat Engines.

Degree: MASTER'S DEGREE IN AERONAUTICAL ENGINEERING (Syllabus 2014). (Compulsory subject).

Academic year: 2024 **ECTS Credits:** 5.0 **Languages:** Catalan

LECTURER

Coordinating lecturer: Bermejo Plana, David

Others: Bermejo Plana, David
Borràs Quintanal, Borja Pedro
Ventosa Molina, Jordi

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE18. MUEA/MASE: The ability to design, execute and analyse propulsion systems tests and carry out the systems' entire certification process.
CE12. MUEA/MASE: Sufficient knowledge of advanced fluid mechanics, particularly experimental and numerical techniques used in fluid mechanics.
CE13. MUEA/MASE: Understanding and mastery of combustion and heat and mass transfer phenomena.

Basic:
CB06. Manage original concepts in research projects.
CB08. Generate decision from incomplete information assuming its social and ethical responsibilities.
CB10. Improve self-learning capacity

TEACHING METHODOLOGY

The teaching of the subject is organized in three methodological blocks:
• Face-to-face sessions in the classroom with theory classes (lectures) and application (examples and problems).
In the face-to-face sessions in the classroom, the teaching staff in charge will present the contents of the course, introducing the theoretical bases of the subject, concepts, methods and resolution procedures and results, illustrating them through convenient examples, visual material and proposing to the students, when considered, exercises and problems to solve.
Additionally, teachers will regularly propose activities to understand and consolidate the concepts worked on in the classroom.
• Practical face-to-face sessions, which may include specific lessons on the use of computer software for combustion, chemical equilibrium and performance of rocket engines, conferences and talks, seminars, laboratory and/or workshop practices, presentation of works/projects and visits to companies.
In the practical sessions with computer software, the teaching staff in charge will guide the student in the analysis and resolution of combustion processes in thermal chemical rockets and their operational performance using specific software. These sessions are scheduled to take place in the school's computer rooms. The methodology and calculation tools will have to be used by the student in solving combustion and rocket problems proposed by the teaching staff.
Conferences, talks, seminars, laboratory/workshop practices, presentation of work and visits to companies will be conveniently announced through ATENEA.
• Independent study and group work through carrying out different activities.
In group work, students will have to collaborate together in small groups on a common goal. During the activity, students create knowledge from the interaction between classmates, instead of the classic teacher-student transfer, students are responsible for both their classmates' learning and their own, and the role of the teacher is that of a facilitator, that is That is, it develops the structure, facilitates the context and provides the learning space. Students are expected to interact, discuss, contrast points of view and solve the problem together.

LEARNING OBJECTIVES OF THE SUBJECT

The basic objectives of this subject are the following:
Knowledge, by the students, of the theoretical foundations and calculation methodology of the combustion processes in chemical thermal rockets, as well as the operating principles and internal ballistics of the different types of chemical thermal rocket motor.
Knowledge, by students, of the theoretical foundations and limitations of chemical thermal rocket propulsion.
Knowledge, by students, of the characteristic elements and systems that make up rocket propellants: combustion chamber, nozzle, storage and feeding system (injectors, pumps, tanks, ...), chemical, thermal and mechanical compatibility of the materials.
Knowledge, by students, of the standard nozzle design procedures.
Knowledge, by the students, of the foundations that allow analyzing, selecting and judging the propulsion system and the elements that compose it, according to the requirements of the mission.
Development, by students, of the basic knowledge and skills necessary to make preliminary designs for thermal chemical rockets with solid, liquid and hybrid propellants.
Knowledge, by students, of experimental testing techniques for propulsion systems.

STUDY LOAD

Type	Hours	Percentage
Hours large group	30,0	24.00
Hours small group	15,0	12.00
Self study	80,0	64.00

Total learning time: 125 h

CONTENTS

Module 1: Specificity and applications of different types of rocket propellants

Description:
Performance parameters, type of missions, types of rocket motor and evaluation of rocket motors.

Full-or-part-time: 4h 10m
Theory classes: 1h
Laboratory classes: 0h 30m
Self study : 2h 40m

Module 2: Applied combustion to rockets

Description:
Basic concepts of combustion, type of propellants, physical model of the ideal chemical thermal rocket engine, stoichiometry, thermochemistry, calculation examples.

Full-or-part-time: 33h 20m
Theory classes: 8h
Laboratory classes: 4h
Self study : 21h 20m

Module 3: Solid rockets

Description:
Elements and arrangement of solid fuel rockets, ignition system, fuel load (grain composition and formulation, grain design and geometry, internal ballistics, combustion and thrust law), instabilities in combustion and operation, design of rocket engines.

Full-or-part-time: 25h
Theory classes: 6h
Laboratory classes: 3h
Self study : 16h

Module 4: Liquid rockets

Description:
Analyse the rocket propellants used in different missions throughout the history of rockets.

Full-or-part-time: 25h
Theory classes: 6h
Laboratory classes: 3h
Self study : 16h

Module 5: Technical performance qualities of rockets

Description:
Ejection velocity of gases in rockets, thrust and expansion ratio, characteristic speed, thrust coefficient, quality of performance of the rocket propellant, total impulse, specific impulse, effective ejection speed, efficiency of the rocket motor, thrust control.

Full-or-part-time: 12h 30m
Theory classes: 3h
Laboratory classes: 1h 30m
Self study : 8h

Module 6: Nozzle design

Description:
Type of nozzles, calculation methods for the design of nozzles, liquid fuel engine nozzles

Full-or-part-time: 25h
Theory classes: 6h
Laboratory classes: 3h
Self study : 16h

GRADING SYSTEM

The grading system for the subject is structured in four blocks:
1) First part exam (P1): topics 1, 2 and 3, studied along the first part of the course. Weight 35%.
2) Second part exam (P2): topics 4, 5 and 6, studied along the second part of the course. Weight 35%.
3) Team work (T). Weight 20%.
4) Conceptualization and resolution of challenges (R). Weight 10%

For students who do not pass the first partial exam (activity 5), a renewal exam is planned to be taken on the day of the second partial exam (activity 6).
Renewal exam guidelines:
• Only those students that have failed the first partial exam (P1 < 5.0) can do the exam.
• The maximum grade is limited to 6.0 of 10.0.
• The final grade corresponding to the first partial exam (P1) will be the highest that the student has obtained among both exams (ordinary exam and renewal exam).

BIBLIOGRAPHY

Basic:
- Sutton, G. P.; Biblarz, O. Rocket propulsion elements [on line]. 8th ed. New York: John Wiley & Sons, 2010 [Consultation: 03/05/2022]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=818989. ISBN 9781118174616.
- Kuo, K. K. Principles of combustion. 2nd ed. New York: John Wiley & Sons, 2005. ISBN 0471046892.
- Malcom W. Chase, Jr. NIST-JANAF thermochemical tables. 4th ed. Washington: American Chemical Society and American Institute of Physics, 1998. ISBN 1563968312.
- Huzel, D. K.; Huang, D. H. Modern engineering for design of liquid-propellant rocket engines. Washington: American Institute of Aeronautics and Astronautics, 1992. ISBN 1563470136.
- Brown, Charles D. Spacecraft propulsion. Washington, DC: American Institute of Aeronautics and Astronautics, 1995. ISBN 1563471280.
- Huzel, D. K.; Huang, D. H. Design of liquid-propellant rocket engines [on line]. 2nd ed. Washington: National Aeronautics and Space Administration, 1971 [Consultation: 12/04/2022]. Available on: https://ntrs.nasa.gov/api/citations/19710019929/downloads/19710019929.pdf.

Complementary:
- Mattingly, Jack D. Elements of propulsion: gas turbines and rockets [on line]. Reston: American Institute of Aeronautics and Astronautics, 2006 [Consultation: 05/05/2022]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=3111475. ISBN 1563477793.
- Turchi, Peter J. Propulsion techniques: action and reaction. Reston: American Institute of Aeronautics and Astronautics, 1998. ISBN 1563471159.
- Oates, Gordon C. Aerothermodynamics of gas turbine and rocket propulsion. 3rd ed. Reston: American Institute of Aeronautics and Astronautics, 1997. ISBN 1563472414.

RESOURCES

Other resources:
Material prepared and/or compiled by the teacher available on the ATENEA virtual campus.