CENTRALE NANTES

ENGINEERING PROGRAMME

2025-2026

Year 2 / Year 3

Specialisation option

Aeronautics

OD AERONAUTIQUE

PROGRAMME SUPERVISOR
Laurent PERRET

Autumn Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 73	12	Core course	DYGAZA DYVOL ISN STAV	Gas dynamics Flight dynamics Introduction to numerical computation Aircraft structure modelling
UE 74	13	Core course	AEFP DYSTR MTURB P1AERO PROAE	Inviscid Aerodynamics Structural dynamics Turbulence Modeling Project 1 Aicraft propulsion

Spring Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 83	14	Core course	AEAC CAE P2AERO SAE SPSAE	Aeroacoustics Aircraft design and construction Project 2 Computational aerodynamics Passive safety of aeronautic structures

Gas dynamics [DYGAZA]

LEAD PROFESSOR(S): Guy CAPDEVILLE

Objectives

A general introduction to the physics of compressible fluid flows with a bias towards aerodynamics.

Course contents

1. Fundamentals in aerodynamics
2. Equations for steady compressible fluid flow.
3. One-dimensional compressible fluid flow.
4. Waves in steady supersonic flows.
5. Jet Propulsion.
6. Practical exercices using STARCCM+.

Course material

[1] A.H. Shapiro, The dynamics and thermodynamics of compressible fluid flow, Vol. I, Ed. Ronald Press, (1953)
[2] M. J. Zucrow, J. D. Hoffman, Gas Dynamics, Vol. I, Ed. Wiley & Sons, (1976)
[3] J. D. Anderson, Modern compressible flows. With historical perspective, Ed. Mc GrawHill, (2003).

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - C2C1 : Represent and model
    - Intermediate

Skills assessed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - Intermediate

Sustainable Development Goals (SDGs) covered by this course

Affordable and clean energy / Responsible consumption and production

Sustainable Development and Social Responsibility Positioning

Clean energy within a framework of sustainable development.

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	26 hrs	6 hrs	0 hrs	0 hrs	0 hrs

Flight dynamics [DYVOL]

LEAD PROFESSOR(S): Laurent PERRET

Objectives

Based on the introductory course on aerodynamics, this course aims to describe and explain the flight characteristics and performance of planes through analysis of the lift and drag characteristics of airfoils, wings and the complete plane.

Course contents

1. Introduction
2. Fluid dynamics and aerodynamics
3. Lift
4. Drag
5. Mach number effect
6. Flight mechanics
7. Flight performance

Course material

- Aerodynamics, Aeronautics and Flight Mechanics, B.W. McCormick, Wiley;
- Introduction to Flight, J.D. Anderson, McGraw Hill;
- Flight Physics, E. Torenbeek & H. Wittenberg, Springer;
- Boundary Layer Theory, H. Schlichting & K. Gersten, Springer;
- Polycopié de Mécanique des Fluides, Pr J.-F. Sini, ECN

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - C2C2 : Solve and arbitrate
    - Intermediate
    - Proficient

Skills assessed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - Intermediate
  - Proficient

Sustainable Development Goals (SDGs) covered by this course

Affordable and clean energy / Climate action / Industry, innovation and infrastructure

Sustainable Development and Social Responsibility Positioning

Improvements in aircraft performance (efficiency, materials, weight, fuel consumption) directly address issues related to sustainable development: any gains translate into lower consumption and therefore reduced greenhouse gas emissions. Issues related to engine technology (new technologies, electric, hydrogen, hybrid) also concern sustainable development.

Controlling aircraft flight performance (related to weight and aerodynamic forces) has a direct impact on efficiency, particularly fuel consumption and the possibility of using engine strategies that do not rely on fossil fuels.

Assessment

Collective assessment: EVC 1 (coefficient 0.33)

Individual assessment: EVI 1 (coefficient 0.67)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	22 hrs	8 hrs	0 hrs	0 hrs	2 hrs

Introduction to numerical computation [ISN]

LEAD PROFESSOR(S): Laurent GORNET / Zhe LI

Objectives

To provide an introduction to numerical modelling techniques.

Course contents

PDE classification. Elliptic/ Parabolic/Hyperbolic equations
Main discretisation techniques: finite difference, finite volume, finite element
Aerodynamic and structure examples
Fluid and structure examples with the code CasT3M (CEA)
PINNs, Deep Learning with TensorFlow (Partial differential equation)

Course material

Résolution numérique des équations aux dérivés partielles, A. Le. Pourhiet, Cepadues
Introduction à la méthode des éléments finis en mécanique des fluides, S. Gounand, CEA
A first course in Finite Elements, J. Fish, T. Belytschko, Wiley
Cours éléments finis, Centrale Nantes, H Oudin

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - C2C1 : Represent and model
    - Intermediate
  - C2C2 : Solve and arbitrate
    - Intermediate

Skills assessed through this course

No skill observed

Sustainable Development Goals (SDGs) covered by this course

Industry, innovation and infrastructure / Quality education

Sustainable Development and Social Responsibility Positioning

Introducing students to numerical methods contributes to the challenges of sustainable development and social responsibility by familiarising them with modelling and simulation tools that enable a better understanding and reduction of the environmental and societal impacts of technical systems. Numerical methods are essential for: - Limiting the need for physical experimentation, thereby reducing the consumption of materials, energy, and associated waste; - Optimizing structures, processes, and systems in order to improve their efficiency, durability, and service life; - Evaluating alternative scenarios (materials, loading conditions, usage conditions) that promote more responsible decision-making. The course also raises students' awareness of: - Digital sobriety, including model selection, required accuracy, and computational cost; - The responsibility of engineers and scientists in the use of simulation tools to support and inform decision-making.

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	8 hrs	8 hrs	0 hrs	0 hrs

Aircraft structure modelling [STAV]

LEAD PROFESSOR(S): Laurent GORNET

Objectives

- Description of linear and nonlinear behavior laws for metallic and composite materials.
- Homogenization methods are presented for material and structure (composite beams).
- Simulations of crack initiation and propagation for static and fatigue loadings
- Finite Element prediction with Abaqus of aeronautic structures with beam, shell and continuum

Course contents

- Composite material homogenization techniques
- Fracture mechanics: energetic theory, singularity, crack propagations, example of fracture mechanics with a Finite Element code.
- Plasticity and instabilities
- Plasticity and instabilities for beam and shell models.
- Damage mechanics: method of local state, fatigue, phenomenology, behavior laws (metal and composite materials).
- Regularization techniques for stress softening behavior laws.
- Finite Element prediction until ultimate failure of aeronautic structures.
- Interactions between experimental data and behavior laws for material and structures

Course material

Aircraft Structures, for Engineering students, THG Megson, Butterworth Heinemann
Généralités sur les matériaux composites, L. Gornet, hal.archives-ouvertes.fr
Mécanique des matériaux solides, J. Lemaitre - JL Chaboche
Mechanics of Aircraft structures, C.T. Sun, Wiley

Skills developed through this course

No skill teached

Skills assessed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - Intermediate
  - Proficient

Sustainable Development Goals (SDGs) covered by this course

Industry, innovation and infrastructure / Quality education

Sustainable Development and Social Responsibility Positioning

The course "Aircraft Structure Modeling" aims to train engineers capable of designing aircraft structures that are both high-performing, safe, and environmentally friendly. It incorporates a sustainable development approach by promoting material optimization. At the same time, it raises students' awareness of social responsibility, with a strong emphasis on safety. This approach helps prepare them to develop sustainable technological solutions in the aerospace industry.

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	24 hrs	6 hrs	0 hrs	0 hrs	2 hrs

Inviscid Aerodynamics [AEFP]

LEAD PROFESSOR(S): Guy CAPDEVILLE

Objectives

- Introduce the conventional models for incompressible subsonic flow.
- Describe the modelling techniques derived from these models.
- Describe the evolution of ideas in aeronautics since the beginning of the nineteenth century
- The tutorials focus on programming one of the models introduced in the course.

Course contents

- Introductory principles in aerodynamics
- Fundamentals of inviscid incompressible flow - Kutta-Joukowski Theorem.
- Incompressible flow around airfoils - Numerical method of vortex singularities.
- Incompressible flow around wings - Prandtl's Lifting line theory.
- Linear theory of thin airfoils - Prandtl-Glauert's correction.
- Computation of aerodynamic features of an airfoil by using the method of singularities.

Course material

- J.D. Anderson, Fundamentals of aerodynamics, Ed. Mc Graw-Hill, (1984)
- A. H. Shapiro, The dynamics and thermodynamics of compressible fluid flow, Vol. I, Ed. Ronald Press, (1953).

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - C2C3 : Think and act in an unpredictable and uncertain environments
    - Intermediate

Skills assessed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - Intermediate

Sustainable Development Goals (SDGs) covered by this course

Affordable and clean energy / Goo health and well-being / Responsible consumption and production

Sustainable Development and Social Responsibility Positioning

Aircraft aerodynamics in the context of sustainable development.

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	24 hrs	8 hrs	0 hrs	0 hrs	0 hrs

Structural dynamics [DYSTR]

LEAD PROFESSOR(S): Pascal COSSON / Patrick ROZYCKI

Requirements

Elementary functions, Differentiation, Integration, Differential equations, Vector Analysis, Linear Algebra

Objectives

In aeronautics, many mechanical systems evolve dynamically and must meet stringent requirements for safety, reliability, and performance. These may include, for instance, wing structures, landing gear assemblies, or fuselage components, for which it is essential to determine natural frequencies and mode shapes, and/or to verify the dimensioning of critical connections. Regardless of the subsystem considered, engineers must be able to analyse the design, dynamic behaviour, and modelling of these complex structures to ensure their proper functioning under all operational conditions.

In response to these challenges, engineers must be able to employ simple analytical approaches, to develop more advanced modelling strategies when necessary and to rely on a sound understanding of available solution methods in order to address a given problem effectively. They must also be capable of intervening in the design and optimisation of these systems so as to enhance their performance and reliability.

The course pursues two main objectives.
- The first objective is to provide engineering students with the methodological tools required to develop simple yet sufficiently representative analytical models, enabling the rapid estimation of relevant orders of magnitude and the formulation of a first reliable solution to a problem in rigid body dynamics.
- The second objective is to acquire a solid foundation in the available solution methods whether analytical or numerical and to foster a critical mindset with respect to their domains of validity, advantages and limitations.

Upon completion of the course, students will be able to propose an appropriate modelling strategy for a given problem, to select a consistent solution approach, and to interpret the resulting data with discernment. They will also be capable of adopting a critical perspective on the computational tools used in industrial practice, in order to confirm or, where appropriate, to question the numerical results obtained.

To this end, the course also relies on the use of a commercial computational code widely recognised in the field of rigid body dynamics. This software will be employed within the framework of an applied project, partly based on a real industrial case. It will enable students to confront the theoretical and/or analytical approaches presented in the course with professional numerical simulations. The project aims to strengthen students' understanding of modelling assumptions, to assess the relevance of the results obtained, and to develop a critical approach closely aligned with industrial engineering practice.

Course contents

1. Modelling a rigid bodies system
   - Configuration, joints, Lagrange's equations, kinematically or not admissible configuration etc.

2. Vibrations
   - Systems of 1 or more degree(s) of freedom, eigenvalue problem, free or forced vibrations etc.

3. Time integration schemes
   - Euler, Runge Kutta, Newmark, implicit or explicit methods, stability etc.

Course material

M. Géradin & A. Cardon, Flexible Multibody Dynamics - A Finite Element Approach, Wiley, 2001

D. Le Houedec, Mécanique des Solides, Nantes

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - C2C1 : Represent and model
    - Intermediate
    - Proficient
  - C2C2 : Solve and arbitrate
    - Intermediate
    - Proficient
  - C2C3 : Think and act in an unpredictable and uncertain environments
    - Intermediate
    - Proficient

Skills assessed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - Intermediate
  - Proficient

Sustainable Development Goals (SDGs) covered by this course

Industry, innovation and infrastructure

Sustainable Development and Social Responsibility Positioning

This course contributes to the development of competences related to sustainable development and the social responsibility of engineers by promoting a reasoned and critical approach to modelling and computation in rigid body dynamics. It enables students to assess the impact of their modelling choices on the design, validation, and optimisation of mechanical systems while encouraging a considered use of resources and limiting material and energy costs, particularly those associated with experimental testing. The associated project, based on a commercial computational code and real industrial cases, places students in a context closely aligned with professional practice. It allows them to confront analytical models with numerical simulations, to evaluate the relevance of the results obtained, and to develop a critical, reflective approach. This experience aims to train engineers capable of making well-informed and responsible decisions in technically complex situations.

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	12 hrs	8 hrs	12 hrs	0 hrs	0 hrs

Turbulence Modeling [MTURB]

LEAD PROFESSOR(S): Laurent PERRET

Objectives

This course provides an introduction to turbulent flows and their numerical modelling.
It is completed by applications on the statistical analysis of a wake flow and the study of turbulence models using CFD code.

Course contents

1. Introduction
2. Turbulence phenomenology
3. The turbulent boundary layer
4. Statistical modeling of turbulence
5. Large Eddy Simulation

Course material

- Boundary Layer Theory, H. Schlichting & K. Gersten, Springer;
- Turbulent Flows, S.B. Pope, Cambridge univ Press;
- Turbulence en mécanique des fluides, P. Chassaing, Cépaduès

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - C2C1 : Represent and model
    - Intermediate
  - C2C2 : Solve and arbitrate
    - Intermediate

Skills assessed through this course

No skill observed

Sustainable Development Goals (SDGs) covered by this course

Affordable and clean energy / Climate action / Industry, innovation and infrastructure

Sustainable Development and Social Responsibility Positioning

Industrial and environmental flows are almost always turbulent due to their characteristic speed and dimensions. The ability to understand, model, and simulate them is crucial to predicting and improving the performance of industrial systems such as energy production systems (exchangers, nuclear power plants, wind turbines, etc.) and aircraft by reducing their drag and therefore fuel consumption. By training students in turbulence modeling, this course contributes to the creation and adaptation of systems for a more rational and efficient use of resources.

Assessment

Collective assessment:	EVC 1 (coefficient 0.5)
Individual assessment:	EVI 1 (coefficient 0.5)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	8 hrs	6 hrs	0 hrs	2 hrs

Project 1 [P1AERO]

LEAD PROFESSOR(S): Guy CAPDEVILLE

Objectives

Study and carry out a technical project in aeronautics in order to consolidate knowledge acquired in the specialisation.

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - C2C2 : Solve and arbitrate
    - Intermediate

Skills assessed through this course

- C1 : Design and prototype innovative systems that create value
  - Intermediate

Sustainable Development Goals (SDGs) covered by this course

Responsible consumption and production

Sustainable Development and Social Responsibility Positioning

Development of technical solutions compatible with sustainable development

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	1	0 hrs	0 hrs	0 hrs	32 hrs	0 hrs

ENGINEERING - OD AERONAUTIQUE

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

Aicraft propulsion [PROAE]

LEAD PROFESSOR(S): Vincent BERTHOMÉ

Objectives

The objective of this course is to study in detail the thermodynamics of turbojet engines used in aeronautical propulsion.

Course contents

The course begins with the historical background of aeronautical propulsion and the associated stakes.

Following this, a presentation of aeronautical propulsion systems (turboshaft and turbojet engines) will be provided. The cycle of a single-flow turbojet engine will be studied as well as its operation without adaptation. Finally, a study of the turbofan engine will be presented.

The final part of the course deals with helicopter engines (general and thermal thermodynamics, role and operating principle, rotary wings).

Skills developed through this course

Sustainable Development Goals (SDGs) covered by this course

Affordable and clean energy / Climate action / Industry, innovation and infrastructure / Responsible consumption and production

Sustainable Development and Social Responsibility Positioning

The PROAE course presents the latest technological advances in the field of aeronautical propulsion, taking into account the constraints of decarbonizing this sector.

Assessment

Individual assessment: EVI 1 (coefficient 0.5)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	30 hrs	0 hrs	0 hrs	0 hrs	2 hrs

Aeroacoustics [AEAC]

LEAD PROFESSOR(S): Guy CAPDEVILLE

Objectives

Understanding and modelling the noise sources generated in a compressible turbulent flow.

Course contents

- Turbulence equations.
- Aeroacoustic analogies
- Specific numerical methods
- Examples: supersonic jets, cavities,...
- Computations using an aeroacoustic analogy

Course material

A. P. Dowling, J.E. Ffowcs-Williams, Sound and sources of sound, Ed. Wiley & Sons, (1982)

Skills developed through this course

- C1 : Design and prototype innovative systems that create value
  - C1C3 : Deliver and create value
    - Intermediate
- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - C2C3 : Think and act in an unpredictable and uncertain environments
    - Intermediate

Skills assessed through this course

- C3 : Manage complex programmes or change responsibly
  - Intermediate

Sustainable Development Goals (SDGs) covered by this course

Affordable and clean energy / Decent work and economic growth / Goo health and well-being / Responsible consumption and production

Sustainable Development and Social Responsibility Positioning

Understanding and developing techniques to reduce the environmental footprint of an aircraft.

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	24 hrs	8 hrs	0 hrs	0 hrs	0 hrs

Aircraft design and construction [CAE]

LEAD PROFESSOR(S): Laurent GORNET / Laurent PERRET

Objectives

The goal of the first part of the course is to provide the basic regulation on the main categories of aircraft, to define the methods of load calculation applied to aircraft (wing, tail plane and fuselage). In the second part, the lecture is based on the metallic and composite materials used in the airframes and the specific processes for the manufacture and assembly of the main components.

Course contents

- Aircraft history,
- Design principles,
- Design loads on aircraft: flight and landing.
- Sizing methods applicable on wing, tail planes and fuselage .
- Metallic and composite Materials used in the airframes
- Manufacturing and assembly processes of the main parts .

Course material

- Résistance des Matériaux appliquée à l'aviation, P. Vallat.
- Calcul des structures d'avions - cours ECP, F. Delisée.
- Aérodynamique - cours ENSAE, P. Rebuffet.
- Le projet d'avion léger, L. de Goncourt.
- Les secrets de la construction des aéronefs légers, M. Fékété.
- Design of Light aircraft (Richard D Hiscocks)
- Aircraft Structures (David J.Peery)

Skills developed through this course

No skill teached

Skills assessed through this course

- C1 : Design and prototype innovative systems that create value
  - Intermediate
- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - Intermediate
  - Proficient
- C3 : Manage complex programmes or change responsibly
  - Intermediate

Sustainable Development Goals (SDGs) covered by this course

Affordable and clean energy / Climate action / Industry, innovation and infrastructure / Quality education

Sustainable Development and Social Responsibility Positioning

By tackling practical issues such as electric propulsion, consumption requirements, material use, weight control, etc., while complying with a set of specifications, students are directly confronted with the challenges faced by today's engineers when designing systems that meet the requirements of fuel efficiency, energy efficiency, and life cycle control.

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	12 hrs	0 hrs	20 hrs	0 hrs	0 hrs

Project 2 [P2AERO]

LEAD PROFESSOR(S): Guy CAPDEVILLE

Objectives

Study and carry out a technical project dealing with aeronautics in order to consolidate knowledge acquired in the specialisation.

Course contents

Examples of previous projects undertaken:
- Modelling of winglets' on the Onera-M6 wing
- Rocket simulation
- Study of the design of ultra-light aircraft
- Study of a ramjet engine
- Aero-elastic behaviour of airfoils and flaps
- Aerodynamic design of a drone
- Flight simulation of a hypersonic vehicle

Skills developed through this course

- C3 : Manage complex programmes or change responsibly
  - C3C3 : Finalise and leverage feedback
    - Intermediate

Skills assessed through this course

- C3 : Manage complex programmes or change responsibly
  - Intermediate

Sustainable Development Goals (SDGs) covered by this course

Responsible consumption and production

Sustainable Development and Social Responsibility Positioning

Development of technical solutions compatible with sustainable development

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	2	0 hrs	0 hrs	0 hrs	48 hrs	0 hrs

Computational aerodynamics [SAE]

LEAD PROFESSOR(S): Boris CONAN / Guy CAPDEVILLE / Laurent PERRET

Objectives

- Computation of classical problem in aerodynamics using specific software.
- Use of theories and models developed in the other courses of the Aeronautics specialisation
- Comparisons between different numerical models.
- Comparisons of numerical results with theory and experience.

Course contents

- Technical methods for generating structured/unstructured meshes.
- Modelling of a supersonic jet in a converging-diverging nozzle.
- Turbulence modelling: turbulent boundary-layer, the backward facing step.
- Supersonic turbojet inlet - diffraction of a shock wave.
- Boundary-layer shock wave interaction.
- Noise generated by a fluid flow.
- Numerical simulation of a transsonic flow around a NACA airfoil.

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - C2C1 : Represent and model
    - Intermediate
  - C2C2 : Solve and arbitrate
    - Intermediate

Skills assessed through this course

No skill observed

Sustainable Development Goals (SDGs) covered by this course

Affordable and clean energy / Responsible consumption and production

Sustainable Development and Social Responsibility Positioning

Study of technical solutions compatible with sustainable development.

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	8 hrs	14 hrs	10 hrs	0 hrs	0 hrs

Passive safety of aeronautic structures [SPSAE]

LEAD PROFESSOR(S): Patrick ROZYCKI

Requirements

Finite Element Method, Constitutive behaviour law, Plasticity

Objectives

The industrial challenges associated with safety, particularly in the transport sector, require an ever more refined understanding of the behaviour of materials and structures subjected to rapid dynamic loading. These challenges, both technical and scientific in nature, call for an integrated approach combining mechanical expertise, numerical tools and experimental methodologies.

This course aims to explore current methods and future developments in this field by addressing three complementary pillars: materials mechanics, numerical simulation and experimentation. The core topics covered include:
- the modelling of material behaviour under dynamic loading (constitutive laws, strain-rate effects, experimental characterisation methods),
- design and sizing principles for crashworthiness,
- numerical simulation (computational tools and codes for model development and validation),
- and experimental techniques for characterising the behaviour of structures under realistic loading conditions.

Upon completion of this module, engineering students will be able to articulate the development of a numerical model in conjunction with the constraints and outcomes arising from experimental investigations. This cross-disciplinary approach will enable them to develop a critical perspective on the limitations and complementarities of the available tools, and to optimise the correlation between experimental data and numerical simulations which is an essential competency for meeting industrial requirements in safety and innovation.

In order to firmly embed the theoretical knowledge within a practical framework, two successive projects will be undertaken by each engineering student.
- The first project will focus on the analysis of an experimental crushing test performed on a vertical drop tower, involving simple structures (metallic tubes with square and circular cross-sections). For obvious safety reasons, the test will be conducted by authorised School personnel, in the presence of the engineering students. This will allow students to:
    o observe the complete experimental protocol,
    o engage directly with the authorised operator to deepen their understanding of the technical choices and implementation constraints,
    o develop the corresponding numerical model based on the collected data,
    o and critically analyse the results by identifying the limitations and challenges inherent to each stage (experimentation, modelling and data correlation).
- The second project will be based on a case study derived from a real industrial problem, enabling engineering students to mobilise the full range of competencies acquired within a professional context.

Course contents

1. Overview of shocks
   - Nature, type and classification of shocks

2 Crash in the field of transportation
   - Overview, safety, different approaches used etc.

3. Numerical modelling
   - Constitutive laws, different time integration methods, non-linearities

4. Experimental devices
   - Description, different types of tests (front or side-impact) etc.

5 Study of an analytical model for circular or square tubes

6 Simple case study
   - Experiment on a simple structure, numerical simulation and experimental/numerical correlations

Course material

N. Jones, Structural Crashworthiness, Cambridge University Press, 1997

Jorge A.C. Ambrósio, Manuel F.O. Seabra Pereira, F. Pina da Silva, Crashworthiness of Transportation Systems: Structural Impact and Occupant, Springer Netherlands, 1997

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - C2C1 : Represent and model
    - Intermediate
    - Proficient
  - C2C2 : Solve and arbitrate
    - Intermediate
    - Proficient
  - C2C3 : Think and act in an unpredictable and uncertain environments
    - Intermediate
    - Proficient

Skills assessed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
  - Intermediate
  - Proficient

Sustainable Development Goals (SDGs) covered by this course

Goo health and well-being / Industry, innovation and infrastructure / Quality education / Responsible consumption and production

Sustainable Development and Social Responsibility Positioning

This course is embedded within a framework of sustainable development and corporate social responsibility by placing the safety of individuals at the core of the issues addressed. The study of the behaviour of materials and structures subjected to rapid dynamic loading directly contributes to the design of safer systems, particularly in the transport sector, and thus plays a key role in risk prevention and user protection. The integrated approach combining modelling, numerical simulation and experimentation fosters the development of innovative industrial solutions while promoting the responsible use of resources. The correlation between experimental testing and numerical analysis helps to reduce reliance on extensive and costly testing campaigns and to optimise design choices in line with the principles of responsible and sustainable production. Through the proposed projects, which are based on real experimental tests and concrete industrial case studies, the course raises awareness among engineering students of their professional responsibility by encouraging them to assess the technical, human and societal impacts of their design decisions within a demanding industrial context.

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	4 hrs	0 hrs	28 hrs	0 hrs	0 hrs