Semester 3

CENTRALE LYON ENISE

Modelling of material removal & wear 3 ECTS

Lecturers: **C. Courbon and F. Cabanettes**

Lectures: 30h | Tutorials: 0h | Labs: 0h | Project: 0h | Autonomy : 60h | Lang. :

Objectives

This course aims to provide students with a comprehensive understanding of the simulation and modelling of material removal and wear processes using finite element analysis (FEA). Focusing on practical applications using the FEA code Abaqus and Matlab, students will learn to set up, simulate, and analyse material removal and wear scenarios, optimize processes, and interpret results to enhance manufacturing efficiency. By the end of the course, students will have the skills to apply these techniques to real-world engineering problems.

Keywords: Material removal, Wear, Finite Element Analysis, Tribology, Thermo-mechanical loadings, Process optimisation

Programme

1. Reminders & Introduction to Abaqus Finite Element code (4h)
2. Modelling of a sliding contact (2h)
3. Modelling of a metal cutting operation (4h)
4. Group work & case studies (8h)
5. Case studies & presentation (2h)
6. Fundamentals on wear and modelling (2h)
7. Hand on the wear model & literature review (2h)
8. Presentation of the model & case studies (4h)
9. Case studies & presentation (2h)

Prerequisites

- Basics in manufacturing processes
- Metalworking processes S1
- Thermo-mechanical behaviour of metals (elasticity and plasticity theories)

Learning outcomes

- Explain the principles and mechanisms of material removal through plastic deformation and shear in subtractive processes, and understand their impact on material performance and tool wear.
- Develop and apply finite element models using Abaqus and Matlab to simulate material removal and wear processes under various conditions;
- Analyse the effects of different processing/contact parameters on wear and process efficiency using computational simulations;
- Formulate and implement strategies to optimize material removal processes and minimize wear through batch simulations and optimization techniques.

Assessment

- Written exam on the theoretical knowledge gained in this course (50%)
- Oral presentation of the final case study (50%)

References

PJ. Arrazola, T. Ozel, D. Umbrello, M. Davies, IS. Jawahir (2013) Recent Advances in Modelling of Metal Machining Processes. CIRP Annals, 62(1):695–718.

S. N. Melkote, W. Grzesik, J. Outeiro, J. Rech, V. Schulze, H. Attia, P.-J. Arrazola, R. M'Saoubi, C. Saldana (2017) Advances in material and friction data for modelling of metal machining, CIRP Annals, Volume 66(2):731-754.

T. Mabrouki, C. Courbon, Y. Zhang, J. Rech, D. Nélias, M. Asad, H. Hamdi, S. Belhadi, F. Salvatore (2016) Some insights on the modelling of chip formation and its morphology during metal cutting operations, Comptes Rendus Mécanique, 344(4–5):335-354.

CENTRALE LYON ENISE

Modelling of thermomechanical processes and surface integrity

3 ECTS

Lecturers: **F. Valiorgue, Y. Saadlaoui**

Lectures: 30h | Tutorials: 0h | Labs: 0h | Project: 0h | Autonomy : 60h | Lang. :

Objectives

Surface integrity is a key concern today, especially for safety-critical components in industries such as energy, aerospace, aircraft, and medical sectors. The first part of this course is designed to provide students with a foundational understanding of mechanics of materials, offering the necessary background to grasp how materials respond to various stresses and strains. Building on this foundation, the course then focuses on deeply understanding and modelling the various modifications that a surface can undergo during metalworking processes. Its main objectives are: (i) to understand the phenomena that govern surface integrity in finishing processes, (ii) to analyse the effects of surface integrity on critical parts and learn how to tailor these effects, and (iii) to model phase transformations that can occur near the surface.

Keywords: Modelling, residual stresses, microstructure, fatigue life, finishing processes

Programme

1. Introduction to the Mechanics of Materials
2. Mechanical Testing and Experimental Characterization
3. Mechanical Behavior Laws (Elasticity, Viscosity, Plasticity)
4. Hardening and Evolution of Plastic Behavior
5. General background in industry
6. Examples of surface integrity issues
7. Surface integrity evolution during machining
8. Surface integrity modelling
9. Surface integrity customisation
10. Examples

Prerequisites

- Strengh of Materials
- Applied Mathematics
- Elementary Basics in manufacturing processes.
- Machining principles.
- Thermo-mechanical behaviour of metals (elasticity and plasticity theories.

Learning outcomes

- Understand and list the different mechanical behavior laws.
- Be able to select the appropriate mechanical behavior based on the physical problem to be modeled.
- Being able to list the surface modifications generated by a finishing process.
- Being able to explain how the surface is modified.
- Being able to link surface integrity and fatigue life.
- Being able to choose a finishing process to control the surface.

Assessment

2 written exams with questions based on lectures content.
1 oral presentation in the end of the tutorials.

References

"Machining - Fundamental and recent advances" - Springer - J. Paulo Davim

Mondelin, F. Valiorgue, J.Rech, M. Coret, E. Feulvarch (2012) Hybrid model for the prediction of residual stresses induced by 15-5PH steel turning, International Journal of Mechanical Sciences 58(1):69-85

CENTRALE LYON ENISE

Surface repairing and functionalization 3 ECTS

Lecturers: **F. Cabanettes, E. Cabrol, A. Sova**

Lectures: 30h | Tutorials: 0h | Labs: 0h | Project: 0h | Autonomy : 60h | Lang. :

Objectives

This course aims to provide students with a comprehensive understanding of surface degradation mechanisms and advanced techniques used to restore and functionalize surfaces. It combines knowledge in tribology with additive manufacturing processes to develop sustainable solutions for enhancing the durability and performance of mechanical components. Emphasis is placed on the identification of wear mechanisms, material repair strategies, and the design of functional surfaces using both subtractive and additive approaches.

Keywords: Wear of materials, friction, lubrication, surface topographies, additive manufacturing, cold spray, laser cladding

Programme

1. Introduction: History of tribology, economical and sustainability aspects.
2. Fundamentals of wear, friction, surface topography characterization (Abott Firestone curve, classical roughness parameters, filtering techniques), lubrication (Stribeck curve, Hydrodynamic and Reynolds equations, EHL, Hamrock and Dowson equations) and lubricants as well as the types of contacts (conformal non conformal, rough).
3. Types of wear and solutions: running in, adhesive, abrasive, the Archard Law, surface fatigue wear, fretting, other types of wear.
4. Presentation of powder based repair processes (cold spray and laser cladding) and functionalization of surfaces (by additive and subtractive processes).
5. This serie of lectures is followed by a case study dedicated to various additive and subtractive processes and the functionality of generated surfaces.

Prerequisites

- Basic knowledge in materials science and thermal engineering
- Fundamentals of machine elements and mechanical design

Learning outcomes

After attending this course, students will:
- Understand the significance of tribology in industrial applications.
- Understand the behaviour of contacting and sliding surfaces.
- Identify the main wear types and propose solutions to reduce them.
- Identify and compare different additive processes for surface repair
- Analyse the microstructural and functional implications of processes
- Evaluate the performance of functionalized surfaces under service conditions

Assessment

1 report and oral presentation on the case studies.

References

I. Gibson, D. Rosen, B. Stucker, Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2014.
J. Villafuerte, Modern Cold Spray: Materials, Process, and Applications, Springer, 2015.
F. P. Bowden and D. Tabor, The Friction and Lubrication of Solids, Oxford University Press.
Bhushan, B., Principles and Applications of Tribology, Wiley, 2013.

Materials processes 6 ECTS

Lecturers: **H. Klocker**

Lectures: 50h | Tutorials: 0h | Labs: 0h | Project: 0h | Autonomy : 50h | Lang. :

Objectives

Provide the students with a good knowledge of plastic forming and additive manufacturing of metals and alloys

Keywords: Plastic forming, hot forming, cold forming, forming processes, metallic additive manufacturing

Programme

1. Basics of plastic deformation
2. Cold forming
3. Hot forming
4. Forming processes
5. Basics of metal solidification
6. Metallic additive manufacturing
7. Processes of metallic additive manufacturing
8. Modelling of additive manufacturing

Prerequisites

- Basics of materials science
- Basics of materials mechanics

Learning outcomes

- Understand the plasticity of metals and alloys in the context of forming
- Good knowledge of the cold and hot forming processes
- Understand the solidification of metals in the context of additive manufacturing
- Good knowledge of the different metallic additive manufacturing processes
- Choose a process for a given application
- Basic knowledge of modelling of additive manufacturing

Assessment

- Written exam (to be confirmed)

References

All course materials will be supplied in class

Materials characterization 3 — 5 ECTS

Lecturers: **C. Minfray, A. Lamirand, V. Barnier**

Lectures: 30h | Tutorials: 0h | Labs: 7h | Project: 0h | Autonomy : 30h | Lang. :

Objectives

Provide the students with a good knowledge of X-ray Photo-Electron Spectroscopy as a materials characterization method

Keywords: X-ray Photo-Electron Spectroscopy, surface analysis

Programme

1. Basics of electron configuration and radiation-matter interaction
2. Principle of XPS
3. Characteristics of XPS: spectral and spatial resolution, limit of detection, etc.
4. Quantification models
5. Technological aspects (instrumentation, vacuum, etc)
6. Case studies in materials science

Prerequisites

- Basics of microscopy and spectroscopy
- Basics of materials and surface science

Learning outcomes

- Good knowledge of XPS as a surface analysis technique for materials
- Interpret XPS spectra
- Apply simple quantification models
- Identify cases where XPS can bring insight in the context of materials science

Assessment

- Written exam

References

All course materials will be supplied in class

Durability of materials 5 ECTS

Lecturers: **C. Bosch, A. Dreano, K. Wolski**

Lectures: 30h | Tutorials: 15h | Labs: 5h | Project: 0h | Autonomy: 50h | Lang. :

Objectives

Durability is a science and technology dealing with the evolution of "in service" properties; it is also known as environmentally sensitive damage and cracking.
The objectives of the module are to present the various damage phenomena encountered by materials in service and to describe the physico-chemical mechanisms responsible for them.

Keywords: Durability, corrosion, stress corrosion cracking, fatigue corrosion, hydrogen embrittlement, tribo-corrosion, oxidation, diffusion, aging metallic alloys

Programme

1. Principle of aqueous corrosion
2. Elements of thermodynamics applied to corrosion
3. Kinetics reactions in corrosion
4. Passivity, localised corrosion, stress corrosion cracking, fatigue corrosion
5. Hydrogen embrittlement
6. Tribo-corrosion
7. Diffusion
8. Oxidation / Corrosion at high temperature
9. Case studies in materials science

Prerequisites

- Basics of materials science
- Basics of materials mechanics

Learning outcomes

- Knowledge of physico-chemical mechanisms of environmental assisted degradation of materials
- Identification of simple cases of damage assisted by environment
- Know how to implement electrochemical technics of characterization

Assessment

- Written exam

References

All course materials will be supplied in class

CENTRALE LYON ENISE | MINES Saint-Étienne | Institut Mines-Telecom

Responsible engineering — 2 ECTS

Lecturers: **Ph. Bertrand et alii**

Lectures: 0h | Tutorials: 0h | Labs: 0h | Project: 28h | Autonomy : 0h | Lang. :

Objectives

This course aims to develop students' awareness and understanding of the major societal and environmental challenges facing engineers today. Through an active, project-based approach, students explore four key pillars of responsible engineering: circular economy, decarbonisation, ethics and social responsibility, and responsible digital technologies. The course enhances their ability to design, evaluate, and defend sustainable and ethical engineering solutions within real-world contexts.

Keywords: Sustainable design, Circular economy, Ethical engineering, Responsible digital technologies, Industry 4.0

Programme

1. Introduction to the Four Pillars of Responsible Engineering: ethics, climate change, circularity, and digital responsibility
2. Launch of the Student Challenge: project briefing and team formation
3. Team Work – Session 1: deep exploration of the challenge and the four pillars
4. Team Work – Session 2: developing, testing, and validating responsible solutions
5. Final Presentations: pitching the project to a jury
6. Industrial Insights: talks and Q&A with professionals on responsible engineering in practice
7. Final Reflection: round-table discussion and feedback session

Prerequisites

- The course is interdisciplinary and accessible to students from all academic backgrounds.

Learning outcomes

Upon successful completion of the course, students will be able to:
- Understand and apply the principles of responsible engineering to real-life challenges
- Integrate sustainability, ethics, and digital responsibility into the design and development of technical solutions
- Collaborate effectively within diverse teams to address complex issues
- Present and justify responsible engineering strategies to both technical and non-technical audiences

Assessment

Assessment is based on a group project, including a concept poster, a technical and responsible design report, and a 10-minute pitch presented to a jury.

References

F. Allais, Sustainable Design for Circular Economy, Wiley, 2022
UNESCO, Engineering for Sustainable Development, 2021
A. Pavlovskaia et al., Responsible Engineering: Ethics, Sustainability and Society, Springer, 2020
Selected case studies and multimedia resources provided throughout the course

French as a foreign language 2 ECTS

Lecturers: **E. Saint-Louis et alii**

Lectures: 0h | Tutorials: 30h | Labs: 0h | Project: 0h | Autonomy : 10h | Lang. :

Objectives

This course will provide students with an advanced level in French. Course sessions will include: Reading comprehension, Written expression, Oral expression, Listening comprehension, Vocabulary and Grammar.

Keywords: French language

Programme	Dependent on student level, the educational method focuses on practical work: 1. Grammatical exercises with multiple examples and oral practice, 2. Listening to oral materials with increasingly difficult characteristics, 3. Discussions, presentations and debates, role-plays, writing short essays and summaries.
Prerequisites	▪ Attending French for Beginner or B1/B2 level
Learning outcomes	After attending this course, students will: ▪ Understand and use common expressions. ▪ Express themselves through a wide range of sentences (daily life, asking questions, and discussion on familiar topics, speaking in public, efficiently and fluently). ▪ Categorize information taken in a written document to be able to use it. ▪ Express their opinion and answer precise questions.
Assessment	Continuous assessment and oral presentations
References	All course materials will be supplied in class

Preparatory R&D project — 3 ECTS

Lecturers: **various**

Lectures: 0h | Tutorials: 0h | Labs: 0h | Project: 0h | Autonomy : 80h | Lang. :

Objectives

This module aims to prepare MSc students for their Master thesis by guiding them through the process of conducting a thorough literature review, familiarizing them with their chosen research topic, and equipping them with the necessary tools and techniques, including experimental setups and numerical models. By the end of the course, students will be well-prepared to undertake their Master thesis with a solid foundation in both theoretical knowledge and practical skills.

Keywords: -

Programme

1. **Topic selection and introduction**
   - Students define a research topic with a supervisor or apply for a research topic proposed by a researcher.
   - Discussion of potential research areas and alignment of student interests
   - Introduction to the research environment and resources available
2. **Methodology**
   - Conducting a comprehensive literature review on the chosen research topic.
   - Developing a research plan with objectives, methodology, and expected outcomes.
   - Training sessions on using experimental setups and tools for numerical simulations.
   - Students work independently on their research project, conducting experiments, performing numerical simulations, and analysing data.
3. **Follow-up and final deliverables**
   - Regular meetings with the supervisor to discuss progress, refine research questions, and finalize the research plan.
   - Preparation of a final presentation and submission of a written report both summarizing/documenting the research process, results, analysis, and conclusions.

Prerequisites

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Learning outcomes

After attending this course, students will be able to:

- Conduct a comprehensive literature review on a chosen research topic, identifying key studies, gaps, and trends.
- Develop a research plan with objectives, methodology, and expected outcomes.
- Gain proficiency in using experimental setups and numerical modeling tools
- Critically analyze and synthesize research findings
- Present their research plan and preliminary findings effectively to peers and faculty.

Assessment

Evaluation will be based on the quality of the literature review, the development and execution of the research plan, the proficiency in using experimental setups and numerical modelling tools, the ability to work independently, and the quality of the final presentation and report.

References

Relevant references will be provided in agreement with the selected R&D topic