Computing and modelling 1 — 5 ECTS

Lecturers: **R. Ferrier**

Lectures: 18h | Tutorials: 18h | Labs: 18h | Project: 0h | Autonomy: 50h | Lang. :

Objectives

The objective of this course is to provide the students the mathematical and numerical tools needed to understand and model common phenomena or systems in materials science or mechanics.

Keywords: vectors, matrices, differential operators, differential equations, geometry, statistics, probability Python programming, Matlab/Octave

Programme

1. Vectors, matrices and tensors
2. Ordinary Differential Equations, Euler method
3. Statistics and probabilities
4. Non-linear problems and solvers (Newton and fixed-point)
5. Differential operators and Partial Differential Equations
6. Signal processing and Fast Fourier Transform

Prerequisites

- Basics of maths and programming (Bachelor level)

Learning outcomes

- Handle mathematical tools (matrices, vectors, tensors, diff. operators)
- Solve PDEs and ODEs
- Formulate and solve a problem in 3D or 2D geometry
- Describe and analyze non-reproducibility of experimental tests
- Serenely handle informatic tools
- Script in Python and Matlab
- Interact with experts in numerical modelling

Assessment

Written exam (60%) and Individual practical exercises (40%)

References

All course materials will be supplied in class

Materials 1 — 5 ECTS

Lecturers: **J. Favre**

Lectures: 25h | Tutorials: 26h | Labs: 0h | Project: 0h | Autonomy: 50h | Lang. :

Objectives

Provide the students with a good knowledge of metallurgy / microstructure / phase transformations, and an advanced expertise in using binary phase diagrams.

Keywords: metallurgy, binary phase diagrams, thermodynamics, phase transformations, microstructures, microstructure-properties relationship, selection of materials

Programme

1. Introduction to microstructure-properties relationship
2. Basics of thermodynamics applied to materials
3. Phase diagrams
4. Selection of materials

Prerequisites

- Basic knowledge of physics/chemistry/thermodynamics

Learning outcomes

- Good knowledge of metallurgy and microstructure
- Understand the concept of microstructure/properties relationship
- Advanced use of binary phase diagrams

Assessment

Written exam

References

All course materials will be supplied in class

CENTRALE LYON ENISE

Laser-matter interaction and induced surface topographies

3 ECTS

Lecturers: **Ph. Bertrand, F. Cabanettes**

Lectures: 18h	Tutorials: 12h	Labs: 0h	Project: 0h	Autonomy : 60h	Lang. :

Objectives

The aim of the course is to provide an understanding of the building mechanisms of volumes and surfaces during laser/matter interaction, ii) an ability to select the proper temperature measuring instrument to control laser/matter interaction based on optical diagnosis and iii) the ability to propose a complete surface characterization workflow (measuring equipment and strategy, filtering technique, roughness parameters) adapted to an industrial application.

Keywords: Radiation, laser/matter interaction, temperature measurement, surface topography, acquisition, filtering techniques and roughness parameters

Programme

1. Radiation: Basics, Definitions, Quantities, Theories
2. Laser based processes to build objects (and surfaces)
   a. Laser technologies
   b. Study and understanding of laser/matter interaction
   c. Structure and material properties, including the laser effects
   d. Temperature fields at the laser/matter interaction and measurements
3. Temperature measurements to control the building process by laser
   a. Infrared pyrometry
   b. CCD camera
4. Surface topography acquisition and data treatment:
   a. Surface topography acquisition: measuring principles and limits
   b. Filtering techniques
   c. Roughness parameters and areal parameters
   d. Case study 2: analysis of surface topography data from research projects

Prerequisites

- Basic knowledge of heat transfer
- Basic knowledge of manufacturing processes
- Basic knowledge of mathematics and statistics

Learning outcomes

- Knowledge on the physical phenomena governing the laser/matter interaction leading to volume and functional surfaces generation
- Understanding the temperature measuring principles by optical means
- Understanding the measuring principles of instruments for surface topography acquisition. Knowledge about the limits of the instruments.
- Understanding the filtering techniques and roughness parameters

Assessment

Home exam on chapter 1 to 3; Case study (per group of max. 5 students) on chapter 4.

References

CENGEL Y., TURNER R., CIMBALA J., Fundamental of thermal-fluid science, 2016
THOMAS Tom R., Rough surfaces. World Scientific, 1998.
BLUNT L., JIANG X., Advanced techniques for assessment surface topography: development of a basis for 3D surface texture standards" surfstand". Elsevier, 2003.

CENTRALE LYON ENISE

Additive Manufacturing 3 ECTS

Lecturers: **Ph. Bertrand, M. Doubenskaia, E. Cabrol, A. Sova, Y. Saadlaoui**

Lectures: 18h | Tutorials: 12h | Labs: 0h | Project: 0h | Autonomy : 60h | Lang. :

Objectives

Additive Manufacturing is the most common name given to a host of related technologies which are used to fabricate physical objects layer-by-layer directly from Computer- Aided Design (CAD) data sources. The key to how AM works is that parts are made by adding material in layers; each layer is a thin cross-section of the part derived from the original CAD data. The objective is to explain the scientific and technological background of various AM technologies and the corresponding application fields.

Keywords: additive manufacturing, rapid prototyping, rapid tooling, rapid casting, topology optimization.

Programme

1. Process Categories to be discussed: Vat Photopolymerisation; Material jetting by single and multiple nozzles; Binder jetting; Material extrusion; Powder bed fusion; Sheet lamination; Direct material deposition; Hybrid AM.
2. Scaling-up and scaling-down AM processes.
3. Materials applied in AM, properties of manufactured parts.
4. Basic drives: Design complexity; Personalised products; Supply chain realignment; Parts functionality; Low volume production.
5. Market of AM, growth areas, AM equipment.
6. Integral analysis of Selective laser Melting and Laser Cladding including experimental parametric analysis, optical diagnostics and numerical simulation.
7. Cold Gas dynamic Spraying as AM process.
8. Basics of topology optimization with practical examples using a finite element code.

Prerequisites

- Basic knowledge in material science
- General knowledge of laser processes
- General knowledge of thermal spraying processes
- General knowledge of thermal engineering
- Basic knowledge finite element methods

Learning outcomes

After attending this course, students will:

- Have basic knowledge of AM including corresponding thermo-physical phenomena, different technologies, eventual applications, materials, etc.
- Be able to select an appropriate AM technology, equipment and material to realise chosen industrial objective.

Assessment

2 hours examination without any technical support: written answers on a few questions based on lectures content.

References

I. Gibson, I. D. W. Rosen, I. B. Stucker // Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2014.

M Doubenskaia, A. Domashenkov, I. Smurov, P. Petrovskiy // Study of Selective Laser Melting of intermetallic TiAl powder using integral analysis, International Journal of Machine Tools and Manufacture, Vol. 129, 2018, pp. 1-14.

Y. Saadlaoui, J-L. Milan, J-M. Rossi, P. Chabrand, Topology optimization and additive manufacturing: Comparison of conception methods using industrial codes. Journal of Manufacturing Systems 43 (2017) 178–186.

CENTRALE LYON ENISE

Metalworking processes 4 ECTS

Lecturers: J. Rech, F. Valiorgue, C. Courbon

Lectures: 28h | Tutorials: 0h | Labs: 12h | Project: 0h | Autonomy : 56h | Lang. :

Objectives

The objectives of this course are to make the students able to control a given manufacturing technology using a systematic approach and to make them aware of the future challenges for some key industrial sectors. The module will be divided in two parts: i) the first one, more technologically oriented, intends to review the basics of metalworking operation especially focusing on machining, present a standard and related instrumentation to control such operations; ii) the second part will provide a scientific insight focused on numerical simulation dealing with the needs of modelling in the whole production chain, the requirements to build a numerical model, the characterisation of the main input data with a special emphasis on material removal and finally how to build a numerical approach to predict the surface integrity of a machined part.

Keywords: manufacturing, cutting, control, numerical simulation, tribology, surface integrity

Programme

1. Control of a metalworking operation (10h + labs)
   a. Basic knowledge on machining, cutting tools, cutting materials, lubrication
   b. Introduction to the methods of instrumentation of machining processes
   c. Methods for the control of machining operations (NFE66-520) – application in labs
   d. Extension to metal forming operation (remote lecture by a partner university)
2. Future challenges in manufacturing (18h)
   a. Introduction to the context and needs of numerical simulation
   b. Experimental methods to investigate a metalworking process
   c. Experimental methods to determine the workmaterial constitutive model
   d. Experimental methods to assess the tribological interaction
   e. Input data and methodology for the numerical prediction of surface integrity

Prerequisites

- Basic knowledge of manufacturing processes
- Basic knowledge of material science

Learning outcomes

- Ability to describe the technological solutions associated with a machining operation
- Ability to put a manufacturing process under control
- Ability to identify the causes of non-quality and to suggest solutions
- Awareness of the benefits and requirements of process modelling
- Ability to select a material and tribological characterization technique
- Be able to develop a simple numerical model to predict residual stresses

Assessment

Part 1: 1 written exam based on lectures content, 1 oral presentation and report of the labs
Part 2: Oral presentation on a research related topic based on journal papers

References

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

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

Rech J, Arrazola PJ, Claudin C, Courbon C, Pusavec F, Kopac J (2013) Characterization of Friction and Heat Partition Coefficients at the Tool–workmaterial Interface in Cutting. CIRP Annals — Manufacturing Technology 62(1):78–82

CENTRALE LYON ENISE

Transverse project in manufacturing 2 ECTS

Lecturers: **C. Courbon, alii**

Lectures: 0h | Tutorials: 0h | Labs: 0h | Project: 24h | Autonomy : 24h | Lang. :

Objectives

The objective of this course is to provide the students a practical experience combining various manufacturing technologies, from additive to surface finishing processes including material removal or surface treatment methods. An actual industrial issue will be used as a case study and the students will be able to propose solutions integrating all the available manufacturing techniques, conduct experiments on representative samples as well as advanced analyses such as microstructural, residual stresses or tribological performances. Designed as a project course, it also intends to foster team working abilities by organising and sharing tasks in smaller groups, planning the work and presenting the results.

Keywords: manufacturing technologies, additive manufacturing, surface analysis

Programme

7. Introduction of the case study
8. Identification of the needs and targeted objectives
9. Structure and planning of the work
10. Design of the samples and set of experiments to perform
11. Organisation of the experimental campaigns
12. Analysis of the results and possible iteration
13. Presentation of the work done

Prerequisites

- Basics of Production Engineering S1
- Additive Manufacturing S1
- Metalworking processes S1

Learning outcomes

Upon successful completion of the course, students will be able to:

- Integrate complementary manufacturing technologies (additive, subtractive, and surface treatments) to address a specific industrial problem.
- Design and implement an experimental plan involving the fabrication, characterisation, and analysis of representative components or samples.
- Apply advanced analysis techniques, such as microstructural observations, residual stress measurements, or tribological testing, to assess manufacturing outcomes.
- Collaborate effectively in a project team, including task planning, time management, and collective decision-making.
- Communicate technical findings clearly, both in written form and oral presentations, to a professional or academic audience.

Assessment

One oral presentation and a summary report answering the industrial need

References

All course materials will be supplied in class

Semester 1 – Elective 1

CENTRALE LYON
ENISE

High temperature processes — 4 ECTS

Lecturers: **M. Doubenskaia, A. Sova**

Lectures: 8h | Tutorials: 12h | Labs: 16h | Project: 0h | Autonomy : 60h | Lang. :

Objectives

Introduction to physics and technologies of materials processing by concentrated energy fluxes (laser, flame/plasma flow) covering a wide spectrum of applications ranging from the traditional ones to the most modern. Presentation of typical equipment and application domains such as laser cutting, laser welding, laser cladding, thermal spray.

Keywords: laser processing, thermal spray technologies, high temperature heat-and mass transfer.

Programme

1. Lectures
   a. Types of laser sources and their applications : cutting, welding, drilling, marking, additive manufacturing;
   b. Industrial Thermal Spraying Technologies: Equipment; physics of coating deposition;
   c. Applied materials and coatings design. Application fields.
   d. Optical diagnostics for modern high temperature technologies.
2. Tutorials:
   a. Different types of effective heat sources used for simulation of materials processing by concentrated energy sources: laser, plasma arc, electron beam;
   b. Calculation of temperature fields in welding and surface heat treatment.
   c. Models for temperature/velocity distribution in high temperature gas flows
3. Labs: (i) Traditional laser applications: welding, surface hardening, cutting, engraving; (ii) cold gas dynamic spraying

Prerequisites

- General knowledge of industrial manufacturing processes.
- Basics of Heat Transfer, Fluid Dynamics and Thermodynamics.
- General knowledge in material science: Typical compositions and microstructures of metals and alloys

Learning outcomes

After attending this course, students will:

- Be able to describe physical phenomena in laser machining and thermal spraying.
- Be able to describe all the technical parameters and materials used in laser or thermal projection processes;
- Be able to implement a control approach for a laser or projection process;
- Master the different modes of heat transfer in solids and apply the results to processes using concentrated energy beams (laser, plasma, electron beam, etc.)

Assessment

One 2 hour exam on the lectures' and tutorials' content and report of the labs

References

William M. Steen, Jyotirmoy Mazumder, Laser Material Processing, 4th Edition, Springer-Verlag London, 2010.
John Ion, Laser Processing of Engineering Materials: Principles, Procedure and Industrial Applications, Elsevier, 2005.
G. Gladush, I. Smurov. Laser Processing of Materials: Theory, Experiment, Springer-Verlag, Berlin Heidelberg, 2011
Thermal Spray Fundamentals: From powder to part; Springer 2014

Production engineering — 4 ECTS

Lecturers: **C. Courbon, J. Rech**

Lectures: 22h | Tutorials: 16h | Labs: 0h | Project: 0h | Autonomy : 76h | Lang. :

Objectives

This course aims to provide students with a comprehensive understanding of production engineering, including both the design of manufacturing processes (industrialisation) and the architecture of production systems. Students will learn how to define, plan, and optimise production routes and system layouts based on functional, technical, and economic requirements. A systematic method is introduced to break down manufacturing processes, sequence operations, and design production system organisations adapted to various industrial constraints..

Keywords: Manufacturing, industrialization, production systems, metrology and control, technical drawing

Programme

1. Introduction to the notion of industrialization
   a. Presentation of the services involved during the development of a product
   b. Notion of functional specifications
2. Recalls on conventional manufacturing technologies
3. Recalls on dimensional product specification, Geometrical Product Specification (GPS) standard and surface topography (roughness, waviness) (filtering ISO 4288)
4. Practical case study: production route planning from technical drawing
   a. Task breakdown, precedence constraints, sequencing, manufacturing flow
5. Production systems engineering
   a. Historical evolution and typologies of production systems
   b. Systems classification based on flexibility, cadence, and product lifetime
   c. Functional decomposition and layout design
6. Group project: design of a production system meeting a specific set of requirements

Prerequisites

- Basic knowledge of manufacturing processes
- Ability to read and interpret technical drawings
- Familiarity with machining conditions and metrology

Learning outcomes

- Understand the principles of product industrialisation
- Break down and schedule manufacturing operations
- Read technical drawings and extract key constraints
- Describe the main types of production systems
- Design and justify a suitable production system architecture

Assessment

1 written exam on a case study + 1 group project designing a production system

References

All course materials will be supplied in class

French as a foreign language 2 ECTS

Lecturers: **M. Leplat, alii**

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

Objectives

This course will provide students with an introduction to the French language. 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

-

Learning outcomes

After attending this course, students will:

- Express themselves through a short series of expressions or easy sentences (daily life, asking questions);
- Understand and use common expressions;
- Categorize the key information taken in a written document to be able to use it;

Assessment

Continuous assessment and oral presentations

References

All course materials will be supplied in class

CENTRALE LYON ENISE

Research methods — 2 ECTS

Lecturers: **Guest lecturer**

Lectures: 0h | Tutorials: 20h | Labs: 0h | Project: 0h | Autonomy : 40h | Lang. :

Objectives

This module conveys the basic principles of scientific work in the field of Engineering Sciences. The students acquire the key aspects (e.g. philosophy of science, scientific ethics) and deploy them to write their own scientific work. Handling of literature sources, collection and analysis of experimental data as well as guidelines for the publication of scientific findings will be treated.

Keywords: French language

Programme

1. Fundamentals of Science
2. History of Science
3. Ethics in Science
4. Finding Literature
5. Reading Literature
6. Citing Literature
7. Writing and Publishing an article
8. Peer Review

Prerequisites

-

Learning outcomes

After attending this course, students will:

- Be familiar with research based learning and working;
- Be familiar with aims, methods, ethics of science ;
- Be able to structure a scientific article or their final thesis independently;
- Be able to participate in science community after graduation.

Assessment

One written scientific paper and associated oral presentation

References

All course materials will be supplied in class