Portfolio

François Vansnick

Graduated with a Master's degree in Mechanical Civil Engineering

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Contents

About me

I have always been passionate about new technologies and driven by a constant desire to learn. My main interests revolve around the automotive industry and motorsport, space exploration and creative fields such as drawing, 3D modeling, and prototyping...

Naturally, this passion led me to pursue studies in civil engineering at UCLouvain. I first earned my Bachelor's degree in Engineering Sciences with a focus on mechanics and computer science. Later, I had to choose between these two areas that were equally important to me. In the end, I decided to specialize in mechanics, as computer science is easier to learn independently, while mechanics requires more structured study.

In September 2025, I completed my Master's degree. My goal now is to keep learning and growing, this time alongside companies, by applying my skills and gaining real-world experience. In short, I am motivated, organized, versatile, and able to multitask.

My Profile

- Name : Vansnick François
- Age : 24 years old
- Location : Lessines, Belgium

Education

Master's Degree in Mechanical Engineering

UCLouvain (Catholic University of Louvain) — 2023 to 2025

Option dynamics, robotics, biomechanics, mechanical design, manufacturing processes and materials mechanics.

Bachelor's Degree in Engineering science

UCLouvain (Catholic University of Louvain) - 2019 to 2024

Option Mechanics and Computer Science

CESS Mathematics and Science

Collège Saint Julien Ath - 2013 to 2019

Certifications

SolidWorks


CERTIFICATE

Dassault Systèmes confers upon

FRANÇOIS VANSNICK

the certificate for

Mechanical Design

November 24 2023

Academic exam at Universite Catholique de Louvain - Ecole Polytechnique de Louvain

MECHANICAL DESIGN

SOLIDWORKS ASSOCIATE

Manish KUMAR
SOLIDWORKS CEO
R&D Vice President

C-7DZRK9GQN4

MATLAB

MathWorks® | *Training Services*

Course Completion Certificate

François Vansnick

has successfully completed **100%** of the self-paced training course

MATLAB Onramp

DIRECTOR, TRAINING SERVICES

27 February 2024

Skills

CAD & Design

- SolidWorks, AutoCAD, Fusion 360

Experienced in creating detailed 3D models and **technical drawings** for mechanical components and assemblies. Skilled in translating design concepts into manufacturable parts and **optimizing assemblies** for performance, cost, and durability.

Simulation & Analysis

- Abaqus, Digimat, Robotran, FEMM

Proficient in performing **Finite Element Analysis FEA**, **Multibody Dynamics** and **structural and thermal analyses**. Able to evaluate mechanical performance, predict real-world behavior and optimize designs for reliability and efficiency.

Programming & Tools

- Python, MATLAB, C, Arduino, Bash, Java, HTML, CSS, Office Suite ...

Experienced in data **analysis and simulation**. Also familiar with **PLC programming** (Siemens) and integration of actuators and sensors for automation and control systems.

Material Selection & Manufacturing

- Ansys Granta Selector

Experienced in selecting appropriate materials for mechanical applications considering performance, cost, and sustainability. Understands **manufacturing processes** such as **machining**, **welding** and **additive manufacturing** and their impact on design and performance.

Industrial Risk, Quality & Business Awareness

- Risk assessment, safety standards, quality management

Basic knowledge of **industrial risk assessment**, **safety standards**, and **quality management** methods like Toyota Production System TPS. Familiar with financial concepts, business operations, and basic legal principles relevant to engineering projects, enabling informed decision-making

Projects

Bachelor's Projects

- **Propeller Launcher**: The first group project consisted of designing a propeller launcher. The goal was to create a system capable of making a propeller fly to a precise height. This project provided hands-on experience in design, 3D modeling, and 3D printing, as well as developing a program to configure the launcher's flight settings.

- **RFID Badge**: The second project was more complex and took place during the COVID-19 pandemic. Due to restrictions, we adapted the project to focus on creating a glass detection system for an automatic beverage dispenser. This involved both hardware design and system integration challenges.

- **Computer Science Project**: Rewrote a Python program in C to run on a Raspberry Pi, ensuring identical input/output behavior. Optimized performance by implementing multi-threading to utilize all four cores. Managed the project via GitLab with continuous integration and automated testing using CUnit, Valgrind, and cppcheck. Developed a Makefile to compile, test, and clean the project while ensuring full compatibility and strict coding standards.

- **Stability Analysis of a Bike**: This project focused on analyzing the stability of a bicycle-pulled trailer, in collaboration with Bpost (cargo bike). Using Robotran software and C programming, we modeled the cyclist and the load, coded the trajectory, implemented the handlebar controller, and simulated tire-ground contact. The work also included designing and analyzing the rear suspension system to optimize performance and safety.

Mechanical Construction Project

The first-year master group project in collaboration with a compagny, consisted of **developing a mechanical design for an automatic optical fiber spooling and coating machine** intended for use in satellites.

Due to a confidentiality agreement with the company, I am unable to disclose specific details about this project.

Master Thesis

My master's thesis, carried out in a team of two in collaboration with a company, consisted of the **design and development of a test bench to accurately measure no-load losses in high-performance micro-motors operating at speeds up to 100,000 revolutions per minute.**

Due to a confidentiality agreement with the company, I am unable to disclose specific details about this project.

Engineering & Simulation Courses

Advanced Manufacturing Technologies

This course provided me in-depth technical knowledge of advanced manufacturing technologies and the **machining of complex parts**. By exploring a wide range of manufacturing processes, we were able to gain a comprehensive understanding of their advantages and limitations. The course also included visits to specialized companies and various laboratories, allowing me to see these technologies in action.

Project: Design a Bottle Opener

In this group project, we were tasked to design and model a bottle opener while taking into account the technical constraints of the chosen manufacturing process, in our case **Selective Laser Melting (SLM)**.

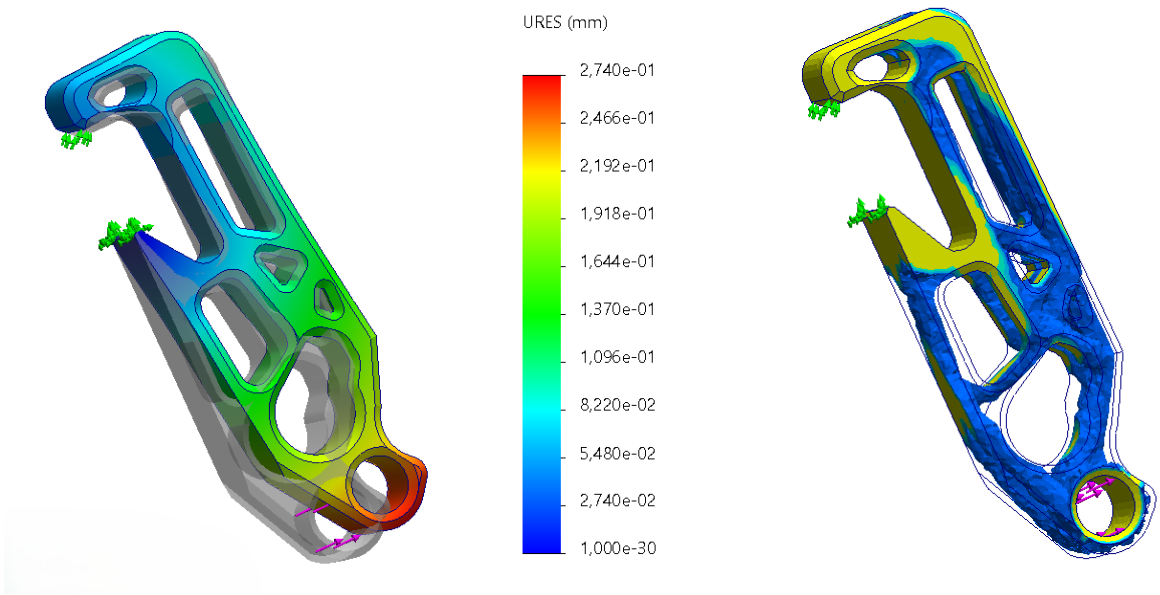
Objectives: Minimize weight while maintaining optimal strength and of course, to ensure the bottle opener functioned effectively.

We modeled the bottle opener in SolidWorks and went through several iterations, applying **topological optimization** to improve performance and material efficiency. Once the design was finalized, we 3D printed the bottle opener using SLM. After printing, we conducted a series of **laboratory tests** to verify that the final product met all the requirements outlined in the project specifications.

First Part:

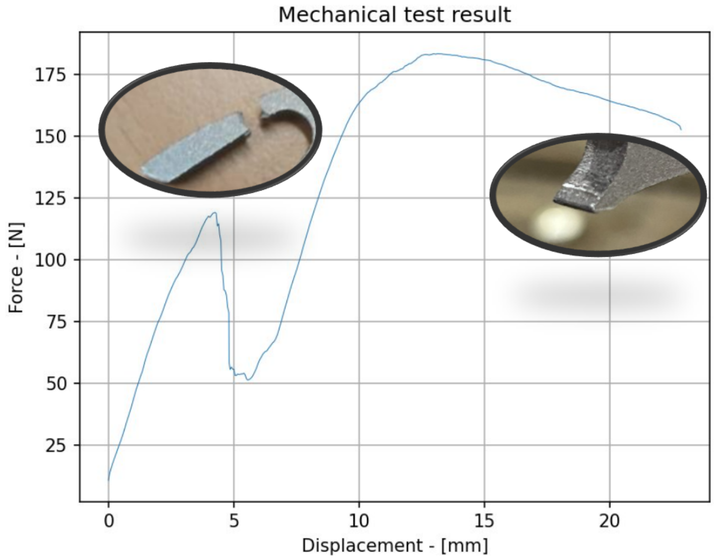
- Developed and compared multiple design concepts, selecting the one that minimized mass despite slightly lower strength.
- Applied force constraints on relevant surfaces to simulate real-world conditions.

- Performed meshing and structural simulations in SolidWorks. Analyzed displacement, stress and deformation results.
- Conducted topology optimization to minimize mass while maintaining strength.
- Iteratively modified the bottle opener design based on simulation feedback until achieving the final optimized model.



Second Part:

- Conducted laboratory tests to obtain the Force–Displacement curve.
- Interpreted the different stages of material deformation based on experimental data.
- Analyzed the microstructure to correlate mechanical behavior with material characteristics.



Project: Process Selection

> **Objectives:** Identify the most suitable manufacturing process for wind turbine blades.

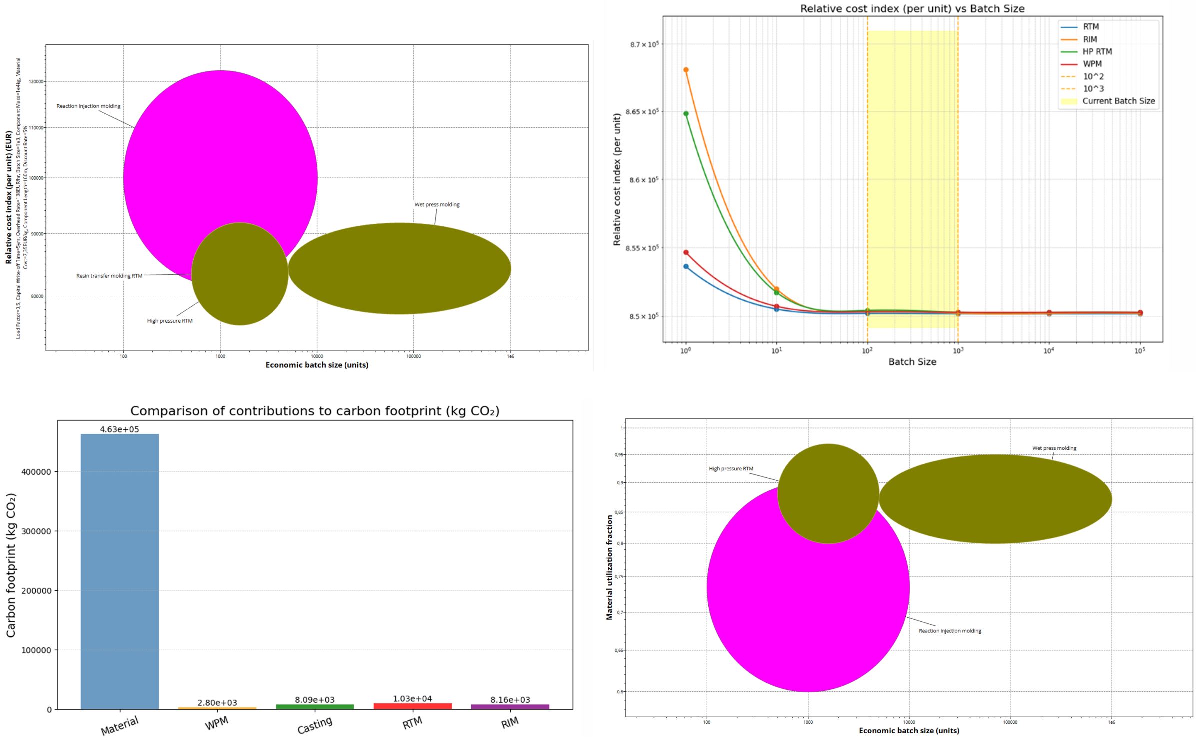
We first defined the blade's primary function, efficiently absorb the wind's kinetic energy to drive the rotor while ensuring no profile distortion during production to maintain aerodynamic efficiency. Additionally, surface roughness had to be minimized to reduce turbulence.

First Part:

- Conducted a functional analysis in accordance with standards to identify key design and process constraints.
- Modeled and detailed the blade geometry through technical drawings to support process evaluation.

Second Part:

The most suitable manufacturing process was identified through a structured approach. Several candidate processes were selected for evaluation. These processes were then compared using multiple criteria such as cost, defect rate, material efficiency, environmental impact, and geometric complexity. Finally, the analysis allowed for a reasoned selection based on the best overall compromise between the evaluated factors and recommendations from different references.



Laboratories: We also had the opportunity to attend several laboratories during which we were able to observe and discover different advanced machining and manufacturing techniques.

Figure 6.1: CNC Machining Laboratories

Biomechanics

This course explored the fundamentals of the structure, function and biological performance of major biomechanical systems. Through both theoretical and practical approaches, we examined how physical principles apply to living systems, providing a solid foundation for understanding human movement and physiological mechanics.

Learning Outcomes:

- **Musculoskeletal Biomechanics:** How bones, muscles and joints produce and control movement.
- **Cardiovascular Biomechanics:** How blood flows through the heart and vessels and how pressure and resistance are regulated.
- **Respiratory Biomechanics:** How the lungs and airways function during breathing.
- **Analytical and Computational Modeling:** How to use equations and computer models to study and simulate these systems.

Project: Mechanical Simulation of Scaffolds for Bone Regeneration

First Part: Experimental characterization techniques and on analytical solutions of biomechanical questions

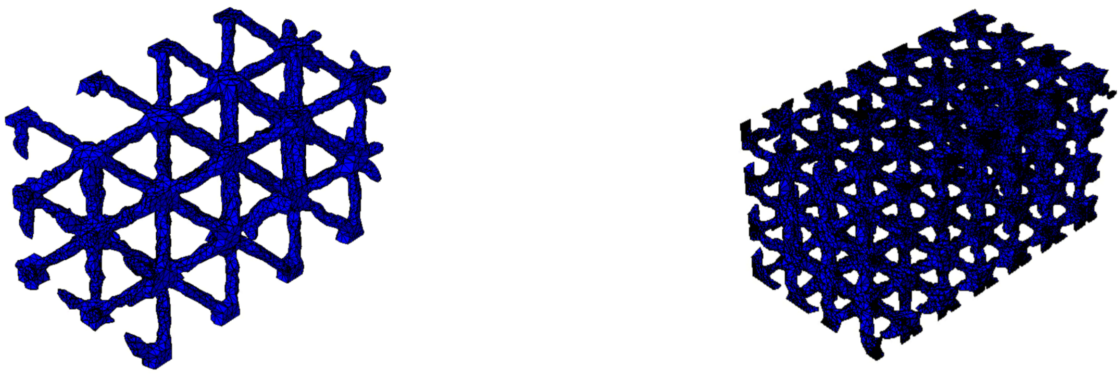
Objectives: Analyze and compare the microstructural and biomechanical properties of different metallic scaffolds in order to determine which design offers the best balance between mechanical strength and biological adaptability.

Using 3D models of metallic scaffolds obtained from **X-ray tomography**, we analyzed their microstructure with the **CTan software**. This allowed us to extract quantitative data such as surface-to-volume ratio, strut thickness, and other structural parameters. We then used **GraphPad Prism** to perform a statistical analysis, comparing and generalizing the properties of the scaffolds according to their type. Finally, we wrote an abstract summarizing our findings and discussed which scaffold design showed the best biomechanical compatibility, in terms of mechanical resistance, adaptability to biological tissues, and potential influence on the bone remodeling process (osteogenesis and osteointegration).

If you would like to read the full abstract, you can consult it at the following address: `Metalic Scaffold Abstract`

Second Part: Numerical Simulation of Scaffold Compression Tests

Objectives: Use numerical tools to obtain a more precise evaluation of the mechanical properties of different metallic scaffolds and to compare the results with the analytical study.



(a) First Scaffold (D1S3) (b) Second Scaffold (D2S2)

Figure 6.2: Metal scaffold studied

We used **Abaqus software** to simulate compression tests on the 3D scaffold models show in Figure 6.2. This allowed us to deepen our understanding of numerical modeling and to determine the mechanical response of each scaffold type under load.

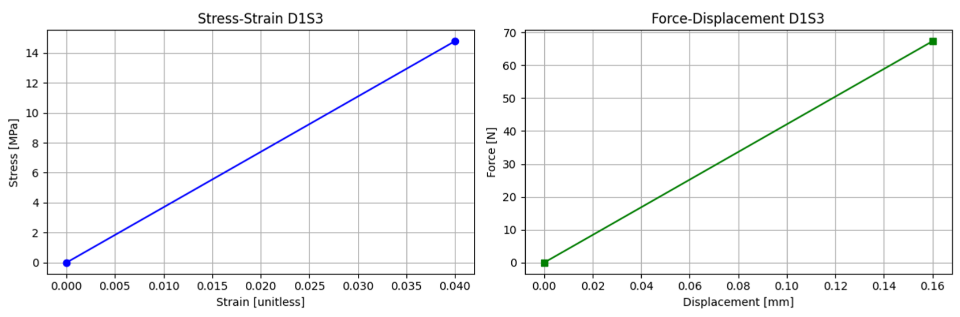


Figure 6.3: Result of the numerical simulation for the first scaffold

The stress–strain data obtained from the simulations were then plotted using Python, and we calculated the Young's modulus (E_{xx}).

Finally, we compared the analytical and numerical results, analyzed the sources of error, and discussed possible mechanical and biological improvements to enhance scaffold performance, such as surface treatments or heat treatments to improve biocompatibility and mechanical strength.

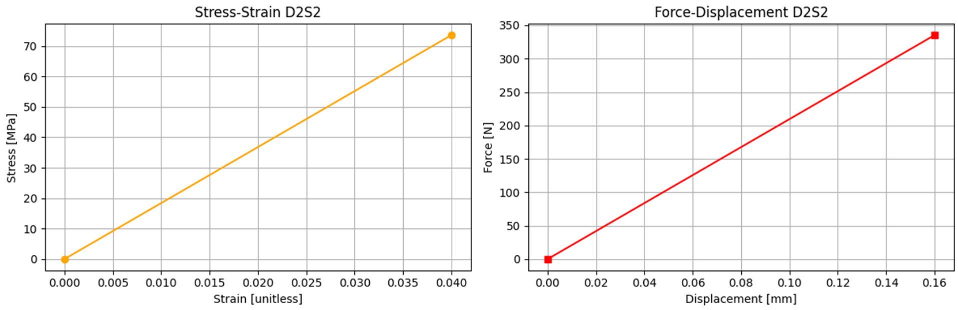


Figure 6.4: Result of the numerical simulation for the second scaffold

Continuum Mechanics

I acquired a solid introduction to continuum mechanics and its applications in solid and fluid mechanics. I learned the fundamental principles of kinematics and dynamics of deformable media, tensor representation of physical fields, and basic thermodynamics. I applied these concepts to infinitesimal thermoelasticity in solids and to Newtonian and ideal fluid flows, including classical analytical examples such as beam theory, Poiseuille and Couette flows, and acoustic waves.

Learning Outcomes:

- Understand and apply the principles of continuum mechanics in solids and fluids.
- Analyze deformation, stress, and motion using tensor calculus.
- Solve analytical problems in thermoelasticity and fluid mechanics.
- Apply conservation laws (mass, momentum, energy) in continuum systems.
- Use different coordinate systems (Cartesian, cylindrical, spherical) for problem solving.
- Relate theoretical knowledge to practical examples of solid and fluid mechanics.

Fluid Mechanics (I & II)

These courses provided a comprehensive foundation in fluid mechanics, covering **incompressible and compressible flows**, **turbulence** and **heat transfer**. I gained strong knowledge of the Navier–Stokes equations, boundary layers, laminar and turbulent regimes, as well as computational modeling of flows using CFD (RANS and turbulence models). The courses also explored **compressible flow phenomena**, **flow around airfoils**, and **applications to environmental and geophysical contexts**, bridging theory, simulation, and real-world case studies.

I also participated in several laboratory sessions, where I explored different flow regimes, such as laminar, turbulent, and compressible flows, along with their characteristic streamlines. I further reinforced my knowledge through various assignments, detailed below.

Introduction to geophysical and environmental dynamics

Objectives: Understanding key physical processes such as pollutant transport and decay, inertial oscillations influenced by the Coriolis force and wind-driven mixing in the ocean

If you would like to read the report, you can consult it at the following address: `Introduction to geophysical and environmental dynamics | Homework Report`

Simulation of Compressible Flow in a Converging–Diverging Nozzle

Objectives: Analyze one-dimensional compressible flow through a converging–diverging nozzle.

The work involved **computing the total pressures required to achieve choked flow** and to produce a normal shock at the nozzle exit. For intermediate total pressures, the shock position, Mach number distribution, static pressure profiles, and mass flow rates were determined. The study aimed to visualize **flow regimes**, understand **shock behavior** within the nozzle, and evaluate associated thermodynamic properties such as total pressure loss and entropy change.

If you would like to read the report, you can consult it at the following address: `Simulation of Compressible Flow in a Converging-Diverging Nozzle | HW Report`

Heat and Mass Transfer

This course strengthened my understanding of heat and mass transfer phenomena **conduction, convection, radiation, diffusion** and their interaction in complex systems. I developed skills in setting up thermal and mass balances, applying analytical solutions and correlations in simple geometries, and considering numerical tools for advanced cases, with a focus on designing and analyzing heat exchangers.

Heat Exchanger Laboratory

Objectives: Experimentally and theoretically evaluate the heat transfer performance of a coaxial water–water heat exchanger under various flow configurations.

This laboratory focused on the theoretical and experimental study of a water–water **coaxial heat exchanger**. The setup consisted of two independent circuits, each using water as the working fluid, and allowed for various flow configurations (co-flow, counter-flow, series, and parallel). We analyzed heat transfer processes by measuring flow rates and temperatures at several points, estimating the global heat transfer coefficient, and comparing different configurations to evaluate performance. Experimental data were then compared to theoretical predictions based on heat exchanger models and $\epsilon - NTU$ analysis.

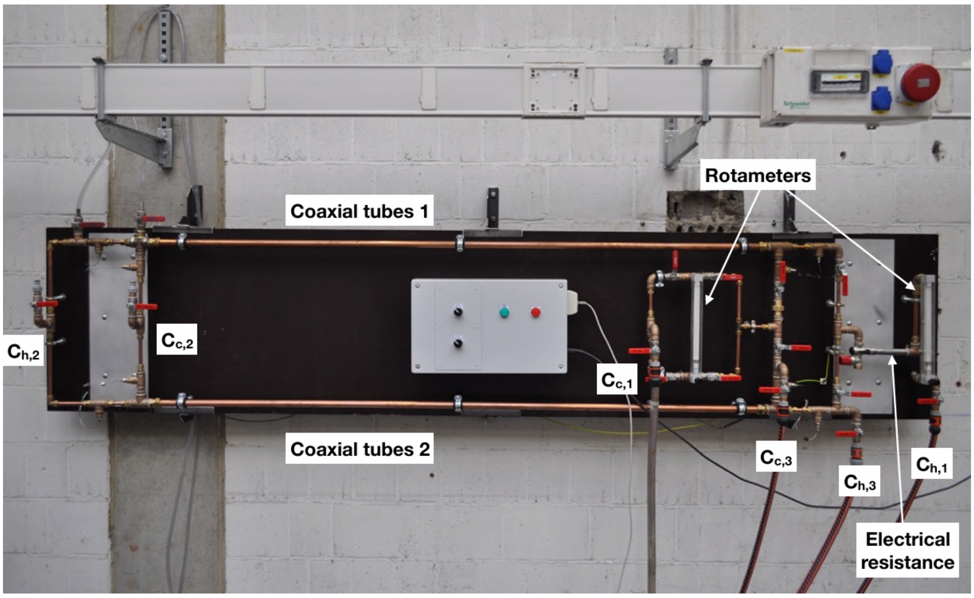


Figure 6.5: Figure adapted from course material: LMECA2854 – Heat and Mass transfer II (UCLouvain, 2024).

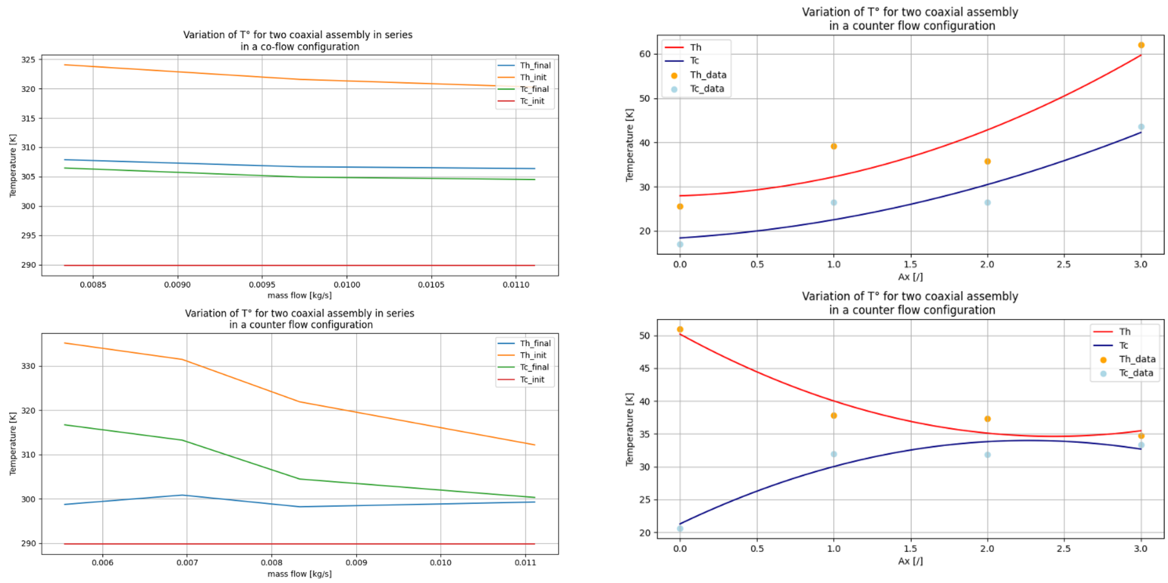


Figure 6.6: Example of Graph Resulting from Heat Exchanger Analysis

Learning Outcomes:

- Understood the principles of heat transfer and exchanger efficiency through comparison of theoretical and experimental results.
- Analyzed laminar co-flow and counter-flow configurations, showing higher efficiency in counter-flow.
- Applied Reynolds, Prandtl, and Nusselt correlations to compute U values and assess the effect of mass flow rate.
- Developed skills in data analysis, Python processing, and theory–experiment comparison.

If you would like to read the full report, you can consult it at the following address:

Heat Exchanger Laboratory Preparation

Heat Exchanger Laboratory (Part 2)

Industrial Automation

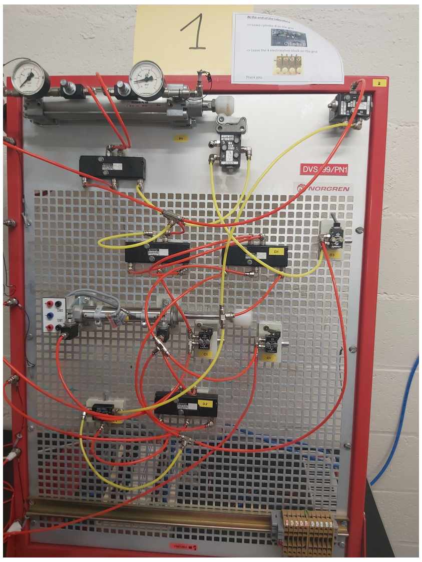
This introductory course in industrial automation provided me with a solid understanding of **sensors**, **actuators (pneumatic and electropneumatic)**, **Programmable Logic Controllers (PLC)**, and **industrial robotic systems**. I gained skills in sequential programming with **Siemens PLCs**, geometric modeling of industrial robots, and trajectory planning, with hands-on experience on didactic benches, an industrial conveyor, and industrial robots.

Pneumatic & Electro-Pneumatic Actuators Lab

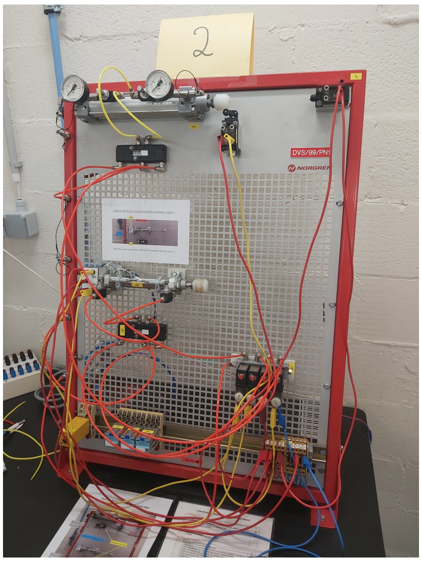
Hands-on exploration of pneumatic and electro-pneumatic systems used in industrial automation. The lab focused on building and troubleshooting sequential circuits (back-and-forth, delay, L, U, and square cycles) using valves, cylinders, sensors, relays, and solenoid controls.

Learning Outcomes:

- Understand the operation of pneumatic and electro-pneumatic components.
- Design and wire basic sequential circuits.
- Apply logical control using bistable and monostable valves.
- Develop diagnostic and problem-solving skills for automation systems.



(a) Pneumatic configuration



(b) Electro-pneumatic configuration

Automated Conveyor Lab – Siemens / Festo

Objectives: Programming a small Festo–Siemens automated conveyor system designed to cap boxes using pneumatic and electromechanical components.

The setup included an **infrared sensor** to detect box presence, a **vacuum gripper** for capping, a **conveyor belt** for transport, and a **rotating gate mechanism** acting as a controlled stop. The system was programmed using Siemens PLC software, integrating sensor feedback and actuator sequencing to achieve a fully automated operation.

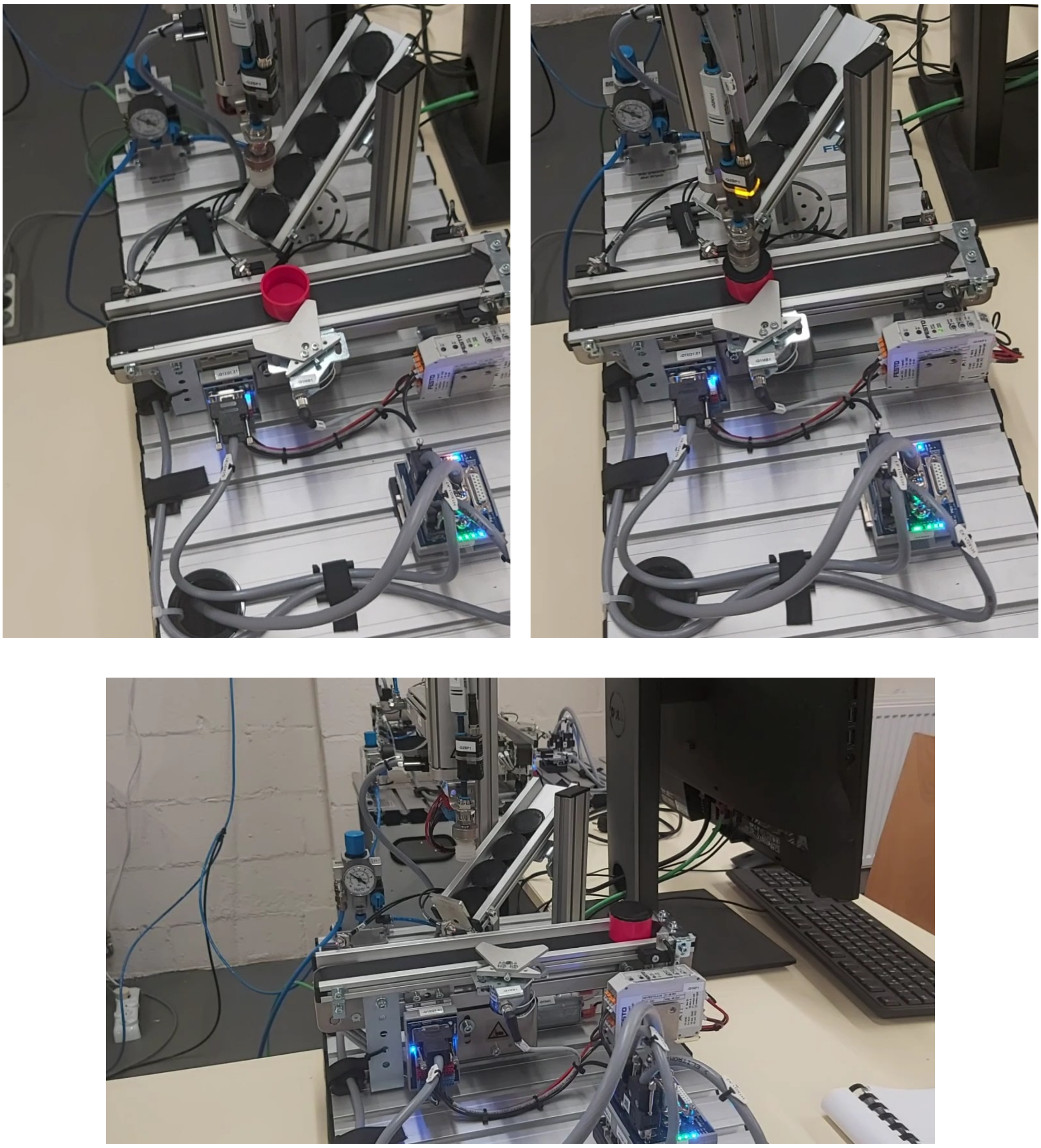


Figure 6.9: Global view of the conveyor system

Internal Combustion Engine

This course provides an in-depth understanding of internal combustion **engine operation, combining thermodynamics, fluid mechanics, and mechanical design**. Students analyze the main engine components and their interactions, study **thermal cycles** and **energy balances**, and assess combustion processes from both technological and environmental perspectives. Topics include intake and exhaust dynamics, supercharging, friction and performance losses, and pollutant emission control. The course also integrates practical tutorials and case studies focused on performance evaluation and combustion optimization.

Learning Outcomes:

- Characterize thermal cycles and calculate basic heat and energy exchanges.
- Analyze fluid flow behavior in pipes and engine components.
- Describe and model the operation and performance of internal combustion engines.
- Understand fuel properties and combustion modes, including efficiency and emission aspects.
- Integrate principles from thermodynamics, mechanics, and energy systems to evaluate engine performance and diagnose operation.

Figure 6.10: Turbocharger

Machine Design

This course introduces the fundamental principles of **mechanical design** applied to the components and systems that make up machines. It covers **functional analysis**, **component selection**, and **dimensioning methods** based on **mechanical strength, fatigue, and compliance criteria**. Students learn to define functional specifications, estimate power and efficiency, and design simple machines using systematic methodologies. The course also emphasizes interpretation of **technical drawings**, **tolerance placement**, and the **selection of standard components such as bearings, transmissions, and fasteners**. Sustainable and safe design considerations, as well as the integration of digital manufacturing technologies, are also addressed to prepare students for future roles in R&D and mechanical engineering.

Project - Energy Recovery from Rain

> **Objective:** Design and prototype a compact system capable of harvesting energy from rainfall on building rooftops.

Our idea was to convert the kinetic energy of rainwater into electrical power through a small-scale hydraulic turbine and dynamo system, with storage in a battery bank for household use.

<u>Key Project Phases</u>:

Concept & Functional Definition: Defined the device's main functions — energy generation from rainwater and storage in a battery system — and established key parameters (power output, flow rate, ...).

System Design & Modeling: Created detailed kinematic and functional schematics, integrating a turbine, shaft, gear train, dynamo, and water management system. Performed component selection and assembly design.

Prototyping: Built a functional prototype using 3D printing for internal components (shaft, turbine, coupling) and laser cutting for the housing. Prototyping allowed verification of assembly feasibility, maintenance access, and system performance.

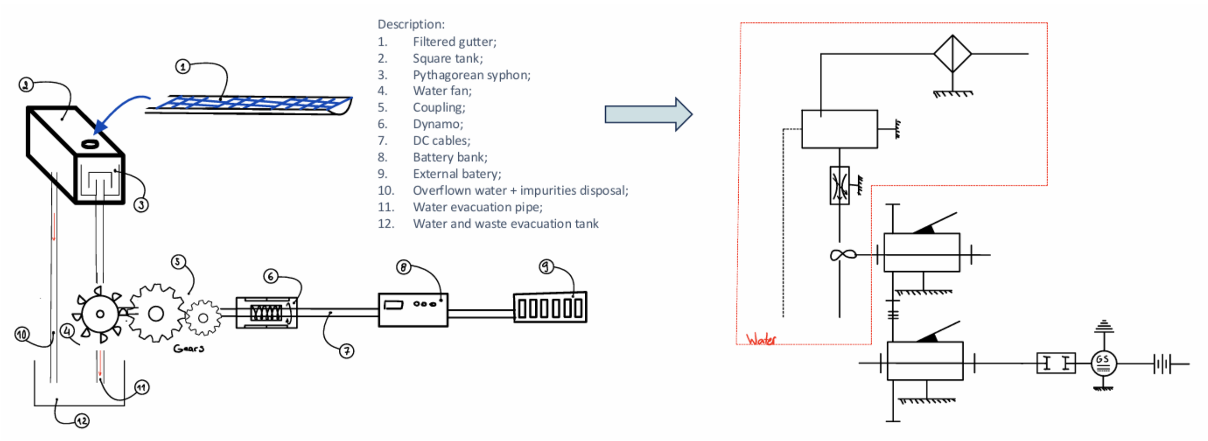


Figure 6.11: Kinematic Schematic

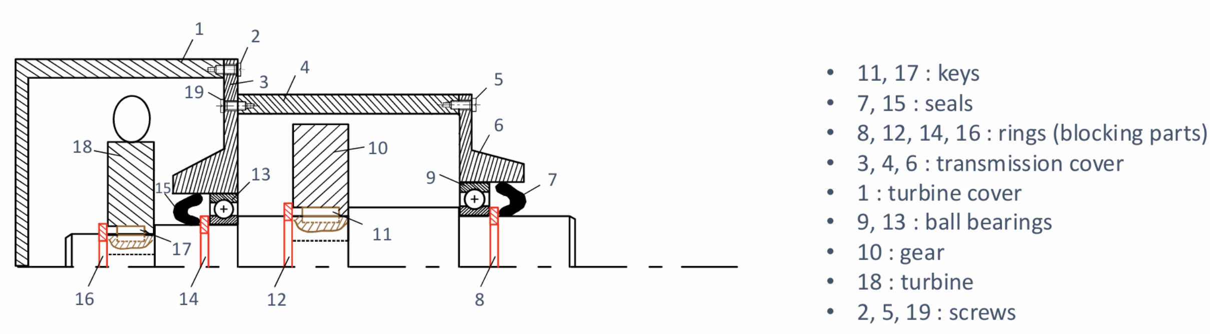


Figure 6.12: Technical Drawing and Assembly

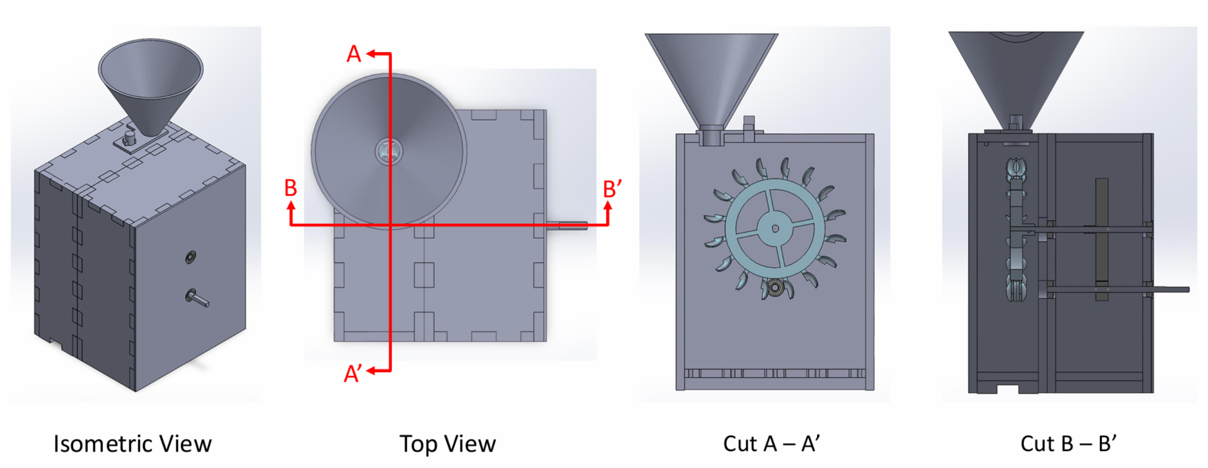


Figure 6.13: Prototype Assembly Views

Validation & Critical Review: Assessed the design's energy output, reliability, and manufacturability. Evaluated advantages and limitations of rapid prototyping (3D printing and laser cutting) in terms of accuracy, structural strength, and scalability.

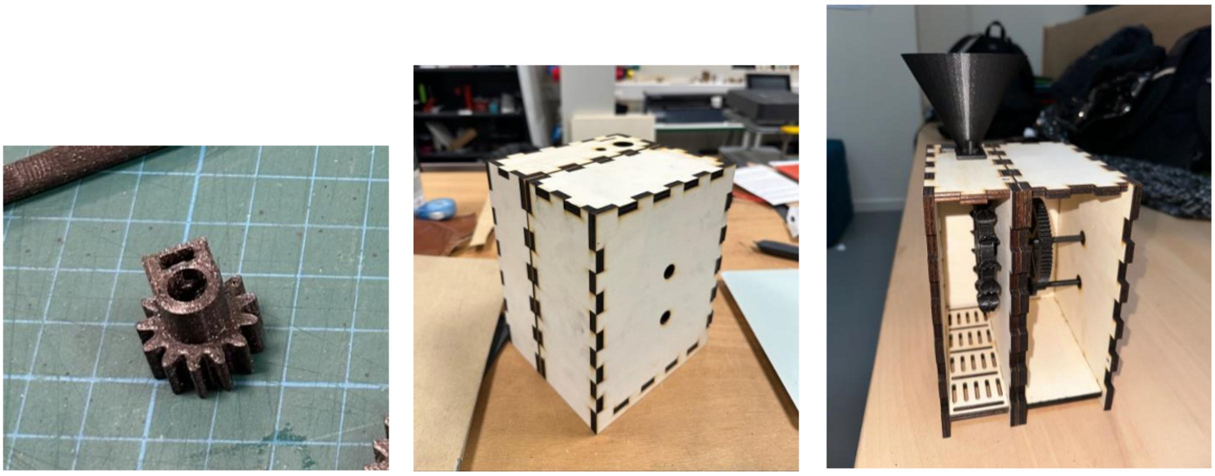


Figure 6.14: Final functional prototype

Mechanical Design in Biomedical Engineering

This course provided me with a solid foundation in biomedical engineering design methodologies, with a focus on the unique requirements of medical and surgical applications. Through a combination of seminars and a hands-on project, I gained experience in:

- **Understanding medical-specific constraints:** learning about biocompatibility, sterilization, ergonomics, precision, and safety.
- **Applying industrial standards:** integrating certification, cost, and feasibility considerations into design.
- **Design methodology:** identifying medical needs, performing risk analysis, reviewing existing solutions, and developing technical specifications.

Project: 3D portable force plate to evaluate return to sport

Objective: Design an innovative 3D portable force plate addressing a real clinical need, in collaboration with a compagny. I was involved in the full design process: defining requirements, modeling, prototyping, and testing.

Note: As the project is conducted in partnership with a company, specific technical details cannot be disclosed.

Learning Outcomes & Skills Acquired :

- **Requirements Analysis & Technical Specifications:** learned to clarify medical needs and translate them into actionable design specifications.
- **Client & Clinician Collaboration:** practiced communication and discussions with clinical and industrial stakeholders.
- **Research & Benchmarking:** conducted a state-of-the-art review of existing devices to inform design choices.
- **Technical Design & Modeling:** gained hands-on experience in developing solutions that meet medical constraints, including modeling and simulation.
- **Integration of Key Concepts:** applied knowledge of sensors, biocompatibility, certification processes, and risk analysis to practical design problems.

Mechanical Manufacturing

This course provided an in-depth understanding of **manufacturing processes** for **metals and polymers**, from fundamental physical principles to industrial applications. The course covered a wide range of **forming**, **machining**, and **joining techniques**, as well as **surface treatments** and **additive manufacturing**.

The main topics included metal casting, machining, forging, extrusion, polymer processing, composite materials, powder metallurgy, surface hardening, and welding technologies. Laboratory sessions and workshops offered practical experience with machine tools, mechanical testing, and material characterization (stiffness, hardening, hardness, toughness).

Key Learning Outcomes:

- Identify and justify the most suitable manufacturing process for a given mechanical part.
- Understand and explain how different fabrication processes affect the mechanical properties of materials.
- Analyze the key challenges and technological solutions associated with each production method.
- Apply theoretical knowledge to real manufacturing contexts through hands-on machining and material testing.
- Understand physical mechanisms underlying material deformation, strengthening, and failure.
- Connect microstructure to performance, linking crystal structure, defects, and grain size to mechanical behavior.

Mechanics of Composite Materials

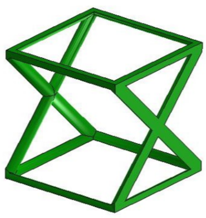
This course provided a comprehensive understanding of the mechanical behavior and design of composite materials, particularly fiber-reinforced composites widely used in aerospace, automotive, and sporting industries. I learned to analyze and model the anisotropic and heterogeneous nature of these advanced materials through both micro-mechanical approaches and laminate theory.

The course covered key topics such as **anisotropic elasticity**, **homogenization methods**, **failure criteria**, and **multiscale modeling**, bridging theory and practical design applications. Through problem-solving sessions and simulations, I developed the ability to predict and optimize the mechanical response of complex composite structures.

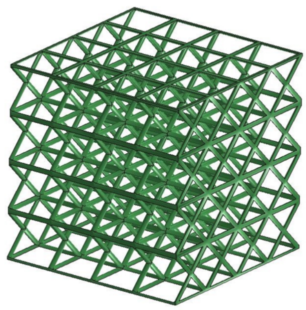
Project: Study of the Effective Properties of Composite Materials

Objective: Analyze and predict the effective mechanical properties of composite materials using multiple modeling approaches from analytical to numerical.

More precisely, the project aimed to predict and optimize the mechanical behavior of fiber-reinforced composites by studying how inclusion shape, orientation, and volume fraction affect stiffness. It included the modeling of a periodic lattice structure to study how geometry influences the mechanical response of lightweight composites. Starting from a unit cell composed of beam elements, I generated the full lattice in Digimat-FE, simulating its deformation under load.



(a) Unit Cell Structure



(b) Completed Lattice Structure

Figure 6.15 shows the relationship between inclusion volume fraction and effective stiffness obtained through full-field homogenization. I analyzed stress–strain curves to extract the effective Young's modulus, demonstrating a near-linear stiffness increase with inclusion content. Using analytical **(Mori–Tanaka)** and **numerical (Digimat-MF/FE)** approaches, I developed a multi-scale modeling strategy to link microstructure to macroscopic performance.

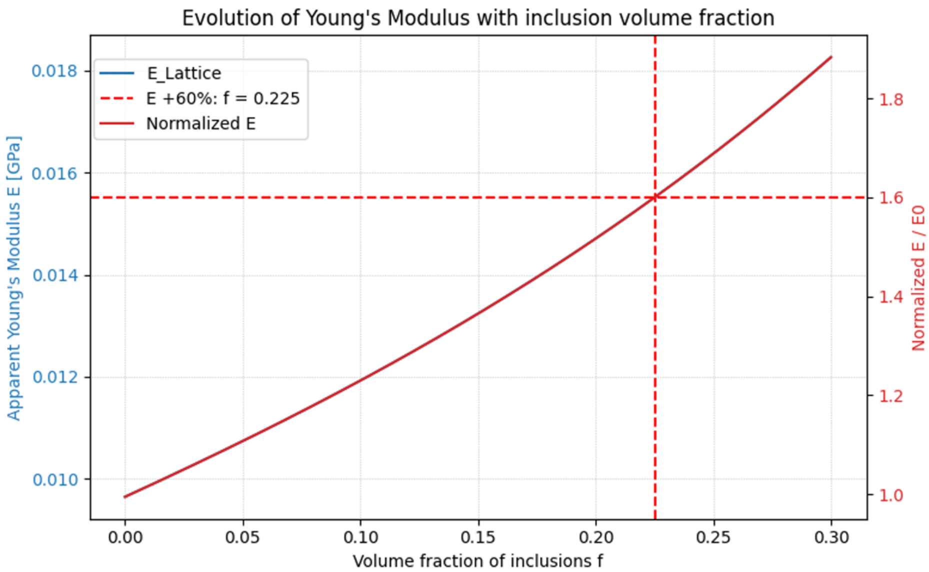


Figure 7: Evolution of Young's Modulus with inclusion volume fraction

Figure 6.15: Example of the result of the material behavior after numerical simulation

If you would like to read the full report, you can consult it at the following address: `Effective properties of composite materials through several approaches`

Mechanics of Materials

This course focused on understanding and modeling the mechanical response of materials under complex conditions, including elastic, plastic, and fracture behaviors. It emphasized the link between microstructure and macroscopic properties, the influence of temperature and strain rate, and the selection of materials with optimized mechanical performance.

Material Selection Project

Objective: Selecting the most suitable materials for the design of youth and professional baseball bats.

Learning Outcomes:

- Applied classical beam theory to model bending stresses and deflection under impact forces.
- Established material selection criteria using parameters such as yield strength, density, toughness, and fatigue limit.
- Utilized the **Granta Selector** database for multi-criteria material screening and comparison.
- Strengthened ability to integrate **sustainability** and **manufacturability** into engineering design decisions.

If you would like to read the full report, you can consult it at the following address: `Material Selection Project`

Damage and Heat Treatment Project

Objective: Analyze the evolution of material damage under cyclic tensile loading and to study the effect of heat treatment on the brittle to ductile transition of metallic alloys.

Learning Outcomes:

- Calculated damage parameters using reductions in Young's modulus after repeated plastic deformation.
- Interpreted true and engineering stress–strain curves to better describe material behavior under tension.
- Investigated the **influence of heat treatment temperatures** on mechanical strength and toughness.
- Explained the **ductile to brittle transition** through microstructural changes observed in SEM images.
- Analyzed the **effects of aging**, element segregation, and yield stress evolution on fracture energy and brittleness.

If you would like to read the full report, you can consult it at the following address: `Ductile Damage`

Fracture Mechanics Project

Objective: Evaluate the fracture toughness and energy release rate of adhesive joints under different loading and temperature conditions and to analyze their behavior through Double Cantilever Beam testing.

Learning Outcomes:

- Computed critical crack length and energy release rate from experimental stress intensity factors.
- Analyzed the **effect of residual stresses** and temperature variations on adhesive fracture behavior.
- Processed experimental data to plot Force and Displacement curves and used the Double Cantilever Beam compliance method to estimate fracture energy.

If you would like to read the full report, you can consult it at the following address: `Fracture Mechanics Project`

Fracture Mechanics Project

Objective: Analyze and compare fatigue behavior in aerospace materials, focusing on the crack initiation, propagation and final fracture mechanisms in additively manufactured and wrought Al7075 alloys.

Learning Outcomes:

- Gained a deep understanding of the three stages of fatigue failure and how microstructural features and residual stresses influence each stage.
- Analyzed crack growth rate curves and applied the **Paris Law** to extract material constants for both alloys.
- Compared additive and wrought Al7075, evaluating their threshold stress intensity, fracture toughness and **total fatigue life** under cyclic loading.
- Calculated critical crack length and fatigue life by integrating Paris' law to predict component lifespan under operational conditions.
- Identified The key design parameter for safe aerospace components, emphasizing material selection and maintenance planning.

If you would like to read the full report, you can consult it at the following address: `Fatigue Mechanics Project`

Material Selection

This course provided hands-on experience in materials selection and design, with multiple assignments covering topics such as **material properties, multi-objective problems, hybrid materials, process selection, and eco-design**. I applied systematic procedures to real-world case studies, using tools like the **EDUPACK material selector**, and developed skills in analyzing design problems, selecting optimal materials, and justifying choices.

If you would like to take a look at the various homeworks, you can consult them at the following address:

First homework on the basics

Second homework on the basics

First homework on multiple constraints and conflicting objectives

Second homework on multiple constraints and conficting objectives

First homework on influence of shape in material selection

Second homework on influence of shape in material selection

Project: Increasing the stiffness of steel sheet

Objective: Design a lightweight, low-cost steel sheet with improved bending stiffness without increasing its mass.

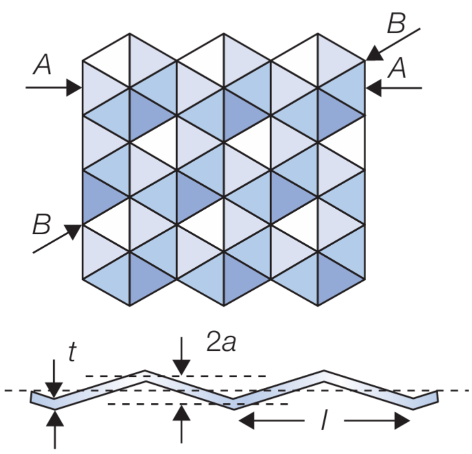


Figure 6.16: Sheet profile Adapted from [1].

- Identified limitations of flat metal sheets like vibration, deformation and fatigue.
- Compared manufacturing techniques (corrugation, folding, embossing, origami folds).

- Design Concept: Proposed a hexagonal grid of dimples to enhance the second moment of area, improving bending stiffness.
- Derived expressions for stiffness and bending shape factors, compared flat and corrugated geometries.
- Analyzed manufacturability, aesthetics and cost of the proposed geometry.

Learning Outcomes:

- Gained hands-on experience with mechanical design optimization for stiffness-limited structures.
- Applied solid mechanics principles (bending stiffness, second moment of area, fracture resistance).
- Learned to balance mechanical performance, manufacturability, and cost in materials engineering.
- Developed ability to propose innovative geometrical solutions for performance improvement.

If you would like to take a look at the project presentation, you can consult it at the following address: `Project 1 Increasing the stiffness of steel sheet`

Project: Material Selection of a fire hose

Objective: Select the optimal material combination for a Type 3 fire hose.

- Established operational constraints like pressure resistance, temperature range, chemical and UV resistance.
- Derived material indices combining density, yield strength and elastic modulus to minimize mass and maximize flexibility.
- Evaluated candidate materials like nitrile rubber, polyester, polyurethane, vinyl ester, etc...
- Modeled hybrid materials.
- Compared embodied energy, CO_2 footprint, recyclability and lifespan of different hose configurations.

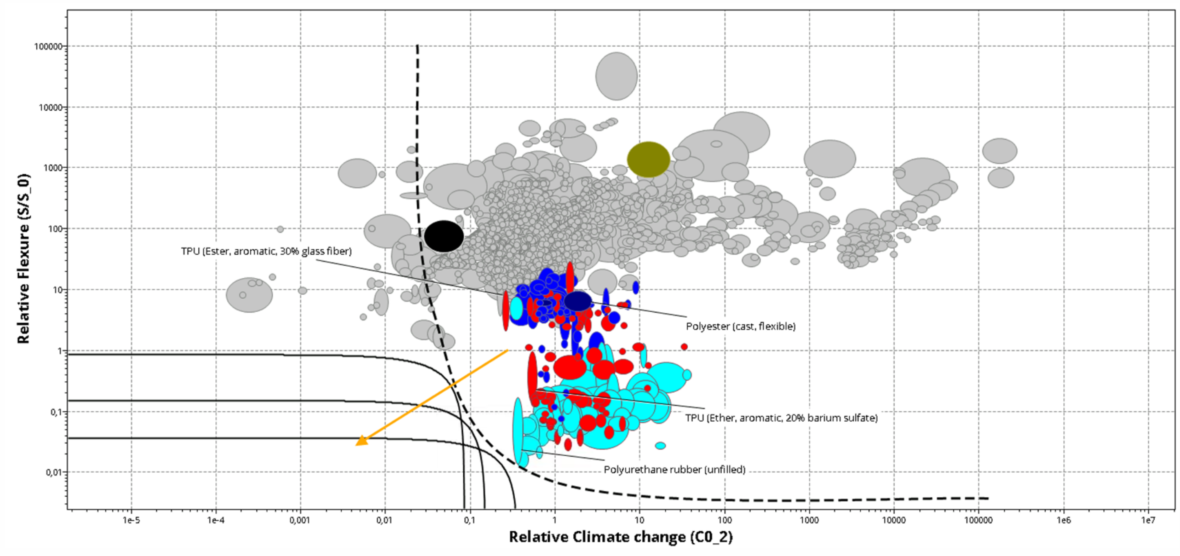


Figure 6.17: Selecting a material for a composite via Granta Selector

Learning Outcomes:

- Developed material selection strategies using Ashby's material indices and mechanical constraints.
- Strengthened skills in composite material analysis and understanding of hybrid material properties.
- Gained insight into sustainability assessment (eco-audit, life cycle, transportation impact).
- Learned to justify engineering choices based on performance, cost, and environmental impact.

If you would like to take a look at the project presentation, you can consult it at the following address: `Project 2 Material Selection of a fire hose`

Multibody System Dynamics

This course introduced the modeling and **dynamic analysis of multibody mechanical systems** composed of interconnected rigid bodies. It covered **tree-like** and **closed-loop structures**, the **automatic generation of dynamic equations**, and **numerical simulation techniques** for differential-algebraic systems. Emphasis was placed on understanding kinematics, dynamics, and computational methods used in multibody software, enabling the analysis and design of robots, vehicles, and other complex mechanisms.

Project: Development of a Generic 2D Multibody Dynamics Program

Objective: design and implement a stand-alone generic 2D multibody simulation program capable of modeling and analyzing the dynamics of mechanical systems.

The program, based on the Recursive Newton–Euler formalism, was applied to a specific case study inspired by the Notre-Dame de Paris roof truss. The objective was to simulate the structural response of the truss under lateral wind loads, analyzing displacements, tilts, and reaction forces at the supports.

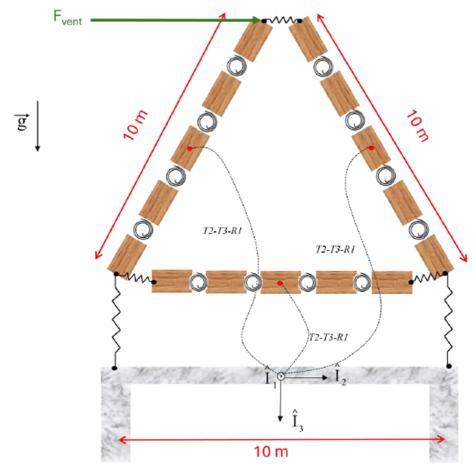


Figure 6.18: Simplified framework - Scheme from [2]

- Modeling and simulation in **Robotran** to obtain reference results for the roof truss.
- Development of a **custom 2D multibody solver** in Python, reproducing the same physical model.
- Validation through comparison between Robotran and in-house simulation results.

- Application and analysis of the full truss under varying wind conditions, with automated data output and visualization.

Learning Outcomes:

- Acquired in-depth knowledge of multibody dynamics and numerical simulation techniques with Robotran.
- Implemented the **Recursive Newton–Euler algorithm** for dynamic systems from scratch.
- Learned to model flexible beams using a finite segment approach.
- Analyzed the mechanical behavior of real-world structures under dynamic loading conditions (wind on the Notre-Dame roof truss).

Solid Mechanics (Deformable Bodies)

I learned how the theory of **isotropic linear elasticity** allows me to solve a wide range of problems in structural design and mechanical equipment. While modern industrial problems are often solved numerically, I focused on understanding the underlying physics and solving analytically key problems related to **bending, torsion, thermal stresses, buckling, and vibrations**. I also studied the **theory of beams** (strength of materials) and methods for solving both statically determinate and indeterminate structures.

Learning Outcomes:

- Solved solid mechanics problems using isotropic linear elasticity
- Applied the theory of beams to determine stress, deformation, and stability.
- Analyzed mechanical vibrations of discrete and continuous systems.
- Evaluated structural stability and buckling in beams.

Thermodynamics and Energy

I learned the fundamentals of **thermodynamics** and **heat transfer**, focusing on **ideal gases, phase changes, and energy systems**. I explored practical applications including **gas turbines**, **refrigeration cycles**, **compressors** and **expansions, humid air**, and **Rankine cycles**. The course emphasized understanding the physical principles behind thermodynamic processes and solving analytical and practical problems related to energy conversion and heat systems.

Learning Outcomes:

- Applied the laws of thermodynamics to gases, vapors, and humid air.
- Analyzed compression, expansion, and energy cycles in turbines, compressors, and refrigeration systems.
- Evaluated heat transfer and thermodynamic efficiency in engineering systems.

Vehicle Dynamics

This course taught me the fundamental theoretical notions and modelling techniques to understand the **kinematic and dynamic behaviour of road and railway vehicles**. It gave me the skills to analyze **vehicle stability, handling, and comfort**, and to model these phenomena mathematically. I studied the dynamics of various vehicles—including bicycles, motorcycles, cars, trucks, and trains—using both "macro" and detailed models of suspensions, wheel/rail or wheel/road contacts, and multibody systems. I also developed the ability to interpret models, perform **parameter sensitivity analyses**, and understand the role of mechanical devices in vehicle performance.

Project: Study of the Anti-Roll Bar and Its Influence on Vehicle Behavior

Objective: analyze and model the influence of the anti-roll bar (ARB) on a vehicle's dynamic behavior

The work began with a theoretical study of vehicle dynamics to understand the principles of roll, pitch, and yaw, and to define the function of the ARB in controlling body roll. Then, a mathematical model of the system was developed to relate ARB geometry, stiffness, and roll angle. This was followed by an analysis of handling characteristics, focusing on the relationship between front and rear ARB stiffness and the resulting understeer or oversteer behavior. Finally, the model was implemented in Robotran to perform numerical simulations, allowing the visualization and quantification of roll angle variations, steering response, and mass transfer during cornering at different speeds and stiffness configurations.

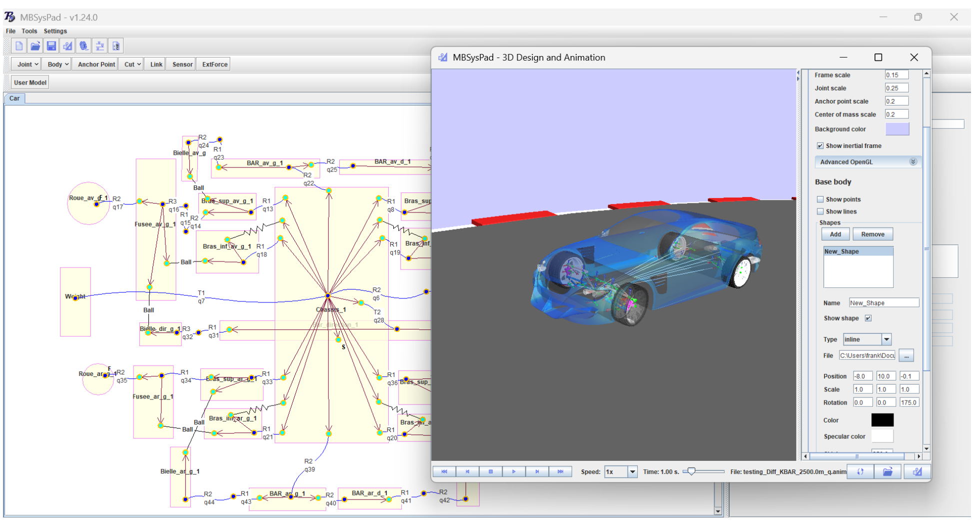


Figure 6.19: Vehicle cornering simulation in MBSYSpad

Learning Outcomes:

- Deep understanding of vehicle dynamics and the trade-off between comfort and handling.
- Experience in mechanical system modeling and simulation using Robotran.
- Ability to analyze complex dynamic systems and interpret simulation data.
- Strengthened skills in engineering problem-solving, optimization, and technical communication.

If you would like to take a look at the full project report, you can consult it at the following address: `Anti-Roll Bar`

Welding Science and Technology

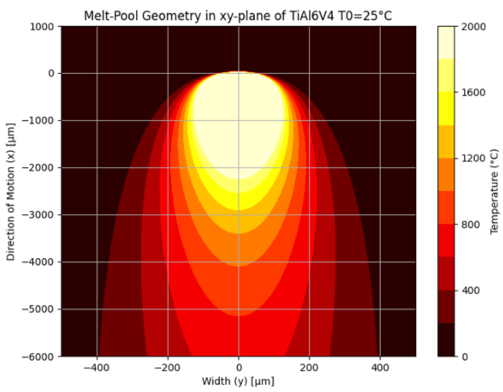
This course taught me the main characteristics, physical principles, and industrial applications of the different welding processes, including gas, arc, resistance, laser, electron beam, and solid-state welding. I learned how to choose the most appropriate welding method for a given assembly, to understand heat flow and its influence on microstructure, and to anticipate residual stresses, distortions, and potential defects. The course also covered the mechanical and metallurgical behaviour of welded joints and methods to prevent cracking.

Project: Heat Flow

Objective: Study and model the influence of material absorptivity and thermal properties on laser welding efficiency and melt-pool formation.

Using the **Rosenthal 3D analytical model**, the absorptivity of modified stainless steel was determined by correlating melt pool width with absorbed energy. The model was then used to visualize temperature gradients and melt pool geometry, showing the effects of material modification on heat diffusion and fusion zone size.

Subsequent analyses compared modified and unmodified stainless steel, as well as different alloys to evaluate how thermal conductivity, preheating temperature, and dimensional constraints affect welding behavior. The results demonstrated the distinct effects of 2D and 3D Rosenthal models on predicting heat flow and highlighted the transition between conduction and keyhole welding modes, illustrating how excessive power density leads to deeper penetration and potential porosity.



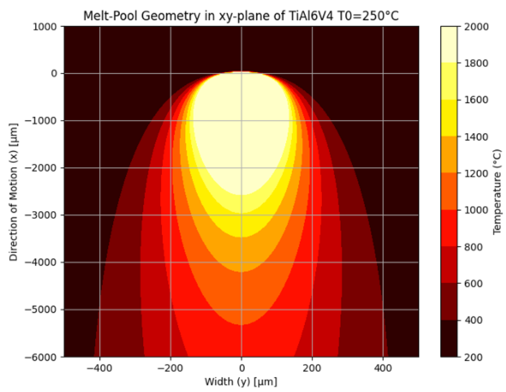


Figure 6.20: Example of melt pool geometry

Learning Outcomes:

- Solid understanding of laser and material interaction and heat transfer in welding processes.
- Practical use of Rosenthal analytical models (2D & 3D) to predict melt-pool geometry and thermal gradients.
- Ability to analyze the impact of material properties (conductivity, absorptivity, diffusivity) on weld quality.
- Insight into process optimization like balancing power, scan speed, and preheating to control weld modes.

If you would like to take a look at the full project report, you can consult it at the following address: `Heat Flow Project`

Homework: Phase transformations in metals and alloys

This project focused on understanding thermodynamic equilibrium and phase transformations in metallic systems. Using Gibbs free energy concepts, binary phase diagrams, and the lever rule, phase compositions and fractions were calculated for alloys such as Pb–Sn, Al–Cu, and Al–Si. The work highlighted the role of eutectic and peritectic reactions in solidification and microstructure formation.

Learning Outcomes:

- Interpretation of phase diagrams.
- Application of the lever rule to determine phase fractions.
- Understanding of thermodynamic stability in alloys.

If you would like to take a look at the full project report, you can consult it at the following address: `Phase transformations in metals and alloys`

Computer Science & Data Courses

Algorithms and Data Structures

This course introduced the fundamentals of algorithm design, analysis and efficiency, focusing on time and space complexity, **sorting and searching algorithms** and **core data structures such as lists, trees, balanced binary trees, heaps, hash tables and graphs**. Advanced topics included union–find, text processing, and pattern matching.

Learning Outcomes:

- Analyze algorithm complexity and performance trade-offs.
- Select and implement appropriate data structures for different problems.
- Design, test and debug efficient algorithms.
- Apply graph algorithms and text data processing techniques.
- Develop strong problem-solving and self-learning skills using reference materials and APIs.

Artificial Intelligence

In this course, I learned to formulate and solve problems using AI search techniques, from uninformed and heuristic search to constraint satisfaction and adversarial search (Minimax, Alpha–Beta pruning, MCTS). I explored knowledge representation and reasoning using propositional and first-order logic and applied these methods to planning and intelligent agent design. The course also addressed the philosophical and ethical aspects of AI, including questions of autonomy and responsibility.

Learning Outcomes:

- Model complex problems and select suitable AI search or reasoning strategies.
- Implement intelligent agents using logic-based and heuristic methods.
- Understand how to evaluate AI system performance and ethical implications.

Project: 2D Rubik's Square Solver

For this project, we implemented a **Python program capable of solving a 2D Rubik's Square** using uninformed search algorithms. The goal was to reach a target grid configuration from an initial one by applying minimal moves. I analyzed and compared depth-first and breadth-first strategies, in both tree and graph search modes, evaluating their performance in terms of time, explored nodes and memory usage.

Project: Page Collect Problem

In short, an agent must collect scattered pages and reach an examiner in the **shortest path**. The project focused on implementing and **comparing informed and uninformed search algorithms**. I designed an admissible and consistent heuristic to optimize pathfinding and analyzed performance across multiple instances based on explored nodes, computation time, and path length.

Project: Adversarial Search

In this project, I implemented and optimized several adversarial **search agents to play the strategic game Fanorona**. The goal was to develop intelligent agents capable of making **optimal decisions** under competitive and time-constrained environments using the Minimax and Alpha-Beta pruning algorithms.

The project involved:

- Implementing a basic **Alpha-Beta agent** to explore game-tree search and pruning techniques.
- Developing a contest-level AI agent with advanced optimizations, such as iterative deepening, heuristic tuning and time management to ensure real-time decision-making.
- We competed against other agents in a tournament, which led us to improve the robustness, fairness, and efficiency of our agent.

Project: Local Search and Propositional Logic

This assignment explored two complementary areas of Artificial Intelligence, local search optimization and propositional logic modeling. In the first part, the goal was to design and compare local search algorithms to solve the **Maximum Vertex Cover problem** efficiently. Two strategies were implemented, max-value and randomized max-value.

The second part focused on logical reasoning and problem formulation. The **N-Queens problem** was modeled using propositional logic and translated into Conjunctive Normal Form to be solved using a SAT solver.

Concepts, Paradigms, and Semantics

In this course, we learned to code in **Oz** in order to deepened my understanding of programming paradigms — functional, object-oriented, and declarative dataflow programming. I learned to **analyze problems**, **design recursive** and **abstract algorithms**, and reason about program correctness and complexity using formal semantics. I also explored concurrent and non-deterministic programming, developing programs that balance efficiency, determinism, and clarity.

Learning Outcomes:

- Select and apply the most appropriate programming paradigm for a given problem.
- Design, test and validate programs using formal reasoning and abstraction.
- Understand functional and concurrent programming principles, including lambda calculus and dataflow models.
- Strengthened my ability to think abstractly and structure complex systems across multiple layers of design.

Computability and Complexity

This course provided a solid foundation in the **limits of computation, logic and complexity theory**. I explored computable vs non-computable functions, **Turing Machines** and **undecidable problems**, while also studying propositional and predicate logic for precise reasoning. I learned to analyze problem complexity, including NP-completeness, and to critically evaluate the capabilities and limitations of algorithms and computer systems.

Learning Outcomes:

- Understanding the limits of what can be computed.
- Mastering logical representation and reasoning for algorithmic problems.
- Recognizing intrinsically hard or undecidable problems.
- Evaluating algorithmic complexity and performance critically.

Computer Networks

This course taught me the fundamental principles of computer and communication networks. I learned how distributed applications exchange information reliably through **layered network architectures** and **standard Internet protocols**. The course covered topics such as reliable data transport, addressing and routing, network interconnection and the functioning of local. I also studied key Internet protocols including HTTP, DNS, TCP/IP, TLS, and Ethernet and learned to evaluate network performance and choose appropriate solutions for different communication needs.

Learning Outcomes:

- Understand the structure and operation of computer networks and their reference models.
- Analyze and explain how Internet protocols ensure reliable data transport and routing.
- Identify communication requirements of distributed or multimedia applications.

Computer Science 1 & 2

These courses taught me the fundamental principles of programming, software design, and algorithmic problem-solving. I learned to analyze computational problems, model and implement solutions in Python and Java and apply key concepts such as object-oriented programming, data structures, recursion and algorithmic complexity. I developed a solid understanding of abstract data types, functional and parallel programming and software testing. Through practical exercises, I learned to design efficient, reliable, and maintainable programs while reasoning about their correctness and performance.

Learning Outcomes:

- Analyze and model computational problems to design effective programming solutions.
- Apply object-oriented principles (abstraction, inheritance, polymorphism) in software design.
- Implement and manipulate linear, tree, and recursive data structures.
- Evaluate the efficiency and correctness of algorithms and programs.
- Apply functional and parallel programming techniques to solve algorithmic problems.

Computer Systems

This course taught me the fundamental concepts of computer systems architecture and operating systems. I learned how computing systems are structured across multiple abstraction layers, from hardware to applications and how processors and operating systems interact to manage resources efficiently. The course covered processor architectures, machine and assembly languages, system calls, processes, threads and multiprocessor systems. I also learned to use and implement operating system functions within applications.

Learning Outcomes:

- Understand the architecture and abstraction layers of computer systems.
- Analyze the roles and functions of operating systems.
- Use and implement system-level functions to manage processes and threads.
- Understand the interaction between hardware, OS, and applications.
- Evaluate processor architectures and multiprocessor environments.

Project: Multithreaded Programming Project in C

Developed and optimized concurrent algorithms such as the Dining Philosophers and Producer–Consumer problems using mutexes, semaphores, and condition variables. Analyzed performance, synchronization efficiency, and scalability on multi-core architectures.

Discrete Mathematics and Probability

This course introduced the fundamental concepts of discrete mathematics and probability theory applied to engineering. I learned to analyze and model discrete systems through **combinatorics**, **graph theory**, and **modular arithmetic**, and to describe uncertainty using random variables, distributions, and statistical estimation. The course emphasized the link between mathematical formalism and real-world problem-solving.

Learning Outcomes:

- Apply combinatorial methods and understand mappings.
- Use graph theory and modular arithmetic in applied contexts.
- Model and analyze random variables and their dependencies.
- Estimate statistical parameters and apply limit theorems.

Numerical Methods

This course taught me the fundamentals of numerical simulation, focusing on the link between physical reality, mathematical models, and numerical solutions. I learned to implement and analyze classical numerical methods in Python, to assess their precision, stability, and convergence, and to critically interpret computational results.

Learning Outcomes:

- Choose and implement appropriate numerical methods in Python.
- Evaluate errors and validate the reliability of numerical results.
- Apply methods for approximation, integration, and differential equation solving.

Statistics and Data Science

This course taught me the fundamental statistical concepts applied to engineering problems, from exploratory analysis and inference to multivariate data analysis. I learned to connect probability theory with statistical inference, to design and validate models, and to apply machine learning techniques such as regression, principal component analysis, and clustering.

Learning Outcomes:

- Analyze and interpret datasets of various sizes and dimensions.
- Build and validate statistical models using inference methods and resampling techniques (Monte Carlo, cross-validation, bootstrapping).
- Apply and evaluate multivariate analysis methods such as linear regression, PCA, and classification/clustering to extract meaningful insights from data.

Management & Professional Context Courses

Financial Performance Indicators

This course introduced the fundamental accounting and financial tools used to evaluate business performance. I learned the principles of financial accounting, management accounting, and investment decision-making, as well as key techniques for analyzing financial statements. The course also addressed both financial and non-financial performance evaluation, including economic, social, and environmental indicators.

Learning Outcomes:

- Understand the structure and principles of financial accounting (balance sheet, income statement).
- Analyze financial statements using ratios, cash flow, and performance metrics.
- Apply management accounting methods to support decision-making and cost evaluation.
- Assess investment projects through NPV, IRR, and payback period.
- Evaluate global performance from financial, social, and environmental perspectives.

Project: Business analysis - Brasserie de Chimay

This project analyzed the financial performance of the Belgian Trappist brewery Chimay using balance sheet, income statement, and financial ratio analysis. The study assessed assets, equity, and liabilities to understand the company's structure and evolution.

Introduction to Business Issues

This course taught me the fundamentals of entrepreneurship, business planning, and strategic management. I learned how firms create value through innovation, market positioning, and business model design, while aligning resources, organization, and governance to achieve long-term objectives. The course also covered financial evaluation, funding strategies, and the importance of ethical and transparent management practices.

Learning Outcomes:

- Analyze and design business models integrating product, market, and value chain perspectives.
- Develop strategic positioning and business planning based on resources, environment, and purpose.
- I understand entrepreneurial behavior, governance, and partnership structures within organizations.
- Interpret and evaluate a firm's financial performance and funding options.

Law, Regulation and Legal Context

This course introduced the legal foundations of business and their role within the economic and innovation environment. I learned the key principles of corporate law, civil liability, and commercial contracts, as well as the legal aspects of employment, insolvency, and intellectual property. The course emphasized how legal frameworks support entrepreneurship, innovation, and strategic decision-making.

Learnings Outcomes:

- Understand the legal structure and responsibilities of a company within its institutional and economic environment.
- Analyze and apply legal principles related to contracts, labor law, and commercial operations.
- Identify and manage intellectual property rights (patents, trademarks, copyrights) in innovation contexts.
- Apply legal reasoning to solve practical business cases and assess compliance risks.

Major Technological Risks in Industry

This course taught me the fundamentals of industrial risk analysis and management, including the modeling of physico-chemical phenomena, dispersion of pollutants, and design of protection systems. It also introduced the concepts of safety culture, quality culture, and the engineer's responsibility within economic, social, and legal contexts. Real industrial case studies and expert seminars helped strengthen a practical understanding of risk prevention.

Learning Outcomes:

- Understand the nature and evaluation of major industrial risks and their real-world consequences.
- Apply risk assessment and mitigation methods to technological and human factors.
- Integrate safety and quality culture into engineering decision-making.
- Recognize the ethical, social, and legal responsibilities of engineers in industry.

People Management

This course focuses on the human aspects of management, combining psychology and organizational behavior to help future engineers understand and manage people effectively. It covers topics such as emotional intelligence, teamwork, leadership, motivation, well-being at work, organizational structures, and project management, emphasizing the balance between technical and interpersonal skills.

Learning Outcomes:

- Understand key concepts in work and organizational psychology.
- Analyze and model individual, group, and organizational behavior.
- Apply management tools and theories to real professional situations.
- Develop leadership, communication, and project management skills.
- Promote well-being and effective collaboration within organizations.

Quality Management and Control

This course taught me the fundamental principles of Quality and Total Quality Management and how they integrate into an organization's overall strategy and operations. I explored how quality impacts products, processes, and employees, and how leadership and continuous improvement drive organizational excellence.

Learning Outcomes:

- Define and analyze the role of Quality within an organization, including its historical and strategic dimensions.
- Link Quality Management with business strategy, HR, R&D, and investment decisions.
- Apply quality improvement tools and develop a Quality Management System based on continuous improvement principles.
- Understand how leadership and corporate culture foster a sustainable quality-driven organization.

Project: Cesim Business Simulation

Throughout this management simulation, I took part in the strategic and operational decision-making of a virtual automotive company competing in global markets. Over eight business rounds, I developed strong skills in **strategic management**, **financial analysis**, marketing and operational optimization. I learned to balance profitability, sustainability, and social responsibility while adapting to market changes.

Key learnings included the importance of **data-driven decision-making**, **cross-functional coordination**, and **long-term strategic vision**. The experience strengthened my abilities in teamwork, leadership, and critical thinking under uncertainty, as well as my understanding of how financial, environmental, and human factors interact within a complex organization.

Mathematics & Modeling Courses

Finite Elements

This course introduces the Finite Element Method as a numerical tool to solve engineering problems across disciplines such as electromagnetism, structural and fluid mechanics and biomedical applications. It combines mathematical foundations, algorithmic implementation in C and practical problem-solving through simulation. The course emphasizes both theoretical understanding and computational efficiency.

Learning Outcomes:

- Understand and apply the fundamental principles of the Finite Element Method.
- Analyze and choose appropriate numerical methods for engineering simulations.
- Implement a complete FEM solver in C for multidisciplinary applications.
- Evaluate and validate simulation accuracy and numerical performance.

Project: Linear Elasticity Simulation

In this project, we implemented a finite element solver in C to model and analyze linear elasticity problems, applied to a real world example, we simulated the deformation of an IKEA chair under load. We designed and meshed the geometry using **Gmsh**, applied Dirichlet and Neumann boundary conditions and explored axisymmetric formulations.

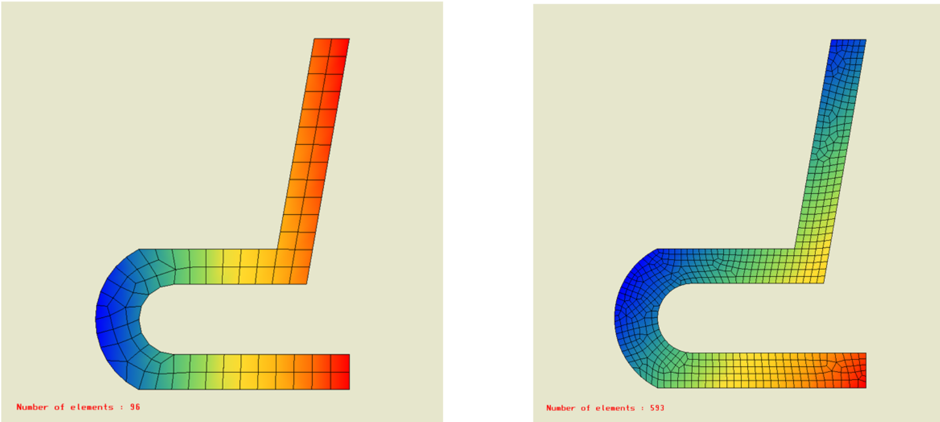


Figure 9.1: IKEA chair with different meshes

We tested different materials (beech wood, bamboo, and plastic) to compare their mechanical behaviors, validating results against real physical observations. We successfully implemented and tested a Cholesky-based solver to compute displacements and stress distributions.

Signals and Systems

This course introduces the fundamentals of signals and systems, covering both continuous-time and discrete-time domains. It focuses on signal representation in time and frequency, system modeling through impulse response, state-space representation and transfer functions, as well as Fourier, Laplace and Z transforms. Students also explore **filtering concepts** and **system stability**, using both theoretical and computational approaches.

Learning Outcomes:

- Understand and apply Fourier, Laplace, and Z transforms to analyze signals.
- Represent and model linear time-invariant systems using different mathematical frameworks.
- Evaluate system stability, controllability, and observability.

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