Teaching Materials for Master's Programmes in Maintenance Engineering

Achieved result of the SMTMC project

Used in accredited Master's curricula since 2022

Prepared by the partner universities of Tunisia and validated by European experts

I. Table of contents

Introduction

This deliverable presents the development of course materials designed to accompany the four Maintenance Engineering training pathways set up as part of the SM-TMC project. These teaching aids have been developed to complement the programmes detailed in deliverable D2.1, in order to offer students and teachers structured training resources adapted to the requirements of the Tunisian industrial sector, while complying with European and international maintenance engineering standards. The development of this pedagogical content is based on an integrated pedagogical approach, aligned with the recommendations of WP1, in particular the analysis of industrial skills needs carried out in deliverable D1.3. The aim is to provide a comprehensive, interactive and professional training programme, equipping students with the skills needed to meet the challenges of modern maintenance, Industry 4.0 and the digital transformation of maintenance.

1. Key principles

The educational content has been developed according to several key principles:

⇒ They are structured in **a modular way,** in line with the priority maintenance engineering skills identified by the academic and industrial partners.

⇒ An **interactive and applied** approach has been adopted, incorporating real case studies, digital simulations and concrete industrial projects.

⇒ By integrating **new technologies** such as the Internet of Things, artificial intelligence, Big Data and augmented reality, students are introduced to advanced maintenance tools.

⇒ They are **aligned with developments in the industrial sector**, guaranteeing greater employability for graduates and adaptation to the new demands of the job market.

This approach aims to equip future maintenance engineers with the knowledge and skills they need to excel in a constantly changing industrial environment.

2. Objectives of WP2.2

- Provide complete, up-to-date course materials for each Masters module.
- Integrate the results of WP1 (needs analysis) and the recommendations of deliverable D1.3.
- Adopt an interactive, practice-oriented teaching approach.
- Using information and communication technologies (ICT) to enrich learning.

3. Methodology

The development of the course materials for the Maintenance Engineering training pathways has followed a **collaborative and progressive** approach, guaranteeing the quality and relevance of the teaching content. This methodology is based on a structuring in several key stages, involving both the **teachers, the teaching teams from Tunisian universities and the European academic and industrial partners involved in the project, the industrial experts and the students** in order to ensure optimum alignment with the requirements of the job market and international academic standards.

3. 1. Needs analysis and content structuring

The first phase involved identifying training needs based on the results of **WP1 (deliverable D1.3)**. A detailed analysis of the skills expected in industry enabled the educational content to be structured around the key themes of **Industry 4.0, predictive maintenance and digital transformation**. This structuring was carried out in collaboration with professionals from the sector, thus guaranteeing **consistency between academic training and industrial expectations**.

3.2. Defining teaching formats and tools

A variety of teaching formats have been adopted to cater for different learning styles and facilitate the acquisition of skills. These include :

- **Course manuals and practical worksheets**, providing an in-depth theoretical

grounding in the fundamental concepts of maintenance.

- **Interactive presentations and educational videos to** help you assimilate the concepts covered visually and dynamically.
- **Real-life case studies**, based practical industrial experience, to help students put their knowledge into practice.
- **Numerical simulations and practical exercises** enable students to maintenance scenarios and understand the mechanisms for detecting and correcting faults.
- **Quizzes and formative assessments**, designed to measure students' understanding and adjust lessons according to the results obtained.

3.3. Validation and testing of teaching materials

Before they were finally incorporated into the curricula of the training courses set up as part of the SMTMC project, the materials underwent **a validation process** involving several levels of assessment:

- **Proofreading and adjustments by teachers and industry experts to** ensure the accuracy and relevance of the content.
- **Pilot testing with students**, with experimental use of certain materials in the classroom and in the workplace.
- **Gathering feedback from students and teachers** to identify areas for improvement and optimise teaching effectiveness.

3. 4. Monitoring and continuous improvement of content

A system for the **continuous assessment** of materials has been put in place to ensure that they are kept up to date and evolve in line with technological advances and market needs. This approach includes :

- **Regular student and teacher satisfaction surveys** to identify strengths and areas for improvement.
- **Ongoing collaboration with partner companies**, to adapt content to changes in

the industrial sector and new maintenance requirements.

- **An annual review process to** ensure that **materials are** kept up to date with technological innovations and feedback from the field.

4. Course materials by training path

4.1 University of Sfax: Professional Masters in Management and Maintenance of Industrial Systems

1) Module 1: Materials and Industry 4.0

Objectives :

- Understand the properties and applications of the main materials (metals, polymers, ceramics and composites) in industry.
- Analyse material failures through real-life case studies.
- Discover Industry 4.0 technologies and their applications in maintenance.
- Develop practical skills in maintenance data analysis.

Supports :

- Course manual on materials and their properties, covering metals, polymers, ceramics and composites, with a focus on materials used in Tunisian industry.
- Case studies on material failures in industry, based on concrete examples from Tunisian companies.
- Interactive presentation on Industry 4.0 technologies, illustrating key concepts and applications in the field of maintenance.
- Practical exercises on maintenance data analysis, using real data from Tunisian companies.

2) Module 2: Maintenance and Logistics

Objectives:

- Mastering the different types of maintenance (corrective, preventive, condition-based, predictive).
- Knowledge of a computer-assisted maintenance management system (CMMS).
- Understand the logistical challenges involved in maintenance and optimise the spare parts supply chain.

Supports :

- A course manual on the different types of maintenance (corrective, preventive, condition-based, predictive), focusing on best practice and international standards.
- Simulation of a computer-aided maintenance management system (CMMS), enabling students to familiarise themselves with maintenance management tools.
- Case study of maintenance logistics in a Tunisian company, illustrating the challenges and solutions for optimising the spare parts supply chain.
- Online quiz key maintenance , to assess students' understanding.

3) Module 3: Maintenance and Diagnostics

Objectives :

- Applying predictive maintenance and equipment diagnosis techniques to industrial cases.
- Use diagnostic tools (vibration analysers, thermal cameras, diagnostic software).

Supports :

- Course manual on predictive maintenance techniques, covering methods for monitoring, analysing and diagnosing equipment.
- Practical work on use diagnostic tools such as vibration , thermal imaging cameras and diagnostic software.
- A visit to an industrial site with a demonstration diagnostic techniques, enabling

students to observe maintenance practices in a real-life situation.

- Case study on solving complex maintenance problems, based realistic scenarios encountered in Tunisian industry.

4) Module 4: Industrial electricity

Objectives :

- Master the fundamentals of industrial electricity (electrical circuits, electrical machines, energy distribution).
- Understanding how electrical circuits work, wiring, measuring and troubleshooting.

Supports :

- A coursebook on the fundamentals industrial electricity, covering electrical circuits, electrical machines and power distribution systems.
- Simulations of electrical circuits, enabling students to understand how circuits work and to carry out virtual experiments.
- Practical work on industrial electrical equipment, to practical skills in wiring, measuring and troubleshooting.
- Visit a power station to find out about the facilities and equipment used to produce electricity.

5) Module 5: Industrial electricity and energy

Objectives :

- Understand the different types industrial energy and the associated regulations.

- Master the tools and techniques for analysing and optimising energy consumption in a real industrial context.
- Exploring energy renewable energy (wind, solar, hydro)

Supports :

- A course manual on the different types of energy used in industry, their advantages and disadvantages, and the regulations in force.
- Case studies on optimising energy consumption in Tunisian companies.
- Simulations of energy production systems (wind, solar, hydraulic).
- Visit a company that has implemented energy efficiency solutions.

6) Module 6: IOT and Big Data

Objectives :

- Understanding the concepts of the Internet of Things (IoT) and Big Data in industrial maintenance.
- Collect and analyse sensor data using IoT platforms and Big Data tools.

Supports :

- Course manual on the concepts of the Internet of Things (IoT) and Big Data, and their applications in industrial maintenance.
- Practical work on collecting and analysing sensor data, using IoT platforms and data analysis tools.
- Development a predictive maintenance project IoT and Big Data.
- Case study on the use of IoT and Big Data improve maintenance performance in a Tunisian company.

7) Module 7: Virtual Reality in maintenance

Objectives :

- Discover Virtual Reality (VR) and Augmented Reality (AR) technologies in the context of training and maintenance.

- Use VR/AR software and equipment to simulate maintenance tasks.

Supports :

- A course manual on virtual reality (VR) and augmented reality (AR) technologies and their applications in training and maintenance.
- Practical work on the use of VR/AR software and equipment to simulate maintenance tasks.
- Development a VR/AR training scenario for the maintenance specific industrial equipment.
- Visit to a company using VR/AR to train its maintenance technicians.

8) Module 8: Automation and Control

Objectives :

- Mastering automated systems and industrial regulation in maintenance.
- Programming programmable logic controllers (PLCs) control maintenance systems.
- Simulate control systems optimise industrial maintenance.

Supports :

- Course manual on automated systems and industrial control, emphasis on maintenance applications.
- Practical work on programming programmable logic controllers (PLCs) to control maintenance systems.
- Simulation of control systems industrial equipment maintenance.
- Case study optimising the regulation of an industrial process to improve maintenance.

9) Module 9: Quality Management and Reliability

Objectives :

- Understanding quality norms and standards (ISO 9001) in industrial maintenance.

- To master the process of setting up quality management systems in maintenance departments.

Supports :

- Course manual quality norms and standards (ISO 9001, etc.) and their application in industrial maintenance.
- Case studies on the of a quality management system in a maintenance department.
- Practical work on the use quality tools (Pareto diagram, cause and effect diagram, etc.) to analyse maintenance problems.
- Simulation of an ISO 9001 certification process for a maintenance department.

10) Module 10: Advanced industrial techniques

Objectives:

- Exploring Industry 4.0 technologies and how they can be integrated into a maintenance department
- Design and manufacture spare parts using additive manufacturing.
- Explore the use of industrial robots equipment maintenance.

Supports :

- A course manual on advanced production techniques, such as additive manufacturing, robotics and Industry 4.0 technologies, and their impact on maintenance.
- Practical work on the design and manufacture of spare parts using additive manufacturing.
- Visit a company that uses industrial robots to maintain its equipment.

- Case study on integration of Industry 4.0 technologies in a maintenance department.

11) Module 11: Ergonomics and MSP

Objectives:

- Mastering the principles ergonomics and musculoskeletal disorders (MSDs)
- Applying ergonomic to the design of workstations and maintenance tools
- Simulating a virtual work environment for ergonomic analysis of maintenance tasks.

Supports :

- Course manual on the principles ergonomics and their application to the design of workstations and maintenance tools.
- Case studies on improving the ergonomics of maintenance workstations to prevent musculoskeletal disorders (MSDs).
- Practical work on the ergonomic analysis of a maintenance workstation and suggested solutions for improvement.
- Simulation of a virtual work environment for ergonomic analysis of maintenance tasks.

12) Module 12: English and

Project Objectives :

- Write technical reports, presentations and professional emails in English.
- Mastering oral communication techniques.

Supports :

- A course manual technical English applied to maintenance, with the emphasis oral and written communication.
- Practical work on writing technical reports, presentations and emails in English.
- Simulation of a project meeting in English, to develop oral communication skills.
- Case study on the management an international maintenance project, using

English as the working language.

13) Module 13: Work placement or final year

Objectives:

- Solve an industrial problem by applying the technical and theoretical skills acquired during the course.
- Working effectively with multidisciplinary teams in a professional environment.
- Write a detailed report and present the final to a jury.

Supports :

- A methodological guide to carrying out a work placement or a research project applied to maintenance.
- Case studies of maintenance projects carried out in Tunisian companies.
- Individual and group tutoring sessions to help students with their placement or project.
- Oral presentation of the work placement or project to a panel of teachers and professionals.

4.2 University of Gabès : Professional Master's Degree in Mechanics and Electronics of Automated Systems

1) Module 1: Applied Scientific Calculus

Objectives :

- Strengthen knowledge of applied mathematics, in particular modelling, differential equations, probability, statistics and numerical techniques.
- Master methods for solving specific problems (linear systems, interpolation, numerical integration).

Supports :

- A course manual on solving problems specific to electromechanicscovering their formulation and the appropriate methods of analysis and solution.
- Master numerical analysis and the application of numerical methods to solve electromechanical problems using IT tools.
- Use Matlab for practical work, in particular solving linear systems, polynomial interpolation and numerical integration

2) Module 2: Industrial computing 1

Objectives :

- Knowledge of Programmable Logic Controllers (PLCs), industrial networks (fieldbus, PLC networks) and IT (OSI model, CAN, ASI, Profibus- DP, Ethernet, TCP/IP protocols).
- Mastering PLC programming languages
- Program and manage industrial systems with Siemens S7-300 and S7-1200 PLCs.

Supports :

- A course on the IEC 1131-3 standard provides an understanding of the specifications relating to Programmable Logic Controllers (PLCs). It also covers mastering PLC programming languages and acquiring the skills needed to control and supervise industrial networks including fieldbus and PLC networks.
- The course material on computer networks covers the OSI model, the different topologies and architectures of computer networks, as well as the standardisation of local computer networks and data link protocols. It also provides an understanding CIM and RLI architecture and a study of several local network protocols such as CAN, ASI, Profibus-DP, Ethernet and Industrial Ethernet, as well as the TCP/IP protocol.
- Practical exercises include interactive animations on the Grafcet, allowing simultaneous and unique sequences to be selected, resumed or managed. These exercises are complemented by the programming Siemens S7-300 and S7-1200 PLCs and the management of industrial systems using these PLCs.

3) Module 3: Mechanics

Objectives:

- Understanding the mechanical characteristics of materials
- Analyse the mechanical behaviour of materials and the strength of mechanical parts.
- Knowing the different elements of motion transmission
- Select the motion transmissions (speed ratios, component alignment) best suited to each situation

Supports :

- This course covers the mechanical characteristics of materials, focusing on their behaviour under the effect of mechanical action. It also covers the study of the strength of mechanical parts, analysing their resistance to fracture, as well as the

study of the deformation of parts under various stresses.

- Case studies are used to solve specific mechanical problems and put the concepts studied into practice.
- Another course aid helps to identify the various components of motion transmission, to choose the type transmission best suited each situation, and to calculate the gear ratio of a transmission. It also includes assembly and alignment of the various components to ensure correct and functional installation.
- Case studies are proposed for the choice and sizing of different types of transmission, to reinforce practical understanding of the processes involved.

4) Module 4: Robotics

Objectives :

- Understanding and sizing industrial sensors and actuators.
- Design and control robotic arms for motor and sensory tasks.

Supports :

- The course includes material on the different types of sensors and actuators, how industrial instruments work and how to define, select and size these instruments.
- Another course material deals with robotic arms, covering the design of mechanical, computer or mixed systems, and helping to understand their ability to replace humans for motor and sensory functions.
- Practical work includes an introduction to Matlab Robotics Toolbox, enabling the study of geometric transformations in the context of robotics. It also covers the modelling and generation of trajectories, the dynamic control of manipulator robots, as well as the management of robot control and obstacle avoidance and the effort control of manipulator robots.

5) Module 5: Transversal 1

Objectives:

- Developing skills in technical English applied electromechanics.

- Project management: structuring, planning, execution and monitoring.

Supports :

- Technical English 1 aims to develop the student's skills in specialised English, enabling them to master technical English applied to electromechanics. It also provides the language tools needed for effective communication in this field.
- A course in Project Management teaches you how to create and work effectively in a team, how to structure and plan a project, and how to prepare for its execution and monitoring.

6) Module 6: Machine control

Objectives:

- Knowledge of electrical machines (MCC, asynchronous and synchronous machines).
- Understand the laws governing the control of electrical machines (alternating and direct current).
- Apply control algorithms (scalar, vector, DTC) using Matlab.

Supports :

- Course manual on the control laws of alternating current machines (asynchronous and synchronous) and their association with static converters in power electronics, and also on the operation of industrial electrical machines (direct current, asynchronous, synchronous) and basic converters (three-phase rectifiers, dimmers, choppers, inverters).
- Case studies analyse the control laws of DC and AC machines, such as scalar, vector, DTC control, etc.
- Study converter control algorithms and their use to control electrical machines at speed using Matlab.
- In practice, work on drives with different machines (MCC: dynamic model, regulation of current, speed and position; asynchronous machine and synchronous machine).

7) Module 7: Advanced mechanics 1

Objectives:

- Calculate and dimension hyperstatic structures using energy methods.
- Analyse the buckling and stability of elastic structures.
- Master the methods of modal analysis and finite elements for vibration analysis.

Supports :

- The aims of this course are to learn how to calculate and dimension a hyperstatic structure, and to consolidate knowledge of plastic and composite materials by mastering their laws of behaviour, particularly for the study of buckling and the stability of elastic structures. It also introduces energy methods for analysing stability problems, studies the behaviour laws of plastic and composite materials using structural mechanics analysis methods, and enables the stability and buckling of structures to be verified while applying energy methods to solve hyperstatic structure problems.
- Practical case studies also present modal synthesis and finite element methods, combining a numerical and experimental approach based vibration tests. The impact of damping and model correction are also discussed.

8) Module 8: Maintenance 1

Objectives:

- Understanding industrial maintenance concepts (preventive and corrective).
- Define the roles of the method and scheduling functions.
- Mastering repair methods and diagnosing mechanical systems. (assembly, alignment, lubrication).
- Know how to analyse faults and apply maintenance techniques to rotating machinery.
- Understanding how CMMS software to manage maintenance.

Supports :

- The course material focuses on the Introduction to Maintenance, its essential role in business, and the different forms and concepts of maintenance. Emphasis is placed on maintenance functions such as methods and scheduling.
- The course includes a review of the basics of maintenance, identification of the types of documentation and mastery of failure techniques. The practical part includes mounting and dismounting bearings, aligning shafts and lubricating systems.
- Practical work focuses learning how use CMMS , how to manage preventive and corrective maintenance, and the procurement needed to ensure an effective maintenance strategy.

9) Module 9: Industrial computing 2

Objectives:

- Modelling, sizing and controlling industrial electrical machines.
- Mastering distribution and use of electrical networks in an industrial environment.
- Design industrial control chains (analogue and digital).
- Programming PLCs (Siemens S7-300, S7-1200, Allen Bradley).

- **Supports :**
  - The course material enables students to analyse, size and use an industrial electrical machine according to industrial realities and requirements, taking into account operation, quality and safety. It also provides an insight into the functions and technology of industrial systems supervision systems.
  - The course includes material on the distribution and use of electrical networks in an industrial environment. It also teaches how to model and identify a physical system, as well as how to choose the components needed for an industrial control chain by mastering analogue and digital industrial controllers.
  - Practical work includes programming S7-300, S7-1200 and Allen Bradley PLCs, as well as configuring software and hardware and controlling industrial processes using these two types of PLC.

10) Module 10: Safety

Objectives:

- Master the concepts of industrial safety and risk management.
- Applying monitoring methods and techniques (vibration analysis, thermography, ultrasound) to detect machine faults.

Supports :

- The course covers the basics of industrial safety, the steps and tools involved in risk analysis, and methods for mitigating risks. It focuses techniques such as vibration analysis, infrared thermography and ultrasonic inspection used to monitor industrial equipment. This enables students to master the concepts of industrial safety and risk management, apply methods to reduce or eliminate risks and use personal protective equipment, learn about fire safety procedures and use the risk matrix, and apply risk analysis techniques.
- One of the course materials deals with the monitoring of mechanical systems. It teaches how to use vibration analysis, infrared thermography and ultrasonic testing to detect faults in machines, particularly rotating machines.

11) Module 11: Transversal 2

Objectives:

- Draw up a business (market , marketing plan, financial plan).
- Reinforce technical English skills for professional communication.

Supports :

- This coursebook teaches you how to draw up a business plan by identifying opportunities and planning the activities needed start up, expand or consolidate a business. It covers market research, developing a marketing, operational and financial plan, and the importance of business support structures.
- A manual of technical English aims to reinforce technical vocabulary in order to facilitate comprehension and oral communication on technical subjects. The

objectives include mastering oral communication for technical conversations, as well as consolidating technical vocabulary and improving professional writing.

12) Module 12: Applied microelectronics

Objectives :

- Acquire in-depth knowledge of electronic board design and production technologies.
- Mastering microcontroller programming for embedded systems and the IoT.
- Apply modern manufacturing to printed circuits.

Supports :

- This course provides in-depth knowledge of electronic board design and production technologies, with a mastery of the vocabulary and principles of the various manufacturing techniques.
- This course offers a modern approach to teaching complex digital systems, with the emphasis on logic. It helps students master the basic elements for building advanced systems, including embedded systems and the Internet of Things.
- Practical work provides hands-on skills in the design and production of printed circuits. They also enable students to master the programming of microcontrollers to create control and power boards and other modern electronic devices.

13) Module 13: Control of dynamic systems

Objectives:

- Apply advanced control techniques to linear servo systems
- Analyse the stability and performance of linear servo systems.

Supports :

- The course material covers various advanced control techniques for linear servo systems, such as state feedback control, internal model control, fuzzy logic,

artificial neural networks and neuro-fuzzy control.

- Case studies using special tools to analyse the performance of a linear servo system to analyse a linear servo system, studying its stability and calculating the steady-state error for different inputs.

14) Module 14: Mechatronic systems

Objectives:

- Master the control and regulation of complex mechatronic systems.
- Understanding the key elements of mechatronic systems
- Design systems integrating sensors, actuators and automated controls.

Supports :

- This course provides the skills needed to master the control and regulation of mechatronic systems. It covers the fundamental principles of the control of complex dynamic systems, the integration of

  automated controls and performance management in industrial environments.
- This course introduces the key elements of mechatronic systems, covering essential technologies and components such as sensors, actuators, control systems and interfaces. The aim is to understand their interaction and their application in the design of integrated mechatronic systems.
- A mini-project to put into practice the skills acquired in the control and regulation of mechatronic systems. Students design and carry out a project incorporating mechatronic components, from sizing to implementation, including programming and performance validation.

15) Module 15: Advanced mechanics 2

Objectives:

- Master the tools of MMC modelling to solve boundary problems in linear elasticity.

- Learn about the concepts of tribology and lubricated contacts (friction, wear).
- Know how to establish and analyse contact forces and coefficients of friction and choose the right lubricants.

- **Supports :**
  - This course is designed to help students master the modelling tools used in MMC, as well as the formulation and resolution linear elasticity boundary problems.
  - A Tribology and Lubricated Contacts course support, the student will be introduced to the recent science of contact between solid surfaces in relative motion: friction, wear and lubrication.
  - Practical cases enable students to work on the following topics: establishing and analysing contact forces between two solids, analysing different lubrication regimes, oil film thickness and estimating friction coefficients. Students also learn how to choose the right lubricant for a specific application and decide on the modifications needed to reduce wear on the materials in contact.

16) Module 16: Numerical mechanics

Objectives:

- Basic knowledge of vibration mechanics and techniques for analysing vibration phenomena in mechanical systems.
- Use numerical methods to model mechanical problems.

Supports :

- This course covers the basics of vibration mechanics by studying the behaviour of discrete and continuous systems, both damped and undamped, as well as the analysis of hyperstatic structures, using solution methods based on energy theorems.
- Practical cases for modelling the vibratory phenomena of mechanical systems, in free and forced regimes, subjected to external stresses or disturbances.
- Case studies on resonance phenomena and their destructive impact, and

understanding the importance of in-depth dynamic analysis for the design vibrating mechanical systems.

- As practical work, the modelling of mechanical problems in various fields (static analysis, mode analysis and vibration frequency) with various types of loading (concentrated loads; distributed loads; constant loads; time-varying loads; forces; moments; pressures; accelerations; imposed displacements; temperature fields).

17) Module 17: Maintenance 2

Objectives:

- Master the fundamentals of reliability in preventive and corrective maintenance.
- Identify, calculate and interpret reliability parameters for industrial systems.

Supports :

- A course on system reliability and maintenance management which aims to teach how to calculate reliability and its various parameters for any type of system, and to analyse and interpret the results and estimate a reliability function for electronic or mechanical components, using historical data.
- Practical case studies to help you understand the importance of reliability in industrial maintenance and how to apply it in this field.
- A course to help you acquire the basic knowledge of maintenance project management, including the managerial and technical skills needed to manage short, medium and long-term projects.
- Practical work on mastering the computer tool for calculating reliability through the calculation of reliability and its parameters, analysing and interpreting the results, estimating the reliability function for electrical/electronic and mechanical systems and calculating the reliability of composite systems.

18) Module 18: Embedded systems

Objectives:

- Knowledge of SOC technologies for embedded systems.

- Master the methodology for designing a system-on-a-chip, including hardware/software codesign.
- Master the basics of programming and integrating microcontrollers into industrial applications.

Supports :

- A course pack will introduce you to SOC (System on Chip) technology and its characteristics, and help you to master the methodology for designing a system on a chip, including hardware/software codesign.
- The course material provides practical skills in hardware programming using logic gates. It also teaches VHDL programming to implement FPGA boards for various applications.
- The practical work offers the opportunity to acquire skills in embedded systems, in particular on the FPGA board of the Altera Cyclone IV E115 family. They enable students to master synthesis and implementation on this type of board for different types of applications.

19) Module 19: Practical activity (internship dissertation)

Objectives:

- Applying knowledge acquired in a professional context.
- Preparing an internship report and defending an internship dissertation before a jury

Supports :

- A methodological guide to carrying out a work placement or a research project applied to maintenance.
- Case studies of maintenance projects carried out in Tunisian companies.
- Individual and group tutoring sessions to help students with their placement or project.
- Oral presentation of the work placement or project to a panel of teachers and professionals.

4.2 Carthage University: Professional Masters in Maintenance Engineering

1) Module 1: Advanced Maintenance

Objectives:

- Understanding maintenance strategies and performance indicators.
- Identify and calculate performance indicators in production and maintenance
- Analysing failures for condition-based and predictive maintenance and dependability.
- Acquire the fundamentals of machine diagnostics using vibration analysis.

Supports :

- Course material on maintenance strategies and performance indicators
- Case studies on predictive failure for condition-based and predictive maintenance.
- Practical workshops on machine diagnostics using vibration analysis

2) Module 2: TPM and the Maintenance Dashboard

Objectives:

- Master the concepts of Total Productive Maintenance (TPM) and maintenance dashboards.
- Designing and analysing dashboards using software such as Power BI.

Supports :

- Course material on Total Productive Maintenance (TPM) and maintenance dashboards.
- Applications and case studies on the implementation of TPM in different industrial contexts.
- Practical exercises on designing and analysing dashboards (Power BI software)

3) Module 3: Industrial Information (PLM)

Objectives:

- Understand the concepts of Product Lifecycle Management (PLM) and Computerised Maintenance Management (CMMS).
- Understanding the steps involved in implementing CMMS in Industry 4.0.
- Familiarise yourself a collaborative PLM tool.

Supports :

- Course material on the concepts of product lifecycle management (PLM) and computer-aided maintenance management (CMMS) and the challenges for Industry 4.0.
- Case studies on implementation of CMMS.
- Practical exercises on managing and integrating product data in a PLM/CMMS system.

4) Module 4: Additive Manufacturing

Objectives:

- Discover additive manufacturing technologies and their industrial applications.
- Acquire skills in 3D modelling, simulation and part printing

Supports :

- Course material on the various additive manufacturing technologies, their applications and the theoretical fundamentals of the technology.
- Practical exercises in 3D modelling, simulation and part printing.

5) Module 5: Deep Learning and Big Data for Maintenance

Objectives:

- Exploring and applying artificial intelligence (AI)

- Introduction to machine learning / Deep Learning and its applications in the context of maintenance and fault detection algorithms and monitoring the state of health of machines and structures

Supports :

- Course material on artificial intelligence (AI) tools and their maintenance applications.
- Interactive presentation illustrating concrete examples of the use of AI for predictive maintenance
- Practical exercises on training AI models using real or simulated data.

6) Module 6: Sensor networks and IoT

Objectives:

- Understanding sensor networks and the Internet of Things (IoT) in Industry 4.0.
- Knowledge of mixed hardware/software design approaches applied to sensor network components / IoT (Internet of Things)
- Familiarise yourself with sensor network platforms (STM 32 with IOT application).
- Implementing sensor networks for industrial maintenance.

Supports :

- Course material on sensor networks and the Internet of Things.
- Industry 4.0 application case studies remote monitoring and predictive maintenance
- Practical exercises on programming and integrating sensors into an IoT network.

7) Module 7: Embedded Systems

Objectives:

- Master the architectures and programming of embedded systems.
- Study industrial applications of embedded systems.
- Know the basics of microcontroller programming.

Supports :

- Course material on embedded system architectures and programming.
- Case studies of industrial applications of embedded systems.
- Practical exercises microcontroller programming.

8) Module 8: Real-time supervision system (LabView)

Objectives:

- Master the basics of how LabView works
- Use LabView supervision, data acquisition and process control.
- Create graphical interfaces and process data.

Supports :

- LabView user manual for real-time supervision, data acquisition, visualisation, alarm management and process control.
- Practical exercises on the creation graphical interfaces and data processing.

9) Module 9: Supervisory Control and Data Acquisition (SCADA)

Objectives:

- Understanding the architecture and control and supervision functionalities of SCADA systems.
- Identify the communication methods between SCADA master units and remote terminal units.
- Designing and using a SCADA system

Supports :

- Course material on the architecture, components and functionalities of SCADA systems
- Case studies on use of SCADA in industry
- Practical exercises on the design and use of a SCADA system

10) Module 10: Evolutionary Computation (Genetic Algorithm)

Objectives:

- Be familiar with the various numerical optimisation
- Master implementation and use of these algorithms on real cases
- Programming genetic algorithms maintenance planning.

Supports :

- Course material on the principles of evolutionary algorithms and their application to strategy optimisation and preventive maintenance planning.
- Case studies of optimisation based on genetic algorithms.
- Practical exercises in programming genetic algorithms.

11) Module 11:

English Objectives :

- technical English in a professional context.
- Develop oral and written communication skills (presentations, reports, emails).
- CVs and covering letters.

Supports :

- Course book on using English in a professional context, covering essential oral and written communication skills.
- Practical exercises in preparation and oral presentation, including speaking techniques and the use of visual aids.
- Practical exercises in writing technical reports, presentations and emails.
- CV and cover letter writing workshops

12) Module 12: Entrepreneurship and Innovation

Objectives:

- Mastering the tools of creativity and innovation
- Understanding entrepreneurial process.
- Understanding the importance of strategic intelligence and intellectual property for an innovative project.

Supports :

- Course material on the principles and tools innovation, creativity and entrepreneurship.
- Practical innovation and creativity workshops to solve an industrial problem.

13) Module 13: Final project

Objectives:

- Learn a methodological approach to solving an industrial problem
- Validate and put into practice the knowledge acquired
- Prepare a scientific report and an oral presentation before a jury.

Supports :

- A methodological guide to carrying out a work placement or a research project applied to maintenance.
- Individual tutoring to support students in their work placements or projects.
- Oral presentation of the work placement or project to a panel of teachers and professionals.

4.4. University of Jendouba: "Mechanical Engineering and Industrial Maintenance" engineering course - 3rd year "Vehicle Technologies" specialisation course

1) Vibration mechanics

Objectives :

- Explain the phenomena of vibrations on machines and the advantages of identifying them Equate the vibrations of discrete and continuous mechanical systems
- Study transient vibrations, frequencies and eigenmodes of systems
- Study the steady state and responses of systems to harmonic or transient loading

Supports :

- Course material on the fundamental principles of mechanical vibrations.
- Practical exercises in vibration modelling and simulation using specialist software.

2) Methods office

Objectives :

- Acquire the specific skills required to draw up and write a machining procedure or range based on a specification and a general drawing or definition of the part.
- analyse the manufacture of mechanical parts and draw up the documents required for their manufacture.
- develop machining processes for turning and milling mechanical parts involving several machining phases.

Supports :

- Course material on methods for producing machining routines.
- Exercises and practical workshops on software (e.g. MasterCam)

3) Quality management

Objectives:

- Master the principles of ISO standards (ISO 9001) and their application in an industrial context.
- Understanding the process of setting up a quality management system (QMS).
- Mastering quality tools (Pareto diagram, cause and effect diagram, etc.) to analyse and resolve problems.

Supports :

- Course material on quality standards (ISO 9001) and continuous improvement .
- Case on the implementation of a quality management .

4) Machine element 1

Objectives:

- Be familiar with the standard machine components and parts used in the construction mechanical structures.
- Understanding the standardisation of mechanical parts.
- Master the principles of mechanical power transmission

Supports :

- Course material on types of standardised parts (bolts, nuts, keys, bearings).
- Practical exercises sizing and selecting power transmission components (shafts, couplings, gears).

5) Machine element 2

Objectives:

- Learn more the complex machine elements and parts used in mechanical structures.
- Analyse advanced standards and norms for dimensioning and selecting mechanical components.
- Optimise mechanical power transmission, taking into account performance and durability constraints.

Supports :

- Be familiar with the standard machine components and parts used in the construction of mechanical structures.
- Understanding the standardisation of mechanical parts.
- Master the principles of mechanical power transmission

6) Stock and equipment management

Objectives:

- Learn the fundamentals of inventory management (ABC, Just-in-Time, MRP methods)
- Integrating inventory management into the company's overall strategy to reduce risk and improve operational performance.

Supports :

- Course material on inventory and supply management strategies.
- Application exercises and case studies stock optimisation in an industrial context.

7) Transmission and braking

Objectives

- Design innovative mechanisms to meet the specific needs of power transmissions.
- Mastering analytical and graphical synthesis approaches for the design of complex mechanisms.
- Analyse mechanical power transmission chains in detail, calculate the associated characteristics (transmission ratio, efficiency, etc.), and select and size transmissions according to performance requirements.
- Sizing brakes and clutches integrated into power transmission chains
- Calculate the mechanical actions on bearings in a preloaded assembly and carry out static and dynamic dimensioning using data manufacturers' catalogues.

Supports:

- Course material on transmission and braking mechanisms (continuously variable transmissions, electromagnetic brakes, etc.).
- Exercises and case studies sizing drive chains.

8) Engine mechanics

Objectives:

- Understand the operating principles of internal combustion and electric motors
- Evaluating engine performance (power, efficiency, fuel consumption)
- Modelling and simulating the dynamic behaviour of engines to optimise performance and reduce emissions.

Supports:

- Course manual on the advanced principles of heat and electric motors,

- Exercises and applications on optimising engine performance in automotive and industrial applications.
- Practical work

9) Materials and damage

Objectives:

- Provide the theoretical basis the mechanics of damage to materials
- Modelling evolution of damage

Supports:

- Textbook on material properties and advanced damage for thermal and electric motors,
- Application exercises and practical work

10) Industrial Maintenance

Objectives:

- Understanding the different maintenance concepts
- Evaluate the costs of a maintenance operation
- Understand the mechanisms by which failures occur and deduce their causes
- Analyse failures qualitatively and quantitatively
- Model the reliability a piece of equipment deduce its availability

Supports:

- Course manual on the fundamentals of industrial maintenance and KPIs
- Application exercises and practical work

11) Packaging and handling systems

Objectives:

- Identifying the design and operating parameters of handling systems;
- Understand the basic principles of packaging and handling systems in an industrial environment.
- The study of efficiency of handling systems, taking account reliability, production capacity, convenience and minimum damage and contamination of agricultural products;
- Study of the influence of the flow properties of bulk food products on the performance of handling systems.

Supports

- Course manual
- Application exercises
- Practical work

12) Mechatronics

Objectives:

- Understand the basics of mechatronics and its applications (robotics, automation).
- Learn the basic concepts of microcontrollers (e.g. Arduino) and program simple systems.

Supports

- Course manual and application exercises
- Practical work on programming sensors/actuators with Arduino.

13) Chassis and structure

Objectives:

The aim of the course is introduce and discuss :

- Overall layout of the vehicle
- Study of a selection of vehicle components and sub-systems
- Discussion of functional aspects, constructive simplicity and manufacturing costs
- Introduction to modern design methods and tools used in the automotive industry: optimisation, simultaneous engineering, inventiveness of innovative solutions, etc.

Supports

- Course manual
- Application exercises
- Practical work

14) Engine testing, diagnostics and troubleshooting

Objectives:

- In-depth knowledge of internal combustion engines and engine mechanics.
- Understanding the operating principles of combustion systems and engine components.
- Practical experience with automotive tools and equipment.

Supports

- Course manual
- Application exercises
- Practical work

10) Engine Mechanics II

Objectives:

- In-depth knowledge fluid mechanics and thermodynamics.
- Understanding of the basic principles of engine mechanics and automotive systems.
- Ability to interpret electrical diagrams and circuit diagrams.

Supports :

- Course manual
- Application exercises
- Practical work

Conclusion:

For the four Maintenance Engineering training courses, the course materials have been developed and validated by the project partners, and will be implemented from the start of the 2022-2023 academic year, following the granting of university accreditation by Tunisia's Direction Générale de la Rénovation Universitaire, which will give legitimacy to the diplomas awarded on completion of these training courses.

In order to guarantee the relevance and quality of the training, regular assessment of the content and teaching methods is essential. This evaluation is carried out in collaboration with industry experts and students. The aim is to ensure that the training remains aligned with the requirements of the job market while complying with international academic standards. This approach helps to maintain the quality of the skills acquired by students and to meet the evolving needs of the maintenance engineering sector.

5. Assessment and continuous improvement

To ensure optimum teaching quality and continuous adaptation to **industrial and technological developments**, a system for **assessing and improving teaching materials** has been put in place. This framework is based on **a regular assessment** involving

teachers, students and partner companies.

5.1 Assessment mechanisms for teaching materials

Course materials are assessed in a number of ways:

- **Student evaluation**: Course evaluation forms are distributed each year to gather feedback on the **clarity of the materials, their usefulness in learning situations and their relevance to labour market expectations**.
- **Feedback from teachers**: A pedagogical analysis is carried out by the teachers responsible for the training courses to identify the strong points and any improvements to be made to the course materials.
- **Feedback from partner companies**: Professionals in the sector are consulted to ensure that the content taught remains **in line with technological developments and the requirements of the job market**.

5.2 Continuous improvement process

A **pedagogical monitoring committee** is responsible for updating the materials according to the results of the assessments. This process includes :

- **An annual review of the materials**, incorporating feedback from stakeholders and developments in the sector.
- **The integration of new case studies and practical examples** from recent industrial experience.
- **The updating of digital and interactive content**, with the addition of simulations and learning tools based on new technologies.
- **Adapting materials to new teaching methods**, taking into account advances in digital teaching and blended learning.

5.3 Performance indicators and impact monitoring

Several **performance indicators** are used to measure the effectiveness of teaching materials are monitored:

- **Student and teacher satisfaction rate**, based on feedback from evaluation questionnaires.
- **Employability rate of graduates**, to assess the relevance of skills acquired in the workplace.
- **Feedback from companies on the level of preparation of graduates**, in relation to the relevance of training to the needs of the sector.
- **Level of integration of new technologies in support materials**, measured by the introduction of simulations, interactive modules and case studies related to Industry 4.0.