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PROJECT NUMBER: 2020-1-BG01-KA202-079042

Co-funded by the Erasmus+ Programme of the European Union

CURRICULUM

for upskilling technicians and engineers in the sector of Machine Building and Mechatronics

2021

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PART 1 TECHNICIANS

1. INTRODUCTION

The present Curriculum is written within the **allCUTE** project under ERASMUS+ Programme. It is designed to improve the technical and generic skills of technicians employed in the sector of *Machine Building and Mechatronics* as a result of the high demand of upskilling on behalf of employers so as to meet the challenges of Industry 4.0.

The Curriculum is based on the findings of a survey carried out among 161 companies in the above sector covering the following European regions:

- Gabrovo, Bulgaria
- Plovdiv, Bulgaria
- East Macedonia and Thrace, Greece
- Pomorskie, Poland
- Nis, Serbia

After analyzing the survey results, the following 8 courses for technicians have been identified as a priority of employers in the respective industrial sector, and underpin this Curriculum:

- Electricity
- Electrical Drives
- Pneumatics and electro-pneumatics
- Hydraulics
- Vacuum and vacuum technology
- Optimal use of compressed air
- Operating CNC Machines
- Operating automated production system

2. TEACHING METHODOLY

The Curriculum is based on blended learning, where ICT is more strategically used. The e-learning part is based on open educational resources - self-study of both theory so that the learners could be prepared in advance for their traditional classroom classes and practice so that the learners could be better prepared for their jobs through learning by doing in real-life industrial settings.

The traditional classroom part is based on active learning techniques (learner-centred) such as flipped classroom, jigsaw, problem- and project-based learning, think-pair-share, etc., where the learners are able to shape their own learning path by the guidance of a VET teacher. Studying the materials in advance, the learners discuss them in the classroom and solve problems on the basis of what they have already learnt thus improving their critical, analytical and creative thinking, motivation, communication, problem-solving, digital skills, etc. Moreover, they receive peer support and teach each other. The VET teacher is a moderator rather than an instructor and the learners are actively involved in the learning process rather than being passive viewers.

The proposed teaching methodology reflects world-wide state-of-the-art teaching techniques as it can be seen in Figure 1 below.

Figure 1: Learning pyramid

3. ASSESSMENT METHODOLOGY

Taking into consideration the course duration and the type and range of knowledge and skills to be acquired, the assessment methodology is based on 3 assessment techniques:

- Reflection by introducing One Minute Paper

At the end of the day's lesson learners answer teacher-posed questions (one minute paper) which prompt them to reflect on the day's lesson.

By implementing this assessment technique, the teacher gets useful feedback on how each learner progresses and what difficulties he / she faces, on the one hand, and learners develop their transversal skills to reflect on, analyze, and self-evaluate their performance, on the other hand.

- Observation by introducing Performance Checklist

At the end of day's lesson the teacher completes the Performance Checklist that states specific criteria and allows teachers to gather information and to make judgements about what learners know and can do in relation to the learning outcomes set. Furthermore,iIt offers systematic ways of collecting data about specific behaviours, knowledge and skills.

- Small-scale project

After completing the course, learners should develop in pairs a small-scale project in a form of a PoewrPoint presentation. By working on a small project, learners have the opportunity to show to what extend they have improved their technical expertise, to develop transversal skills, such as team work, communication, problem solving, critical thinking, etc. Last but not least they can also enhance their digital competence.

Where a small-scale project is not suitable, tests could be used to assess learners' knowledge and skills.

4. COURSE DESCRIPTION

4.1. Course 1- Electricity

Course duration (days): 3 - 4

Academic hours: 20 (8 theory + 12 practice)

Course overview:

Electricity training course – provides a foundational understanding of how electricity works in commercial and industrial settings. Includes hands-on electrical skills improvement and is designed to train maintenance technicians and other personnel working in industrial plants and commercial buildings.

In this course, learners are immersed in practical, real world examples. They'll learn how to use electrical test equipment in their everyday jobs before moving on to an in-depth discussion about major electrical components, where and how these electrical components work, and their purposes within electrical systems. The goal of this basic electrical training course is to teach students how to reduce electrical equipment downtime, improve overall efficiency and safety, and fix problems they've been unable to solve on their own.

Course learning outcomes:

- Acquire skills in using electrical measuring devices.
- Calculate impedance, apparent, active, and reactive power and power factor in a single phase AC circuit and correct a lagging power factor.
- Be aware of electrical hazards and able to implement basic actions to avoid unsafe work conditions.
- Use Ohms Law and use it to solve for current, potential, and resistance in DC and AC circuits.
- Use multi-meters, wattmeters, Wheatstone bridges, oscilloscopes etc to measure electrical quantities and troubleshoot electrical problems.
- Provide examples of the use and advantages of three phase power.

Required resources (e.g. equipment, materials, tools, software, etc.):

PC – personal computer, MS Office (Word, Excel, PowerPoint), Multimeter, oscilator, resistors, capacitors, electrical motors, thermal camera etc

Topics	Problems to be solved
T1 - Introduction to Electricity 1.1 What is Electricity 1.2 How Electricity is Generated 1.3 How Electricity is used	
T2 - Electrical Resistance 2.1 What is Electrical Resistance? 2.2 Definition 2.3 Units and measurement of Resistance	• Measuring resistance
T3 - Voltage 3.1 What is a voltage 3.2 Measurement of voltage	• Measuring voltage
T4 - Electrical Current 4.1 AC vs DC Current 4.2 Measurement of current	• Measuring current
T5 - Inductors	• Inductor
T6 - Capacitors 6.1 Capacitor 6.2 Charging and discharging a capacitor 6.3 Transient behavior of capacitor	• Capacitor
T7 - Oscilloscope 7.1 Description of Oscilloscope 7.2 Measuring shape of a waveform (a graph of voltage over time) 7.3 Measuring amplitude and frequency of a signal 7.4 Detecting glitches and noise in a signal	• Measuring quantities with an osciloscope

T8 - Three phase circuit 8.1 Electric power single and three phase power active reactive apparent	• Three-phase circuits
T9 - Thermographic testing of electrical equipment. 9.1 How does thermography work? 9.2 How can thermography be used to inspect electrical equipment? 9.3 What are the benefits of thermographic inspection? 9.4 Who may perform thermographic inspections? 9.5 When is a thermographic scan needed?	• Finding errors in electrical equipment
T10 - Electrical Safety	• Safety Precautions for Electrical System

Recommended reading resources:

1. JONES, Ray A.; JONES, Ray; JONES, Jane G. *Electrical safety in the workplace*. Jones & Bartlett Learning, 2000.
2. Bird, John. *Electrical circuit theory and technology*. Routledge, 2014.
3. Alexander, Charles K. *Fundamentals of electric circuits*. McGraw-Hill, 2009.
4. https://www.fluke.com/en-us/learn/blog/thermal-imaging/electrical-systems

4.2. Course 2 - Electrical Drives

Course duration (days): 5 days

Academic hours: 30 (15 theory + 15 practice)

Course overview:

This course is aimed at the acquisition of theoretical and practical skills in the field of electrical drive. In this regard, after a brief overview of the basic concepts in electrical engineering, the most popular types of electrical motors and converters are discussed. After the acquisition of the relevant knowledge, the next stage related to the studying of the wider used variable-frequency servo drives begins.

Course learning outcomes:

After having followed the course, the participants will be able to:

- define the electrical circuit parameters as a function of the load
- specify the converter types and components following the energy transfer direction
- appoint the appropriate control method, according to the relevant converters
- determine the electrical motor types in dependence upon its construction and the grid.
- select the appropriate electrical drive according to the relevant system.

Required resources (e.g. equipment, materials, tools, software, etc.):

Electrical test bench and motor test bench, Personal computer, LTspice simulation software, MS Office

Topics	Problems to be solved
T1. Basic concepts of electrical engineering - Electrical circuit - Resonance - Power in electric circuit - Semiconductors	• Solving practical problems in the electrical engineering field
T2. Rectifiers and filters - rectifiers with active loads	• Studying basic diode rectifier systems and Associated smoothing filters

- rectifiers with inductive or capacitive load - passive filters	
T3. Power converters - inverters - DC-DC converters	• Analyzing different types of power converters
T4. Constant and variable-frequency control - Pulse width modulation (PWM) - Phase-shift control	• Generating PWM and phase-shifted signals using microcontroller
T5. D.C. motors - Torque production - Shunt, Series and Compound motors	• Analyzing the behavior of DC motors under load
T6. Induction motors - The rotating magnetic field - Torque production - Single-phase induction motors - Three-phase induction motors	• Testing a three-phase induction motor
T7. Stepper motors - Introduction - Principle of motor operation	• Acquiring experience with stepper motor control
T8. Electrical drives - Basic concepts - Basic elements - Advantages and disadvantages	• Identification of the basic components of an electric drive system
T9. Variable-frequency drives (VFD) - Introduction - Application - Control	• Performing speed control of a motor using VFD
T10. Servo drives - Introduction - Application - Control	• Analyzing a servo drive system

Recommended reading resources:

[1] Dokic, B. and Blanusa, B., *Power electronics converters and regulators.* 3th ed. Switzerland: Springer International Publishing, 2015

[2] Mohan, N. , *Power electronics.* New Jersey: Hoboken , 2011

[3] Hughes, A., *Electric Motors and Drives. Fundamentals, Types and Applications*, 3th ed., Elsevier, 2006

4.3. Course 3 - Pneumatics and Electro-pneumatics

Course duration (days): 3 - 4 day

Academic hours: 24 (12 theory + 12 practice)

Course overview: This course introduces users to the basic principles, laws and components used in pneumatic and electro-pneumatic systems. It covers the types, operating principles and symbols for the different components used in industrial applications.

Course learning outcomes: On completion of the course, participants will be able to:

- understand the characteristics, generation and preparation of air;
- provide a knowledge base of the main components of the pneumatic systems and their functions and symbols;
- identify various schematic symbols used in pneumatics, design a basic pneumatic schematic drawing from a given requirement;
- identify, inspect, adjust and replace of a wide range of pneumatic automation tools - pneumatic valves, actuators, grippers, proximity sensors logical elements, relays, timers, flow controls, etc.;
- to know and implement basic schemes in pneumatic manipulators in automated systems;
- understand how PLCs are interfaced and used to control pneumatic systems.

Required resources (e.g. equipment, materials, tools, software, etc.): Pneumatic circuit drawing software (for training). PLC Programming Software (for training)

Topics	Problems to be solved
T1. Theoretical basics. Dimensions. Pressure and flow. Properties of gases. Pneumatic gas laws. Humidity. Measurement methods.	• Relationship between pressure, volume and temperature for an ideal gas. • Samples of the use of compressed air as the

	source of power are demonstrated. • The main factors are considered in selecting the pneumatics.
T2. Compressed air production. Reciprocating compressors. Screw compressors. Pressure receivers. Compressed air drying. Water separators. Symbols. Advantages, disadvantages and conditions in the application of the main elements by type in the production of compressed air.	• Principle of operation, construction and suitability in various applications.
T3. Preparation of compressed air. Filters. Pressure regulators. Lubrication of compressed air. Groups for the preparation of compressed air.	• Principle of operation, construction and suitability in various applications. • Main characteristics of the preparation elements. • Fault indicators and rules for diagnosis and maintenance are defined.
T4. Pneumatic actuators. Cylinders (single - double acting). Types of cylinders. Pneumatic gripers. - Symbols - Sensors - Compared to hydraulic cylinders - Identifying defects and their removal	• Principle of operation, construction and suitability in various applications. • Pneumatic cylinder installation (mounting).
T5. Sensors for pneumatic cylinders. Main characteristics. Advantages, disadvantages and conditions in the application.	• Sensor installation and test.

	• Integration of sensors depending on the technology in additional peripheral control devices.
T6. Pneumatic valves. Types of valves. Hand valves, mechanical valves, air operated valves. Direct actuated and pilot actuated valves. Solenoid valves. Symbols.	• Valve identification. • Valve installation and test. • Detection of defects and their elimination.
T7. Elements for regulating the flow, timers, logic elements. Check valves, speed controllers, quick exhaust valves, soft starters *etc.*	• Installation and test. • Tuning up the devices.
T8. Pneumatic and mechanical controlled circuits. Single acting cylinder control. Double-acting cylinder control. Cycle control of single acting cylinder. Cycle control of double-acting cylinder. Finding errors in pneumatic circuits	• Implementation, test and adjustment of basic control schemes. • Work on a scheme or compiling one.
T9. Electro-pneumatic control. Single acting cylinder control. Double-acting cylinder control. 5/3 valve – basic circuit. Cycle control of cylinder with sensor. Cycle control of two double acting cylinders with sensors. Finding errors in the electro-pneumatic circuits	• Implementation, test and adjustment of basic control schemes. • Work on a scheme or compiling one.
T10. Sequence solution methods. Repeat pattern sequence. Non-repeat pattern sequence.	• Mechanical, electro-pneumatic and PLC problem solving.
T11. PLC Pneumatic Circuit Control. Programming, implementation and verification of programs.	• Implementation and test of management schemes including program compilation

T12. Pneumatics applications in continuous production processes.	• Pneumatic devices in processes such as: dosing, spraying, molding, flow control, level control, etc.

Recommended reading resources:

1. Croser P., F. Ebel, Pneumatics, Basic Level, FeSTO Didactic Gmbh & Co., Textbook TP 101 edition (January 1, 2002)
2. Jay F., Basic Pneumatics: An Introduction to Industrial Compressed Air Systems and Components, Revised Printing, Carolina Academic Press, 2013
3. https://learnchannel-tv.com/pneumatics/basic-laws/
4. https://www.hydraulicspneumatics.com/technologies/cylinders-actuators/article/21885196/sensor-choices-for-pneumatic-cylinder-positioning

4.4. Course 4 - Hydraulics

Course duration (days): 3 - 4 days

Academic hours: 24 (12 theory + 12 practice)

Course overview: The “hydraulics” course aims the obtainment of system of knowledge by the students on the theory, calculations, design and operation of elements and systems in the field of hydraulic-based driven mechanisms in the machines from the industry. The subjects of the studies are: the structure, principles of operation and characteristics of the hydraulic machines and elements as well as the methods for synthesis of hydraulic systems for driving and control of machines and equipment. Primary attention is given to the ways of managing of force and velocity characteristics, problems related to the realization of the cycle, synchron, etc., operation, technical difficulties and troubleshooting of hydraulics systems.

Course learning outcomes: At the end of the course the students shall know the principles of operation and the types of hydraulic systems. They shall be able to define what fluid force is and shall know where it is applied. They shall know which the basic components of fluid systems are and what the ways for

correct and reliable operation of hydraulic systems are. They shall be able to synthesize hydraulic systems of their own and to correctly determine the ways of operation of hydraulic systems. The students shall be familiar with the ways of controlling and setup of hydraulic systems and establishing of reliable and effective operation.

Requred resources (e.g. equipment, materials, tools, software, etc.): Hydraulic equipment, Computer, Simulation software, MS Office

Topics	Problems to be solved
T1. Introduction to hydraulic drives. Structure of volumetric fluid systems. Operating principle. Classification and application of hydro systems. Symbol of the elements.	• Preparation of a hydraulic system according to a given scheme. • Pressurization of a flow volume by creating resistance. • Calculation the power to drive a gear pump; • Experiment - Gear pump, shut-of valve, pressure gauge.
T2. Basic parameters of hydraulic drives. Basic calculations. Working scheme. Basic calculations - velocity, pressure, forces, power, flow, conditional hole, efficiency.	• Measure the pressure p end delivery Q of a gear pump dependent upon the resistance (flow cross section of a shut- off/flow control valve). • Prepare the pump characteristic curve. • Experiment - Gear pump, shut-of valve, pressure gauge.
T3. Pressure valves Elements for pressure regulation in hydro-systems. Pressure relief valve with direct and indirect control. Pressure relief valve in systems with hydro-accumulator and non-adjustable pump. Pressure reducing valves. For all valves - device, principle of operation, characteristics,	• Preparation of a hydraulic system according to a circuit diagram; • Understanding the characteristics of a directly controlled pressure relief valve; • Calculation of spring force required at given pressure; • Experiment - Pressure relief valve

regulation, selection, place for connection to the system, symbol.	• Experiment - Pressure control valve (pressure reducer) • Build a hydraulic system according to a circuit diagram • Determine the characteristics of a 2- or 3-way pressure reducing valve
T4. Directional control valves Directional control valves - Coordinating elements in the system - constructions, purpose, control methods, main characteristics and parameters, basic schemes, choice and place of connection in the system, symbol Directional control valve.	• Preparation of a hydraulic system according to a circuit diagram; • Understanding the characteristics of a directional control valve; • Directing or preventing the flow through selected passages.
T5. Cylinders Hydraulic cylinders - action, types, characteristics, selection, connection in the system, damping. Power cylinders for limited rotational movement. Plunger and telescopic power cylinders. Features of the installation of power cylinders.	• Experiment - Single acting cylinder - Preparation of a hydraulic system according to a circuit diagram; - Actuating the 4/2 directional control valve should cause the extension and retraction of a single-acting cylinder with return spring; - Calculation the maximum cylinder force. • Experiment – Double acting cylinder - Preparation of a hydraulic system according to a circuit plan; - Actuating the 4/2 directional control valve should cause the double acting cylinder (differential cylinder) to move forward and retract; - Calculation the maximum cylinder forces and speeds.
T6. Hydraulic control devices	• Experiment - Check valve

Hydraulic devices for flow ratio - flow dividers, manifold valves. Proportional control devices - proportional distributors, valves and flow regulators. Check valves and 1-way restrictor - adjustable. For all elements in the topic - device, action, characteristics, selection, place of inclusion in the system, symbol	- Preparation of a hydraulic system according to a circuit diagram; - By actuating the 4/2 directional control valve check for the presence of flow and blocked position; • Experiment - One-way restrictor - Build a hydraulic system according to a circuit plan. -Finding the behavior of a cylinder during outward motion and retraction.
T7. Speed control elements. Flow control valve (restrictor) - types, features of construction, operation and installation. Basic calculations. Choice. Minimum stable flow. Place the restrictor in the hydro systems. Adjustment of "input", "output" and in the parallel circuit	• Experiment - Flow control valve (restrictor)- Preparation of a hydraulic system according to a circuit diagram; - Finding the dependence of the flow volume QS set on the flow control valve an the existing pressure difference. • Experiment – Differential circuits -Build a hydraulic system according to a circuit plan without/with regeneration; - Actuating the 4/2 directional control valve should cause the cylinders to move forward in both systems, and in the regenerative circuit (differential circuit) with greater (doubled) speed; • Experiment – Speed control Build a hydraulic system according to a circuit diagram, providing rapid traverse, adjustable working feed and rapid returns; - Investigation the Relationship in such a circuit

T8. Variable flow control valve Two-way flow control valves - principle of operation, characteristics, choice, place of the regulator in the hydraulic system. Three-way flow control valves. Energy effect	• Preparation of a hydraulic system according to a circuit plan; • Finding how the flow rate set on the flow regulating valve is independent from the overall pressure difference.
T9. Fluids for hydro-systems Properties of fluids density, compressibility, viscosity, etc.). Requirements and selection of fluid.	• Fluid friction -Build a hydraulic system according to a circuit plan; -The measurement should show the pressure drop caused by flow resistance in lines of different length, the flow through hydraulic equipment changing.
T10. Basic hydro-schemes for propulsion and control Basic connection schemes of single- and double-acting cylinders. Schemes for driving one and several engines. Schemes for regulating the speed of a power cylinder. Systems with sequential and synchronous operation. Synchronization systems.	• Cushioning -Build a hydraulic system according to a circuit plan without/with cushioning (counter pressure). -Investigation which circuit allows motion of a pulling load free from jerks. -What cushion pressure must be set to prevent the dropping of a load having the mass. • Pilot-controlled check valve -Build a hydraulic system according to a circuit diagram. -Installation a pilot controlled check valve the differential cylinder. -Retraction should nevertheless also be possible. • Meter-in flow control -Build a hydraulic system according to a circuit diagram.

	-Observing of the behavior of the cylinder and the pressure during the outward and retraction stroke. Meter-out flow control -Build a hydraulic system according to a circuit diagram. -Observing of the behavior of the cylinder and the pressure during the outward and retraction stroke. • Pressure controlled sequence functions -Build a hydraulic system whit two parallel cylinders. -The working position II must only move outward after the clamping piston I has moved into the extreme outward position. -Retraction may occur with any order of movements. • Pressure relief valve – with pilot -Studying of the function of a pilot controlled pressure relief valve. -By comparison with the direct controlled pressure relief valve, find the difference between the two.

Recommended reading resources:

[1]. Joseph H. Spurk, Nuri Aksel, Strömungslehre. Springer

[2]. R.S. Khurmi Textbook of Hydraulics, Fluid Mechanics and Hydraulic Machines, S Chand & Co, 1987

[3]. E. Totten, Victor J. De Negri. Handbook of hydraulic fluid technology CRC Press | 2012 | Second edition.

[4]. David H. Myszka, Machines & Mechanisms Applied Kinematic Analysis 4th Edition ISBN: 9780133464146, 0133464148. VitalSource

[5]. Dr. R. K. Bansal, A Textbook of Fluid Mechanics and Hydraulic Machines Paperback, Laxmi Publications,2005, ISBN-10-8131808157

[6]. Sukumar Pati, Textbook of Fluid Mechanics & Hydraulic Machines, 1st Edition 1259006239 · 9781259006234, 20012

[7]. V. Sokolov, O. Krol, Installations Criterion of Deceleration Device in Volumetric Hydraulic Drive, Science Direct Procedia Engineering 206 (2017) 936–943

4.5. Course 5 - Vacuum and Vacuum Technology

Course duration (days): 3 day

Academic hours: 18 (9 theory + 9 practice)

Course overview: This course introduces users to the basic principles, laws and components in vacuum technology used in automation. It covers the types, operating principles and symbols for the different technical devices used in industrial applications.

Course learning outcomes: On completion of the course, participants will be able to:

- understand the characteristics, generation and preparation of compressed air vacuum;
- provide a knowledge base of the main components of the vacuum systems and their functions and symbols;
- identify various schematic symbols used in vacuum technology, design a basic schematic drawing from a given requirement;
- identify, inspect, adjust and replace of a wide range of vacuum automation tools - valves, actuators, suction cups, sensors, relays, timers, flow controls, etc.;
- design and calculate necessary parameters of vacuum systems;
- know and implement basic schemes in manipulators in automated systems.

Required resources (e.g. equipment, materials, tools, software, etc.):

Topics	Problems to be solved
T1. Vacuum theoretical basics. Expressions and units. Measurement methods. Vacuum quality.	• Vacuum application. Introducing on theory of gases. • Sorption phenomena in vacuum. • Condensation and evaporation. • Physical processes in vacuum.

T2. Compressed air vacuum production. Vacuum turbines. Displacement pumps - piston pump, membrane pump , vane pump, roots pump. Advantages, disadvantages and conditions in the application.	• Construction, working principles and characteristics of technical means of obtaining vacuum**.**
T3. Compressed air-driven ejector pumps. Single-stage ejector. Multi-stage ejector. Ejectors with integrated control components. Energy-saving modules.	• Construction, working principles and characteristics. • Selection aid for vacuum ejectors
T4. Vacuum systems for material handling. Centralized and decentralized vacuum system. Elements for preparation – tanks, supply lines, vacuum regulators, filters, drain separators, vacuum modules for ejector and vacuum *p*ump systems.	• Working principles and construction of a separate components of vacuum systems.
T5. Suction cups (vacuum pads). Types, advantages and limitations. Thread systems. Suction cup selection. Modular suction cups.	• Determination of forces. • Selection depending on the application, environmental conditions and working material.
T6. Vacuum sensors and switches. Main parameters - transistor output, vacuum level, hysteresis etc.	• Determination of main parameters - span, range, transistor output, vacuum level, hysteresis etc.
T7. Vacuum valves – types and operation. Operational valves, closing valves and sealing valves. Vacuum valves for the specific application. Types of control.	• Determining the right vacuum valve for the specific application.
T8. Vacuum, pneumatic and electro-pneumatic controlled circuits. Technology use in pick and place applications, Vacuum molding,	• Identifying faults and their removal.

vacuum holding and chucking, packaging and dosing.	
T9. Vacuum suction control circuits. Vacuum control element calibration.	• Identifying faults and their removal. • Solutions to minimize compressed air consumption.
T10. Integrated applications with pneumatic drives.	• Integration of devices using vacuum in pneumatic circuits. • Vacuum ejector control.
T11. Electronic vacuum regulators.	• Adjustment of the operation and parameters of electronic regulators with proportional action.
T12. Use of vacuum in continuous production processes - freeze drying, filtration, distillation, test equipment, etc.	• Specific requirements and solutions.

Recommended reading resources:

[1]. Akram H., A. Fasih, Selection criterion of gauges for vacuum measurements of systems with diverseranges", Physics Procedia 32, 503-512, 2012.

[2]. Chambers A., Basic Vacuum Technology, 2nd edition, CRC Press, 1998

[3]. T. A. Delchar T., Vacuum Physics and Techniques, St Edmundsbury Press, UK, 1993

[4]. Jousten K., Handbook of Vacuum Technology, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2008

[5]. Umrath W. Fundamentalsof Vacuum Technology, Cologne, 1998

4.6. Course 6 - Optimal Use of Compressed Air

Course duration (days): **3 - 4 days**

Academic hours: **24 (12 theory + 12 practice)**

Course overview: The course introduces the basic physical aspects and technology of production and use of compressed air in manufacturing plants. The general provisions in the design and construction of a pneumatic system, its basic elements, energy values and consumption of each of them, energy/work balance and principles of efficiency are considered. Attention is paid to the most important in theoretical and practical terms problems related to the use, transport and accumulation of compressed air, energy saving and protection of the environment from harmful effects related to the production and consumption of compressed air.

Course learning outcomes: The course aims to provide specialized knowledge on the main problems of pneumatic systems in manufacturing plants and solutions for energy efficiency. The problems provided in the program are aimed at further developing the knowledge in the field of energy efficiency of pneumatic systems and provide additional information about the potential opportunities for real energy savings in practice.

After completing the course, participants will have knowledge in the areas of:

- structure of the pneumatic system - actuators, blowing elements, etc.;
- knowledge of basic concepts and characteristics determining the quality of compressed air, conductivity, flow rate, leakage;
- determining the energy efficiency of elements of the pneumatic system;
- air flow optimization, energy optimization of blowing applications, actuators, etc., energy optimization of vacuum systems.

Required resources (e.g. equipment, materials, tools, software, etc.): Pneumatic equipment, Computer, Simulation software, MS Office

Topics	Problems to be solved
T1. Energy efficiency - essence, purpose and benefits of energy efficiency	
T2. Structure of the pneumatic system	
T3. Some properties of compressed air	
T4. Basic problems with compressed air	
T5. Basic causes of energy losses in the manufacturing plant	• Calculation of air consumption in a pneumatic system • Sizing leaks and calculating losses from them • Calculation of energy loss in compressed air supply systems.
T6. Potential for savings in pneumatic systems in air production – Compressors – Dynamic control in air production. Aims and objectives of control.	• Calculation of electricity consumption of a compressor, cost of air produced • Calculation of savings when reducing the compressor outlet pressure
T7. Potential for savings in pneumatic systems in air preparation	• Investigation of the effect of a clogged filter
T8. Potential savings in pneumatic systems for the distribution and supply of air	• Calculation of pressure drop in the main line • Calculate the pressure drop in the supply line

T9. Potential savings in compressed air systems at consumers	• Study of the influence of the inlet pressure on the consumption of compressed air • Measurement of pressure drop in different wiring schemes without actuators • Study of the possibilities for energy saving in blowing applications • Calculate the consumption of a pneumatic unit with more than one actuator • Speed and backpressure control of a double-acting double-sided cylinder by means of combined energy-saving pressure and flow regulators
T10. Energy efficiency in vacuum systems	• Energy optimization of vacuum systems
T11. Monitoring and optimization	• Optimization

Recommended reading resources:

[1]. Harris P., O'Donnell G.E., Whelan T. (2012) Energy Efficiency in Pneumatic Production Systems: State of the Art and Future Directions. In: Dornfeld D., Linke B. (eds) Leveraging Technology for a Sustainable World. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-29069-5_62

[2]. Modelon. Modeling of Pneumatic Systems (Tutorial for the Pneumatics Library), 2010

[3]. Shi, Y., Cai, M., Xu, W. et al. Methods to Evaluate and Measure Power of Pneumatic System and Their Applications. Chin. J. Mech. Eng. 32, 42 (2019). https://doi.org/10.1186/s10033-019-0354-6

4.7. Course 7 - Operating CNC Machines

Course duration (days): 3 - 4

Academic hours: 24 (8 theory + 16 practice)

Course overview:

The goal of this course is to teach persons with a technical background, how to program and operate Computer Numerical Control (CNC) machines, particularly lathes and milling machines. This course bridges the gap between what classical technical education in manufacturing, and modern production techniques by using CNC machine tools. The machines, control units, coordinate systems, parts, materials, tools, and other important elements of flexible and adaptable technological system are covered and presented in this course. Manual and Conversational programming of CNC machines is included in the curriculum, and CAM software simulation and execution will be just introduced to the trainees. Each learning unit will have theoretical part and practical part. Theoretical part will introduce and explain important concepts, and in the practical part trainees will be applying gained knowledge to solve different problems.

The daily assessment will be conducted at the end of each day, in order to check gained knowledge. Final assessment will be performed at the end of the course, and also, the quality of the course will be validated through trainee evaluation of course material and trainers.

After the course competition, trainees will be able to independently create a program for the part manufacturing on lathe or milling machine.

Course learning outcomes:

- Knows the operational principles and components of the CNC machine.
- Plans and creates programming code (so-called G-code) for controlling the operation of CNC machines.
- Capable of the implementation of technological procedures for machining, by using the appropriate functionalities of the control unit.
- Defines the operational/manufacturing parameters of the machining technological process.
- Capable of using simulators for code prototyping (in a case of applicable simulator)

- Reengineering of the existing G-code.
- Good knowledge of machine specific coordinate system and important points.
- Capable for tool calibration and measurement
- Introductory knowledge about existing CAM software packages.

Required resources (e.g. equipment, materials, tools, software, etc.): PC – personal computer, CAM simulation software (for demonstration), CNC code simulator, MS Office (Word, Excel, Power Point)

Topics	Problems to be solved
T1 - CNC machines, introduction, and principles of work 1. Introduction to CNC machines 2. Differences between classical machines and CNC 3. Classification of CNC systems 4. Components of CNC machines 5. Overview of Numerical Control Units 6. Data structures and data input	• Identification of Numerical Control Units and their specifications and applications • Identification of machine specific characteristics and work specification • Identification of machine components and their functions. • Adaptable and flexible control of technological processes • Safety training
T2 - Concepts of CNC machine control 1. Introduction to CNC control 2. CNC control unit structure and components 3. CNC control unit technical characteristics 4. CNC control unit functional characteristics 5. Program input 6. Program Error Detection 7. Program optimization 8. DNC systems 9. Adaptable control 10. Flexible technological systems	
T3 - CNC system programming methods 1. Manual programming 2. Conversational Programming 3. CAM System Programming	
T4 – Work Safety 1. Personal behavior 2. Workplace clothing 3. Overall safety regulations 4. CNC Safety practices	

T5 -Technological preparation for CNC machining 1. Technological preparation for manufacturing 2. Coordinate systems and zero points 3. Characteristic points of the machining system 4. Part dimensioning 5. Development of the technological process 6. Forming the manufacturing plan 7. Forming the Clamping plan 8. Definition of the tool set 9. Definition of the cutting parameters 10. Design of the tool path and simulation 11. Demonstration of the creation of technological process for the lathe, and milling machine – working examples.	• Understanding technological processes and their parameters. • Resolving simple manufacturing examples by using a CNC lathe. • Resolving simple manufacturing examples by using a CNC milling machine.
T6 G-code structure and syntax 1. Program structure and syntax 2. Basic G and M functions 3. Other applicable functions 4. Demonstration of the code for lathe, and milling machine – working examples.	
T7 – Tools calibration and path optimization 1. Tool corrections and adjustments 2. Definition of the tools path	• Successful implementation of learning outcomes and creation of working CNC programs.
T8 Introduction to CAM software 1. Demonstration of the various CAM software 2. CAM software simulation for the generation of G-Code.	
T9 - Program management and execution (Example for lathe training)	
T10 - Program management and execution (Example for milling training)	
T11 - Independent work with supervision and help	

Recommended reading resources:

[1] Alan Overby, CNC Machining Handbook: Building, Programming, and Implementation Paperback, 2010, Link

[2] Lorenzo Rausa, CNC 50 Hour Programming Course: (Second Edition / January 2018), Link

4.8. Course 8 - Operating Automated Production System

Course duration (days): 3-4

Academic hours: 24 (10 theory + 14 practice)

Course overview: The aim of the course is to familiarize participants with basic concepts and issues in the field of automation of manufacturing processes and production systems; functioning and operation of automated production systems; application of flexible automation means and integration of technological processes as well as CAx computer systems supporting technological preparation of production; indication of current trends and development directions regarding automation of production systems.

Course learning outcomes:

- familiarisation with basic issues and concepts in the field of automation of manufacturing processes and production systems,
- providing structured and in-depth knowledge of the functioning and operation of automated production systems using the means of flexible automation and integration of technological processes,
- presentation of examples of means and computer tools supporting the technological preparation of production,
- discussion of development trends in the automation of production systems.

Required resources (e.g. equipment, materials, tools, software, etc.):

CAD software – Inventor; CAM software – Edgecam; CAPP software – Preactor APS

Topics	Problems to be solved
T1. Basic concepts and issues in the field of automation of manufacturing processes and production systems	• selection of type and form of organisation of automated production systems

T2. Operation and maintenance of automated production systems	• identify the advantages and limitations of automating production systems, • comparative analysis and evaluation of alternative solutions for the structures of automated production systems
T3. Flexible automation means and integration of technological processes; automation of machining processes	• identification and selection of appropriate means for carrying out the tasks of process components and planning their performance under conditions of automated production systems, • simulation and analysis of operation of integrated production systems in the context of production flow optimisation within the existing limitations and technological capabilities of the equipment
T4. Computer-aided technological preparation of production	• selection of appropriate CAx systems supporting technological preparation of production, • simulation and visualisation of machining of selected components in automated production systems
T5. Trends and developments in the automation of production systems	• overview of selected solutions for automation of production systems, • definition of directions and perspectives for further development of production systems in the context of implementation of the *Industry 4.0* concept

Recommended reading resources:

[1] Karkalos, N. E., Markopoulos, A. P., & Davim, J. P. (2019). *Computational Methods for Application in Industry 4.0*. Springer International Publishing.

[2] Rawat, D. B., Brecher, C., Song, H., & Jeschke, S. (2017). *Industrial Internet of Things: Cybermanufacturing Systems*. Springer.

[3] Gunal, Murat M. (Ed.) (2019). Simulation for Industry 4.0 Past, Present, and Future Series: Springer Series in Advanced Manufacturing.

[4] Selected articles from the journals:

- *Journal of Manufacturing Systems, e.g.*

Deja, M., & Siemiatkowski, M. S. (2018). Machining process sequencing and machine assignment in generative feature-based CAPP for mill-turn parts. *Journal of Manufacturing Systems*, *48*, 49-62.

- *Journal of Intelligent Manufacturing, e.g.*

Deja, M., & Siemiatkowski, M. S. (2013). Feature-based generation of machining process plans for optimised parts manufacture. *Journal of Intelligent Manufacturing*, *24*(4), 831-846.

PART 2 ENGINEERS

1. INTRODUCTION

The present Curriculum is written within the **allCUTE** project under ERASMUS+ Programme. It is designed to improve the technical and generic skills of engineers employed in the sector of *Machine Building and Mechatronics* as a result of high demand of upskilling on behalf of employers so as to meet the challenges of Industry 4.0.

The Curriculum is based on the findings of a survey carried out among 161 companies in the above sector covering the following European regions:

- Gabrovo, Bulgaria
- Plovdiv, Bulgaria
- East Macedonia and Thrace, Greece
- Pomorskie, Poland
- Nis, Serbia

After analyzing the survey results, the following 6 courses for engineers have been identified as a priority of employers in the respective industrial sector, and underpin this Curriculum:

- Basic schemes in automated pneumatic systems
- Energy efficiency in pneumatic systems
- Hydraulics, proportional hydraulics
- Electrical engines and complex electrical drives
- Automated manufacturing systems
- Quality assuarance, quality control and testing.

2. TEACHING METHODOLY

The Curriculum is based on blended learning, where ICT is more strategically used. The e-learning part is based on open educational resources - self-study of both theory so that the learners could be prepared in advance for their traditional classroom classes and practice so that the learners could be better prepared for their jobs through learning by doing in real-life industrial settings.

The traditional classroom part is based on active learning techniques (learner-centred) such as flipped classroom, jigsaw, problem- and project-based learning, think-pair-share, etc., where the learners are able to shape their own learning path by the guidance of a VET teacher. Studying the materials in advance, the learners discuss them in the classroom and solve problems on the basis of what they have already learnt thus improving their critical, analytical and creative thinking, motivation, communication, problem-solving, digital skills, etc. Moreover, they receive peer support and teach each other. The VET teacher is a moderator rather than an instructor and the learners are actively involved in the learning process rather than being passive viewers.

The proposed teaching methodology reflects world-wide state-of-the-art teaching techniques as it can be seen in Figure 1 below.

Figure 1: Learning pyramid

3. ASSESSMENT METHODOLOGY

Taking into consideration the course duration and the type and range of knowledge and skills to be acquired, the assessment methodology is based on 3 assessment techniques:

- Reflection by introducing One Minute Paper

At the end of the day's lesson learners answer teacher-posed questions (one minute paper) which prompt them to reflect on the day's lesson.

By implementing this assessment technique, the teacher gets useful feedback on how each learner progresses and what difficulties he / she faces, on the one hand, and learners develop their transversal skills to reflect on, analyze, and self-evaluate their performance, on the other hand.

- Observation by introducing Performance Checklist

At the end of day's lesson the teacher completes the Performance Checklist that states specific criteria and allows teachers to gather information and to make judgements about what learners know and can do in relation to the learning outcomes set. Furthermore,iIt offers systematic ways of collecting data about specific behaviours, knowledge and skills.

- Small-scale project

After completing the course, learners should develop in pairs a small-scale project in a form of a PoewrPoint presentation. By working on a small project, learners have the opportunity to show to what extend they have improved their technical expertise, to develop transversal skills, such as team work, communication, problem solving, critical thinking, etc. Last but not least they can also enhance their digital competence.

Where a small-scale project is not suitable, tests could be used to assess learners' knowledge and skills.

4. COURSE DESCRIPTION

4.1. Course 1 - Basic Schemes in Automated Pneumatic Systems

Course duration (days): 4 - 5

Academic hours: 30 (15 theory + 15 practice)

Course overview: This course provides maintenance personnel with the skills and knowledge necessary to carry out maintenance tasks on pneumatic and electro-pneumatic systems. The course upgrades knowledge of pneumatic and electro-pneumatic systems acquired from a basic level. A practical approach is applied in the course. The training is based on industry standard components widely used in industrial systems.

Course learning outcomes:

- Evaluate, use and adjust various sensors;
- Calculation of basic parameters in the stages of compressed air production and in local stations or manipulators;
- Develop basic sequence control systems;
- Evaluate, use and adjust peripherals such as timers, counters, programmable relays, etc;
- Implement a controller with command action in combination with sequence control;
- Use pneumatic circuit drawings as an aid to systematic fault-finding;
- Carry out repairs to pneumatic systems;
- Understand how PLCs are interfaced and used to control pneumatic systems;
- Use and adjustment of pneumatic actuators and regulators with proportional control.

Required resources (e.g. equipment, materials, tools, software, etc.): Pneumatic circuit drawing software. PLC Programming Software.

Topics	Problems to be solved
T1. Basic steps to air preparation equipment calculation and selection.	• Calculating compressed air consumption for a particular installation. • Choosing an air compressor based on capacity and pressure values. • Choosing compressed air dryer. • Oil lubrication system and lubricating oil.
T2. Basic steps to build compressed air piping systems.	• Determine the distribution system. • Determine the storage system. • Pipe material types and selection. • Air flow measurement and pressure drops.
T3. Design complete pneumatic control systems.	• Pneumatic circuits drawing. • Timing diagrams. • Simulation tools.
T4. Design of pneumatic and electro-pneumatic control circuits for feeder modules.	• A mechanical system for transportation, positioning and manipulation is considered. A set of tasks in different applications is solved.
T5. Design of pneumatic and electro-pneumatic control circuits with timers.	• Develop basic sequence control circuits with timers (pneumatic and electronic). • Set and coordinate delays.
T6. Design of pneumatic and electro-pneumatic control circuits with counters.	• Develop basic sequence control circuits with counters (pneumatic and electronic). • Efficient use of the functions of programmable electronic counters depending on circuit design.
T7. Design of pneumatic and electro-pneumatic control circuits with pressure programmable relay. Multifunctional pressure transmitters.	• Adjust programmable pneumatic relay – switch level threshold, hysteresis, inverting function, etc. • Specifics of use in: back pressure control, object detection, soft start, etc.

	• Operation and setup of pressure transmitters with analog output.
T8. Design of pneumatic and electro-pneumatic control circuits with logic elements.	• Implementation with equivalent schemes. • Implement logic operations for feedback signals. • Trigger synthesis.
T9. Design of pneumatic and electro-pneumatic control circuits with vacuum equipment.	• Integration of devices using vacuum in pneumatic circuits. • Vacuum ejector control.
T10. Pneumatic circuit design using PLC.	• Explain various programming approaches used in PLC. • Describe the functions of memory functions, timers and counters. • Design PLC circuits for single and multi-actuators. • Design PLC circuits for non-repeat pattern sequence.
T11. Pneumatic valve actuators and *positioners*. Principle of operation, parameters and applications.	• Adjustment of pneumatic actuators - diaphragm, butterfly valve and vane. • Positioner setting - stroke characteristics, sensitivity, etc.
T12. Electronic pressure regulators. Principle of operation, parameters and applications.	• Adjustment of the operation and parameters of electronic regulators with proportional action.

Recommended reading resources:

1. Parambath J.,Pneumatic Systems and Circuits - Advanced Level (Pneumatic Book Series), 2020
2. Parr A., Hydraulics and Pneumatics , 3rd Edition, Butterworth-Heinemann, 2011
3. Sivaraman I., Pneumatics and Pneumatic Circuits, Dr.Ilango Sivaraman, 2015
4. Turner I, Engineering Applications of Pneumatics and Hydraulics, Routledge, 2020

4.2. Course 2 - Energy Efficiency in Pneumatic Systems

Course duration (days): 4-5

Academic hours: 25 (10 theory + 15 practice)

Course Overview:

This course covers issues on how to improve energy efficiency in pneumatic systems, as reducing energy consumption is a priority in almost every manufacturing plant and industrial facility.

Ways for improving energy efficiency of pneumatic systems from using methods that range from better engineering decisions in the design stage, to adjustments and maintenance on existing systems, like correct size components in pneumatic actuators, sensors and control components, the effect of leakage, artificial demand, optimizing pressure, will be developed through this course.

In order to check gained knowledge a daily assessment will be conducted by the end of each day. Final assessment will be performed at the end of the course.

Course learning Outcomes:

After the completion of this course, the participant is able to:

- Measure the air consumption of various pneumatic applications and operation of electro pneumatic power circuit.
- Understand and evaluate the relation between the consumption and the cost of energy sources of pneumatic system in process, compressed air system performance improvement.
- Apply efficiency measures in the preparation and distribution of compressed air
- Apply efficiency measures in the consumption of compressed air
- Correct the failures that caused efficiency wastes energy.
- Apply efficiency measures in pneumatic circuits, machines and components.
- Select efficient components for various applications.

Topics	Problems to be solved
T1 1.1 Reduce pressure drop in the distribution system 1.2 Avoid inappropriate use of compressed air.	• Reducing the over-pressurisation in air system of pneumatic system
T2. Turn off the power during downtime of pneumatic systems.	• Energy saving in pneumatic system
T3. Involve the OEM in designing more energy efficient machines and compressor air systems.	• Pressure loss in compressor air systems in pneumatic system
T4. Add sensors to high pressure and consumption machines and processes.	• The reduction of the efficiency of the pressure machine due to the incorrect selection and addition of sensors in high pressure and consumption processes.
T5 5.1 Reduce leakage 5.2 Reduce air system leaks.	• Reduce leakage and reduce air system leaks in a pneumatic system
T6. Optimize compressed air systems.	• Resolution of problems: overheating in the pneumatic system.
T7. Incorporate air saving circuits where appropriate.	• How to rectify common problems in air saving circuits for pneumatic system
T8. Energy savings starts at the top of organizations and relies on all-inclusive teams.	• The energy waste and low energy efficiency of the pneumatic system where it starts from the top of the organisms and is based on all-inclusive groups.

Required resources (e.g. equipment, materials, tools and software):

PC – personal computer, PneuCalc simulation software (for demonstration) or Automation Studio 5.5 software for hydraulic and pneumatic system design, training, maintenance, and troubleshooting, MS Office (Word, Excel, Power Point)

Recommended reading resources:

1. https://www.semanticscholar.org/paper/Analysis-of-the-Energy-Efficiency-of-a-Pneumatic-Yang-Tadano/900fdb305237bd818a244b9060a136d381be3434
2. https://www.semanticscholar.org/paper/Air-recovery-assessment-on-high-pressure-pneumatic-Trujillo-Gamez-Montero/9983842d395f396ce577cc8c2779e78753887421
3. https://www.semanticscholar.org/paper/Cost-effectiveness-of-restoring-energy-in-execution-Blagojevic-Seslija/ba33382d0d71757134dac756dd4773414c626f8f
4. https://www.semanticscholar.org/paper/A-New-Efficiency-Index-for-Analysing-and-Minimizing-Parkkinen-Zenger/42c4b2064b84ff66e95a257943c76d44366a761d
5. https://www.semanticscholar.org/paper/Energy-saving-measures-on-pneumatic-drive-systems-Hepke-Weber/1b672cf1b4ce068f5541c389f3482fb37b6dfcc4
6. https://www.sciencedirect.com/science/article/pii/S240584402030671X
7. https://www.semanticscholar.org/paper/Energy-efficiency-of-high-pressure-pneumatic-Trujillo/b0218db6e2ee138ae75e49a329bd577e63159c16
8. http://www.doiserbia.nb.rs/img/doi/0354-9836/2016/0354-98361600022S.pdf
9. https://swsu.ru/sbornik-statey/pdf/InTech-Increasing_the_energy_efficiency_in_compressed_air_systems.pdf

4.3. Course 3 - Hydraulics, Proportional Hydraulics

Course duration (days): 3 - 4

Academic hours: 24 (10 theory + 14 practice)

Course overview:

The scope of the course covers issues from basic and elementary power hydraulics to advanced control of the actuators with the use of proportional and servo technique.

Pumps, hydraulic motors, actuators and control elements are characterized together with principles of their selection for the hydraulic system.

The course also covers the analysis and operation principle of both simple and more complex (proportional and servo) hydraulic systems.

Course learning outcomes:

After completing the training, the employee is able:

- to analyze, diagnose and explain the principle of operation of a hydraulic system;
- to choose components for the hydraulic system;
- to design basic hydraulic systems.

Required resources (e.g. equipment, materials, tools, software, etc.):

It is recommended to conduct didactic classes in a hydraulics laboratory.

Topics	Problems to be solved
T1. Elements of hydraulics circuits (pumps, motors and valves).	• operating parameters of pumps and motors, • rules for the selection of pumps, motors and valves for the hydraulic system
T2. Basic circuits with hydraulic cylinder and motor.	• differential connection of cylinder and system operation analysis

	• analysis of the operation of systems with basic valves
T3. Control of speed of a motor with the use of throttle valve	• analysis of the throttle circuit with throttle valve and flow regulator • analysis of the motor speed characteristics
T4. Volumetric control of motor speed	
T5. Circuits with flow regulators.	
T6. Pump regulators.	• construction and principle of operation of pumps regulators • selection of regulators for pumps • analysis of hydraulic circuit with pump with regulators
T7. Proportional valves.	• construction and principle of operation of proportional valves • characteristics of proportional valves • examples of hydraulic circuits with proportional valves • principles of selection of proportional valves for circuits with motor and actuator
T8. Electronic control of proportional valves.	• signals controlling proportional valves • electronic control cards and their selection for valve
T9. Introduction to systems with servo valves.	• the essence of the servo valve and its function in the system, • construction and principle of operation of servo valve

Recommended reading resources:

[1] Yeaple F.: Fluid power design handbook. Macel Dekker INC. 1984.

[2] Hydraulic Trainer Volume 1. Basic principles and components.

[3] Hydraulic Trainer Volume 2. Proportional and Servo Valve Technology.

[4] Cundiff J.: Fluid Power Circuits and Controls. CRC Press 2002.

[5] Akers A., Gassman M., Smith R.: Hydraulic Power System Analysis. CRC Press 2006.

[6] Parr A.: Hydraulics and Pneumatics. Elsevier 1999.

[7] Dindorf R.: Napędy Płynowe. Podstawy teoretyczne i metody obliczania napędów hydrostatycznych i pneumatycznych. Kielce University of Technology Publishing House. Kielce 2009.

[8] Doddannavar R., Barnard A.: Hydraulic Systems. Operation and troubleshooting for Engineers & Technicians. Elsevier 2005.

4.4. Course 4 - Electrical Engines, Complex Electrical Drives

Course duration (days): **3 - 4**

Academic hours: **24 (10 theory + 14 practice)**

Course overview: In the last 30 years, the introduction of power electronic drives with motors has led to new design opportunities. The increased integration of these drives and machines has triggered a quantum leap in productivity, efficiency and system performance.
This practical, hands-on course will give you a solid introduction to this rapidly expanding field under the guidance of industry experts

Course learning outcomes:

- general principles of construction and physical basics of electric machines and drives;
- general information of construction, performance and modelling of generator or motor sets with variable speed;
- general knowledge about simulation, modelling and development of electric drives.

Topics	Problems to be solved
T1. Definition, functions and features of an electromechanical systems and drives.	• General structure and elements' functions of electromechanical systems and drives; • Electromechanical systems' modeling, simulation, and design using CAD techniques; • Electric motor simulations, e.g. a DC brushless motor, PMSM and induction motor;
T2. Electromechanical system components and their functions.	
T3. Electrical machines and material technology. Classification of electrical machines.	
T4. Properties and characteristics of motors and generators.	
T5. Structures of electromechanical systems used in industry.	

T6. Electromechanical system development, evolutions and trends.	• Manufacturing automation in CAM systems. CNC characteristic of systems of numerically controlled machines tools. Structure, principle of operation, control method, programming.
T7. Power units used in electric and hybrid vehicles.	
T8. Electromechanical systems with piezoelectric machines.	
T9. Electromechanical energy storage devices.	
T10. Electromechanical drives developed with nanotechnology.	
T11. Basic definition and terms: physical model, mathematical model, simulation, design. Modelling and simulation process.	

Recommended reading resources:

[1] Gieras J.: Advancements in electric machines. Springer Netherlands, 2008

[2] Bishop Robert H. (Editor): The Mechatronics Handbook. CRC Press, 2002.

[3] Krause P.C. : Analysis of Electric Machinery and Drive Systems, Wiley-IEEE Press, 2013

[4] Gerling D.: Electrical Machines. Mathematical Fundamentals of Machine Topologies, 2015

[5] Karnopp D. C., Margolis D. L., Rosenberg R. C.: System dynamics, modeling and simulation of mechatronic systems. John Wiley Inc, 2000.

[6] Lyshevski S. E., Nano- and micro-electromechanical systems: Fundamental of micro- and nano-engineering. CRC Press, 2000.

4.5. Course 5 - Automated Manufacturing Systems

Course duration (days): 3 - 4

Academic hours: 24 (8 theory + 16 practice)

Course overview:

The goal of this course is to teach persons with engineer and technical backgrounds, how to design and analyze automated manufacturing systems. This course bridges the gap between classical technical education in manufacturing, and modern techniques for automation especially by using programmable logic controllers PLC-s. The sensors, actuators, automatic data identification, Boolean logics, common and advanced control systems, and programmable logic controllers are covered and presented in this course. Ladder logic, instruction list, and functional block programming are included in the curriculum. Each learning unit will have a theoretical part and a practical part. The theoretical part will introduce and explain important concepts, and in the practical part, trainees will be applying gained knowledge to solve different problems.

The daily assessment will be conducted at the end of each day to check gained knowledge. A final assessment will be performed at the end of the course, and the quality of the course will be validated through trainee evaluation of course material and trainers.

Course learning outcomes:

- Knowledge of the sensors and actuators operational principles.
- Knowledge of important numerical, alfa-numerical codes and automatic data identification techniques.
- Capability of the designing and implementation of logical functions, logical circuits, and minimization techniques.
- Knowledge of analysis and designing of control systems and advanced control systems.
- Knowledge of architecture and structure of programmable logic controllers PLC-s.
- Good knowledge of PLC communication and networking.
- Capability of the PLC programming by ladder logic, instruction list programming and functional block programming.
- Introductory knowledge about existing PLC software packages.

Required resources (e.g. equipment, materials, tools, software, etc.): PC – personal computer, PLC simulation software (for demonstration), MS Office (Word, Excel, PowerPoint)

Topics	Problems to be solved
T1. Sensors • Sensors classification and methods of measuring non-electrical quantities. • Fiber optic sensors.	• Sensors application in the operation monitoring process of the automated manufacturing systems. • Analog and digital signal processing and transmission of measuring signals.
T2. Actuators • Piezoelectric actuators. • Micromechanical actuators (micromechanical switches, light modulators and optical display elements, micromechanical valves and pumps, micropositioning elements, micromotors).	• Compatibility of actuators with other components of the automated manufacturing system. • Proper selection of actuators in order to achieve efficient and optimal operation of the automated manufacturing systems.
T3. Numbers and Data • Introduction to Number bases, Codes and Coding. • Codes and Coding: BCD, Aiken Code, Gray Code, ASCII Code. • Automatic Data identification: Bar Code, RFID.	• Understanding number bases and number conversions. • Identification and understanding of different codes.
T4. Boolean Logic Design • Introductio to Boolean algebra. • Basic Logical Functions • Logic Circuits. • Minimization of Boolean functions. • Quine-McCluskey algorithm. • Karnaugh maps.	• Understanding Boolean algebra. • Resolve and design simple logic circuits. • Understanding Minimization of Boolean functions.
T5. Control System Analysis and Design • Transfer Function, State Space and Block Diagram System Representation. • Controllability and Observability. • System Response in Time and Frequency Domain. • Control System Stability Analysis Methods. • Control System Design.	• Modeling and Analysis of Linear Continual Systems. • Stability Analysis. • Control System Design.
T6. Advanced Control Systems • Nonlinear Control Systems. • Digital Control Systems. • Optimal Control Systems.	• Control System Analysis and Design using Advanced Techniques. • Intelligent Control System Design and Implementation.

• Model Predictive Control. • Fuzzy Modeling and Control. • Sliding Mode Control. • Machine Learning Techniques.	
T7. Programmable Logic Controllers - PLC-s • Programmable Logic Controllers – Introduction; PLC Operation. • PLC Hardware Structure. • PLC Communication and Networking. • PLC Installation and Wiring. • PLC Programming.	• Selecting Hardware Configuration of Control System with PLC. • Installation, Wiring and Communication/Networking of PLC PLC Programming.

Recommended reading resources:

[1] Ogata, K., Modern control engineering. Upper Saddle River, N.J: Prentice Hall, 1997.

[2] Siddique Nazmul, Hojjat Adeli, Computational intelligence: synergies of fuzzy logic, neural networks and evolutionary computing. John Wiley & Sons, 2013.

[3] William Bolton, Programmable Logic Controllers, Sixth Edition (6th. ed.). Newnes, USA, 2015.

4.6. Course 6 - Quality Assurance, Quality Control and Testing

Course duration (days): 3 - 4

Academic hours: 24 (8 theory + 16 practice)

Course overview:

This is a three-day program in which participants learn the basics of engineering experience, quality assurance, quality control, and testing. Also, special attention will be paid to the theory of design and analyze industrial experiments and the failure mode effects analysis. The goal of this course is to introduce insignificance and place of the: concept, process, methods, and examples of product quality (QA/QC), statistical process control (SPC), design of experiments (DOE), and the Failure Mode Effects Analysis (FMEA).

To this aim theoretical foundations of quality control are covered along with a definition of DOE terms such as independent (input) and dependent variables (output), factors, noise, levels, the design matrix, error, etc. The theoretical part, also, provides an overview and analysis of the basic parameters and conditions for the implementation of material processing through the FMEA method, provides the ability to determine weighting factors for error severity, frequency, and the ability to detect errors.

The daily assessment will be conducted at the end of each day, to check gained knowledge. Trainees will get a chance to analyze different case studies and analyze them on paper and the computer. The final assessment will be performed at the end of the course, and also, the quality of the course will be validated through trainee evaluation of course material and trainers.

Course learning outcomes:

- Introduction to standardization, a quality system in material processing and mastering practical problems of quality.
- Acquiring basic skills and knowledge necessary to manage the quality, which should result in improving the quality of products/services, reducing costs, and increasing profits?
- Increased understanding of the importance of quality management in organizations.
- Master the key concepts of DOE, the strategy of experimentation, and basic principles.
- Identify when and why to apply DOE (experiment goal, appropriate factors, and responses).
- Develop a mathematical model for representing the process/system under investigation.

- Interpret the outcome of designed experiments.
- Transfer high knowledge and technical experience by method FMEA.
- Identification and quantification of some key errors in the metal forming process.

Required resources (e.g. equipment, materials, tools, software, etc.): PC – personal computer, MS Office (Word, Excel, PowerPoint)

Topics	Problems to be solved
D1.T1 - Introduction to Quality Control and the Quality Assurance 1. The concept of product quality 2. History of quality assurance and standardization	• Introduction to the elements, place, and importance of quality • Measurement quality assessment • Determining the value of measurement error and measurement uncertainty • Application of statistical methods in production process control
D1.T2 – The Concept of Quality Control in Manufacturing 1. What is quality control? 2. Benefits of using quality control in manufacturing 3. Measurement quality and measurement uncertainty	
D1.T3 - Statistical process control (SPC) 1. Basic statistical methods in engineering/industrial practice 2. Statistical foundations and methods of quality improvement 3. Statistical analysis of samples	
D2.T4 - Introduction to industrial experimentation 1. DOE goals 2. General model of process/system 3. Typical applications of experimental design 4. Strategies for conducting industrial experiments	• Identification of controllable, uncontrollable, and noise factors for a given industrial process/system • Identification of process/product performance characteristics for a given industrial process/system • Design experiment (define goal, factors, levels, output) for a given process/system • Development of design matrices for factorial designs. • Resolve and analysis of factorial experimental designs – case studies.
D2.T5 Guidelines for designing industrial experiments 1. Basic principles of DOE 2. Basic steps in planning, performing, and analyzing industrial experiments	

3. Overview of factors and process performances 4. DOE terminology	
D2.T6 – Factorial designs 1. Design of experimental matrix 2. Estimation and analysis of main and interaction effects 3. Development of a mathematical model and its statistical assessment	
D2.T7 Analysis of case studies – modeling and analysis of a given industrial process/system – working examples	
D2.T8 - Independent work with supervision and help	
D3.T9 Introduction in FMEA method, definition weight factors and recognition level of risk	• Identification of key parameters • Severity level of identification errors in FMEA analysis. • Occurrence level of identification errors in FMEA analysis
D3.T10 - Sheet metal forming 1. FMEA analysis punching and blanking process and generated RPN level of identification errors 2. FMEA analysis bending process and generated RPN level of identification errors	
D3. Independent work with supervision and help	
D4.T11 - Bulk metal forming 1. FMEA analysis hot forging process and generated RPN level of identification errors 2. FMEA analysis extrusion process of hollow elements on high temperature and generated RPN level of identification errors	• Possibility of detection for identification errors in FMEA analysis • Case studies • Course evaluation

Recommended reading resources:

[1] Quality Assurance and Quality Control Guidelines FTA-IT-90-5001-02.1 - Federal Transit Administration | PDF Free Download

[2] Amitava Mitra, (2008). Fundamentals of Quality Control and Improvement, John Wiley & Sons

[3] Neyestani, B. (2017). Seven Basic Tools of Quality Control: The Appropriate Techniques for Solving Quality Problems in the Organizations

[4] Muhammad Hashim, (2013). Quality control, Quality assurance, systems and application.

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ANNEXES

ASSESSMENT FORM 1

One Minute Paper (self-assessment on a daily basis)

Date:_____ **Course:**_____
Name:_____

The topic today was

_____

_____

Regarding this topic I already know

_____

_____

I like most	**I do not like**
I learned today	**I did not understand**

I still need to improve

_____

_____

I would like to ask for additional information about

_____

_____

I evaluate my performance today as

☐ **very good** ☐ **good** ☐ **satisfying** ☐ **dissatisfying**

ASSESSMENT FORM 2

Performance Checklist					
Name:	**Course**:				
Evaluation criteria	**Rating scale**				
5 – highest / **1** - lowest	5	4	3	2	1
Knowledge reproduction and organization					
able to apply the learning material in a familiar learning situation					
able to apply old knowledge in a familiar learning situation					
Knowledge transfer, creativity, problem solving					
applies the knowledge acquired in new learning situations					
comes up with ideas, identify new problems and find alternative solutions					
Self-study					
completes assignments without any help or support					
sets aims for himself / herself					
Motivation for learning					
strives to finish assignments					
does not get discouraged when failing to solve the problem immediately					
Communication, interaction and cooperation competence					
willingly works in a team					
accepts help from other team members					
ready to help other team members					
Digital competence					
able to work with MicroSoft Office or other applications if required					
able to easily search for and find information on the Internet					

Date: **Teacher:**

ASSESSMENT FORM 3

Project and Presentation Evaluation		
Name:		
Topic:		
Course:		
Team members:		
	Highest points	**Reached points**
Presentation 60%		
1. Structure (e.g. introduction, conclusions, transitions)	**2**	
2. Language comprehension and accuracy	**1**	
3. Balance between text and visual elements	**1**	
4. In-depth and scientifically accurate content	**4**	
5. Presenting the information	**4**	
Project 40%		
6. Layout (structure, ideas, graphics)	**3**	
7. Resources	**1**	
8. In-depth and scientifically accurate content	**4**	
Total points	**20**	
Comment:		

Mark:

Date: **Signature:**
(teacher)