Cracow University of Technology

Course syllabus

binding for the doctoral students of the CUT Doctoral School commencing their studies in the academic year 2022/2023

Information on the course

Name of the course in Polish	Metrologia
Name of the course in English	Metrology
Number of the ECTS points	1
Language of instruction	Polish
Category of the course	Choosable
Field of education	Engineering and technology
Discipline of education	Mechanical engineering
Person responsible for the course Contact	Prof. Jerzy A. Sładek, *doctor habilitatus* jerzy.sladek@pk.edu.pl

Type of course, number of hours in the study programme curriculum

Semester	Credit type (G / NG)*	Lecture	Practical classes	Laboratory	Computer Lab	Project Class	Seminar
2, 3, 4, 5	G	15	0	0	0	0	0

*G – graded credit, NG – non-graded credit

Course objectives

Code	Objective description
Objective 1	Introduction of the doctoral students to modern coordinate measurement systems and their areas of application in mechanical engineering as well as the assessment of the accuracy of measurement systems, relation to the measurement unit and structure, and the use of standards.
Objective 2	Introduction of the doctoral students to systems used for measuring internal structures of machine parts and large-scale metrology systems.
Objective 3	Introduction of the doctoral students to the trends in the development of coordinate metrology in the field of hardware solutions and methods of measuring accuracy assessment - the theory of measurement uncertainty.

Learning outcomes

Code	Description of the learning outcome adjusted to the specific characteristics of the discipline	Learning outcome symbol in the CUD DS	Methods of verification
OUTCOMES RELATED TO KNOWLEDGE			

EUW1	The doctoral student describes modern coordinate measurement systems, explains the principle of operation of five-axis coordinate systems and nano and micro coordinate machines, describes in-process metrology systems, defines the concepts of in-situ, in-line, in-process control, lists contact and optical sensors used in active control systems. The doctoral student knows the methods and standards for assessing the accuracy of coordinate systems.	E_W01, E_W02	Involvement in class activities, graded oral responses.
EUW2	The doctoral student explains the principle of operation and construction of industrial tomographs, describes the methods of checking the accuracy of computer tomographs and measurements carried out with their use, lists the systems used to measure large-size elements, explains the method of using functions and systems used to enlarge the measuring space of measuring devices.	E_W01, E_W02	Involvement in class activities, graded oral responses.
EUW3	The doctoral student explains modern methods of measuring the accuracy of measurements, lists numerical and simulation methods (Virtual CMM) and artificial intelligence tools that are used to assess and forecast measurement uncertainty (artificial neural networks, Monte Carlo method, etc.), describes the method of determining measurement uncertainty online, defines the terms Digital Twin and Metrological Digital Twin.	E_W01, E_W02	Involvement in class activities, graded oral responses.
OUTCOMES RELATED TO SKILLS			
EUU1	The doctoral student selects appropriate modern measurement systems for the selected task in the field of metrology, selects the right type of sensors for the performed intra-process control tasks, and analyzes the measurement uncertainty using numerical and simulation methods and artificial intelligence tools.	E_U01	Involvement in class activities, graded oral responses.
OUTCOMES RELATED TO SOCIAL COMPETENCES			
EUK1	The doctoral student is ready to recognize the importance of knowledge about modern systems and methods in the field of metrology, including coordinate metrology.	E_K03	Involvement in class activities, graded oral responses.

Course outline

No.	Contents	Learning outcomes for the course	No. of hours
LECTURE			
W1	Modern coordinate measurement systems. Five-axis coordinate systems, measuring heads used in five-axis coordinate systems. Nano and micro CMMs.	EUW1, EUU1	3

W2	In-process metrology systems. In-situ, in-line and in-process control. Contact and optical sensors used in active control systems. The role of coordinate metrology in digital production and the Industry 4.0 concept.	EUW1, EUU1, EUK1	3
W3	Computed tomography in industrial applications. Principle of operation and construction of industrial tomographs. Methods for checking the accuracy of computer tomographs and the measurements carried out with their use.	EUW2, EUK1	2
W4	Measurements of large-size elements. LaserTracker systems, LaserRadar, internal GPS, photogrammetry, multisensory systems. Functions and systems used to enlarge the measuring space of measuring devices.	EUW2, EUU1, EUK1	3
W5	Modern methods of assessing the accuracy of measurements. Numerical and simulation methods as well as artificial intelligence applied for the assessment and forecasting of measurement uncertainty. Online measurement uncertainty determination, virtual models of measurement systems. Digital Twin and Metrological Digital Twin.	EUW3, EUU1	4

The ECTS points statement

WORKING HOURS SETTLEMENT	
Type of activity	Average number of hours (45 min.) dedicated to the completion of an activity type
SCHEDULED CONTACT HOURS WITH AN ACADEMIC TEACHER	
Hours allotted in the syllabus	15
Consultations	0
Examination / course credit assignment	0
HOURS WITHOUT THE PARTICIPATION OF AN ACADEMIC TEACHER	
Independent study of the course contents	10
Preparation of a paper, a report, a project, a presentation, a discussion	5
ECTS POINTS STATEMENT	
Total number of hours	30
The ECTS points number	1

Preliminary requirements

No.	Requirements
1	Basic knowledge of metrology.

Course credit assignment conditions / method of the final grade calculation

No.	Description
COURSE CREDIT ASSIGNMENT CONDITIONS	
1	75% attendance in class.
2	Oral test on the use of modern systems and methods in the field of coordinate metrology related to the subject of the doctoral dissertation carried out by the doctoral student.
METHOD OF THE FINAL GRADE CALCULATION	

Grade for the oral test, taking into account the attendance and the involvement in class.

Additional information

None specified

The course reading list

1	Sładek J., *Dokładność pomiarów współrzędnościowych*, Kraków, 2011, Wydawnictwo Politechniki Krakowskiej.
2	Sładek J.A., *Coordinate Metrology*, 2016, Springer Verlag.
3	Ratajczyk E., Woźniak A., *Współrzędnościowe systemy pomiarowe*, Warszawa, 2016, Oficyna Wydawnicza Politechniki Warszawskiej.
4	Hocken R.J., Pereira P.H., *Coordinate Measuring Machines and Systems*, Boca Raton, 2017, CRC Press.
5	Smith G.T., *Machine Tool Metrology. An Industrial Handbook*, Cham, 2016, Springer.