RTU Course "Computer-Aided Analysis of Mechanical Systems of Machines"

15325 Teorēt.mehānikas un materiālu pretestības katedra

General data

Code	MTH503
Course title	Computer-Aided Analysis of Mechanical Systems of Machines
Course status in the programme	Compulsory/Courses of Limited Choice
Course level	Post-graduate Studies
Course type	Academic
Field of study	Mechanics, Mechanical Engineering, Machine Building
Responsible instructor	Auziņš Jānis
Academic staff	Januševskis Aleksandrs
Volume of the course: parts and credits points	1 part, 4.0 Credit Points, 6.0 ECTS credits
Language of instruction	LV, RU, DE
Possibility of distance learning	Not planned
Maximum auditorium capacity	25
Maximum number of students per semester	25
Abstract	Matrix methods in mechanism kinematics and dynamics. The method of constraints for planar kinematic analysis. Revolute, prismatic, gear and cam pairs are considered together with other 2 degrees-of-freedom types of constraints. Formal description of kinematic diagrams. The automatic assembly of the systems of equations for position, velocity and acceleration analysis. Geometry of masses. Forward and inverse tasks of geometric, statistic, kinematic and dynamic analysis. Dynamics of planar systems. Computation of planar generalized forces for external forces and for actuator-spring-damper element. Relations between transfer velocity, angular velocity of rigid body and generalized velocities: analogue matrices. Simple applications of inverse and forward dynamic analysis. Numerical integration of first-order initial-value problems. Accuracy and stability of integration methods. Kinematics of rigid bodies in space. Reference frames for the location of a body in space. Euler angles and Euler parameters. Velocity, acceleration and angular velocity. Relationship between the angular velocity vector and the time derivatives of Euler parameters. Kinematic analysis of spatial systems. Basic kinematic constraints. Joint definition frames. Denavit-Hartenberg notation. The constraints required for the description in space of common kinematic pairs (revolute, prismatic, cylindrical, spherical). Equations of motion of constrained spatial systems. Computation of spatial generalized forces for external forces and for actuator-springdamper element. Computation of reaction forces from Lagrange's multipliers. Dynamical models of AC and DC electromotors, internal-combustion and diesel engines. Dynamical models of control systems: PID controllers. 2D simulation packages: Working model 2D. 3D simulation packages MSC ADAMS: ADAMS View. Parametric optimization.Programs ADAMS Insight, EDAOpt.
Goals and objectives of the course in terms of competences and skills	Develop knowledge and skills of basic mechanism and machine analysis. Develop understanding of various classes of linkages. Develop understanding of kinematics and dynamics of rigid bodies in mechanism chains. Develop understanding of forward and inverse kinematic and dynamic problems. Develop understanding of the basics of numerical integration for machine dynamic simulation. Develop knowledge of machine drive and control system simulation. Develop ability to perform position, velocity, acceleration and force analysis on 2D and 3D mechanisms and machines by use of commercial software. Develop understanding of how to analyze machines and how to properly report the results.
Structure and tasks of independent studies	Students must carry out following home works: 1. Simulation of planar mechanisms with software Working Model 2D: four-bar, crank, crank-rocker, cam, double-pendulum mechanisms, Scara-type robot simulation. 2. Simulation of machines with electro drive - electric car. 3. Simulation of machines with PID controllers - balancing of unstable mechanical system: inverted pendulum. 4. Non-linear oscillation system. 5. Simulation of automatically controlled spatial mechanism with MSC ADAMS software: Puma-type 3-link manipulator with PID control. 6. Optimization of cam mechanism parameters. 7. All students are obliged to carry out the course project: parametric optimization of the given mechanism.
Recommended literature	1. E. J. Haug, "Computer-Aided Kinematics and Dynamics of Mechanical Systems, Volume I: Basic Methods", Allyn and Bacon, 1989. 2. M. T. Heath "Scientific Computing, An Introductory Survey", 2nd ed., 2002 3. R.L. Woods, Modelling and Simulation of Dynamic Systems, Prentice Hall, 1997 4. Working Model 2 D User's Manual, MSC Software, 2005 5. MSC.ADAMS Basic Full Simulation Package. Training Guide, MSC, 2005. 6. Lekciju slaidu faili pdf formātā.
Course prerequisites	Mathematics, physics, mechanics, Theoretical mechanics.

Course outline

Theme	Hours
Classification of tasks of machine analysis. Forward and inverse problems of position, kinematics and dynamics.	4
Euler angles and parameters, rotation matrices, its derivations and relation with angular velocities. Inertia tensor.	4
Newton-Euler equations in a matrix form.	4
Kinematic links and pairs. Kinematic chains, constraint equations. Rotation, translation, cylindrical, spherical joint.	4
Kinematic chains, closed kinematic loops. Degrees of freedom. Generalized coordinates.	4
Lagrange's equations of the second type in a matrix form.	4
Numerical methods of dynamics. Numerical methods for ODE's, its application in dynamics of mechanisms.	4
Formalism of description of mechanism kinematics. Denavit-Hartenberg notation.	4
Viscous and dry friction. Methods of link contact simulation.	4
Force calculation in kinematic chains. Planar and spatial trusses.	4
Mechanism simulation software: WorkingModel 2D, MSC ADAMS	4
Connection between dynamic simulation software and virtual prototyping software SolidWorks, AutoCad.	4
Controlled systems, drive and control system block-diagrams.	4
Formalism of drive and control systems. Electrodrive, internal-combustion and diesel engine dynamic models.	4
Consideration of link elasticity and joit gap. Import of elastic models of bodies from FEM software (ANSYS, SolidWorks)	4
Optimization of machines. Software EDAOpt, ADAMS Insight.	4

Learning outcomes and assessment

Learning outcomes	Assessment methods
Knowledge of vector and matrix mathematics for the analysis of mechanisms.	Exam questions
Knowledge of common elements in machine design.	Exam questions
Ability to perform kinematic analysis of mechanisms.	Independent task/work
Ability to perform dynamic simulation of machines.	Independent task/work
Ability to apply numerical integration methods.	Independent task/work
Proficiency to apply software to solve engineering problems including ODE's, systems of linear equations, and eigenvalue analysis.	Independent task/work
Compute kinematics and dynamics of 3D mechanisms using Euler angles, Euler parameters, rotation matrices, constraint vectors.	Coursework
Ability to develop and utilize models of machines.	Exam questions
Ability to optimize of machines.	Coursework
Use of commercially available mechanism analysis software and understand the underlying algorithms and theory behind them.	Coursework

Study subject structure

Part	CP	ECTS	Hours per Week			Tests		
			Lectures	Practical	Lab.	Test	Exam	Work
1.	4.0	6.0	1.0	3.0	0.0		*	