**Spatial Mechanisms and Dynamical Systems**

Code: MK5DINRG06RX17-EN

ECTS Credit Points: 6

Evaluation: exam

Year, Semester: 1stspringsemester

Its prerequisite(s): -

Further courses are built on it: Yes/No

Number of teaching hours/week (lecture + practice): 4+2

**Topics**:

Linear and nonlinear dynamical system analysis in time-domain. Differential equations. Duhamel principle and transfer function. Convolution. Typical signals for system analysis. Harmonic functions as input signals for dynamical systems. Ergodic excitations. Dirac and Heaviside functions. Transfer characteristics. Stochastic signals and environmential vibrations on dynamical systems. Autocorrelation function and cross-correlation function. Hamilton-Jacobi equations. Virtual work principle. D'Alembert principle. Classification of the constraints. First order Lagrange equation.

Second order Lagrange equation. Holonomic and nonholonomic constraints.

Generalization of Lagrange principle for 1-DOF and higher DOF dynamic systems.

Analysis of linear systems in complex frequency domain. Integral transformations for analysis of mass-spring-damper systems. Laplace transform for mathematical solution of DEs and for analysis of mass-spring-damper systems. Asimptotic principles. Stability of linear systems. Nyquist criteria Routh-Hurwitz criteria.

Analysis of linear systems in frequency domain. Fourier integral. Fourier transform. Analysis of signals and systems by Fourier transform. Bending vibrations of power transmission systems. Simulation in Matlab, Labview and Simulink. Continium vibrations. Torsional vibrations of shafts. Laval-rotor. Rayleigh quotient iteration, Stodola (convergence), Rayleigh's principle, Dunkerley's estimate. Longitudinal and torsional vibrations of prismatic bars.

Vibration of continuum bars The Sturm-Liouville task and relationship with the standing wave solution. Longitudinal vibrations of prismatic beams.

Spatial mechanisms. Robot manipulators. Kinematics and dynamics of wrist movements, kinematic chains, Lagrange equations, TTT / RTT / RRR work spaces. Robotics in machine industry.

Spatial mechanisms direct and inverse kinematic and dynamical characterization tasks, Lagrange equations. Denavit-Hartenberg principle. Grashof principle and Roberts principle for spatial mechanisms. Simscape simulation for spatial mechanisms.

Vibraton analysis of cutting machines in manufacturing technology, spindles, rotors as special dynamic systems. Simulations of dynamic systems in Matlab Simulink. Vibration isolation systems, calculation, vibration reduction, critical frequency, resonance, environmental noise and vibration reduction methods.

**Literature:**

*Compulsory:*

* Allan G. Piersol, Thomas L.Paez: Harris’s Shock and Vibration Handbook, Sixth Edition, McGrraw-Hill,2010. ISBN [978-0-07-163343-7](callto:978-0-07-163343-7)
* S. Graham Kelly: Mechanical Vibrations Theory and Applications, University of Akron, 2012. ISBN -13: [978-1-4390-6214-2](callto:978-1-4390-6214-2)
* Harold Josephs- Ronald J. Huston: Dynamics of mechanical systems. 5th Edition, CRC Press Inc., 2006. ISBN [0-8439-0593-4](callto:0-8439-0593-4)
* Parasuram Harihara, Dara W. Childs: Solving Problems in Dynamics and Vibrations Using MATLAB, Dept of Mechanical Engineering, Texas, A & M University, 2014
* Eugene Avallone: Standard Handbook for Mechanical Engineers, Eleventh Edition,McGrraw-Hill,2010. ISBN-13: [978-0-07-142867-5](callto:978-0-07-142867-5)

**Schedule**

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| **1st week Registration week** | |
| **2nd week:**  **Lecture:** Mathematical basics. Matrices. Tensors. Diff. equations. Eigenvalues. Numerical methods.  **Practice:** Matlab applications. | **3rd week:**  **Lecture:** Linear and nonlinear dynamic system analysis in time-domain. Differential equations. Duhamel principle and transfer function. Convolution.  Typical signals for system analysis. Harmonic functions as input signals for dynamical systems. Ergodic excitations.  **Practice:** Differential equations and calculations. |
| **4th week:**  **Lecture:** Dirac and Heaviside functions. Transfer characteristics. Stochastic signals and environmential vibrations on dynamical systems. Autocorrelation function and cross-correlation function  **Practice:**  Labview and Matlab signal generation for system analysis. | **5th week:**  **Lecture:** Hamilton-Jacobi equations. Virtual work principle. D'Alembert principle. Classification of the constraints. First order Lagrange equation.  Second order Lagrange equation. Holonomic and nonholonomic constraints.  **Practice:** Lagrange equations for dynamical systems. Solution of Diff. equations. |
| **6th week:**  **Lecture:** Generalization of Lagrange principle for 1-DOF and higher DOF dynamical systems.  **Practice:**  Examples and calculations of 1-DOF and higher DOF mass-damper-spring systems. | **7th week:**  **Lecture:** Analysis of linear systems in complex frequency domain. Integral transformations for analysis of mass-spring-damper systems. Laplace transform for mathematical solution of DEs and for analysis of mass-spring-damper systems.  **Practice:** Laplace transform applications for dynamical systems. |
| **8th week: 1st drawing week** |  |
| **9th week:**  **Lecture:** Analysis of linear systems in frequency domain. Fourier integral. Fourier transform. Analysis of signals and systems by Fourier transform. Stability of linear systems. Nyquist criteria Routh-Hurwitz criteria.  **Practice:** Analysis of harmonic signals with Fourier transform. | **10th week:**  **Lecture:** Bending vibrations of power transmission systems. Laval-rotor. Rayleigh quotient iteration, Stodola convergence, Rayleigh's principle, Dunkerley's estimate. Longitudinal and torsional vibrations of prismatic bars.  Vibration of continuum bars The Sturm-Liouville task.  **Practice:** Simulation in Matlab, Labview and Simulink. |
| **11th week:**  **Lecture:** Spatial mechanisms. Robot manipulators. Kinematics and dynamics of wrist movements, kinematic chains, Lagrange equations, TTT / RTT / RRR work spaces. Robotics in machine industry.  Spatial mechanisms direct and inverse kinematic and dynamic characterization tasks, Lagrange equations.  **Practice:** Simscape simulation for spatial mechanisms. | **12th week:**  **Lecture:** Spatial mechanismsDenavit-Hartenberg principle. Grashof principle and Roberts principle for spatial mechanisms.  **Practice:** Simulation in Simulink and Labview. |
| **13th week:**  **Lecture:** Vibration analysis of cutting machines in manufacturing technology, spindles, rotors as special dynamic systems.  **Practice:** Simulations of dynamic systems in Matlab Simulink. | **14th week:**  **Lecture:** Vibration isolation systems, calculation, vibration reduction, critical frequency, resonance, environmental noise and vibration reduction methods.  **Practice:** Passive and active vibration isolation system calculations. Vibration measurement and methods for mitigation. |
| **15th week: 2nd drawing week, End-term test** |

**Requirements**

**A, for a signature:**

Participation at practice classes is compulsory. Students must attend practice classes and may not miss more than three practice classes during the semester. In case a student does so, the subject will not be signed and the student must repeat the course. Students can’t take part in any practice class with another group. Attendance at practice classes will be recorded by the practice leader. Being late is equivalent with an absence. In case of further absences, a medical certification needs to be presented. Missed practice classes must be made up for at a later date, being discussed with the tutor.

During the semester there are two tests: the mid-term test is on the 8th week and the end-term test is on the 15th week. Students must sit for the tests.

**B, for grade:**

The course ends in **exam grade**. The grade for the test is given according to the following table:

Score Grade

0-59 fail (1)

60-69 pass (2)

70-79 satisfactory (3)

80-89 good (4)

90-100 excellent (5)