MEDTEC SHOOL

Course: AUTOMATION AND MECHATRONICS

Year: 2nd

Period: 1st semester

Credits: 6.00

Objectives

Module 1

The aim of the course is to provide students with the basic knowledge for the comprehension of dynamic mechanical systems behavior, by analyzing the applied forces and the motions which follow from them. The main mathematical methods for the study of kinematics, statics and dynamics will be presented and specific medical applications will be analyzed.

Module 2

The aim of the course is to introduce the student to a basic knowledge of automatic control, i.e., of the methods and tools that make a system behave as desired, exploiting the principle of feedback control. For this, elements of dynamic systems theory (both in time domain and frequency domain) will be given, along with techniques to analyze closed loop control systems, with an eye to some medical applications.

Prerequisites

Some basic knowledge of mathematics are needed, with specific reference to operations on complex numbers, vector analysis, differential and integral calculus, linear ordinary differential equations, and matrix algebra.
Fundamentals of experimental physics: kinematics, dynamics of the material point, work and energy, system dynamics.

Contents

Module 1

1. Kinematics

Basic concepts of 2D and 3D kinematics of a particle: frame of reference, trajectory, law of motion. Position, velocity and acceleration: cartesian coordinates and polar coordinates approach.

2D kinematics of a rigid body: velocity and acceleration in a rigid motion. Rivals theorem. Instant Centres of rotation.

2D kinematics of a system of rigid bodies. Degrees of freedom and joints. Structures and mechanisms. Vector displacement, velocity and acceleration closure equations. Examples: double pendulum (prosthetic arm, gym machineries), slider-crank mechanism (volumetric pump).

2. Static force analysis

Equilibrium of the material point. Equilibrium of the rigid body: cardinal equations of statics. Constrains and reactions. Equilibrium of the systems of rigid bodies.

3. Dynamic force analysis

Center of gravity and inertia matrix (mass moment of inertia): systems of particles (discrete systems) and rigid bodies (continuous systems).

Basic concepts of Newton laws for the particle. Dynamics of the rigid body: Newton-Euler equations. Dynamic equilibrium equations (d'Alembert's principle). Dynamics of the systems of rigid bodies. Theorem of the kinetic energy (power balance).

Examples: prosthetic arm, volumetric pump.

4. Mechanical vibrations

Harmonic oscillator. Interaction between vibrations and human body: sensitivity of different organs to vibrations (seminar).

5. Workshop

Exoskeleton/prosthetic arm: kinematics, static and dynamic force analysis.

Module 2

1. Introduction

The control problem. Examples. Open loop and closed loop control. Instrumentation.

2. Dynamic systems

Role of the dynamic analysis. Definition of the dynamic systems. Equilibria. Linear stationary systems. Transfer functions. Stability of dynamic systems. Responses of first and second order systems.

3. Frequency response

Harmonic response of dynamic systems. Graphical representation of the frequency response: Bode diagrams.

4. Block diagrams

Series, parallel and feedback connections. Stability of interconnected systems.

5. Analysis of control systems

Stability of feedback systems: the Bode criterion and the phase margin. Dynamic performance: speed and damping of the responses. Bandwidth of the control system. Steady state performance.

6. PID controllers

Industrial controllers. Elements on the digitalization of the control law.

7. Applications

Selected applications of control in biomedical systems: artificial pancreas, control of anesthesia, prosthetic arm.

8. Workshop

Exoskeleton/prosthetic arm: design of a control scheme.

Teaching Methods

Lessons and practice sessions. Students are encouraged to actively participate to the lectures with questions and comments.

Verification of learning

The final assessment will be a written exam, consisting of both numerical exercises and theoretical questions. The written test can be integrated by an oral discussion at the instructor's discretion.
In the written exam the student should be able to:

Module 1

- apply the main principles and the main theories for the study of static and dynamic mechanical systems of rigid bodies;
- perform kinematic and dynamic analyses of simple 2D mechanical systems;
- evaluate motion and load acting on a 2D mechanical system.

Module 2

- write in the form of a dynamic system (in time or frequency domains) the model of a physical system;
- demonstrate knowledge of the main definitions, concepts and properties related to dynamic systems;
- analyze simple control systems, estimating both steady state and dynamic performance;
- demonstrate knowledge of the simplest control laws (PID controllers) and their use.

Texts

Module 1

- R.C. Hibbeler, Principle of Statics and Dynamics, Editor: Pearson, Prentice Hall;
- K. J. Waldron, G. L. Kinzel, Kinematics, Dynamics, and Design of Machinery, Editor: Wiley & Sons;
- In Italian: Nicolò Bachschmid, Stefano Bruni, Andrea Collina, Bruno Pizzigoni, Ferruccio Resta, Alberto Zasso, Fondamenti di meccanica teorica e applicata 2/ed, Editore: McGraw-Hill, Anno edizione: 2010, ISBN: 9788838665097 (with solved exercises).

Module 2

- Karl Johan Astrom and Richard M. Murray, Feedback systems - An Introduction for Scientists and Engineers, https://www.cds.caltech.edu/~murray/books/AM05/pdf/am08-complete_22Feb09.pdf;
- Norman S. Nise, Control Systems Engineering, Editore: John Wiley and Sons, Inc., ISBN: 978-0470917695.