UNIVERSITY OF LJUBLJANA
Faculty of Mechanical Engineering

Mechanics of Light-weight Structures (6040-M) 5 ECTS

Lecturer: **M. Brojan**

Lectures: 30h | Tutorials: 10h | Labs: 20h | Project: 65h | Lang. :

Objectives

This course provides a comprehensive foundation in the principles of lightweight (LW) structural design and efficient material use. It begins with an experimental, theoretical, and numerical investigation of layered and fiber-reinforced composite materials. Structural optimization is introduced to their minimize weight. Because LW structures are typically thin or incorporate such elements, a major focus of the course is the analysis of stability and the prevention of buckling. Beyond failure avoidance, the course introduces concepts from nonlinear mechanics to demonstrate how structural instabilities can be deliberately exploited to achieve advanced and novel functionality.
Upon completion of the course, students will have developed the following competencies:

- the ability to design and optimize lightweight structures for efficient material use,
- the ability to analyze and prevent failure in lightweight structures due to loss of stability and other mechanisms,

Programme

Part I: Materials and Optimization for Lightweight (LW) Design

- **Introduction:** Basics of LW structures; efficient material use and favourable stress distribution.
- **Weight Optimization of Layered Materials & Fibre-reinforced Composites:** Practical laboratory work, design principles, theory and numerical analysis of thin-skin and fiber-reinforced structures.
- **Formal Optimization Methods:** Definition of an optimization problem (objective function, design variables, equality/inequality constraints, Karush-Kuhn-Tucker conditions); application to thickness optimization and improving the load-carrying capacity of classical and composite structures.
- **Applied Project:** Optimization of a composite beam (working example: a composite aircraft wing).

Part II: Stability of Slender Structural Elements

- **Review and Challenges:** Slender elements (beams, plates, shells) in composite structures; problems in application (discontinuities, nonlinearities, imperfections, interaction effects).
- **Basic Stability Concepts:** Stability; limit load and bifurcation buckling; theory and experiments.
- **Buckling of Beams:** Physically correct equilibrium on a deformed beam; influence of imperfections; buckling under self-weight; beams on discrete elastic supports and elastic foundations (wrinkling);
- **Buckling of Plates and Shells:** Experimental and theoretical exploration of critical buckling forces for plates and shells; experiments and theory of wrinkling of composite plates.

Prerequisites

Enrolment conditions for the Master's study programme of Mechanical Engineering - Research and Development program.

Learning outcomes

Thorough professional theoretical and practical in a selected field of expertise that is supported with a broad theoretical and methodological basis. Be aware of the benefits and requirements of process modelling:

- In-depth knowledge of design principles for making LW structures and optimization.
- In-depth knowledge of nonlinear response of structural elements and solution methods for the design of LW structures

Assessment

20 % Examination (lectures - theory)
60 % Examination (exercises – design calculations)
10 % Laboratory exercises
10 % Homework

Literature

S.P. Timoshenko, J.M. Gere: Theory of Elastic Stability
G. Simitses & D.H. Hodges: Fundamentals of Structural Stability
J.M.T. Thompson & G. W. Hunt: General Theory of Elastic Stability
J. Singer, J. Arbocz, T. Weller: Basic Concepts, Columns, Beams and Plates (Volume 1 & 2)
D. Bigoni: Nonlinear Solid Mechanics - Bifurcation Theory and Material
Z.P. Bazant, L. Cedolin: Stability of Structures: Elastic, Inelastic, Fracture, and Damage Theories