240054 - Continuum Mechanics

Coordinating unit: 240 - ETSEIB - Barcelona School of Industrial Engineering
Teaching unit: 737 - RMEE - Department of Strength of Materials and Structural Engineering
Academic year: 2019
Degree: BACHELOR'S DEGREE IN MATERIALS ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
ECTS credits: 4,5
Teaching languages: Catalan, Spanish

Teaching staff

Coordinator: MIQUEL FERRER BALLESTER
Others: Teoria:
MIQUEL FERRER BALLESTER
XAVIER AYNETO GUBERT
JOSEP Mª PONS POBLET

Pràctiques de Laboratori:
JORDI BONADA BO
JORDI FÀBREGA FREIXES
JORDI GUILERA DOMINGO
JOSUÉ LÓPEZ HERMOSO
ROMÀ SUÑÉ LAGO

Opening hours

Timetable: Please, check the notice board of the Dep. RMEE

Degree competences to which the subject contributes

Specific:
11. Knowledge and capacities to apply fundaments of materials' elasticity and resistance to the behaviour of real solids.

Transversal:
1. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
2. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
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Teaching methodology

Mixed theory/problems sessions: lectures and participatory self-assessment programmed activities to do in classroom and outside of it.

Lab sessions: 2h sessions, learning based in experiment. Groups of 15 people organized in teams of 3 students. Five sessions must be carried out: 1. material testing, 2. photo elasticity 3. finite element simulation. The fourth session consist of a draft presentation of the homework. Finally, in the fifth session, the teams must hand in the course work and make a presentation.

Course work: Self-learning and cooperative. The team of three people formed in the lab groups perform a small project of free design of a piece or resistant element with the help of finite element software, optimize the piece, build a prototype and test it in the lab.

Learning objectives of the subject

At the end of the course, students should be able to:
- Analyze the fields of displacements, velocities and accelerations of the continuum, as well as their gradients, from the equations of continuum kinematics.
- Calculate and describe strains and strain rates of continuum by tensorial algebra.
- Analyze the stress state and identify their main characteristics.
- Identify different constitutive models for continuum.
- Relate the stress and strain states for linear elastic continuum.
- Solve the elastic problem under different boundary conditions, calculating the stress and strain states at any point.
- Calculate the elastic safety factor in continuous using the appropriate failure criterion. Identify the appropriate elastic failure criterion based on the nature of the material.
- Construct an appropriate numerical model using finite element method for analysing linear elastic strains and stresses.
- Recognize and identifying the appropriate boundary conditions based on a real situation of any object.
- Design a simple mechanical part or element and optimize its strength and stiffness.
- Analyze the results of finite elements simulations.
- State the basic laws of continuum dynamics.

Study load

<table>
<thead>
<tr>
<th>Total learning time</th>
<th>Hours large group:</th>
<th>Hours small group:</th>
<th>Guided activities:</th>
<th>Self study:</th>
</tr>
</thead>
<tbody>
<tr>
<td>109h 24m</td>
<td>35h 06m</td>
<td>6h 48m</td>
<td>0h</td>
<td>67h 30m</td>
</tr>
<tr>
<td></td>
<td>32.08%</td>
<td>6.22%</td>
<td>0.00%</td>
<td>61.70%</td>
</tr>
</tbody>
</table>
## Content

<table>
<thead>
<tr>
<th>(ENG) - Continuum kinematics</th>
<th>Learning time: 29h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 11h</td>
</tr>
<tr>
<td></td>
<td>Self study: 18h</td>
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</tbody>
</table>

**Description:**
Analysis of the displacements, velocities and accelerations fields, by both Lagrangian and Eulerian formulation. Deduction of the strain rate tensor and both finite or small strain tensor.

**Related activities:**
Programmed exercises 2.1 to 2.25, both in and outside the classroom.

**Specific objectives:**
- Analyze the displacement, velocity and acceleration fields from continuum kinematics equations.
- Calculate and describe the continuum strain rate and strain using the tensorial algebra.

<table>
<thead>
<tr>
<th>(ENG) - Stress</th>
<th>Learning time: 32h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 10h</td>
</tr>
<tr>
<td></td>
<td>Laboratory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Self study: 18h</td>
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</tbody>
</table>

**Description:**
Definition of the stress vector, intrinsic components of stress, stress tensor, equilibrium conditions, principal stresses and directions, Mohr circles, elastic failure criteria.

**Related activities:**
Programmed Exercises 3.1 to 3.12, both in and outside the classroom

**Specific objectives:**
- Analyzing the stress state and identifying its main features.
- Representing any tensor magnitude by Mohr circles.
- Calculate the elastic safety factor of a mechanical component, using the appropriate failure criterion according to the nature of the material behaviour (brittle/ductile).
### Constitutive Models. Linear Elasticity

**Learning time:** 44h 30m  
- Theory classes: 15h  
- Laboratory classes: 4h  
- Self study: 25h 30m

**Description:**  
Constitutive equations, the principles of virtual work and power, generalized Hooke's law, the elastic problem, plane stress, plane strain, axisymetry, the finite element method.

**Related activities:**  
Activities 4.1 to 4.4 and 5.1 to 12.5 for both within and outside the classroom.  
Guided coursework.  
Laboratory practices.

**Specific objectives:**  
- Identify different continuum constitutive models.  
- Relate strain and stress states of linear-elastic continuum.  
- Solve the elastic problem in different boundary conditions, calculating the stress and strain states at any point.  
- Build a suitable numerical model using the finite element method for the analysis of linear-elastic stresses and strains, recognize and identify the appropriate boundary conditions based on a real situation of any object.  
- Design a simple mechanical part or element and optimize its stiffness and strength.  
- Analyze the results of finite elements simulations.

### Continuum Dynamics

**Learning time:** 7h  
- Theory classes: 1h  
- Self study: 6h

**Description:**  
Control volume, Reynolds' theorem, mass, momentum, angular momentum conservation principles, the principles of virtual work and power.

**Related activities:**  
6.1 to 6.3 activities inside the classroom.

**Specific objectives:**  
- Stating the basic laws of the continuum dynamics.
### Planning of activities

#### (ENG) EXERCICIS DINS DE L'AULA

**Description:**
Programmed activities to be solved by teams of 2-3 students, within the classroom.

**Support materials:**
The programmed activities are available in the digital campus.

**Descriptions of the assignments due and their relation to the assessment:**
The "Deliverable" activities are uploaded to the digital campus and solved by the professor on the board during the next class. Students correct their own exercises. The marks are not included in the global evaluation of the subject.

**Specific objectives:**
- Reversed learning: deducing theory concepts from an exercise, prior to the formal theory lecture.
- Practicing concepts that have been already explained.
- Cooperative learning.
- Self-evaluation, co-evaluation.

<table>
<thead>
<tr>
<th><strong>Hours</strong></th>
<th>10h</th>
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</thead>
<tbody>
<tr>
<td><strong>Theory classes</strong></td>
<td>10h</td>
</tr>
<tr>
<td><strong>Laboratory classes</strong></td>
<td>10h</td>
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#### (ENG) PRACTIQUES DE LABORATORI

**Description:**
Laboratory sessions to practice with experimental and numerical methods.

- Practice 1: Materials testing
- Práctica 2: Photoelasticity
- Práctica 3: The finite element method
  (Practices 4 and 5: see Coursework)

**Support materials:**
Laboratory of Elasticity and Strength of Materials (LERMA). Machinery for testing and specimens, tools and photoelastic bench, ANSYS finite elements software. Practices guides.

**Descriptions of the assignments due and their relation to the assessment:**
During the 2h lab sessions, each team of 3 students, write in-situ a report containing the description, calculations and conclusions. The reports are delivered at the end of each lab session. The grade of this report signifies the 3% of the global subject grade. On the other hand, practices 1 and 2 are also evaluated within the mid-term exam (40% of the exam, 4/10 test questions), i.e., 8% of the final subject grade. Therefore, the total weight is 11%.

**Specific objectives:**
- Experimental methods for material characterization
- Photoelasticity for the visualization and experimental determination of stress/strain states
- Finite elements software for the analysis of the stresses and strains of an elastic solid.
- Training in finite element simulation to ease the Coursework development.
**Qualification system**

\[ NF = 0.2 \times NEP + 0.1 \times NEC + 0.05 \times NL + 0.15 \times NTR + 0.5 \times NEF \]

**NF:** FINAL MARK
**NEP:** MARK OF THE MID-TERM EXAM (Test of 10 questions)
**NEC:** COURSE EXERCISES MARK (exercises to be solved within the classetime, pop quizzes)
**NL:** MARK OF THE LAB (evaluation of the three reports + coursework draft)
**NTR:** MARK OF THE COURSEWORK

NEF: MARK OF THE FINAL EXAM (two parts, each one of them will include both problems and theoretical questions)

In the case of extraordinary reevaluation, the entire subject content will be evaluated (laboratory sessions as well). The exam will consist of two parts (each one of them will include both problems and theoretical questions). The new mark NERAVA will replace the marks NEP+NEC+NL+NEF, so the final reevaluation mark will be as follow: \[ NF = NTR \times 0.15 + NERAVA \times 0.85 \].

**Regulations for carrying out activities**

**MID-TERM EXAM:** 10 questions test with 4 possible answers. An optical-mark-recognition system is used for automated correction of responses. Theory chapters 1 and 2 as well as lab practices 1 and 2 are evaluated. Wrong questions rest 0.25 points to the mark. Only an A4 formulary with formulas, titles and drawings (no explanations) can be used as well as a basic calculator (no programmable ones or with massive memory).

**LABORATORY:** each team of 3 people must write report during the practises 1, 2 and 3 and which will be handed in by the end of the session. The evaluation of these reports (0.03) and the draft presentation of the course work (0.02) signifies the mark NL.

**COURSEWORK:** the teams of 3 people must write a complete course work report and prepare an oral presentation. The exposition and defence of this work, as well as the prototype testing, represent the last session of the laboratory. The oral exposition, the result of the testing and the global report are evaluated by two professors in order to set the mark NTR.

**FINAL EXAM:** consists of two 1h-duration parts, approximately, including either theoretical questions and conceptual exercices. Only an A4 formulary with formulas, titles and drawings (no explanations) can be used as well as a basic calculator (no programmable ones nor with massive memory).

**REPEAT STUDENTS:** NL and NTR grades can be kept by signing up ONLY to the theory group (10, 20, 30...) and NOT to any laboratory subgroup (11, 12, 21, 22...), otherwise, Lab sessions and Course Work will be carried out again.
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Bibliography

Basic:


Complementary:


Others resources:

Hyperlink

http://mmc.etseib.upc.edu/index.swf

Computer material

ANSYS Educational