VNIVERSITAT DE VALÈNCIA

Course Guide
34774 Theory and design of machines and process equipment

COURSE DATA

Data Subject	
Code	34774
Name	Theory and design of machines and process equipment
Cycle	Grade
ECTS Credits	6.0
Academic year	2022 - 2023

Study (s)

Degree	Center	Acad. year	Period
1401 - Degree in Chemical Engineering	School of Engineering	3	First term

Subject-matter

Degree	Subject-matter	Character
1401 - Degree in Chemical Engineering	11 - Equipment materials and design	Obligatory

Coordination

Name	Department
FERNANDEZ DOMENE, RAMON MANUEL	245 - Chemical Engineering
SOLSONA ESPRIU, BENJAMIN EDUARDO	245 - Chemical Engineering

SUMMARY

This course is divided into two different parts. The first one is the basis of the Theory of Machines and Mechanisms, whereas the second one deals with the mechanical design of process equipment.

The most simple and widely used mechanisms are considered and in particular the basis for the analysis of planar mechanisms is introduced at both kinematic and dynamic points of view. In that sense there is a special emphasis on vectorial methods to calculate velocities and forces acting on a mechanism.

Subsequently rotating mass balancing is treated which is a basic aspects for machine design.

As far as the mechanical design of process equipment is concerned, the second part of the course is

dedicated to the design of equipment undergo pressure by establishing a clear difference between that working under pressure and that working under vacuum. There is also a unit dedicated to the mechanical design of towers used in the process industry. They have to be able to withstand the effects of wind and seismic activity. Finally the mechanical design of pipes is considered.

The mechanical design is performed using the standards from API-ASME (American Petroleum Institute and American Society of Mechanical Engineers) which are widely accepted.

The contents of the course are: Principles of Theory of Machines and Mechanisms and Mechanical

design equipment, which are structured in the units listed in section Description of Contents.

The general objectives of the course are:

•To make use from a practical point of view of the concepts of Mechanics which have been seen in the subject of Physics I.

•To develop in students the ability to propose and solve numerical problems in which mechanisms

appear as well as to interpret the results.

• To develop strategies to design mechanically the industrial equipment containing liquids and solids.

• Enhance students' skills in reasoning and systematic work.

• Promote and encourage those values and attitudes that must be inherent to engineers.

Theoretical lessons will be in Spanish and the practical classes in Spanish or Valencian, in agreement with the webpage of the Degree.

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

Other requirements

To successfully pass the subject is advisable that students possess a series of prior knowledge at the level demanded in subjects studied previously. This knowledge comprises:

Mechanics
Materials science

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- G3 - Knowledge of basic and technological subjects that allows students to learn new methods and theories and provides them with versatility to adapt to new situations.

- G4 - Ability to solve problems with initiative, decision-making skills, creativity and critical reasoning and to communicate and transmit knowledge, abilities and skills in the field of industrial engineering.
- G6 - Ability to deal with specifications, regulations and mandatory standards.
- G8 - Ability to apply the principles and methods of quality control.
- G10 - Ability to work in a multilingual and multidisciplinary environment.
- G11 - Knowledge, understanding and ability to apply the necessary legislation for practising professionally as a qualified industrial technical engineer.
- R7 - Knowledge of the principles of the theory of machines and mechanisms.
- R8 - Knowledge and use of the fundamentals of the strength of materials.

1. To know and understand the principles of kinematics and dynamics of mechanisms and machines (G3, R7, R8).

2. To know the fundamentals and methodology of the kinematics of mechanisms and their application to the analysis of simple systems (G3, G4, R7).

3. To assess the suitability of a mechanism design(G4, G6, G11, R7).

4. To select the appropriate equipment and/or element for a particular application and justify their choice (G4, G10, R7, R8).

5. To know and be able to select and size transport, handling and storage of solids and fluids systems (G3, G4, R7, R8).

6. To know and apply regulations and industry codes in the mechanical design of equipment and simple structural elements (G6, G8, G11).

7. To know and apply principles of safety in the design of mechanical equipment and simple structural elements (G6, G8, G11).

After completing the course, students will be able to:

• Calculate the degrees of freedom of a mechanism.

• Describe the operation of the most common single mechanisms.

• Determine if in a four-bar mechanism some of them can make a complete circuit.

• Calculate the position of the bars of a mechanism and/or their length.

• Calculate the relative velocity and acceleration between two points on a mechanism by using vectorial methods.

• Calculate the velocity and acceleration of the bars of a mechanism knowing the angular velocity and acceleration of the motor bar by using vectorial methods.

• Apply the Coriolis acceleration to calculate the acceleration of prismatic pairs showing rotation.

• Calculate the reactions in a bar mechanism and the torque or the external force that must be applied to statically balance it when known forces act on certain bars.

• Apply the principle of superposition to calculate the reactions in the joints of a bar mechanism and the force that statically balances it.

• Define the components of inertia of a bar that moves in the plane.

• Calculate the velocity and acceleration of different points of a mechanism when external forces are not balanced.

• Calculate the force that must be applied to a mechanism so that a desired kinematic state is produced.

• Perform a matrix analysis to determine the dynamics of a bar mechanism

• Determine whether a system of rotating mass is balanced and calculate the mass to balance it.

• Determine if an engine is balanced

• Sort the tensions that can occur in vessels containing fluids.

• List the different procedures for calculating the wall thickness of a pressure vessel.

• Calculate the wall thickness of a container and a head to withstand a certain pressure.

• Calculate the maximum working pressure of a vessel and a head made from plates of commercial thickness.

• Calculate the thickness of vacuum vessels.

• Determine the number of stiffening rings in vacuum vessels.

• Calculate the shear stress and bending moment due to wind for a column.

• Determine the period of actual vibration due to wind for a column and its maximum allowance.

• To design a tower to support its weight.

• Calculate the shear stress and bending moment of a column due to seismic loads.

• Determine if a column is able to withstand seismic loads in the area where it will be located.

• Calculate the effect of eccentricity in a column equipped with external accessories.

• Calculate the wall thickness of a column subjected to a combination of loads.

• Estimate the point of the tower where longitudinal and tangential stresses are equal.

• Make the most economical proposal of plate thickness at various heights of the tower.

• Calculate strengths in pipes due to changes in direction.

• Calculate the overpressure due to water hammer.

In addition to what has been said before, the course will encourage students to develop several social and technical skills, among which the following are noteworthy:

• Capacity for analysis and synthesis.

• Ability to argue from rational and logical criteria.

• Ability to communicate in a properly and organized manner.

• Ability to develop a problem in a systematic and organized manner.

• Ability to work and distribute the personal time.

• Ability to work in groups.

DESCRIPTION OF CONTENTS

1. INTRODUCTION TO THE THEORY OF MACHINES AND MECHANISMS. BASIC CONCEPTS.

Basic concepts and general definitions. Degrees of freedom of a mechanism. Kinematic Inversions. The Grashof condition. Mechanical advantage. Dead point. Kinematic diagrams. Practical application of different mechanisms: Four-bar mechanisms; Crank-rocker mechanism; Slider-crank mechanism.

2. GEOMETRIC ANALYSIS OF PLANAR MECHANISMS

Introduction. Analytical methods: Ravens method.

3. KINEMATIC ANALYSIS OF PLANAR MECHANISMS BY VECTORIAL METHODS

Introduction. Speeds on the machines: Position, displacement and velocity of a point; Position, displacement and angular velocity of a solid; Method of relative velocity. Accelerations in machines: Acceleration of a point; Relative acceleration of two points either; Acceleration of two points on a rigid body; The Coriolis component of acceleration.

4. DYNAMIC ANALYSIS OF PLANAR MECHANISMS

Introduction. Static in machines: Transmission of forces in mechanisms; Conditions for static equilibrium; Principle of superposition. Dynamic Analysis: External actions; Internal actions or reaction; Dynamic equilibrium of a particle with mass; Components of inertia of a bar in planar motion; Components of inertia of a planar bar. Dynamic analysis. Matrix method.

5. MASS BALANCING

Introduction. Balancing of rotors: Static equilibrium; dynamic equilibrium; Analytical method to calculate the mass balancing. Balancing of engines: Single-cylinder engines; Multi-cylinder engine.

6. MECHANICAL DESIGN OF VESSELS UNDER INTERNAL PRESSURE

Introduction. Vessels under internal pressure. Mechanical design of vessels under internal pressure: Design of tanks containing gases; Design of tanks containing liquids; Vessels with intermediate walls; Thick-walled vessels; Methodology to design the thickness of a vessel under internal pressure. Solid storage systems.

7. MECHANICAL DESIGN OF VESSELS UNDER EXTERNAL PRESSURE

Introduction. Design of cylindrical vessels. Design of conic shells and heads. Design of spheres and spherical, ellipsoidal and torispherical ASME code heads: Spherical shells and heads; ellipsoidal 2:1 and torispherical heads. Stiffening rings design: Number of stiffening ring; Design of stiffening rings.

8. HIGH TOWERS MECHANICAL DESIGN

Introduction. Design of towers to support the wind action or pressure: Design for a tower with constant wind load (Pw); Design for a tower with variable diameter; Design for a constant diameter tower and a wind load that varies with altitude. Design of towers to support their weight. Tower design to withstand vibration. Design of towers to withstand seismic loads. Design of towers to withstand eccentric loads. Elastic stability conditions: Tray supports: stiffeners, tubes for fluid rise or fall. Combination of stresses: Estimation of the distance where the longitudinal and tangential stresses are the same. Skirt support design.

9. MECHANICAL DESIGN OF PIPES

Introduction. Wall thickness in pipes. Pipe support. Water hammer in pipes.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	30,00	100
Classroom practices	30,00	100
Development of group work	10,00	0
Preparation of evaluation activities	15,00	0
Preparing lectures	28,50	0
Preparation of practical classes and problem	35,00	0
Resolution of online questionnaires	1,50	0
TOTAL	**150,00**	

TEACHING METHODOLOGY

The development of the course is structured around the theory classes and practical activities. Some of these activities will be evaluated and will contribute to the final mark.

In the theory classes (G3, G6, G7, G11, R7, R8) lecture model will be used to explain the most complex or difficult notions and always during periods of less than 30 minutes. Many of the theoretical concepts will be prepared by students working with the material provided to them.

Problems (G3, G4, G6, G8, G10, G11, R7, R8) will be developed in practical class sessions following two models. Some problems will be

solved by the teacher so that students find out the way to address them, while others will be solved by students, individually or in groups under the supervision of the teacher. After the work, the problems will be collected, analyzed and corrected by the teacher or the students.

The proposed work for the students (G3, G4, G6, G8, G10, G11, R7, R8) will be of several types: Questions or short exercises, problems similar in complexity to those of the exams and self-correcting tests performed in the e-learning platform. All of these activities will be done in class or at home, and will have a timetable for completion and delivery, their contribution to the final mark being established as well. After correction, the students will be informed of their results and will be given with a summary of the most common mistakes.

EVALUATION

In a first round, the assessment of student learning will be carried out using two models:

1) Through continuous assessment where activities delivered by students and the marks obtained in individual exams will be taken into account (Model A).

2) From the mark of a final exam to be held on the scheduled date and the activities delivered in time along the course (Model B).

In model A the student evaluation will be carried out considering two separate blocks:

Block I: issues 1 to 4; and Block II: issues 5 to 9.

The exam of Block I will be carried out after finishing the subject of this block, whereas the exam of Block II will be on the date of the first call. The requirements to be qualified by the model A) are:

- deliver in time all the activities with an average score of 5 or over.

- to get in each of the individual exams a mark equal or greater than 4.5.

The final mark for this model A) will be calculated using the following criteria:

20% Activities delivered (G4, G6, G8, G10, G11, R7, R8)

48% Individual exam Block I (G3, G4, G6, G11, R7, R8)

32% Individual exam Block II (G3, G4, G6, G11, R7, R8)

To pass the course with this model A) the final mark will have to be equal to or greater than 5. Any student who does not meet any of the mentioned requirements will have to pass the course on the first round by the model B), or go to the second call if a mark equal or greater than 4.5 is not achieved in the exam of block II.

In model B) the student has to do a final exam of the two blocks, on the date scheduled, which will only count 80% of the final mark, whereas the remaining 20% of the mark will be obtained from the activities delivered on time. In the final exam a mark equal or greater than 4.5 must be obtained and, in order to pass the course, the final mark must be equal or greater than 5.

In the second call, only the model B is applicable. If during the course the students have not done the Activities, they will be able to do them before the exam of the second call.

In any case, the evaluation system will be governed by that established in the regulations of the Universitat de València about the evaluation ("Reglament de Avaluació i Qualificació de la Universitat de València per a Graus i Màsters"; https://goo.gl/UdDYS2).

REFERENCES

Basic

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- Pressure Vessels Field Manual. Common Operating Problems and Practical Solutions M. Stewart, O. T. Lewis (Elsevier, 2013); Libro en formato electrónico para miembros de la UV

Additional

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- Problemas resueltos de teoría de máquinas y mecanismos J. L. Suñer et al. (Editorial UPV, 2001)