

Academic Year: ( 2023 / 2024 )

Review date: 05-12-2023

Department assigned to the subject: Continuum Mechanics and Structural Analysis Department

Coordinating teacher: ARTERO GUERRERO, JOSE ALFONSO

Type: Electives ECTS Credits : 6.0

Year : 4 Semester :

## REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

We advise you not to take this course if you have not passed the following subjects:

Mechanics of structures  
Elasticity and Strength of materials.

## SKILLS AND LEARNING OUTCOMES

CB1. Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study

CB2. Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.

CB3. Students have the ability to gather and interpret relevant data (usually within their field of study) in order to make judgements which include reflection on relevant social, scientific or ethical issues.

CB5. Students will have developed the learning skills necessary to undertake further study with a high degree of autonomy.

CG1. Ability to solve problems with initiative, decision-making, creativity, critical reasoning and to communicate and transmit knowledge, skills and abilities in the field of Industrial Engineering.

CG3. Ability to design a system, component or process in the field of Industrial Technologies to meet the required specifications

CG4. Knowledge and ability to apply current legislation as well as the specifications, regulations and mandatory standards in the field of Industrial Engineering.

CG5. Adequate knowledge of the concept of company, institutional and legal framework of the company. Organisation and management of companies.

CG6. Applied knowledge of company organisation.

CG8. Knowledge and ability to apply quality principles and methods.

CG9. Knowledge and ability to apply computational and experimental tools for the analysis and quantification of Industrial Engineering problems.

RA1. Knowledge and understanding: Have basic knowledge and understanding of science, mathematics and engineering within the industrial field, as well as knowledge and understanding of Mechanics, Solid and Structural Mechanics, Thermal Engineering, Fluid Mechanics, Production Systems, Electronics and Automation, Industrial Organisation and Electrical Engineering.

RA2. Engineering Analysis: To be able to identify engineering problems within the industrial field, recognise specifications, establish different resolution methods and select the most appropriate one for their solution

RA3. Engineering Design: To be able to design industrial products that comply with the required specifications, collaborating with professionals in related technologies within multidisciplinary teams.

RA4. Research and Innovation: To be able to use appropriate methods to carry out research and make innovative contributions in the field of Industrial Engineering.

RA5. Engineering Applications: To be able to apply their knowledge and understanding to solve problems and design devices or processes in the field of industrial engineering in accordance with criteria of cost, quality, safety, efficiency and respect for the environment.

RA6. Transversal Skills: To have the necessary skills for the practice of engineering in today's society.

## OBJECTIVES

Knowledge of the types of protection used in transports and infrastructures against projectiles and explosives.

Knowledge of the main material models used for dynamic loadings

Acquisition of the fundamentals of the impact analysis and the propagation of elastic and plastic waves.

Knowledge about dynamic characterization of materials

Acquisition of the technological knowledge needed to calculate analytically protections of metals, ceramics, metal+ceramic, fabrics and composites

Ability to characterize experimentally material in the dynamic regime (medium and high strain rate).

Ability to use specific software to analyze, design and calculation of structural elements against impact, developing a critical awareness.

Know and apply science knowledge and technology based on the industrial technology engineering.

Capacity to design, develop, implement, formulate and solve problems inside wide and multidisciplinary context, being able to integrate knowledge, working on multidisciplinary teams.

Understand the impact of the industrial technology engineering on the environment, sustainable development and importance to work on a professional job environment.

Be able to communicate knowledge and conclusions clearly, orally or written, into specialized and non-specialized public

Learning ability that lets you to continue study along the whole life for an adequate professional development.

Incorporate new technologies and tools from the industrial technology engineering in its professional skills.

Managing projects and human teams.

## DESCRIPTION OF CONTENTS: PROGRAMME

Topic 0: STRUCTURE AGAINST IMPACT: CONCEPT, INTEREST AND MATERIALS. Introduction.

Topic 0.1: Types of protection. Momentum, impact and impulse

Topic 0.2: Materials used for protection.

Topic 1: ADVANCE MATERIAL MODELS FOR DYNAMIC LOADING. Introduction

Topic 1.1: Metals. Tresca and Von Mises.

Topic 1.2: Ceramics. Mohr and Drucker-Prager.

Topic 1.3: Composite. Orthotropic elasticity. Failure criteria (Tsai Hill) and damage model (linear). Delamination (Brewer failure criteria and linear damage model).

Topic 2: ELASTIC AND PLASTIC WAVES. Introduction.

Topic 2.1: Elastic wave propagation.

Topic 2.2: Plastic wave propagation.

Topic 2.3: Shock wave and Equation of state.

Topic 3: DYNAMIC MATERIAL CHARACTERIZATION. Introduction

Topic 3.1: Medium strain rate characterization. Charpy test and low velocity impact test.

Topic 3.2: High strain rate characterization. Hopkinson bars and Taylor tests.

Topic 4: VIRTUAL TESTING: MEF MODELS APPLIED TO DYNAMIC CHARACTERIZATION. Introduction

Topic 4.1: Explicit MEF

Topic 5: PENETRATION MECHANICS OF METALS, CERAMICS, FABRIC AND COMPOSITE. Introduction

Topic 5.1. Penetration mechanics in metals. Piercing vs Plugging.

Topic 5.2. Empirical models. Thor, SRI and BRL equations. Cunniff curves. Lambert Jonas.

Topic 5.3. Analytical models. Pack-Evans. Tate & Alekseevskii. Rosenberg & Dekel. Energetic balance. Averbuch & Bodner. Florence model

Topic 5.4. Penetration mechanics in composite and fabrics. Energy balance. Roylance.

Topic 6. APPLICATION OF DESIGN OF STRUCTURE AGAINST IMPACT. Introduction.

## LEARNING ACTIVITIES AND METHODOLOGY

In each week one lecture session (master class) and one practical session (in reduced groups) will be taught. The first is geared to the acquisition of theoretical knowledge, and the second to the acquisition of practical skills related to theoretical concepts. Additionally, students will complement the classes with work at home, using material provided on Aula Global.

This subject has an important practical component. In addition to these sessions, 2 laboratory practical

sessions and 5 practical computer sessions using a FEM code (LS-DYNA) will be imparted. These labs are imparted in reduced groups (maximum 20 students). These practices are mandatory.

At the end of the semester tutorial session will be held. Students also have the possibility of individual tutorials.

During the course 2 partial exams will be done (45 min aprox) to evaluate the knowledge acquisition

#### ASSESSMENT SYSTEM

Final exam : 0%

Continuum evaluation: 100%

- Report experimental lab: 25%
- Partial exam 1: 25%
- Partial exam 2: 25%
- Report numerical lab: 25%

<b>% end-of-term-examination:</b>	0
<b>% of continuous assessment (assignments, laboratory, practicals...):</b>	100

#### BASIC BIBLIOGRAPHY

- Johnson W. Impact Strength of Materials, Edward Arnold, 1972
- P J Hazell Armour:materials, theory and design, CRC Press, 2016
- T. X. Yu, Xinming Qiu Introduction to Impact Dynamics, Wiley, 2018
- Z. Rosenberg and E. Dekel Terminal Ballistics, Springer Berlin Heidelberg, 2012
- Zukas et al Impact Dynamics, Krieger Publishing Company, 1992

#### ADDITIONAL BIBLIOGRAPHY

- Abrate, S Impact on composite structures, Cambridge University Press , 1998
- Graff, K. F Wave motion in elastic solids, Dover Publications, Inc. New York, 1975
- Sidney S. Jacobson Donald E. Carlucci, Donald E. Carlucci Ballistics: Theory and design of guns and ammunition, second edition, CRC Press, 2013
- Vicente Sánchez Gálvez Materiales para la defensa: Cuaderno 10, Cátedra ISDEFE-UPM, 2012
- Zukas, J.A High velocity impact dynamics, John Wiley & Sons, 1990
- Zukas, J.A., Walters, W.P.. Explosive effects and applications, Springer, 1998