



UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2022/2023
MASTER'S DEGREE (MSC)	AEROSPACE ENGINEERING
SUBJECT	EXPERIMENTAL STRESS ANALYSIS
TYPE OF EDUCATIONAL ACTIVITY	C
AMBIT	20907-Attività formative affini o integrative
CODE	01258
SCIENTIFIC SECTOR(S)	ING-IND/14
HEAD PROFESSOR(S)	PITARRESI GIUSEPPE Professore Ordinario Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	6
INDIVIDUAL STUDY (Hrs)	96
COURSE ACTIVITY (Hrs)	54
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	1
TERM (SEMESTER)	1° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	PITARRESI GIUSEPPE Tuesday 14:00 15:30 Ufficio del docente (stanza O119) ubicato Edificio 8 primo piano plesso dell'Ex Istituto di Costruzione di Macchine (in fondo al corridoio centrale). Thursday 14:00 15:30 Ufficio del docente (stanza O119) ubicato Edificio 8 primo piano plesso dell'Ex Istituto di Costruzione di Macchine (in fondo al corridoio centrale).

<p>PREREQUISITES</p>	<p>Basic knowledge of the below-listed subjects is advised:</p> <ul style="list-style-type: none"> - Maths: Tensorial Calculus, Complex Numbers, Trigonometry, - Physics: basic notions of Electrical Circuits, Heat Transfer by conductivity and irradiance, Electromagnetism. - Mechanics of Continuum: Stress and Strain Tensorial formulations and relationships, Isotropic/Orthotropic behavior, Elastic behavior and generalized Hook's law.
<p>LEARNING OUTCOMES</p>	<p>KNOWLEDGE AND COMPREHENSION OF: Students attending the course will gain knowledge on four common approaches to modern Experimental Mechanics:</p> <p>1) Electrical strain gauges. Students will learn how to select and use electrical strain gauges for strain measurements on different materials, environments and stress fields. In addition, they will learn how to exploit this technology for the correct conditioning and use of load cell and extensometer transducers.</p> <p>2) IR Thermography. The principles of IR irradiation will be provided in order to use thermal cameras for the correct evaluation of an object's temperature field. Students will, in particular, learn how the temperature of structures can be processed in the time or frequency domain for retrieving information on the stress field (Thermoelastic Stress Analysis) or the structural integrity (InfraRed Non-Destructive Testing) of materials and components.</p> <p>3) Optical Methods 1: interferometry, Photoelasticity, Optical Fibres, and Fibre-Bragg Grating sensors: The principles of coherent light, polarized light, and interferometry will be presented under the perspective of measuring displacement and deformation of loaded structures. The photoelastic Stress Analysis technique will be presented in detail, with lab implementation of photoelastic stress analysis experiences.</p> <p>4) Optical Methods 2: Digital Image Correlation: Students will learn about the principles of digital image correlation algorithms, the influence of optical camera parameters, and how to implement a DIC-2d experiment, interpreting results in terms of accuracy of measured displacements and strains.</p> <p>It is finally observed that the knowledge gained on Electrical Strain Gauges and IR Thermography is useful to gain the second level qualification as personnel performing industrial Non-Destructive Testing, according to the International Standard EN ISO 9712.</p> <p>Ability to: From the theoretical knowledge and comprehension of the experimental techniques, and through the lab activities, students will gain the ability to:</p> <ul style="list-style-type: none"> - Select the most appropriate experimental stress analysis technique based on the material/component to analyze and information to retrieve; - choose and set up the instrumentation for the specific technique; - perform the measurements; - record and classify data and results from testing; - present data through reports.
<p>ASSESSMENT METHODS</p>	<p>Only one oral examination session is required. A constant attendance of the lab activities is mandatory. In particular, attendance of 70 % of lab hours is required. Furthermore, a final written report on class exercises and lab activities is required, This report is to be prepared by a team group of 4-5 students and will be subject to evaluation during the final examination. Team groups will be established at the beginning of the course and will remain unchanged for the whole duration of the course.</p> <p>Students who book for their examination must submit their final Team report to the lecturer at least three days in advance on the date of the exam. The report is provided in an electronic version (pdf format) by email.</p> <p>A typical exam will last between 30 and 60 minutes, and will be structured as follows:</p> <ul style="list-style-type: none"> - one question on each of the following techniques: Strain Gauges; Photoelasticity; Fibre Bragg Grating Sensors; Digital Image Correlation; IR-Thermography and Thermoelastic Stress Analysis; - overview of the lab report. <p>All questions will require an oral discussion. Furthermore, some questions may require some short math demonstrations, writing of important equations, or sketch drawings.</p> <p>The following aspects of the exam performance will be considered and marked</p>

	<p>by the lecturer:</p> <p>a) The level of details and ability to make comparisons and links among techniques, among solutions and with experiences learned during the lab activities;</p> <p>b) The clearness of the answer and proper use of technical terminology;</p> <p>c) The effectiveness of using graphical and mathematical representations to derive knowledge and supplement the oral exposition;</p> <p>d) The ability to organize and perform team activities, the quality of the lab report in terms of completeness, the rigor of data post-processing and interpretation of results, and general effectiveness of the graphical presentation of the report.</p> <p>The above described four performance factors (a,b,c,d) will receive a separate mark that can be:</p> <p>excellent (9 points): Very good knowledge of all topics and relative interactions (a), very good technical language skills (b), Very good ability to derive analytically answers to problems (b,c,d), the student is able to apply the knowledge in an elegant and effective way to solve problems and answer questions (c,d), The student is able to organize, describe and communicate the results and test setups in a very elegant, synthetic and effective way, providing an overall original contribution (d).</p> <p>Good (7 points): Good knowledge of all topics (a), good technical language skills (b), good ability to apply the knowledge to derive answers to problems (b,c,d), The student is able to organize, describe and communicate the results and test setups in an effective way (d).</p> <p>Sufficient (6 points): has complete knowledge of topics but shows a limited ability to use such knowledge (a), comprehensible technical language skills (b), the student has a limited ability to describe and solve problems analytically, with only sufficient drawing skills (c,d), The student is able to organize, describe and communicate the results and test setups in a sufficient way (d).</p> <p>Mediocre (4 points): has a not-complete knowledge of topics and shows a lack of ability to use such knowledge (a), low technical language skills (b), the student has a lack of ability to describe and solve problems analytically without the help of the teacher (c,d), The student organizes, describes and communicates the results and test setups in a confused and often misleading way, with a low level of details (d).</p> <p>Insufficient (0 points): his knowledge of topics is unacceptably limited (a,b,c), the lab report is copied from the work of colleagues and the student does not demonstrate to have understood its content, is not able to justify choices made and does not demonstrate to have contributed to its preparation (d), the lab reports contain macroscopic errors on the description of setups and data treatment (d).</p> <p>The final mark will result from adding the scores assigned to each performance factor: a,b,c,d. An example is as follows: a=7, b=6, c=4, and d=0 will gain a final mark of 17. The maximum vote of 30 is obtained when the total score is higher than 30.</p>
EDUCATIONAL OBJECTIVES	<p>The course provides knowledge on techniques for the experimental measurement of stresses, strains and displacements on rigid structures when subject to in-service or other specific loading scenarios. Such quantities are fundamental for the evaluation of structural performances.</p> <p>Students will learn the theoretical background and implementation schemes of some of the most influential techniques used in modern Experimental Mechanics, which can be applied for the evaluation of complex structures as well as the characterization of the mechanical behaviour of traditional and innovative materials.</p> <p>This knowledge completes that on analytical and numerical approaches of Structural Mechanics, allowing students to gain a comprehensive qualification for the evaluation of innovative materials, in terms of structural performances and structural integrity.</p>
TEACHING METHODS	<p>The whole course comprises 36 hours of lectures and 18 hours of laboratory group activities for a total of 54 hours, typically delivered in about 12 weeks, with 5 hours per week.</p> <p>Lectures will consist of oral presentations assisted by the contemporary use of</p>

	<p>multimedia power-point projection and a checkboard.</p> <p>Lab activities will be held, whenever possible, in lecture theatre O007, which is equipped for the implementation of experimental setups regarding Electrical Strain Gauges (installation and measurement), IR Thermography, Digital Image Correlation, and Photoelastic Stress Analysis.</p> <p>Some lab activities will be held in the "Laboratorio Prova Materiali e Componenti" of the DICGIM department (O002). Here students will find and be introduced to some common testing facilities for materials mechanical testing.</p>
SUGGESTED BIBLIOGRAPHY	<p>[1]A. Ajovalasit, D. Cerniglia, G. Petrucci, G. Pitarresi – Introduzione ai metodi di Meccanica Sperimentale dei Solidi. Ed. Aracne, Marzo 2018 (ISBN: 978-88-255-1152-9).</p> <p>[2]A. Ajovalasit, G. Pitarresi – Estensimetri a fibra ottica con reticolo di Bragg. Dispensa interna fornita dal docente (internal report provided by the lecturer).</p> <p>[3]G. Pitarresi – Appunti e slides del corso (slides and notes).</p> <p>Book [1] can also be found on-line, on specialized electronic book web shops. PDF electronic versions are also available from http://www.aracneeditrice.it/, www.amazon.it, www.libreriauniversitaria.it. The hard copy will take about 5-10 days time for delivery.</p> <p>The lecturer's slides and internal booklets [2,3] will be available from a web cloud repository. A link to such web cloud will be provided by the lecturer upon request, and by default to all students attending the class.</p>

SYLLABUS

Hrs	Frontal teaching
9	<p>Electrical Strain Gauges (ER): Features of ERs (2), selection criteria for ERs (1), the Wheatstone bridge circuit for electrical resistance measurements (1), ER installation configurations for simple loading cases (1), influence of leads in Wheatstone bridges for ERs (1.5), Shunt calibration of Wheatstone bridge (0.5), processing of in-plane strain data from single and rosettes ERs (1.5), strain data processing on orthotropic materials (0.5). (in brackets the hours spent for each topic).</p>
8	<p>Thermal Methods for Structural Analysis. Infrared Thermography: basic concepts on radiation heat transfer (1); Problems related with measurement of temperature from Infrared Thermal Cameras (1); State of the art on commercial IR Camera Systems (0.5); Thermoelastic Effect based Stress Analysis: TSA (2); Lock-In treatment of thermal data (2); Application case studies of TSA (1);</p>
7	<p>Optical Methods #1: photoelasticity and interferometric techniques. Displacement/strain measurement by optical methods: general principles, coherent light, Interferometry (1 hour). Birefringent materials and the photoelastic effect (1 hour); The Optics of polariscope (1 hour); Acquisition of photoelastic data and material photoelastic calibration (1 hour); White Light Photoelasticity (1 hour); Automatic photoelastic stress analysis by digital methods: RGB photoelasticity (0.5 hour); Phase Stepping methods (0.5 hour); Photoelastic coatings (1 hour).</p>
9	<p>Optical Methods #2: digital image correlation techniques. Principle of two-dimensional DIC (1 hour); Displacements and deformations in the Continuum Mechanics: Deformation of subsets and shape functions (0.5 hour); Determination of strains (0.5 hour); Correlation functions and their optimization (1.5 hour); The evaluation of strains from the displacement field (0.5 hour); Experimental implementation of DIC techniques: Preparation of samples and characteristics of speckles (0.5 hour); Optical setup and image acquisition (1 hour); Systematic and random errors in DIC (1 hour); Stereo Digital Image Correlation: the three dimensional case (1 hour); Calibration of the stereo-vision system (0.5 hour); Determination of shape and displacements (0.5 hour); Basics principles of Digital Volume Correlation (0.5 hour).</p>
3	<p>Optical methods #3: Fibre Bragg Grating strain gauges: Principle; experimental information and characteristic relationship; application to stress fields and materials; strain and temperature sensitivity; Comparison between FBG ed ER and field of application of FBGs.</p>

Hrs	Workshops
18	<p>ERStrainGauges_1 - installation and checkup of a single grid ER gage on a steel component (3 hours). ERStrainGauges_2 - measurements on bending and torsional beams and ERs with various configurations (1.5 hours). ERStrainGauges_3 - influence of leads on ER strain gauges measurements (1.5 hours). ERStrainGauges_4 - measurements with ER rosettes from metallic and polymer matrix composite materials (1.5 hours). ERStrainGauges_5 - conditioning and measurements with strain gauge transducers (load cells, extensometers, etc.), and use of high-end data loggers (1.5 hours).</p> <p>Photoelasticity_1 - use of the polariscope in monochromatic and white light, with different photoelastic models (3 hours).</p> <p>DIC_1: Implementation of a DIC-2D setup by means of the N-Corr software (3 hours).</p> <p>IR-Thermography_1 - determination of the emissivity of a generic real material according to the ASTM standardized procedure (1 hour). IR-Thermography_2 - Implementation of Thermoelastic Stress Analysis measurement, with acquisition and lock-in post-processing of thermal data from a sample subject to sinusoidal fatigue loading on a servo-hydraulic testing machine (3 hours).</p> <p>Regarding the ER Strain Gauges experiences, the class will be divided into groups, who will run all lab experiences separately. Each group is requested to prepare a final report describing all lab experiences. This report will also contain the post-processing of data and presentation and discussion of results where appropriate. The student's participation in the lab activities and the final report will contribute to the final assessment and final mark achieved (see also the "assessment methods" section of the present document).</p>