UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2017/2018
MASTER'S DEGREE (MSC)	MECHANICAL ENGINEERING
SUBJECT	EXPERIMENTAL STRESS ANALYSIS
TYPE OF EDUCATIONAL ACTIVITY	C
AMBIT	20933-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	EXPERIMENTAL STRESS ANALYSIS - Corso: INGEGNERIA AEROSPAZIALE EXPERIMENTAL STRESS ANALYSIS - Corso: AEROSPACE ENGINEERING
YEAR	2
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).

DOCENTE: Prof. GIUSEPPE PITARRESI

PREREQUISITES	A basic knowledge of the below listed subjects is advised to help a full and prompt understanding of Experimental Stress Analysis topics: - Maths: Tensorial Calculus, Complex Numbers, Trigonometry, - Phisics: basic notions of Electrical Circuits, notions of Heat Transfer by conductivity and irradiance, notions of Electromagnetism. - Statistics: basic knowledge of statistical treatment of data. Accuracy, Precision and Bias, sensitivity and resolution of measurements. - Mechanics of Continuum: Stress and Strain Tensorial formulations and relationships, Isotropic/Orthotropic behaviour, Generalised Hook's law and Thermal stresses. - Mechanics of Materials: Ductile and brittle behaviour, Elastic stiffness/ compliance parameters, basic Fracture Mechanics, Static and Fatigue strength behaviours.
LEARNING OUTCOMES	Knowledge and comprehension of: Students attending the course will gain knowledge on four main approaches of Experimental Mechanics: 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. 2) IR Thermography. The principles of IR irradiation will be provided in order to use thermal cameras for the correct evaluation of an object 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. 3) Optical Methods 1: interferometry and Photoelasticity: The principles of coherent light, polarized light, and interferometry will be presented under the prospective of measuring displacement and deformation of loaded structures. Photoelastic Stress Analysis technique will be presented in details, with lab implementation of photoelastic stress analysis experiences. 4) Optical Methods 2: Digital Image Correlation: Students will learn about the principles of digital image correlation algorithms, the influence of optical and tele-camera parameters, and how to implement a DIC-2d experiment, interpreting results in terms of accuracy of measured displacements and strains. 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. Ability to: From the theoretical knowledge and comprehension of the experimental techniques, and through the lab activities, students will gain the ability to: - choose and implement electrical strain gauge setups for measuring strain fields on isotropic and orthotropic materials; - post-process strain gauge signals to obtain information on the stress/strain field, and material elastic/plastic/physical parameters; - condition and measure with electrical strain gauge based transducers such as load cells or extensometers; - operate IR Cameras and interpret correctly thermograms from different environment conditions; - post-process thermal data in the time and frequency domains, and propose setups of Active Thermography for NDT analyses; - implement optical setups for Photoelastic Stress Analysis, and interpret the photoelastic maps to retrieve information on the stress field; - implement Digital Image Correlation setups at different geometric scales, being able to comprehend the influence of various tuning parameters (hardware and software) on the accuracy level of measured displacements and strains. More in general students will be able to: - Select the most appropriate experimental stress analysis technique based on the material/component to analyse and information to retrieve; - choose and setup the instrumentation for the specific technique; - perform the measurements; - record and classify data and results from testing; - present data through reports.
ASSESSMENT METHODS	Only one oral examination session is required. A constant attendance of the course is considered an important prerequisite to access examination. In particular attendance of the 70 % of lab hours is considered essential. In fact the experience gained in the lab is unique and hardly achievable by any self-preparation. Furthermore the report on the lab

activities, to be prepared by each student singularly, will be subject to evaluation and contribute to the final mark.

Students who book for their examination must submit their report on lab activities to the lecturer with at least one week advance from the day of the exam. The report can also be provided in electronic version by email.

A typical exam will last between 30 and 60 minutes, and will be structured as follows:

- one questions on Strain Gauges Techniques;
- one question on IR Thermography techniques;
- one question on Digital Image Correlation techniques;
- one question on Photoelasticity and optical techniques in general;
- overview of the lab report together with the examiner, who can ask some specific comments or explanations on the content of the report.

All questions will require an oral discussion. Furthermore some questions may require some short math demonstrations, writing of important equations or sketch drawings. For this reason the student will be provided with blank sheets and pen for writing down the necessary notes.
At least one question will require a written response involving a brief math demonstration.

The following aspects of the exam performance will be considered and marked by the lecturer:

a) The level of details and ability to make comparisons and links among techniques, among solutions and with experiences learned during the lab activities;

b) The clearness of the answer and proper use of technical terminology;

c) The effectiveness of using graphical and mathematical representations to derive knowledge and supplement the oral exposition;

d) The quality of the lab report in terms of: completeness of content, rigor of data post-processing and interpretation of results, general originality/effectiveness in the graphical presentation of the report.
Please notice that Lab reports are not expected to became or perform as textbooks, with long over-detailed descriptions of background theory. Instead, ability to synthesis and conciseness will be considered as an added value.

The above described four performance factors (a,b,c,d) will receive a separate mark that can be:

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).

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).

Sufficient (6 points):
has a 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).

Mediocre (4 points):
has a not-complete knowledge of topics and shows an almost null ability to use such knowledge (a), low technical language skills (b), the student has a null 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 low level of details (d).

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). The final mark will result from adding the scores assigned to each performance factor: a,b,c,d. An example is as follow: a=7, b=6, c=4, d=0 will gain a final mark of 17. The maximum vote of 30&Lode is obtained when the total score is higher than 30.
EDUCATIONAL OBJECTIVES	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. Students will learn the theoretical background and implementation schemes of some of the most influential techniques used in 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. This knowledge completes that on analytical and numerical approaches of Structural Mechanics, allowing students to gain an in-depth and comprehensive qualification for the application of new and innovative Materials, the evaluation of structural performances and the evaluation of structural integrity. The lab activities carried out during the course will also provide basic measurement skills useful for any prospective of engagement in scientific research activities, in both industrial or academic contexts.
TEACHING METHODS	The whole course comprises 36 hours of lectures and 18 hours of laboratory group activities for a total of 54 hours (9 hours per credit for a total of 6 credits). The whole 54 hours are typically delivered in about 12 weeks, with 5 hours per week. Lectures will consist of oral presentations assisted by the contemporary use of multimedia power-point projection and checkboard. Checkboard will be preferred for topics with prevalent analytical and mathematical developments, while power-point for more effective graphical representations and video tutorials. Lab activities will be held in lecture theater O007, which is equipped as a didactic laboratory for the implementation of experimental setups regarding Electrical Strain Gauges (installation and measurement), IR Thermography, Digital Image Correlation and Photoelastic Stress Analysis. 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, such as electro-mechanic and servo-hydraulic universal testing machines and typical accessories and transducers for the characterization of the mechanical behavior of materials and structures.
SUGGESTED BIBLIOGRAPHY	[1]A. Ajovalasit, D. Cerniglia, G. Petrucci, G. Pitarresi – Introduzione ai metodi di Meccanica Sperimentale dei Solidi. Ed. Aracne (2017). [2]G. Pitarresi – Appunti e slides del corso (slides and notes). 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/. The lecturer's slides and notes [2] will be available from a web cloud repository. The same cloud will contain a selection of technical/scientific documents (mostly in pdf format), allowing a deeper but optional insight on several specific topics of the course. A link to such web cloud will be provided by the lecturer upon request, and by default to all students attending the class.

SYLLABUS

Hrs	Frontal teaching
9	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).

SYLLABUS

Hrs	Frontal teaching
9	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); Passive and Active Thermography and applications to Non-Destructive materials Evaluation (IR NDT): Pulsed Thermography (0.5); Lock-In Thermography (0.5); Pulsed-Phase Thermography (0.5).
9	Optical Methods #1: photoelasticity and interferometric techniques. Displacement/strain measurement by optical methods: general principles, coherent light, Interferometry (1.5 hour). Birefringent materials and the photoelastic effect (1 hour); The Optics of polariscope (1.5 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 (1 hour); Phase Stepping methods (1 hour): Photoelastic coatings (1 hour).
9	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 Corrrelation (0.5 hour).

Hrs	Workshops
18	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 stran 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). Photoelasticity_1 - use of the polariscope in monochromatic and white light, with different photoelastic models (3 hours). IRThermography_1 - detrerrmination of the Emissivity of a generic real material according to an ASTM standardized procedure (1 hour). IRThermography_3 - 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 (2 hours). IRThermography_2 - implementation of a active IR NDT technique for the NDT evaluation of a Fiber Reinforce Polymer matrix composite panel with embedded delamination defects (1 hour). DIC_1: Implementation of a DIC-2D setup by means of the N-Corr software (2 hours). Regarding the ERStrainGauges experiences, the class will be divided into four groups, who will run all lab experiences separately. Each student 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. Both the student active participation in the lab activities and the final report will contribute to the final assessment and final mark achieved by the student (see also the "assessment methods" section of the present document).