UNIVERSITÀ DEGLI STUDI DI PALERMO

SCHOOL	POLYTECHNIC SCHOOL
ACADEMIC YEAR	2016/2017
SECOND CYCLE (7TH LEVEL) COURSE	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 Associato Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	6
INDIVIDUAL STUDY (Hrs)	96
COURSE ACTIVITY (Hrs)	54
PROPAEDEUTICAL SUBJECTS	
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).

DOCENTE: Prof. GIUSEPPE PITARRESI

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 11 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 and Photoelasticity. 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.
ASSESSMENT METHODS	Only one oral examination session is required. 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 session will last between 30 and 60 minutes, and will be structured as follows: - two questions on Strain Gauges Techniques; - one question on IR Thermography 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 representations as a tool to deliver the answer; d) The ability to derive results and knowledge from handling general mathematical laws and mathematical/graphical instruments; e) 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 performance objectives will receive a separate mark that can be: excellent (7 points), good (5 points), sufficient (4 points), mediocre (3 points), Insufficient (0 points). The final mark will result from adding the scores assigned to each performance objective: a,b,c,d,e.

	The maximum vote of 30&Lode is obtained when the total score is higher than 30. The report evaluation must score at least mediocre. A score of insufficient on the lab report will determine a failed exam.
LEARNING OUTCOMES	Knowledge and comprehension of: Students attending the course will gain knowledge on three main tools of Experimental Mechanics: 1) Electrical strain gauges. this technique is the widest used and reliable technology for point-wise strain and displacement measurement on rigid structures. Students will learn how to select and use electrical strain gauges for direct strain measurements on different materials, environments and stress fields. Also 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 extrapolation of an object temperature field. Students will then learn how the temperature of structures can be useful 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. The principles of coherent light, polarized light, interferometry will be presented under the prospective of measuring very small displacement fields for the evaluation of elastic-plastic deformation of loaded structures. The Photoelastic Stress Analysis technique will then be presented in details as a benchmark and training for the appraisal of the powerful potentialities of optical methods in Experimental Mechanics. In general the knowledge gained on Electrical Strain Gauges and IR Thermography will be equivalent if not superior to that required by the International standard EN ISO 9712, regarding the second level qualification and certification of personnel who performs industrial Non-Destructive Testing. 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 algorithms of digital image post-processing on both photoelastic and thermographic/thermoelastic maps. 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.
EDUCATIONAL OBJECTIVES	The course wants to provide knowledge on techniques and approaches 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 and the integrity of traditional and innovative materials and their structures. 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 behavior of materials. This knowledge will be complementary to the analytical and numerical approaches of Structural Mechanics, allowing students with an interest towards development of new innovative Materials and Structural Design to gain a fundamental tool for their tasks.
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 of instruments. - 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.
SUGGESTED BIBLIOGRAPHY	[1] A. Ajovalasit – Analisi sperimentale delle tensioni con gli estensimetri elettrici a resistenza. Ed. Aracne (2006). [2] A. Ajovalasit – Analisi sperimentale delle tensioni con la fotomeccanica. Ed. Aracne (2006). [3] G. Pitarresi – Appunti e slides del corso (slides and notes). Books [1,2] 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 [3] will be available from a web cloud. 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
13	Electrical Strain Gauges (ER): Historical evolution of strain gauge concepts and the electrical Strain Gauge ER (1), 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 (1.5), influence of leads and contact resistance in Wheatstone bridges for ERs (2.5), Wheatstone bridge non-linearity (0.5), 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), use of ERs for measuring Thermal Stresses (0.5), influence of measurement and alignment errors in ER measurements (0.5). (in brackets the hours spent for each topic).
11	Thermal Methods for Structural Analysis. Infrared Thermography: basic concepts on radiation heat transfer (2); Problems related with measurement of temperature from Infrared Thermal Cameras (1); State of the art on commercial IR Camera Systems (0.5); Passive and Active Thermography and applications on Non-Destructive materials Evaluation (IR NDT): Pulsed Thermography (2); Thermoelastic Effect based Stress Analysis: TSA (1); Lock-In treatment of thermal data (2); Lock-In Thermography for Infrared Non-Destructive Testing (0.5); Pulsed-Phase Thermography and Frequency Modulated Thermal Wave Thermography (0.5) Thermoelastic Stress Analysis with orthotropic materials (1.5).
12	Optical Methods for structural analysis. Displacement/strain measurement by optical methods: general principles, coherent light, Interferometry (2 ore). Birefringent materials and the photoelastic effect (1 ore); The Optics of polariscope (2.5 ore); Acquisition of photoelastic data and material photoelastic calibration (1.5 ore); White Light Photoelasticity (2 ore); Automatic photoelastic stress analysis by digital methods (2 ore); Short overview of Digital Image Correlation techniques (1 ore).

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 (2 hours). Photoelasticity_2 - implementation of two digital methods of automatic photoelasticity, to be applied on data collected from real photoelastic models and from a Virtual Polariscope (2 hours). IRThermography_1 - detrerrmination of the Emissivity of a generic real material according to an ASTM standardized procedure (1 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 (1.5 hours). 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 (2.5 hours). 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 postprocessing 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 assesment and final mark achived by the student (see also the "assessment methods" section of the present document).