Course-Plan

School : School of Engineering
Department : Mechanical Engineering
Course Code : ME 511
Course Name : Experimental Stress Analysis for Design
Total Class Hours: **39**

Instructors: **Rakesh Bhadra**

1. **Abstract**

The course covers the basic aspects of experimental stress analysis that includes exhaustive treatment of the most versatile techniques like photoelasticity and strain gauges. In addition, it also provides the fundamental aspects of other experimental techniques such as Moiré, Brittle Coatings, Holography etc. The course also introduces some of the important experimental techniques such as Sachs boring, hole drilling, and neutron diffraction for the analysis of residual stresses.

2. **Objectives:**
    - To understand 'Stress Analysis' in a complete sense.
    - To provide a clear understanding of the analytical, numerical and experimental analysis of stresses.
    - To introduce with different experimental methods for the analysis of service stresses.
    - To introduce with different experimental techniques for the analysis of residual stresses.

3. **Prerequisite of the course:** Solid Mechanics, Theory of Elasticity and plasticity

4. Course Outline and Time Plan

Sl. No.	Topics	Contents	No. of classes (each of hours)
1.	Overview of Experimental Stress Analysis, Review of Stress and Strain Analysis: Stress-strain relations and general equations of elasticity	✓ Overview of experimental stress analysis, Stress analysis – Analytical, Numerical and Experimental approaches, Specific domain of these approaches, Advantages and disadvantages. ✓ Direct information provided by various experimental methods – brief description, Visual appreciation of field information, ✓ Stress, Strain and Displacement fields for various problems: (i) Beam under pure bending— Analytical solution, Fringe contours from various experimental methods, (ii) Cantilever beam with an end load— Analytical solution, Fringe contours from various experimental methods, (iii) Disc under diametral compression – Analytical solution, Fringe contours from various experimental techniques, (iv) Clamped circular plate under a central load – Analytical solution, Fringe contours from various experimental techniques. Physical principle behind various experimental techniques— Strain Gauges, Photoelasticity, Moiré and Brittle Coating. ✓ Discussion on selection of an experimental technique.	6
2.	Strain Measuring Devices: Strain gauges	**Introduction to Strain Gauges:** Strain Gauges- Physical principle, Historical development, Development of SR-4 gauges, Strain sensitivity of a conductor, Gauge construction, Gauge length, Gauge length error in measurement, Thumb rule in selection of gauge length, Commonly used strain gauge materials, Semiconductor strain gauges. **Strain Sensitivity of a Strain Gauge, Bridge Sensitivity, Rosettes:** Strain sensitivity of a strain gauge, Transverse sensitivity factor, Gauge factor, Experimental determination of gauge factor, Wheatstone bridge, Strain measurement options, Bridge sensitivity, Bridge factor, Accuracy achievable in Foil strain gauges, Linearity, Hysteresis and Zero shift, Determination of strain at a point, Three element rectangular rosette. **Strain Gauge Alloys, Carriers and Adhesives:** Delta rosette, Metallic alloys commonly employed, Advance, Isoelastic alloy, Karma alloy, Thermally induced apparent strain, Nichrome-D, Strain gauge carriers, Types, Cements for bonding a strain gauge: Cynoacrylate, Epoxy cements and Polyester cements. **Performance of Strain Gauge System:** Ceramic cements, High temperature strain gauge, Flame spraying Rokide process, Strain gauge linearity, Hysteresis, Drift, Stability, Heat dissipation, Allowable power density, Selection of bridge voltage, Sensitivity of gauge to temperature, Strain sensitivity of a conductor as a function of temperature. **Temperature Compensation, Two wire and Three-wire Circuits:** Temperature compensation, Temperature compensated gauges, Measurement techniques: Two-wire circuit, Gauge factor desensitization, Role of change in temperature, Three-wire circuit, Benefits of three-wire circuits. **Strain Gauge Selection:** Selection compromises, Strain gauge designation	15

		systems, Various gauge patterns for different applications, Guidelines for strain gauge selection. **Bonding of a Strain Gauge:** Temperature effects guiding the selection of certain parameters, Importance of following a bonding procedure, Surface preparation: Strain gauge installation kit, Solvent degreasing, Surface abrading, Layout lines, Surface conditioning, Neutralizing. Strain gauge bonding: Strain gauge handling, Strain gauge alignment, Catalyst application, Bonding with adhesive. Strain sensitivity of a strain gauge, Transverse sensitivity factor, Gauge factor, Experimental determination of gauge factor, Wheatstone bridge, Strain measurement options, Bridge sensitivity, Bridge factor, Accuracy achievable in Foil strain gauges, Linearity, Hysteresis and Zero shift, Determination of strain at a point, Three element rectangular rosette. **Strain Gauge Alloys, Carriers and Adhesives:** Delta rosette, Metallic alloys commonly employed, Advance, Isoelastic alloy, Karma alloy, Thermally induced apparent strain, Nichrome-D, Strain gauge carriers, Types, Cements for bonding a strain gauge: Cynoacrylate, Epoxy cements and Polyester cements. **Performance of Strain Gauge System:** Ceramic cements, High temperature strain gauge, Flame spraying Rokide process, Strain gauge linearity, Hysteresis, Drift, Stability, Heat dissipation, Allowable power density, Selection of bridge voltage, Sensitivity of gauge to temperature, Strain sensitivity of a conductor as a function of temperature. **Temperature Compensation, Two wire and Three-wire Circuits:** Temperature compensation, Temperature compensated gauges, Measurement techniques: Two-wire circuit, Gauge factor desensitization, Role of change in temperature, Three-wire circuit, Benefits of three-wire circuits. **Strain Gauge Selection:** Selection compromises, Strain gauge designation systems, Various gauge patterns for different applications, Guidelines for strain gauge selection. **Bonding of a Strain Gauge:** Temperature effects guiding the selection of certain parameters, Importance of following a bonding procedure, Surface preparation: Strain gauge installation kit, Solvent degreasing, Surface abrading, Layout lines, Surface conditioning, Neutralizing. Strain gauge bonding: Strain gauge handling, Strain gauge alignment, Catalyst application, Bonding with adhesive.	
3.	Photoelasticity	**Theory of photoelasticity:** Physical principle, Historical development, Various branches of photoelasticity, Birefringence, Nature of light, Polarisation, Methods to get polarized light, Understanding polarization, Class experiment on showing crossed polarizers, Passage of light through isotropic media, Snell's laws, Passage of light through crystalline media, Retardation Plates, Stress-optic Law. **Analysis techniques:** Plane polariscope, Circular polariscope, Determination of Photoelastic Parameters at an Arbitrary Point, Tardy's Method of Compensation, Fringe thinning methodologies. **Three dimensional photoelasticity:** Three dimensional photoelasticity, Stress freezing, Slicing, Application to a complex problem, Integrated photoelasticity, Principle of optical **equivalence.**	**8**

4.	Brittle coating methods of strain indication	Historical development of brittle coatings, Methodology of brittle coatings, Crack patterns produced by direct loading, Uniaxial, Biaxial and Isotropic stress fields, Steps in brittle coating tests, Coating selection, Surface preparation. **Analysis of Brittle Coatings:** Undercoating, Application of the coating, Drying. Coating stresses, Uniaxial specimen stress, Nature of coating stress, Calibration of brittle coatings, Influence of Poisson's ratio mismatch, Crack patterns by refrigeration, Crack patterns by relaxation, Stresscoat.	**5**
5.	Residual Stress Analysis	Analytical and numerical solution of residual stresses in metal working processes (autofrettage, welding etc.), Experimental methods for assessing residual stresses: Sachs boring, X-ray diffraction, neutron diffraction and hole drilling method, inference of residual stresses from microhardness test.	**5**
		Total	**39**

Textbooks

1. Dove R.C. and Adams P. H. Experimental Stress Analysis (McGraw Hill, 1992)
2. Dally J.W. and Riley W.F. Experimental Stress Analysis (McGraw-Hill Inc., New York, 1998)
3. Srinath, L.S. and Raghavan M.R. Experimental Stress Analysis (Tata McGraw-Hill, 1998).

References

1. Freddi A. Olmi G. and Cristofolini L. Experimental Stress Analysis for Materials and Structures (Springer, Switzerland, 2015)
2. Timoshenko S.P. and Goodier J.N. Theory of elasticit, (McGraw-Hill International Editions, 1970).
3. Sharpe W.N. Handbook of Experimental Solid Mechanics (Springer, 2008).
4. Noyan I.C. and Cohen J.B. Residual Stress (Springer, 1987)
5. Kandil F.A., Lord J.D., Fry A.T. and Grant P.V. A review of residual stress measurement methods—A guide to technique selection (NPL Report MATC (A)04, February 2001, NPL Materials Centre Queens Road, Teddington, Middlesex, UK).
6. Kamal S.M. Borsaikia A. and Dixit U.S. Experimental assessment of residual stresses induced by the thermal autofrettage of thick-walled cylinders, Journal of Strain Analysis, Vol. 51(2), pp. 144−160, 2016.

5. Evaluation Plan

Test No.	Marks	Duration (minutes)
Assignments (5 assignments)	50	-
Mid-Semester Examination	40	90
End-Semester Examination	60	120
Total	**150**	

All the tests will be held as per the schedule notified by the Controller of Examinations, Tezpur University.

6. Pedagogy:

Lectures, Discussions, Assignments, Group work.

7. Expected Outcome:

After completion of this course, students shall be able to

(a) understand the different experimental techniques for stress analysis,

(b) select a suitable method for experimental determination of service stresses for a problem on hand,

(c) interpret the results obtained from different experimental methods,

(d) understand the concept of residual stresses and understand different experimental techniques for its analysis.