Photoelasticity

Course contents:

In the course an overview of photoelasticity and its several variants ranging from conventional transmission photoelasticity to digital photoelasticity is presented. A representative fringe pattern for each of the variants is provided to give a glimpse of the range of problems it can solve. The technique basically provides the difference of principal stresses/strains and their orientation at every point in the model domain. It is the only whole-field technique which can study the interior of a three dimensional model. The advancements in digital photoelasticity have made photoelastic analysis more efficient and reliable for solving engineering problems. Photoelasticity is useful as a design tool, to understand complex phenomenological issues, and as an excellent teaching aid for stress analysis. It can be used to study models made of transparent plastics, prototypes made of different materials, and also directly on end products such as glass components. With developments in rapid prototyping and novel methods for fringe plotting from finite element results, the technique is ideally suited for hybrid analysis of complex problems.

Subjects covered by the lectures are

- Basic of Optics, Interference of Light Waves
- Polarization of light, Birefringence, Retardation Plates
- Stress-optic Law
- Fringe Contours in Plane Polariscope
- Variants of Photoelasticity
- Digital Photoelasticity
- Fusion of Photoelasticity Rapid Prototyping and Finite Element Analysis
- Interpretation of Photoelasticity Results
- Stress Separation Techniques
- Techniques for the Quantitative Evaluation of Image Data in Optic Metrology
- Techniques for the Qualitative Evaluation of Image Data in Optic Metrology

Learning outcomes of the course :

Through a deep understanding of the theory and the realization of a project, the student will be able to apply theoretical and experimental tools to solve photomechanics (photoelasticity) problems. In particular:

- He will be know basic principle of modern optical methods in experimental solid mechanics such as photoelasticity, holographic interferometry, specle metrology, fringe projection.
- He will have a deep understanding of photoelasticity methods and will be able to summary, compare and explain them.
- He will have a deep understanding of the optic experimental methods in solid mechanics, and will be able to summary, compare and explain them. He will also know their application range.
- He will be able to apply the resolution methods to classical problems of photomechanics.
- He will be able to analyse and to evaluate (justify and criticise) these methods.
- He will be able to analyse new problems.
- He will be able to use experimental methods of solid mechanics.

Prerequisites and co-requisites/ Recommended optional programme components :

Basic knowledge in

- Solid mechanics
- Finite-element method
- Vector calculus
- Plasticity Theory
- Elasticity Theory
- Creep Theory
- Fracture Mechanics
- Finite Element Methods

Planned learning activities and teaching methods :

Exercises with professor assistance and personal project.

Mode of delivery (face-to-face ; distance-learning) :

Face-to-Face

Required readings :

- Springer Handbook of Experimental Solid Mechanics. Editor Pr. W.N. Sharpe. New York : Springer Science+Business Media, LLC. 2008. 1083 p.
- Asundi A.K. Matlab for Photomechanics. Oxford: Elsevier, 2002. 199 p.
- Razumovsky I.A. Interference-Optical Methods of Solid Mechanics. Springer-Verlag Berlin Heidelberg 2011. 180 p.
- Frocht, M.M.: Photoelasticity. John Wiley and Sons, New York (1941).
- Smith, C.W., Kobayashi A.S.: Experimental Fracture Mechanics. In: Kobayasi, A.S. (ed.) Handbook on Experimental Mechanic, Ch. 8. Prentice-Hall, Inc., Englewood Cliffs (1987).

Assessment methods and criteria:

Evaluation is based on the realization of a project related to the use / development of experimental method (photoelasticity) specific to fracture mechanics and on an examination.
The examination is based on the whole content of the class. Problems similar to the ones studied during the classes, and new problems will be part of the questions. Justification using the theoretical content is also asked.
Participation to the examination and achievement of the project are mandatory.

Course Contents

Photoelasticity

Nature and Description of Light
What Is Light? How Is Light Described? The Quantum Model. Electromagnetic Wave Theory. Maxwell's Equations. The Wave Equation. The Harmonic Plane Wave.
Interference of Light Waves
The Problem and the Solution. Collinear Interference of Two Waves
Path Length and the Generic Interferometer
Index of Refraction. Optical Path Length
Photoelasticity
Polarization. Birefringence. Retardation Plates.

Transmission Photoelasticity
Physical Principle. Stress–Optic Law
Fringe Contours in a Plane Polariscope. Jones Calculus. Ordering of Isoclinics. Ordering of Isochromatics. Calibration of Model Materials
Variants of Photoelasticity
Three-Dimensional Photoelasticity. Dynamic Photoelasticity. Reflection Photoelasticity. Photo-orthotropic Elasticity. Photoplasticity.
Digital Photoelasticity
Fringe Multiplication and Fringe Thinning. Phase Shifting in Photoelasticity. Ambiguity in Phase Maps. Evaluation of Isoclinics. Unwrapping Methodologies. Color Image Processing Techniques. Digital Polariscopes
Fusion of Digital Photoelasticity Rapid Prototyping and Finite Element Analysis
Interpretation of Photoelasticity Results
Stress Separation Techniques
Shear Difference Technique. Three-Dimensional Photoelasticity. Reflection Photoelasticity
Photomechanics.
Photomechanics.Introduction to MATLAB. MATLAB for Image Processing.
MATLAB for Photomechanics (PMTOOLBOX). Image Processing in Photomechanics.
MATLAB Demonstration. Digital Photoelasticity. Digital Polariscope. Phase-Shifting in Digital Photoelasticity. Phase-Shifting Method with a Normal Circular Polariscope. Isoclinic Ambiguity. Dynamic Phase Shift Photoelasticity.

Moire Methods. Digital Moire. Interferometry. Gabor Strain Segmentation. MATLAB Demonstration. Diffrentiation of Low Density Fringe Patterns. MATLAB Demonstration

Recommended Literature
1. Ramesh K. *Digital Photoelasticity: Advanced Techniques and Application* (Springer, Berlin, Heidelberg 2000)
2. Ramesh K. Digital photoelasticity – current trends and future possibilities, Proc. of Int. Con. Comp. & Exp. Eng. and Sciences Chennai 2005 (Tech Science, Forsyth 2005) pp. 2159–2164
3. K. Ramesh: PHOTOSOFT H: A comprehensive photoelasticity simulation module for teaching the technique of photoelasticity, Int. J. Mech. Eng. Edu. **25**(4), 306–324 (1997).