Thus, for making photoelastic models, the scale of the models and loads may be chosen as convenient. The model results can be related to the prototypes by following the laws of similarity, provided the model and the prototypes are geometrically similar and the distribution of the loading is the same for both. The similarity relations do not apply near points of loading and the principle of Saint Venant is usually invalid for other regions.

Physical Principle Used in Photoelasticity – a brief discussion

Certain non-crystalline or amorphous materials notably some polymers, are optically isotropic under normal conditions but become double-refractive/ birefringent when stressed. This effect normally persists while the load is maintained but vanishes almost instantaneously or after some interval of time after removal of load. This phenomenon of temporary or artificial birefringence was first noted by Brewster in 1823 and the physical characteristic of photoelasticity is based on this.

This property of these materials is exploited to determine stress field in a model using the “Stress - optic law”. Formulated by Maxwell in 1852 the Stress optic law states that:

\[ \sigma = \frac{C \nu}{a} \left( \frac{\partial \varepsilon}{\partial x} \right) \]

Where,

- \( \sigma \) - Stress difference (MPa)
- \( C \) - Stress optic constant (1100 for silica)
- \( \nu \) - Poisson’s ratio
- \( a \) - Thickness of the specimen (mm)

Components of Polariscope

In a transmission polariscope, light is transmitted through the model. The photoelastic material or the polarscope material can either be a lens or diffused light type. Figure 3 shows the components used in transmission photoelasticity.

Model to Prototype Relations

One of the first questions that come up in anybody’s mind is how does one relate the results from conducting experiments on plastics to prototypes?

The validity can be explained from considering the nature of the equations that are necessary for solving the stress distribution. In 2D problems, the equations of equilibrium together with the boundary conditions and the compatibility terms in terms of stress components give us a system of equations that are usually sufficient for complete determination of the stress distribution. The equilibrium equations are:

\[ \frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} = 0 \]

\[ \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \sigma_y}{\partial y} = 0 \]

The compatibility conditions for plane stress and plane strain conditions in terms of stress components are:

\[ \frac{\partial \sigma_y}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} = 0 \]

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It is interesting to note that in the case of constant body force, the equilibrium determining the stress distribution do not contain material elastic constants. Thus, the stress magnitude and their distribution are same for all isotropic materials. However, the strains and also deformations are functions of elastic constants. Equations (2) to (5) also indicate that the stress distribution in the elastic state is independent of the loads and the scale of the model.

Polarization of light

In photoelasticity, light is used as a sensor. Typically for a known incident light, the emergent light is analyzed for stress information. Light waves are transverse waves having two vector fields namely electric and magnetic. Most light sources consist of a large number of randomly oriented atomic or molecular emitters. The light rays emitted from such a source will have no orientation and the tip of the light vector describes a random vibration motion in a plane transverse to the direction of propagation. If the tip of the light vector is forced to follow a definite law, the light is said to be polarized.

Transmission Photoelasticity

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One uses polarized light to visualize a photoelastic model for ease of data interpretation. The instrument used to observe photoelastic phenomenon is called a Polariscope.

Polarization

In a transmission polariscope, light is transmitted through the model. The photoelastic material or the polarscope material can either be a lens or diffused light type. Figure 3 shows the components used in transmission photoelasticity.

Plane Polariscope

One of the simplest optical arrangements possible is a plane polariscope. Figure 4 shows the optical arrangement of a plane polariscope, light incident on the model is plane polarized. As the light passes through the model, the state of polarization changes from point to point depending on the principal stress direction and the magnitude of principal stress difference. The information about the stress field can be obtained if the state of polarization of the emergent light is studied. This is easily achieved by introducing a polarizer at 0°. Since, this optical element helps to analyze the emergent light, it is known as analyzer.

With the introduction of an analyzer, fringe contours appear black on the screen. The fringe contours correspond to those points where intensity of light transmitted is zero. Since the analyzer is kept at 0°, it is possible only if the emergent light from the model has no plane of polarization along the vertical.

For the basic principle is that, by external means, the interaction provided by the model is compensated such that a fringe pattern exists through the point of interest. The additional retardation added or subtracted is known as fractional retardation. Analyzer can be used as a compensator. The use of analyzer as a compensator is known as Tardy’s method of compensation.

Calibration of Photoelastic Model Material

The stress-fringe values vary with time and also from batch to batch. Hence, it is necessary to calibrate each set of calibration at the time of the test. Calibration is performed on simple specimens whose clored forced stress field is known. Although the stress fields for simple tension or beam under pure bending is known, the use of circular disc under diametral compression is preferred for calibration. This is because the specimen is compact, easy to machine and can also be loaded easily.

The principal stress difference at any point in the disc can be expressed as:

\[ \sigma_{11} - \sigma_{22} = 4 \pi r \]

At the centre of the disc due to symmetry, the shear stress is zero and the principal stress difference is obtained as:

\[ \sigma_{11} - \sigma_{22} = 4 \pi r \]

From Eq. (1) and Eq. (8) the material stress fringe value can be obtained as:

\[ F = \frac{\sigma_{11} - \sigma_{22}}{4 \pi r} \]

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The method is advantageous up to the third order fringe on the face, as beyond this the colours merge. Another question is how to determine fringe order at a point on a stress field which is not a bright or dark fringe as usually determined through the fringe gradient information is known.

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Specimen handling and Maintenance

Photoelastic specimens should be stored in vacuum desiccator with samples wrapped using tissue paper. The desiccator base is filled with silica gel to absorb moisture and lid base interface is greased to prevent fresh air moisture from entering. When handling samples one should not touch the containers as it induces spurious fringes show as time edge effect (Fig. 11).

Reference