Photoelastic Experiments with a Transmitted-Light Polariscope

Objectives:

- To become familiar with a Transmitted-Light Polariscope
- To physically see the effects of loading various specimens and their unique stress concentrations
- To develop an understanding of the isochromates; the stress gradients that are observed as continuous lines alternating between light and dark

Introduction

The photoelastic method has been used since 1930 and remains one of the most interesting methods in optical tension analysis. The photoelastic principle is particularly suited for the analysis of stress distribution in flat models.

The photoelastic method utilizes the physical property of particular transparent materials to demonstrate double refraction under stress. Double refraction results from the fact that some materials that are isotropic in an unstressed state act as anisotropic if their molecular structure changes due to mechanical loading. The refraction index depends on the effective stresses in the material.

Anisotropy can be explained as follows: If a compressive strain is acting in the x direction the molecular structure is compressed in that direction. The medium becomes “optically more dense” and the refraction index increases. At the same time, in the y direction (perpendicular to x), the material undergoes positive lateral strain. Thus the molecular structure is uncompressed and the material becomes “optically thinner” and the refraction index falls.

In a flat state of stress, for each point there are two principal sections lying perpendicular to one another, the principal stresses and . With these two variables and the principal direction \( \mathbf{a} \), Mohr’s circle can be used to graphically and mathematically determine all stresses \( \sigma_x \), \( \sigma_y \), and including their magnitude and direction. See Figure 1 and Figure 2 below.

For our experiment, we require light whose vector only oscillates in a perfect direction. This result is achieved by transmitting light through a polarization filter. The polarization filters are plastic sheets whose long-chain molecules have been oriented parallel with respect to one another by mechanical extension and results in a predominant direction. After emerging from the polarization filter, the light is “linear polarized.” The second polarization filter, whose direction of polarization is exactly perpendicular to that of the first can be used to verify this process, and is referred to as the “analyser.”
If the model is free of stress, there is no double refraction. The model will not display any stress concentrations. If a load is applied and increased, a path difference results, which increases proportionally to the magnitude of the difference in the principal stresses. Viewing the model through the analyzer results in the highest possible brightness. We can now observe the continuous lines alternating between light and dark: the isochromates.

Isochromates are lines of equal principal stress difference, starting from the case we can identify the isochromates by orders. Starting from the “zero-th” order, we count the number of phase displacements of whole wavelengths (1st, 2nd, 3rd order isochromates etc.). The arch shown in Figure 3 is loaded with a single force. The high isochromate density can once again be identified inside the arch. This is where the highest stresses occur.
Equipment

- Light source
- Two polarization filters
- Two quarter wave filters
- Load frame
- Various models
- Models A-D
- Mounting Brackets

Procedure

1. Begin by turning on the light source, which requires a warm-up time of approximately 7 minutes before reaching its full brightness. We will be using the monochromatic light source.
2. Position the equipment according to Figure 5.
3. Position the filter axes as follows: 1. Polarization filter 0°, 1. Quarter wave filter 45°, 2. Quarter wave filter 315°, and 2. Polarization filter 270°. See Figure 6.

4. Insert the pressure piece into the adjusting nut from below. **Note:** The pressure piece is loose and remains in the adjusting nut without being secured. It is held in position by the model.
5. Begin with Model A, which must now be positioned in the framework using the two model mounting “brackets.” Bracket 1 is positioned in the center of the bottom portion of the framework.

6. Place Model A on top of Bracket 1, and finally place Bracket 2 on top of the model. The final setup should resemble Figure 8.

7. Rotate the pressure spindle downwards until you contact Bracket 2. Once contact has been made, rotate the pressure spindle an additional ¼ of a turn to load the model. The Isochromes should now be visible. Using a camera, photograph the loaded model for later analysis.

8. Unload the model and repeat steps 5 through 7 for Models C and D.

9. For Model B, leave Bracket 1 in place, but do not place Bracket 2 on top of the model. Observe the residual stresses found in Model B. Using a camera, photograph the unloaded model for later analysis.
Results

Now you are ready to write a report using the format prescribed. Here is a brief outline of what your report should contain and below are some questions you should answer.

**Report Outline**

- **Title Page**
- **Table of Contents**
- **Table of Figures**
- **Table of Tables**
  List of tables of collected data
- **Abstract**
  General description of the report
- **Introduction**
  Expand on the abstract
- **Theory**
  Give background information on photoelastic stress analysis; describe what an isochromate is and how it relates to the stress distribution of a loaded material
- **Experimental Setup**
  Picture and brief description
- **Procedure**
  This should describe what you did to run the experiment
  Give a basic description of why isochromes will follow basic loading
- **Data**
  All that was collected with brief descriptions of each photo
- **Results**
  Count the isochromes found in each loaded and unloaded model. Figure out which model has the least stress concentrations Explain the occurrence of the residual stresses found in Model B
- **Conclusions**
- **References**
- **What Have You Learned?**
  (This information is for the grader. It is not technically part of a technical report so include it on its own page as the last page) – A brief explanation of what you learned in this lab. No more than half a page.