Lab 2 – Photoelasticity

Section 5, Group 5

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09/15/2023

Introduction

The purpose of this lab was to get all the students acquainted with the idea of stress concentrations and the effects that it can and will have on the discontinuities that can be found in the structure of an aircraft. This was done through visualization using photoelasticity of samples with holes and curves in it. The structures were placed under stress at points to show the patterns of the stress concentrations.

Discontinuities are responsible for interrupting the stress path in a structure, causing the known stress concentrations. Some causes of stress concentration can be seen in Figure 1.

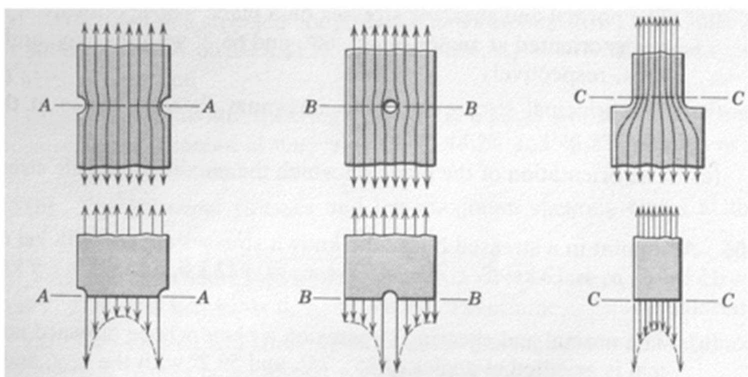

Figure 1. Stress concentration cases

Photoelasticity will provide us with the ability to visualize the stress curves. The photo elastic effect comes from birefringence (how the speed of light changes when the material it is traveling through changes) induced by stresses. It applies to transparent materials that exhibit stress-induced birefringence. Loading the samples causes pattern fringes.

Materials, Apparatus, and Procedures

The main material used in this lab was a light field polariscope that was used to test stress concentrations. The frame of the polariscope has multiple knobs that when twisted, apply a stress on the specimen at that point. This works through the polarizing lenses above and below the said specimen to put the stress contours into the visual range.

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Data

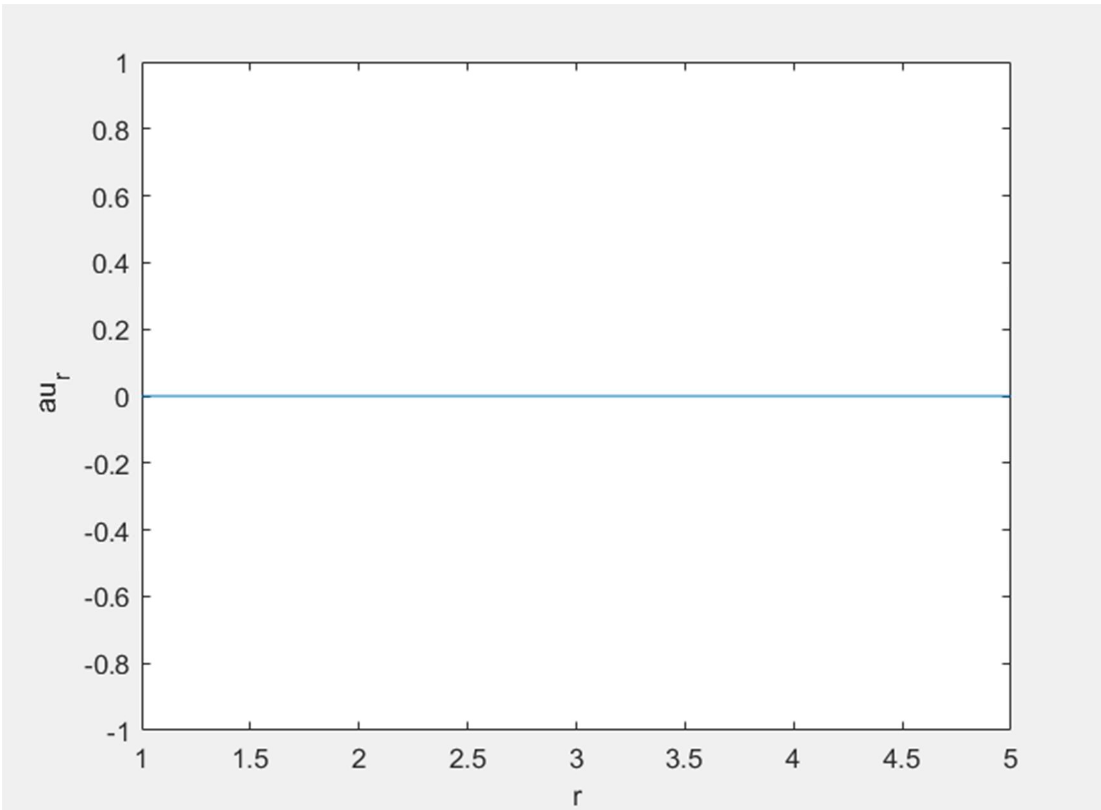

Figure 1. $\tau R\theta/\sigma_0$vs r from one to five

In this equation, there is a sin(2*theta). Since in this model theta was set to zero, the only value that this equation could equal is zero.

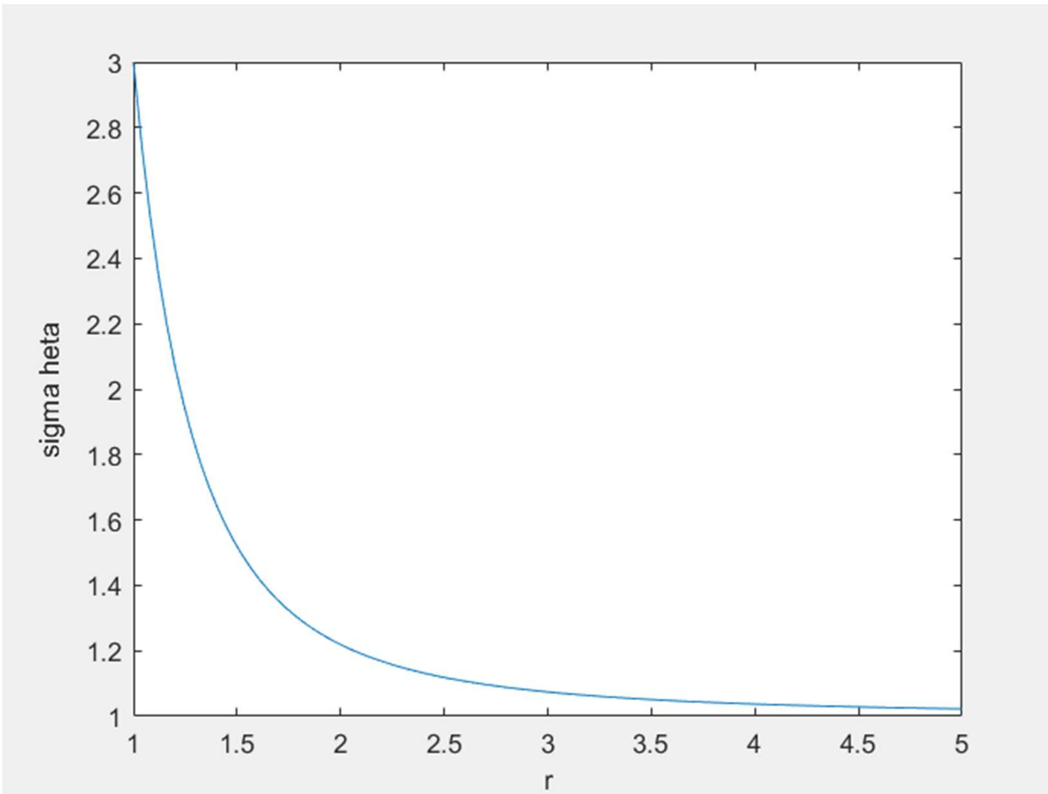

Figure 2. graph of $\sigma\theta/\sigma_0$ vs r equals one to five.

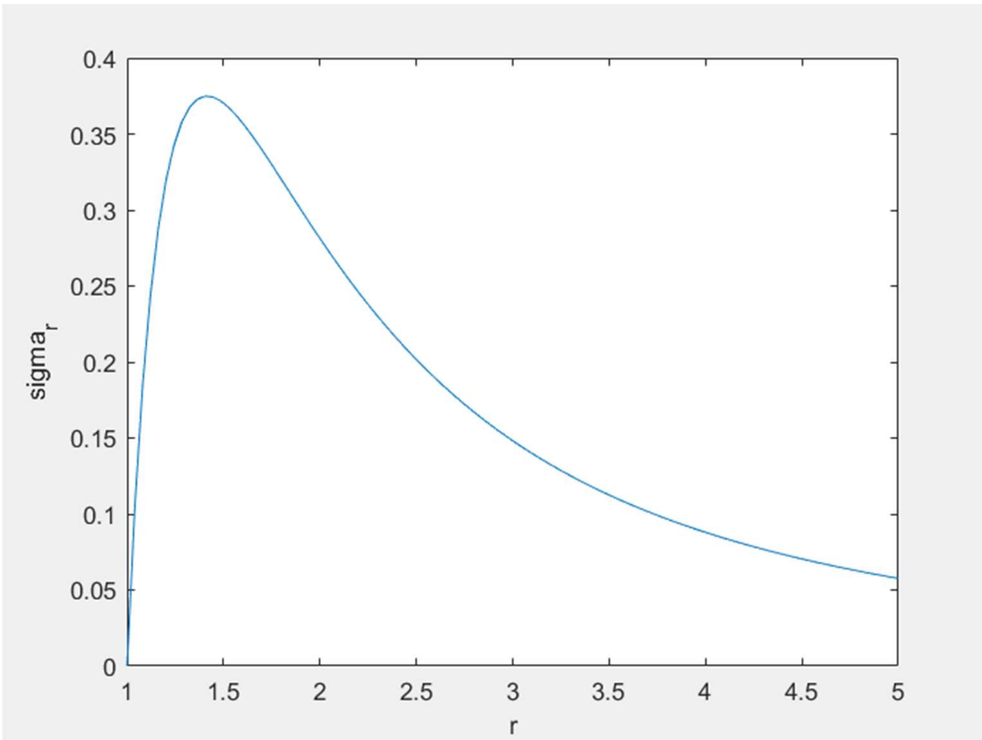

Figure 3. graph of $\sigma R/\sigma_0$ across r equals 1 to 5

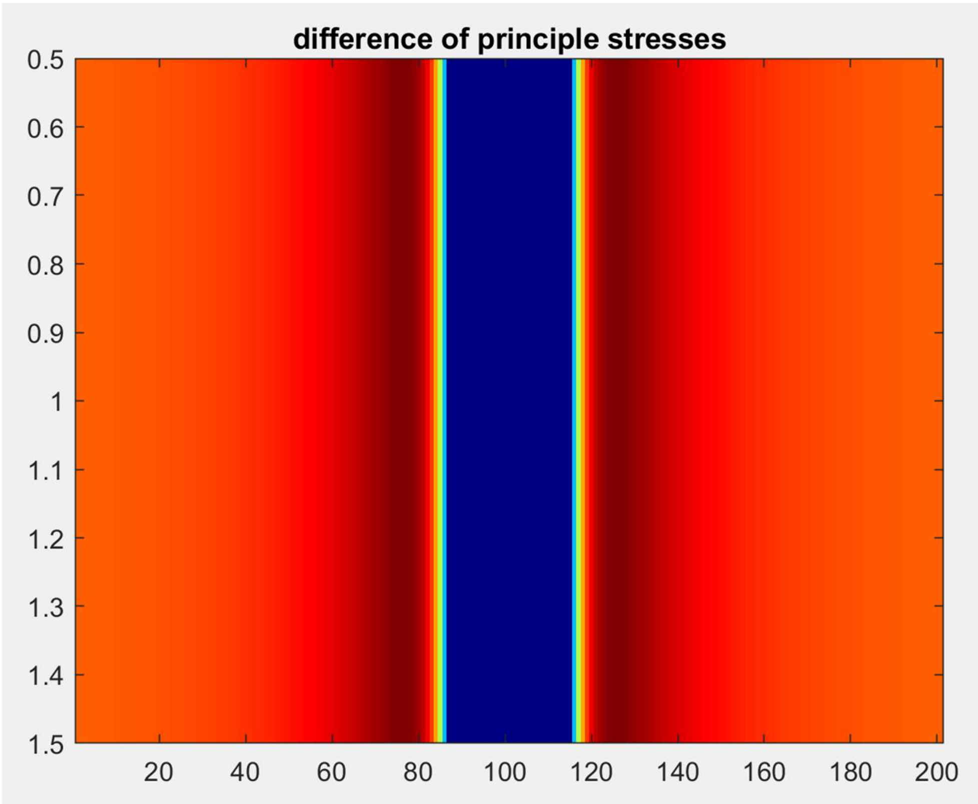

Figure 4. This model helps visualize the fringe patterns that should be seen at stress concentrations.

Analysis

1) You can observe from Figure 2 that σ_θ reaches maximum at r/a = 1, which is at r=a. You can also conclude that the stress concentration factor would be equal to $\sigma_{\theta\ max}$ which is 3. This is true because we divided equations 1-3, refer to Figure 5, by σ_0. Looking at Figure 2 we see that the decay of the stress concentration is very rapid because of the concave manner of the graph.

$$\sigma_r = \frac{\sigma_0}{2}\left[\left(1-\frac{a^2}{r^2}\right)-\left(1-\frac{4a^2}{r^2}+\frac{3a^4}{r^4}\right)\cos 2\theta\right] \quad (1)$$

$$\sigma_\theta = \frac{\sigma_0}{2}\left[\left(1+\frac{a^2}{r^2}\right)+\left(1+\frac{3a^4}{r^4}\right)\cos 2\theta\right] \quad (2)$$

$$\tau_{r\theta} = \frac{\sigma_0}{2}\left(1+\frac{2a^2}{r^2}-\frac{3a^4}{r^4}\right)\sin 2\theta \quad (3)$$

Figure 5. Equations 1-3 from the lab instructions

2) Equation 4 refers to a stress equation at the boundary of the circular hole in Figure 6 to the right. You can solve this equation to find a singular point where all the stresses vanish by using a little bit of trigonometry. Looking at the equation, you can see that for the stresses to vanish, you need the term inside of the parenthesis to equal zero. For that to be true, 2cos2θ must equal -1. To satisfy this, θ must be 60 degrees. A singular point where all stress would be zero, would be at the point where theta is equal to 60 degrees.

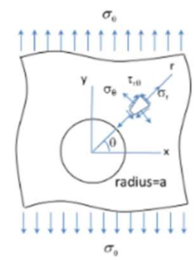

Figure 2 Stress setup around a circular hole in an infinite plate under tension

At the boundary of the hole (where r=a), these equations simplify to

$$\sigma_r = 0, \quad \sigma_\theta = \sigma_0(1 + 2\cos 2\theta), \quad \tau_{r\theta} = 0 \qquad (4)$$

Figure 6. Equation 4 from the lab instructions

3) The required plots have been inserted above in the data section of the report.

Conclusion

Our lab experiments on stress concentration revealed notable patterns in stress amplification about discontinuities. We observed that radial normal stress reached a peak at a specific distance from the center of the hole, resulting in a notable concentration of stress in that region. Furthermore, tangential normal stress showed a higher concentration near the hole's edge, both stress components declining as we moved away from the center. These findings have practical implications for understanding how stress accumulates around discontinuities, which is valuable knowledge for aerospace engineering applications.