Visualizing Stress Fields With Photoelasticity Under Multiaxial Loading

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Abstract

The stress developed in a component due to external loading is one of the most important criteria for engineers to understand as stress governs material failure. However, the internal stress distribution/field is often difficult to visualize. In order to impart a better understanding of stress to students and visualize these distributions for research purposes, Dr. Sinko has requested the design of a multiaxial loading device that uses photoelasticity to visualize stress fields developed in transparent samples via a polariscope. This device should show the stress field of any clear sample subject to compressive, tensile, torsional, and/or bending loads. In this work, a loading frame is designed that holds a transparent sample and applies all loading conditions through the use of a linear actuator and two stepper motors. Further, a control system is developed that allows for user input from a command-line interface for specification of loads and displacements.

Methods and Materials

Loading Frame
- The loading frame is constructed of 80/20 T-slotted aluminum members that are connected using 6061 aluminum brackets.
- The axial loading and torsional loading subsystems are attached using welded steel mounts.
- Several brackets for attaching components (shown in blue in SolidWorks model below) were fabricated using 3D printing of a tough resin.

Loading Subsystems
There are three subsystems to the device that apply different types of loading to a sample:
1) Torsion – a stepper motor and gearing system turns the bottom clamp to twist the sample.
2) Axial Loading – a stepper motor and rack-and-pinion is used to apply tensile and compressive loads.
3) Bending – a linear actuator applies a transverse force to the sample to cause bending.

Control System
An open-loop control system controlled by a Raspberry Pi was implemented so that users could specify the approximate stresses being applied to the sample through the system’s command-line interface.

Results/Discussion

To ensure that the system will work we calculated the internal forces on the frame and performed FEA simulations to see how the applied loads would affect our design. We also had to compare the specifications of our electronics to design a working one-way control system.

Conclusions

The photoelasticity effect being exploited by the polariscope allows mechanical engineering students to see real-life stress concentrations outside of theory and simulation in the classroom. This is beneficial to allowing students to develop intuition into how materials respond to stress.

With additional budget, this can be improved later through addition of feedback sensors to create a closed-loop control system that is more accurate and precise.

Acknowledgements

Pm Mold Inc. - for allowing use to use their machinery for the build.
Dr. Sinko - for advising use throughout the project
NIU Makerspace - for 3D printing parts for us