Shear Stress Sensor Design

EML 4551C-Senior Design- Fall 2012

NEEDS ASSESSMENT AND PROJECT SCOPE

Sponsor: Dr. Ben Dickinson, Eglin AFRL

benjamin.dickinson.ctr@eglin.af.mil

Faculty Advisor: Dr. William Oates

woates@eng.fsu.edu

Department of Mechanical Engineering

Team 3 Members:

Matthew Carmichael

Tyler Elsey

Luiz Paes

Department of Mechanical Engineering, Florida State University, Tallahassee, FL

Table of Contents

Needs Assessment:

A testing apparatus for cholesteric crystals is required to determine if the crystals are able to be used as a consistent visual meter for shear stress.

Project Scope:

Problem Statement:

There currently isn't a shear stress sensor that only measures shear stress. The current methods unintentionally measure part of the normal component of pressure on the body as the shear stress. The current methods are also large and expensive. The cholesteric crystals attributes indicate that they might be able to only measure the shear component of stress; decoupling the shear from the normal stress. The cholesteric crystals can also be modularly attached to materials and measured with only a fiber optic spectrometer. This would make it possible to cheaply measure shear stresses outside of the lab environment.

Background:

The liquid crystals are not a new item, but they have never been used to find shear stress. Dr. Dickinson from Eglin Air Force Base will be our sponsor providing us with the resources to fund the project. However our faculty advisor Dr. Oates will be providing most of the background information along with a lab and materials. The physical design will be to create a testing apparatus, but the data collected during experiments will be the bulk of our effort. The data collected will show how cholesteric crystals react to shear stress under various conditions. Eglin and Dr. Oates both hope to use this data to determine if this method of testing shear stress is viable for use on aircraft, underwater, robots, and other equipment. There are currently other shear stress sensors existing (MEMS shear sensors and oil films) but there isn't a method that is widely used and simple. There currently isn't much research in regards to using liquid crystals for sensing shear stress but there is a patent for the cholesteric crystals in the form of a polymer.

Objectives:

To design an apparatus that will apply forces to the cholesteric liquid and to collect data on the reaction of the cholesteric liquids under the applied forces in a horizontal direction (representing shear stress). The data collected will be visual in which the color change of the testing liquid should determine the amount of force applied from the servo motor. For a successful project a wide range of information is to be collected in the spring semester. We hope to find a correlation in the colors displayed and the shear stresses acting on the specimen. If there is a correlation in the colors displayed and the shear stress applied, then cholesteric liquids can be used as a new possibility for shear stress sensors in a more cost effective manner.

Methodology:

With a current patent being the basis for the project the design of the apparatus is essentially set, but the apparatus is still to be completed with designing components. The components which are still to be designed are which light source is to be used, the holding apparatus of the light and spectrometer, block that applies shear stress, and the connecting link for the load cell and load block. Once these previously stated components are complete, data collection is to begin for the forces on the specimen. After data collection, finding a relation of the wavelengths reflected from the specimen and the loads can be determined. If there is a relation in the information gathered then the possibility of getting solid samples for testing will be attempted. For applications in shear stress sensors comparing the current options in sensors and the projects feasibility will be compared for the determination of the sponsor.

RESEARCH:

- Comparable shear sensors
    - Cost of the shear stress sensors
    - Accuracy of the shear stress sensors
    - How the sensors are affected by different pressures in the atmosphere
    - Hysteresis of the current sensors
    - Range of current shear stress sensors
    - Sensitivity of sensors
    - How the sensors are scaled
- Current patent for cholesteric testing
    - How the apparatus is setup
    - Formula for forces applied on samples
    - How the cholesteric liquids are being used

DESIGN:

- Determine light source
- Create holding apparatus for light source easily showing angle of light
- Adjustable device for spectro-meter showing the angle
- Block that applies load to specimen
    - Design with the possibility of changing the temperature to the specimen
- Connecting rod for load cell to load block
- Possibly designing equipment for ease of removing residue

EXPERIMENT:

- Design a LabVIEW program to display results
- Determine the wavelengths reflected under certain forces
- Test the range in which the samples are effective
- Run experiments with different combinations of cholesteric samples

RESULTS:

- Collect data and show correlation
- Create designs for how the results can be implemented for sensors
- Suggest how the cholesteric liquids can be used by the sponsor
- How the sensors can be arranged to be effective

Expected Results:

Once designed, the sensor will be able to measure the shear stress based on the relation between the optical output of the cholesteric liquid and the applied load. Moreover, different types of responses due to changes in temperature and reflection angle should be computed also. In the final product, a static and dynamic behavior report should be provided.

Constraints:

The constraints imposed on the sensor design regard to determine uniquely shear stress relative to normal stress. The range of load applicable is 1N. In addition, the tests must be conducted with a specific cholesteric liquid which sensitivity is a function of its optical properties. The time available for the project development is straight. The first set of experiments should be completed by December 7th. Besides that, the project budget to conceptualize and build the device is $2000. Since our project is mostly research based we do not have many constraints. Our main goal is to find the constraints of the cholesteric crystals, such as; maximum and minimum stress measurements, endurance, and temperature limits.