# Fiber Optic Sensing System Demonstration on Pressure Vessels

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# Background

- Born in Alexandria, MN
- Attended Robotics Club at South Dakota State University (SDSU)
- A Formal Activities Chair for American Society of Mechanical Engineers at SDSU, 2013 to 2014
- Graduated from SDSU with a Bachelors in Mechanical Engineering in May 2014
- Interned at four organizations:
  - University of Minnesota: Morris, MN, Summer of 2010
  - Gryodata: Houston, TX, Summer of 2012
  - NASA Goddard Space Flight Center: Greenbelt, MD, Summer of 2013 and 2014
  - With help from the North Dakota Space Grant, NASA Armstrong Flight Research Center: Palmdale, CA, Spring 2015
- Currently working as a contractor at Snap-On Tools in Algona, IA

# Fiber Optic Sensing System (FOSS)

- FOSS is a system that uses lasers to detect Strain in the fibers
- Fiber Bragg Grating(FBG) in the fibers at regular intervals
- FBG change index of refraction and grating planes when fiber is experiences strain
- The laser transmitted through the grating
- A small wave length of the laser is reflected back
- The reflected wave length is then measured
- Allows for measurement the elongation of the fiber
- Is applied for strain gauges on aircraft
- Is currently being tested to detect fluid levels at different temperatures

# Fiber Bragg Grating

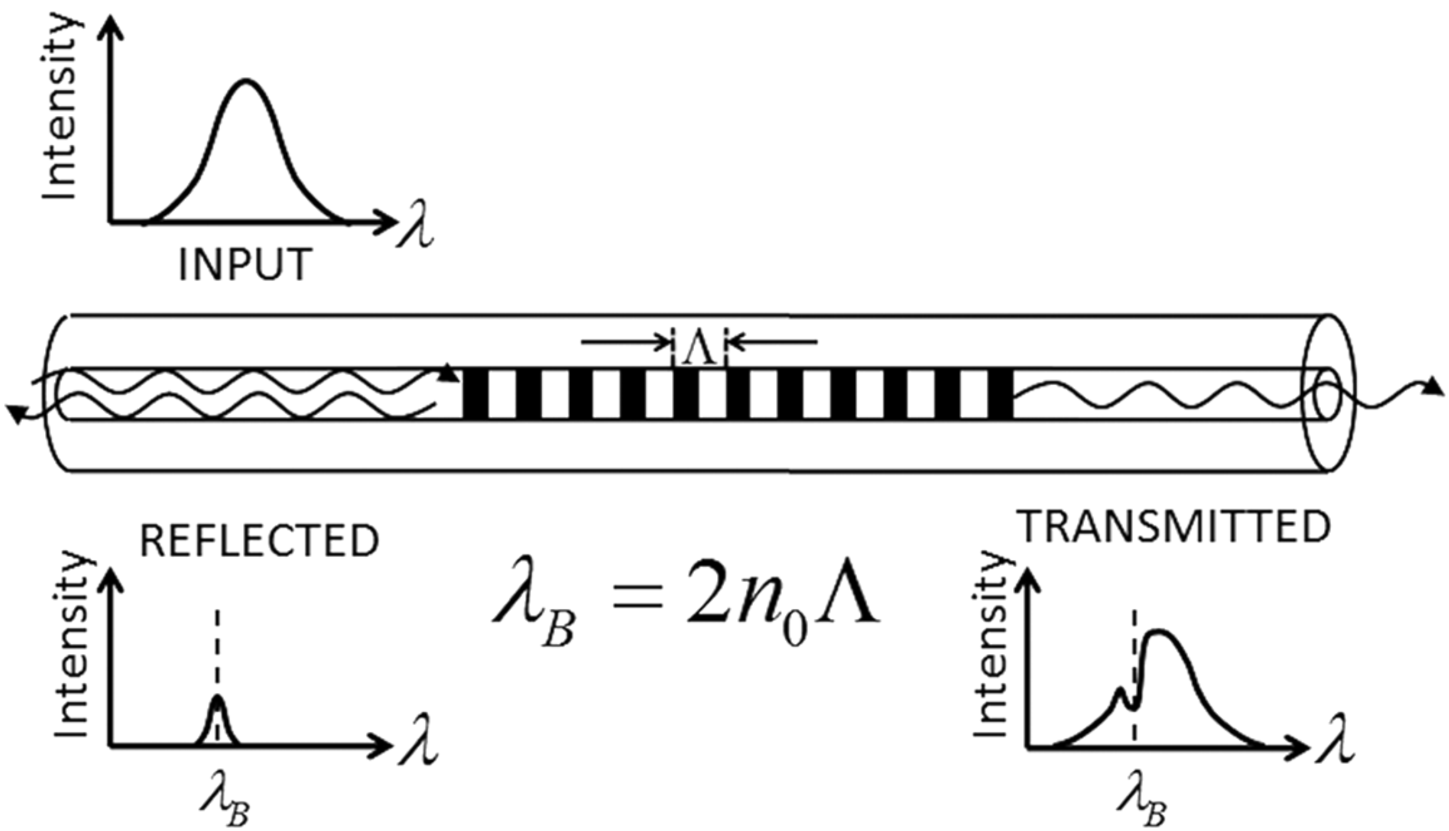



Figure 1: Reflected and transmitted light through a Bragg grating (1)

# Statement of The Problem

- The Pail in Figure 2. is created to test the FOSS systems on a containers which would be later used in demonstration
- The demonstration requires interaction to show the FOSS sensor reading
- Minimum protection with the fibers
- Make a system that would restrict the participants contact with the pressure vessel

Figure 2: Original Pail

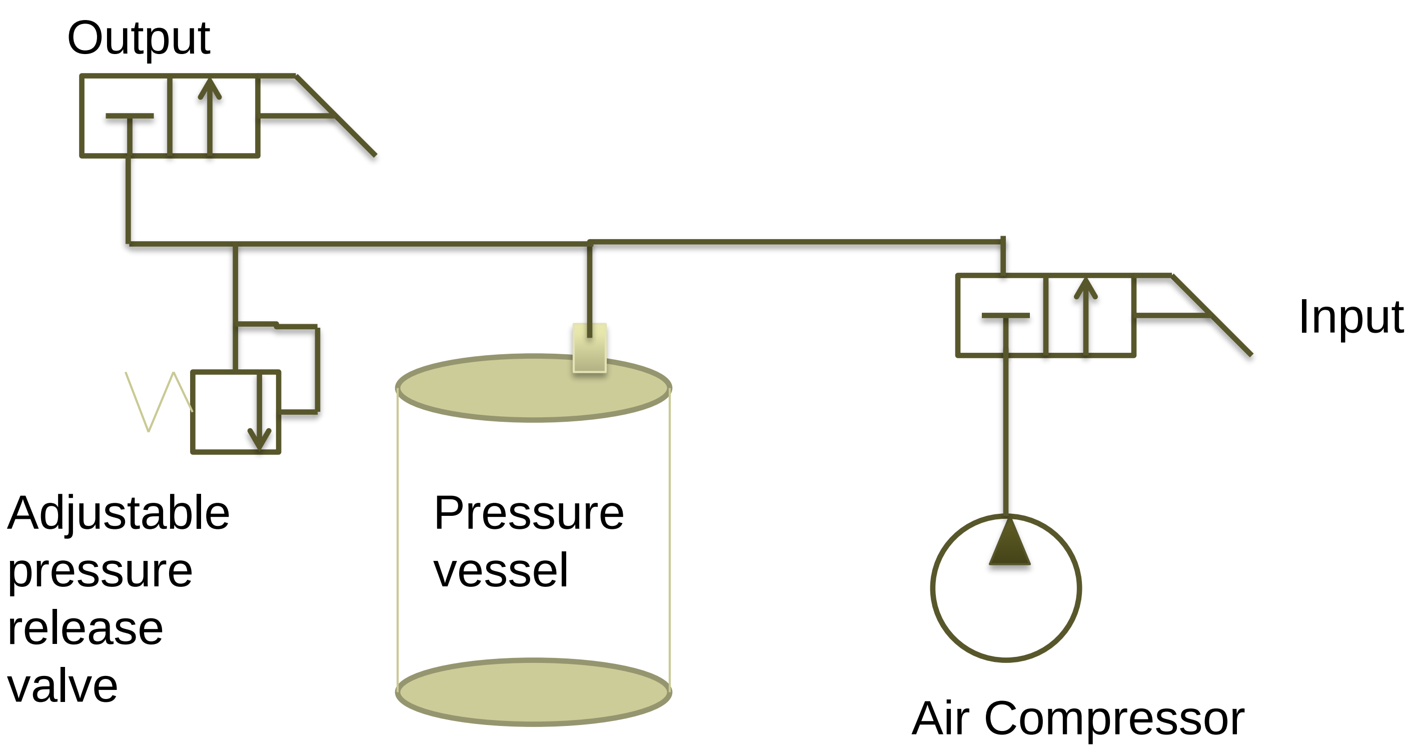
# Objectives

- To demonstrate the Fiber Optic Sensing System (FOSS) capabilities with a pressure vessel
- Allow participants to increase and decrease pressure inside a pressure vessel
- Have a system that would allow participants interact with the vessel through two controlled devices
- Create a map of the sensors for the new pressure vessel with FBG fiber
- Safety devices that would prevent failure of the pressure vessel or damage the FBG fiber

# Proposal

- To make a system that uses pneumatic valves to allow air pressure to increase or decrease inside the pressure vessel
- The pressure controls of the system are two, two stage (open or close) air direction mechanical operated valves that can return to close automatically.
- FOSS system integrated on the pressure vessel to demonstrate the abilities of the FOSS for pressure containers
- A pressure relief valve to prevent future damages to the FOSS system's fiber optics and pressure vessel

# Proposed design



# Advantages and Disadvantages

Advantage:

- Physical contact has been reduced to two levers from the valves
- Can connect to an air compressor that is available at current facility
- Programming is not needed for pressure control
- Pressure relief valve to control the Max pressure allowed in the pressure vessel

Disadvantage:

- No visible pressure gauge
- Pressure vessel not designed to hold pressure or minimum pressure
- Compressor output pressure need regulation
- Needs an external air supply

# Changes to the design

- A air tank has been added to make the system portable to power scarce locations
- FBG has been added to the air tank
- Programs had been created to map the sensors on the tank
- A program has been created to indicate operator when the pressure inside the pressure vessel is at critical levels
- The input directional valve been replaces with a ball valve and a flow regulator valve with a pressure gauge

# Pail (Pressure Vessel)

- UN-Compliant Plastic Shipping Pail with Opening, Round, Flip-Up Handle, 5 Gallon Capacity, Blue
- 3 loops of FBG epoxy onto the exterior of the pail
- FBG protected with a clear tape
- A existing cap from previous pail is used
- Connects to the FOSS system
- Max pressure is small (Unreadable from the Pressure Gauge)

Figure 3: New Pail With FBG

# Air Tank

- JEGS Performance Products W10005 Portable Air Tank
- Has 2.25 loop of FBG
- Has a protective layer of clear tape for the FBG
- The hose provided with the tank has been removed for a slide connect tip
- Has a valve that opens or closes the tank


Figure 3: Air Tank With FBG Fiber

# Pressure Vessel System (With out compressor)

Figure 4: pressure vessel with hose and valves

# Mapping and Warning Indication

- The primary language used is LabVIEW
- The map is created using a simple helix equation

$$x = (\frac{d}{2}) * \sin(\omega * t)$$

$$y = (\frac{d}{2}) * \cos(\omega * t)$$

$$z = t$$

- The program would beep when the strain of the pail reaches critical
- Current level is 600 micro strain
- The frequency of the beeping increases as the strain reaches critical
- A emergency beeping is active when the strain is above critical

# Pressure Vessel Demonstration

# Air Tank Demonstration

# Results

- A pressure vessel that uses pneumatics to increase or decrease the amount of pressure
- A system that is mobile if needed
- Both the pail and the air tank can be demonstrations of the FOSS system
- The system can indicate if the pressure vessel is going over the recommended strain
- Maps that shows the both thermal and stress induced strain
- Pail’s Max. Pressure is lower that it is unreadable on the pressure gauge
- The system with no FBG: $277.20

# References

1. Emmons, M., Karnani, S., Trono, S., Mohanchandra, K., Richards, W., & Carman, G. (n.d.). Strain Measurement Validation of Embedded Fiber Bragg Gratings. *International Journal of Optomechatronics,* 22-33.

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