Measuring Liquid Level Using Fiber Optic Sensing

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Introduction

Fiber optic sensing can be used to measure changes in liquid level when there is a temperature difference between the liquid and surrounding air. One example is measuring the level of fuel in a tank, where fiber is especially advantageous as a sensor because it is chemically inert and does not pose an ignition hazard. Measurements can be obtained through a single optical connection of the fiber to a Luna ODiSI-B system. The sensor itself is very simple, consisting of a single polymer coated fiber. The purpose of the test described here is to demonstrate measuring fuel level using the ODiSI system.

Test Setup

In this test, two fiber sensors, one polyimide coated and one acrylate coated, were independently used for measuring liquid level changes. A graduated cylinder was filled with gasoline and the cylinder was placed in a larger container filled with ice. The two containers were placed on a stack of seven ¾" thick HDPE blocks. The tests were conducted in a fume hood to avoid exposure to gasoline fumes. Air temperature in the fume hood measured with a thermocouple was 21.2°C and the gasoline temperature was 2.3°C. Each sensor was zeroed when it was suspended from the sensor stand in the fume hood. The sensor was then immersed in the gasoline. Once surface tension was broken, the sensor hung straight down from the point of suspension. Measurements were taken continuously at 10 Hz as each block was removed one at a time. The sensors were interrogated using a Luna ODiSI-B. The test setup is shown in Figure 1.

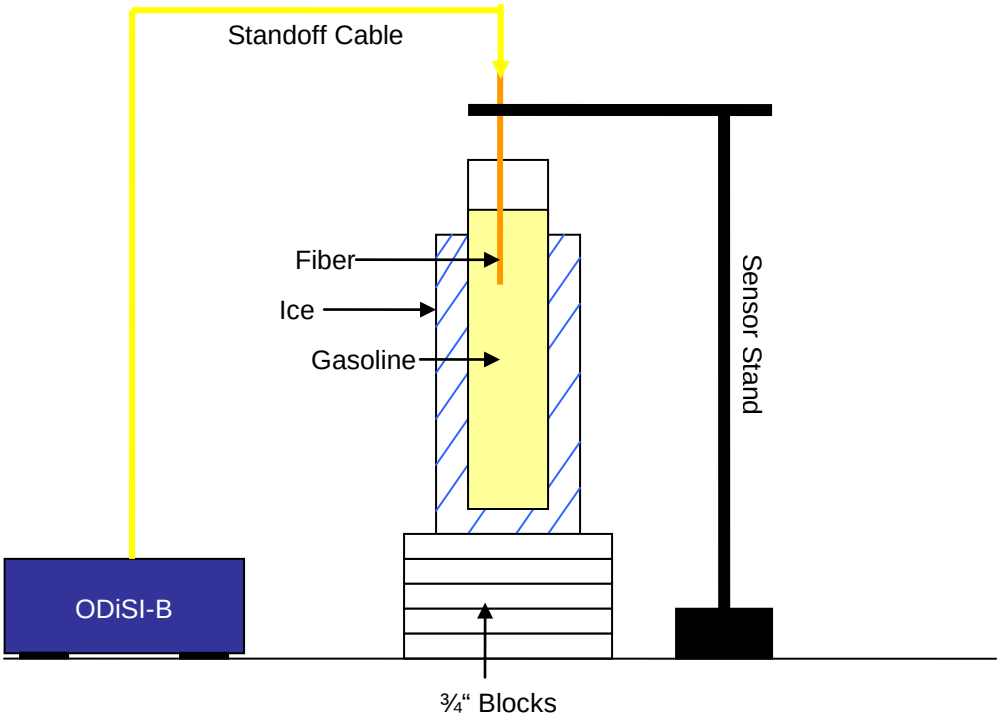

Figure 1 – Test Setup

Results

Figure 1 shows the temperature profile along both Acrylate (Fig 2A) and Polyimide (Fig 2B) sensors as spacers were removed. Each sensor was zeroed in air. When submerged in gasoline, the temperature profile along the fiber shows the transition from outside air temperature to the temperature of the chilled gasoline. The temperature transitions between these two levels over a distance of around 6 inches.

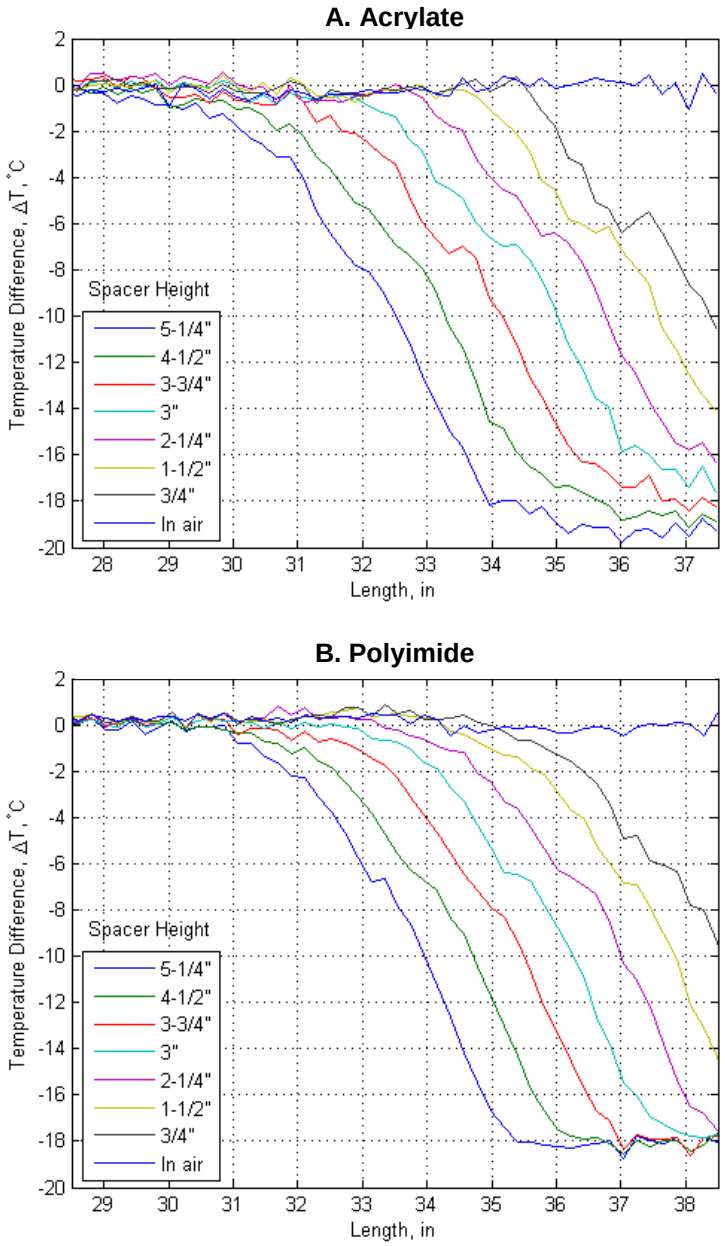

Figure 2 – Temperature profile along the sensor as spacers are removed for both Acrylate (A) and Polyimide (B) coated fiber sensors.

Liquid level changes can be correlated to the location along the fiber where a certain temperature threshold is crossed, termed height reference location (H_{RL}). In this test, a normalized temperature value of 40% of the minimum temperature measured during the test was selected as the crossover point that relates to the H_{RL}. The H_{RL} versus time is shown on Figure 3 for both Acrylate (Fig 3A) and Polyimide (Fig 3B) sensors. As the spacers are removed one by one, the H_{RL} advances in discrete steps. The H_{RL} plateau averages are shown in red on Figure 3. The Acrylate and Polyimide coated fibers were tested independently, so variations in time duration of the height plateaus is expected.

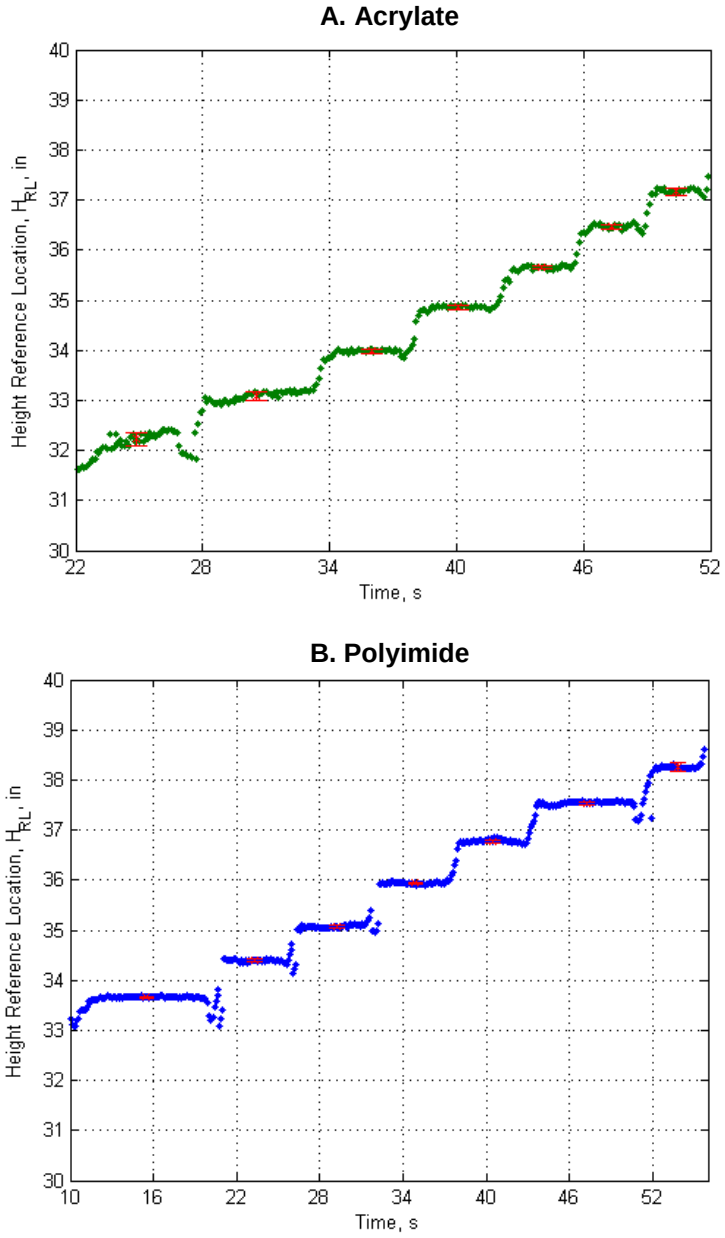

Figure 3 – Height reference location (H_{RL}) for Acrylate (A) and Polyimide (B) coated fiber sensors with average location at plateaus in red

Relative height was determined by taking the difference between subsequent average H_{RL}. Figure 4 shows the height measurement error, calculated as follows:

$$\text{Error} = |H_{RL\_n+1} - H_{RL\_n} - \text{Expected Value}|$$

$H_{RL\_n+1} - H_{RL\_n}$ is the difference between subsequent H_{RL} steps. The expected value is the spacer height of 0.75 inches. Height measurement appears to be accurate within 0.15 inches. Inaccuracies in temperature measurement may be due to gasoline wicking up the fiber. In addition, the fiber may not have remained completely straight in the graduated cylinder as spacers were removed.

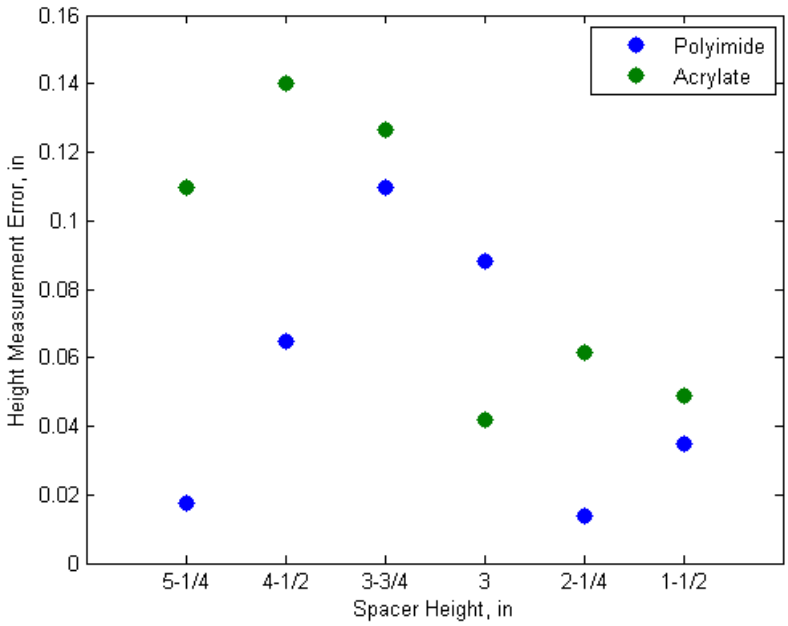

Figure 4 –Height measurement error.

Summary

This Engineering Note demonstrates the ability to use Acrylate or Polyimide coated fiber optic sensors to measure changes in liquid level where a temperature difference exists between the liquid and surrounding air. One possible application is measuring fuel levels in a tank. This note demonstrates that fiber optic sensing with ODiSI-B can provide a simple, safe and accurate solution for measuring changes in fuel level.

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