ME 197 - Undergraduate Research

Internally Integrated Pressure Sensors in Soft Actuators

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I. Introduction

The scope of this research was to incorporate pressure sensors to the interior of a soft sleeve based actuator opposed to having an external sensing system. This new factor will be based on the fabric soft-based actuator design created from Professor Realmuto. The goal is to compare the pressure and force reading from the use of an internal variable resistor (pressure sensor) to external testing using solenoid valves.

II. Methods

A. Solidworks 3D Modeling

The first thing done for this research was to make all necessary changes and adjustments to the parts that are used to assemble the actuator in order to incorporate the pressure sensor. The sensor was incorporated into the collar component. This was done by creating a small slit for the sensor to be inserted (refer to Figure 1). The slit adjustment was made by creating a cut-extrude on the collar Solidworks model with a sketch of 7.07 mm x 0.52 mm (refer to Figure. 2). These dimensions were made based on the bottom section of the sensor where the prongs are placed. After this adjustment was made the new collar was 3D printed.

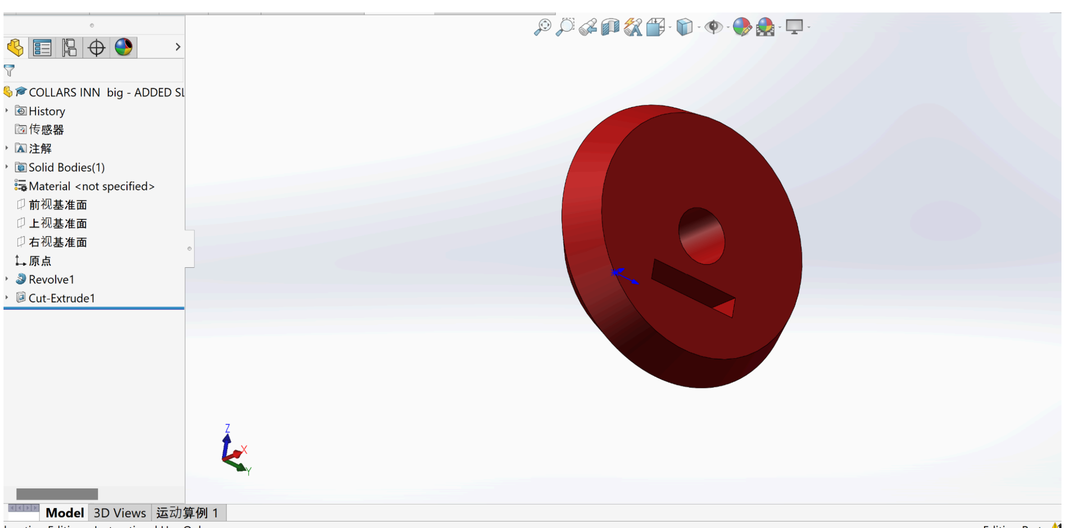

Figure 1. The new collar part with the added slit to hold the pressure sensor.

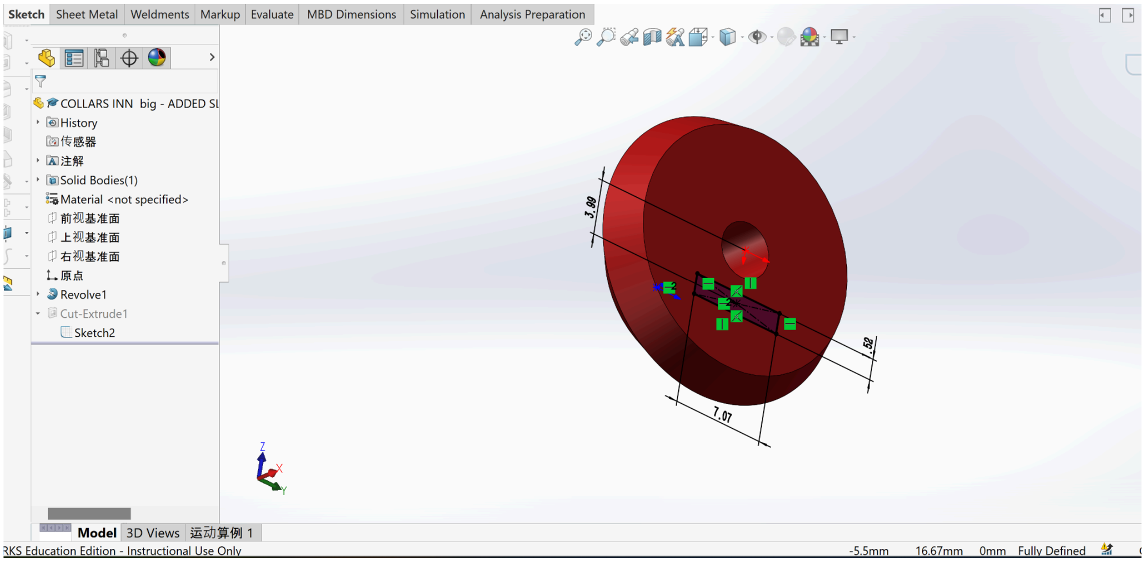

Figure 2. Dimensions of slit.

B. Actuator Assembly

Now that the collar was printed it was time to insert the sensor. It was inserted into the slit of the collar and a waterproof silicon was used as an adhesive to secure the sensor in the slit. It sat overnight in order for the silicon base to completely cure. As seen in Figure 3, the sensor was positioned in the slit just enough for the prongs to stick out from the larger half of the collar. Two wires were also soldered to the two prongs of the sensor since the prongs of the sensor would not be able to reach through the collar, so there would be no way to measure the resistance after pressure is applied (refer to Figure 4).

Now the collar is ready to be attached to the full assembly. The components used for the assembly are: fabric sleeve, rubber pipe, air pressure tube, clips, and collar. As a reference to build off of, an old model of the actuator was deconstructed to fully understand the assembly so that a replication with the new collar could be made. The fabric sleeve from the old model was used for the new one instead of having to sew a new one.

Similar to the collar, another adjustment had to be made in order to accommodate the pressure sensor. The hole that is meant to hold the pressure tube was not wide enough to fit both the tube and wires (connected to sensor) initially. So after shaving/drilling through the hole to slightly widen it, the tubes were able to fit. After a few mistakes with constructing it and a few do-overs, the final model of the actuator embedded with a pressure sensor was complete (refer to Figure 5). Now testing of the resistance would be conducted.

Figure 3. Sensor embedded into collar through silicon base.

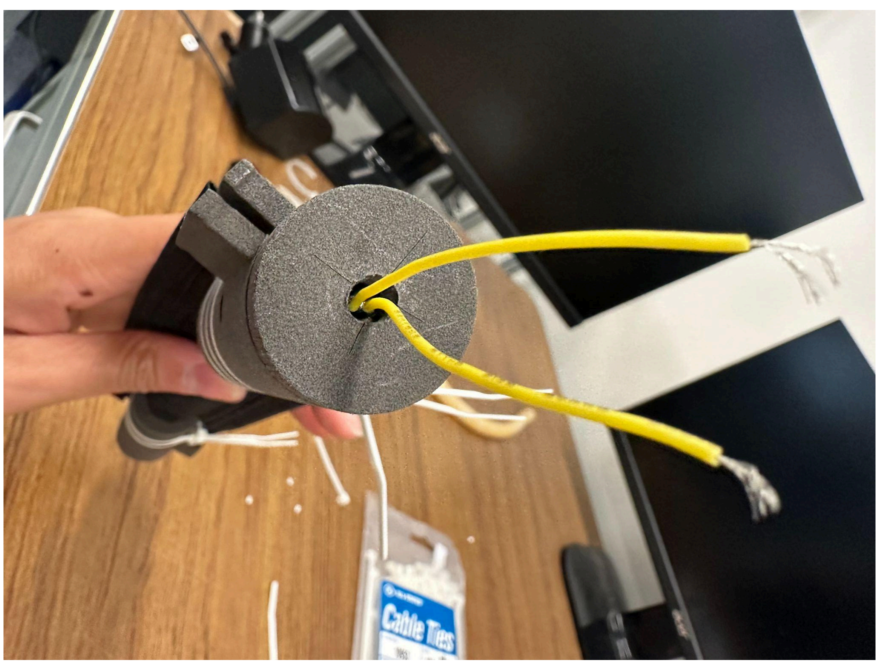

Figure 4. The two soldered wires that are attached to the inner pressure sensor.

Figure 5. Full assembly of new fabric based actuator.

III. Results

A. Testing

The testing of this pressure sensor was planned by creating a program that measures the amount of pressure change based on force/displacement change. But before applying this program to the actuator, we thought it was necessary to test the pressure sensor to make sure it works properly.

To see if the sensor works properly we manually input air pressure into the pipe of the actuator. The testing apparatus for this contained the actuator pipe attached to the solenoid valve, and the valve attached to the air compressor (Figure 6). Using a Digital Multimeter (DMM), we first measure the resistance from the sensor before adding pressure. It gave 0 Ω which we assumed fitting since there was no change in force or displacement that could be sensed. When connecting it to the solenoid valve we started with an input air pressure of 25 Psi but there was no change in resistance from the DMM reading. A few more trials were done after and there weren't any changes. We hypothesized about an error in assembly causing a leak so the assembly was re-done and focusing on possible points of leakage in areas like the clips and tubing that could affect the pressure flow through the sleeve. But this as well did not change the resistance. We decided to test the pressure sensor itself by simply pressing down on the tab of the sensor and it also displayed 0 Ω. It was possible that this may have been damaged during assembly, so an unused one was tested as well and still saw the same value. We currently can't figure out why the pressure sensors aren't working as they should so transitioning to a program wasn't practical.

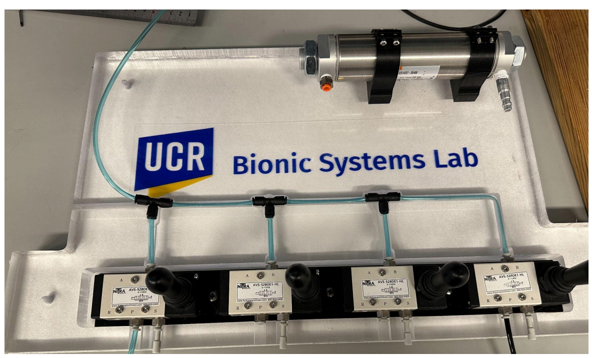

Figure 6. Solenoid and Air Compressor apparatus.

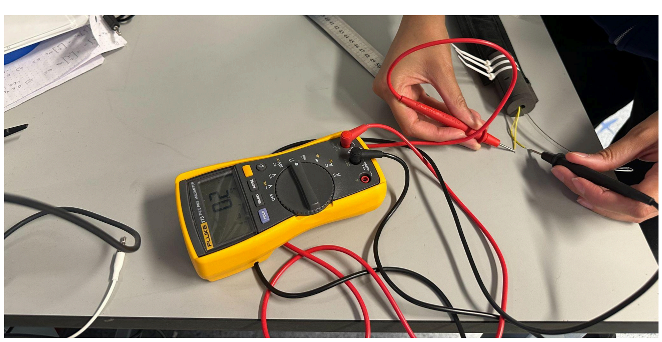

Figure 7. Digital Multimeter (DMM) setup.

B. Error Analysis

Since the experiment did not work as intended it is necessary to address factors that could be the cause of error and plan how this would be addressed in the future. The main error was the functionality of the pressure sensor. When tested for functionality using the DMM there was no change in resistance when applying pressure by just the use of a thumb. This done with the pressure sensor completely disassembles from the actuator. The first possible thought was damage on the prongs of the sensor. There is a lot of moving during the assembly while already being soldered to extension wires, so it is possible the prongs were damaged. There were already times when the prong was completely removed from the sensor by accident, but for the final assembly the prongs were attached. The internal wires in the sensor could have been damaged from frequent moving. This could have been preventable by heat shrink tubing the soldered wires together in order to protect the sensor during assembly. Another possible error could be the pressure tab's positioning in the actuator. The tab is inside since the rest of the sensor is coming through the collar. There is a possibility that this position was not appropriate for the type of result we're looking for. But these two uncertainties don't explain why no change in resistance was seen. Let it be known a non air pressure test was also done on a sensor with no wires soldered to it.

C. Intended Results

Even though further testing could not be conducted, we feel that it is still important to show the hypothesized results for future progress of this research. What we intended to have was a graph displaying the nonlinear relationship between force and pressure (refer to Figure 8 for intended graph). This would be done by creating a program that would input 1.8 V into a circuit seen in Figure 9 composed of a variable resistor (pressure sensor), and a plain resistor. The graph would show a growth of pressure that would plateau for a while and eventually descend (information was already known). But unfortunately this could not be incorporated with the new pressure sensor so we couldn't advance to this stage from testing the sensor.

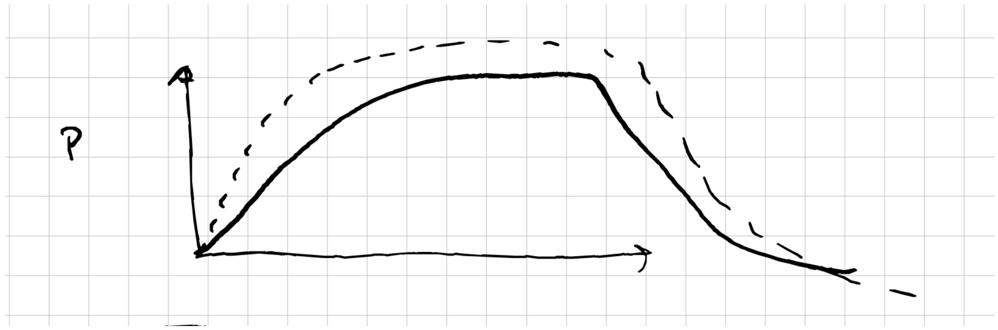

Figure 8. The change in pressure display derived from the circuit in Figure 8.

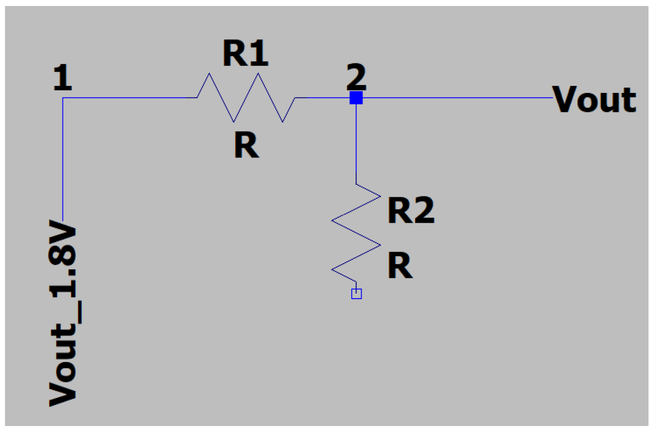

Figure 9. Circuit diagram (Vout_1.8V should be Vin_1.8V)

IV. Conclusion

The scope of this project was to create a soft-sleeve based actuator with an embedded pressure sensor to concur if using an internal system works better than an internal system. The intended data would display the pressure change from a voltage divider with the pressure sensor as the variable resistor. And we would compare this to a system that uses external sensing.

It started with adding a slit to the original model of a collar in order for the pressure system to be incorporated into the actuator. After printing was done a silicon base was made to hold the sensor inside of the collar's slit. Full assembly was constructed for the actuator. Two wires were soldered to the prongs of the sensor so that the prongs could be reached from the exterior of the actuator for testing. They're needed to measure the resistance of the sensor and to incorporate into an embedded system.

Before testing with a program was done, we first tested the new actuator with an air compressor and solenoid valves. The wires of the sensor were attached to a DMM in order to measure the resistance change. With no air pressure the resistance read $0\ \Omega$, which we expected. But with air pressure it had the same reading so no resistance change was seen. Currently we can only hypothesize that the sensor isn’t functioning properly and this could possibly be from damage, but other sensors were tested with just a load being applied to the sensor and there was also no change in resistance. Since the sensor was not working properly it wouldn’t make sense to move forward with creating an embedded system to create our graph of the pressure change.

The intended testing would be to create an embedded system with a voltage divider circuit including the pressure sensor as a variable system. This would be embedded with a program that could have an input from 0V to 1.8V and plot a diagram showing the nonlinear relationship between force and pressure change. The plot from this testing would be compared to external testing (without use of the internal sensor). This would be ideal to use in order to compare the efficiency of using an internal sensor for testing instead of external testing but unfortunately the issue with the pressure sensor functionality created a hold in the testing process.

To review, this research project displayed the integration of a variable into the initial design of the soft-sleeve based actuator, which required the use of Solidworks, assembly, air pressure testing (solenoid valves), and embedded systems. And the deliverables would be taken from comparing the use of internal pressure sensors vs. external sensing for the movement of the actuator. I’d like to thank Professor Realmuto for the opportunity to be a part of the Bionic Systems Lab. And also a special appreciation to Tuo Liu, Xinyao Wing, and Burak Balta for taking time out of their schedule to assist me with my work.