Plasticity Model: Displacement Measurement

Project 8

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Introduction

A model is to be created for Dr. Feigenbaum's Engineering Plasticity course. The model will be used purely for educational purposes. The model will be based on a theoretical example posed to students, involving springs and a frictional block. The movement of the block and springs roughly approximate a materials behavior in the plastic region. The behavior can be related to a materials behavior graphed on a stress strain curve. Feigenbaum would like the model to display force, related to stress, and displacement, related to strain, on a digital screen. Students will be able to interact with the model and manually change, in real time, the force and displacement curves.

In order to do so the model must record displacement and force data. The team has determined that for time and simplicity's sake, force can be derived using spring and friction coefficients using pure displacement data. Though there is potential to use a strain gauge later in the project for more accurate force measurements. In either case, a displacement measurement device is necessary to transmit this data into a data acquisition system.

The following sections discuss the possible devices and ultimately the first iteration of the displacement sensor and mounting system.

Displacement Sensor Requirements

The team has determined that the data acquisition system that will be used is a Raspberry Pi. Therefores the displacement sensor used must be compatible, creating an analog signal that the Raspberry Pi can process. A few other requirements are that the sensors must be small enough to fit within the size and weight requirements of the overall project. The sensor must also be durable, reliable, and capable of recording data for the required displacement length.

Concepts

There are several designs that could be used for the project applications which are, optical, linear proximity, ultrasonic and contact displacement sensors. While all are would be capable of recording displacement the complexity of all sensor types except contact displacement are in most regards to expensive and time consuming to implement within the project limits.
The following sections describe several types of contact sensors:

Linear Potentiometer:

A linear sliding potentiometer is a type of resistor. When there is a displacement change smalls gaps between wire coils change in size. “This gap (displacement) is output linearly as the differential voltage of the coils, and therefore the displacement of the object can be determined by detecting this differential voltage”[3]. Figure 1 shows a linear potentiometer produced by P3 America Precision instruments. Linear potentiometers are readily available. The two important specifications that determine the cost of the potentiometer are the stroke length or allowable displacement and the resistance error. The potentiometer shown below has a stroke length of 11.5 millimeters and a resistance of 10 kilohms with and error of 15 percent.

Figure 1: P3 America Linear Potentiometers

Rotating Potentiometer:

A rotating potentiometer is another type of resistor. As the knob is spun there is a differential voltage. For the purpose of measuring linear displacement a rotating potentiometer can be used in conjunction with a pulley system. If the dimensions of the pulley are know as a wire or string is pulled on the pulley the rotating potentiometer can be calibrated to relate the differential voltage to a rotation. Figure 2 shows a possible design from the National Program on Technology Enhanced Learning[1]. The design uses a threaded drum, coil spring and potentiometer attached to a shaft.

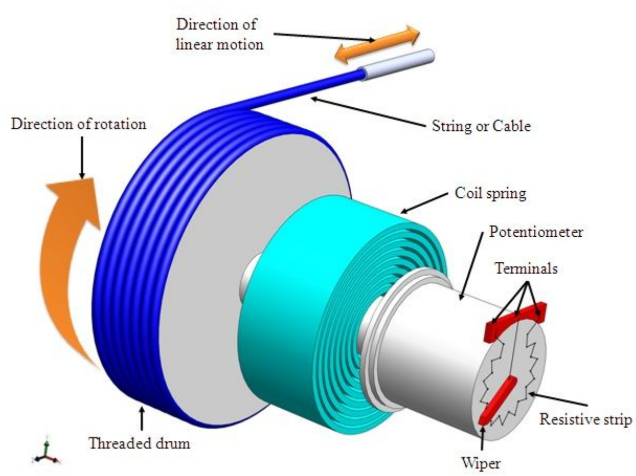


Figure 2: NPTEL Displacement Measurement Design

Sliding Potentiometer:

Sliding potentiometers are potentiometers which are made to track displacement. “Resistance increases in direct proportion to the distance traveled along the resistive element.”[2]. Figure 3 shows a schematic of one such slider.

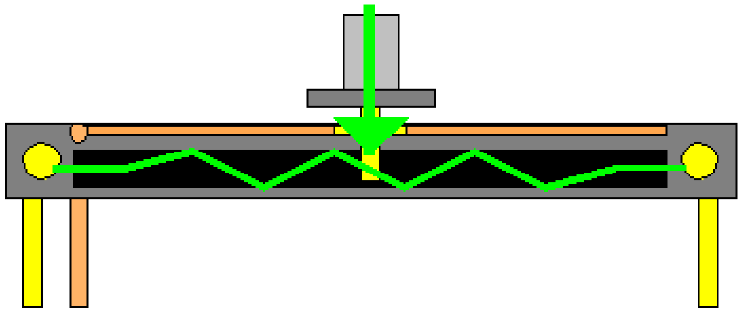


Figure 3: Sliding Potentiometer Design from Engineering 360

While there are sliding potentiometers that are mass produced many of them are designed for small displacements. The maximum displacement the sensor must handle for this project is approximately 16 inches. It is possible to design a custom sliding potentiometer using wire. The wire can be used as the resistance and as long as the material is known the resistance can be determined per unit length. There is wire that is produced to have higher than normal resistances and are specifically used for applications like this one. The resistance values for this specialty wire are also more accurate which means that the final calibration will have less error. This other style of sliding potentiometer can be considered as a fourth concept.

Rationale for Design Selection

Figure 4 shows the pugh chart was used to evaluate the 4 concepts against three criteria: cost, feasibility, performance. These criteria were chosen as the budget for the project is limited, the team has low experience with these systems and the ability for the sensor to produce accurate and precise data is highly important to the customer.

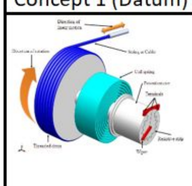
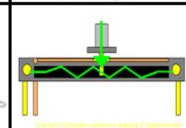
Criteria \ Concepts	Concept 1 (Datum)	Concept 2	Concept 3	Concept 4
				
Cost	0	-1	-1	+1
Feasibility	0	0	+1	+1
Performance	0	+1	0	+1
Sum	0	0	+2	+3

Figure 4: Displacement Sensor Pugh Chart

The datum used in the pugh chart above was the rotating potentiometer design. This was chosen as the datum because the raspberry pi that the team will be using to process the data already has code available for gather and processing rotating potentiometer data. The design was also conducive of easy prototyping.

The highest scoring concept is the diy sliding resistor. It hit all three of the criteria. It is low cost because all that is required is wire. The analog hat being used with the raspberry pi can easily process the signal and the performance can be modified by changing the wire properties and the voltage through the wire.

Wire Analysis

The general schematic for the sliding wire potentiometer is shown in Figure 5 below.

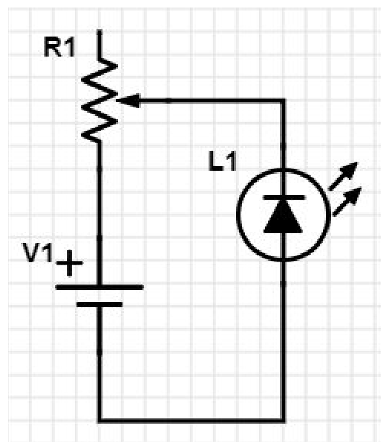
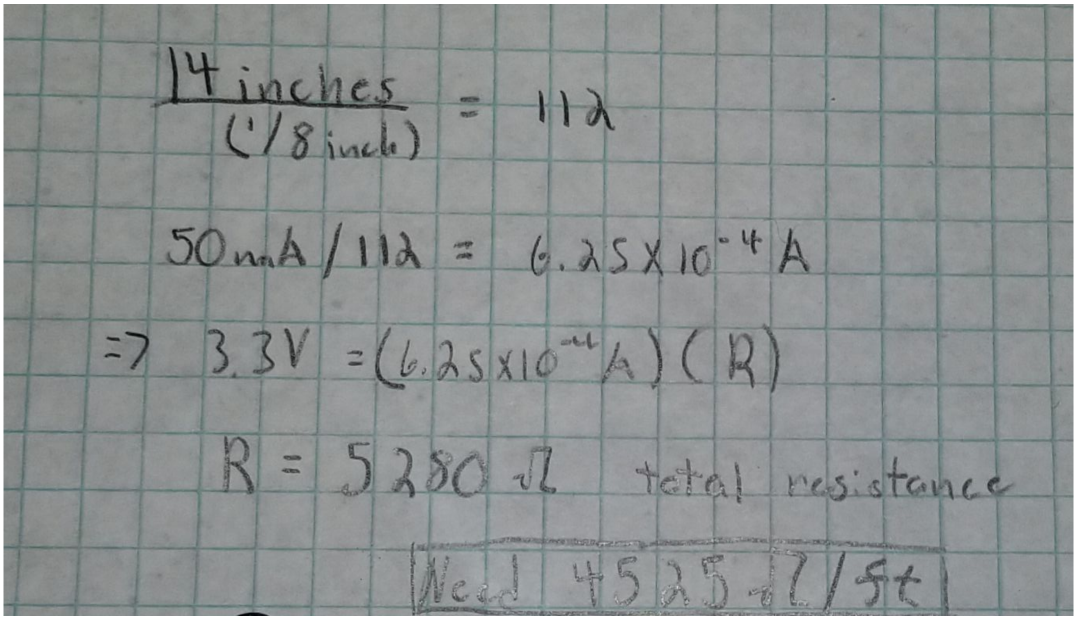


Figure 5: Sliding Wire Potentiometer Schematic

The resistor (R1) is the wire that will be used as the variable resistor. The Raspberry Pi will provide the voltage output (V1). Finally, a load will be added, most likely a LED (L1), to ensure that if the circuit were to short the Raspberry Pi would not be damaged. Calculations in Appendix A show how the specific resistance required was determined based on a voltage output from the Raspberry Pi of 3.3 volts. It was determined that the required resistance for the wire needs to be 4525 ohm/ft. This used the general requirements of having a resolution down to an eighth of an inch, using the raspberry pi as the power source and a total length of 14 inches.

In conclusion the team may need to seek an external power source other than the Raspberry Pi as the maximum current may not provide high enough resolution.

Appendix A: Resistance Calculations



$$\frac{14 \text{ inches}}{(1/8 \text{ inch})} = 112$$

$$50\text{mA} / 112 = 6.25 \times 10^{-4} \text{ A}$$

$$\Rightarrow 3.3\text{V} = (6.25 \times 10^{-4} \text{ A})(R)$$

$$R = 5280\ \Omega \quad \text{total resistance}$$

Need $4525\ \Omega/\text{ft}$

References

[1] Engineering 360. (n.d.). Linear Potentiometers Information. Retrieved April 4, 19, from https://www.globalspec.com/learnmore/sensors_transducers_detectors/linear_position_sensing/ linear_potentiometers

[2] Guwahti, I. (13, September 13). Mechanical Engineering - Mechatronics and Manufacturing Automation. Retrieved March 28, 19, from https://nptel.ac.in/courses/112103174/4

[3] Omron. (2007). Displacement Sensors / Measurement Sensors. Retrieved March 26, 19, from http://www.ia.omron.com/support/guide/56/introduction.html

[4] Strangio, C. E. (n.d.). 4 Wire Testing | Resistance Measurement to within 1mΩ | How-To. Retrieved April 7, 19, from https://www.camiresearch.com/Campaigns/Web-Articles/4-wire-testing.html

[5] Tyger, C. (2019, March 21). Mounting a Constant Force Spring on a Spool. Retrieved March 26, 19, from https://www.vulcanspring.com/blog/mounting-a-constant-force-spring-on-a-spool/