To: [redacted]

From: Jefferson Lee

Subject: Lab 02 – Electromechanical Measurement

Summary

From the electromechanical measurement laboratory, it can be summarized that the main objective was to gain knowledge of an electromechanical device, or also known as a relay. This was done by objectively completing measurements of forces, distances, and voltages and acquiring the knowledge of a few equations focused on steady state values, time constants, electromechanical systems, and measurements. From confidence intervals in statistical calculations, it was concluded that the processes in measuring and acquiring data from electromechanical systems is a long process that requires high accuracy and precision. The data collected points towards an average force (in Newtons) between 0.459139, 0.651661 to open the electromagnetic relay. While measuring the time constant, it was found that a 28.6% difference arose when comparing to a simulated value from the aid of LabView. Lastly, in order to close and re-open an electromagnetic relay, an average of 6.794 V and 2.700 V is needed respectively.

Introduction

In the experiment, an electromagnetic relay was used: this device is able to utilize the magnets inside to create a magnetic field, which then is used to open and close the switch inside. This is primarily used to perform mechanical operations. The first step was to investigate the internal mechanisms and see the different arrangements of pins inside. After a brief observation and disassembly, measurements were made on the distances between the action lever inside. From measured forces and the distances, determining the effective spring constant that exists in the relay was performed. Lastly, the voltage and resistances of the relay was to be inspected through observing the voltages needed to open and close the relay. LabView was also used to help investigate the τ value of the relay.

Body

From inspecting the pins on the electromagnetic relay and its energizing coil, it can be determined which pin is which. Below is an annotated figure (figure 1) displaying the correct pin locations.

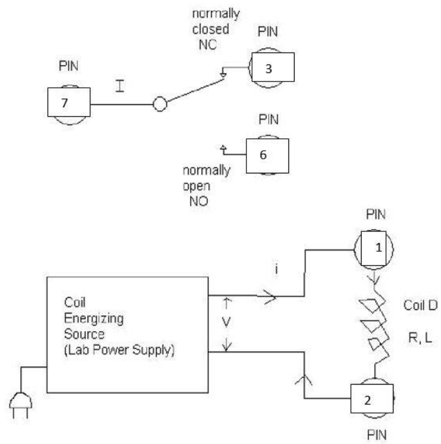


Figure 1: Pin locations of the electromagnetic relay

From knowing the locations of the pins, it is now possible to determine the basic movements and properties of the relay. First, the forces needed to move the inside mechanisms of the relay is calculated. The forces needed to open and close the moveable area down to the fixed contact point is calculated and measured as below. Five separate measurements of the force are in tabular form below.

Table 1: Force (N) required to move the inside mechanism	
Measurement No.	*Force (N)*
1	0.488
2	0.463
3	0.581
4	0.648
5	0.597

In order to summarize the data, a 95% confidence interval was used. To perform this, a few values must be calculated first. As n = 5, ν = 4, and in a 95% confidence interval, $\alpha = \frac{1-0.95}{2}$ = 0.025. From the table in appendix B, t = 2.776. This means finding the lower and upper intervals for the measured force in the 95% confidence interval will be as follows:

$$\mu = \bar{x} \pm t * \frac{S_x}{\sqrt{n}}$$

$$\mu = 0.5554 \pm 2.776 * \frac{0.077526}{\sqrt{5}}$$

$$\boldsymbol{\mu_{force}} = [\mathbf{0.459139}, \mathbf{0.651661}]\ \boldsymbol{N}$$

As we used an ohmmeter to calculate when the circuit was completed and the relay had touched, it could be theorized that the same method could be used but to use the ohmmeter to test the normally closed circuit for an open circuit. This could be done by reading the ohmmeter which should stay at a positive ohm reading, as the normally closed circuit does have a current passing through. After the relay has opened, the reading in the ohmmeter should switch quickly to zero or an infinite number as no current continues flowing.

In order to calculate the corresponding displacement from the spring, it is formulized from the properties of similar triangles. This is possible to compute due to the measurements D1 and D2 having measurable distances. The measured values of D1 and D2 is 8.50 mm and 22.76 mm respectively. The distance of E along D is assumed to be 0.5588 mm as given in the attached figure (figure 4) in appendix C, we can calculate the displacement from the spring to be 0.2087 mm. This is done from the following relationship:

$$\frac{x}{8.5} = \frac{0.5588}{22.76}$$

$$x = 0.20869\, mm \approx \mathbf{0.000209\, m}$$

From this calculation, it is possible to calculate the Keq to be $K_{eq} = \frac{F_S}{x} = \frac{0.554}{0.2087*10^{-3}} = \mathbf{2654.53\ N/m}$. The uncertainty of this value can be calculated from the uncertainty in F and in x, resulting in a net uncertainty of $\sqrt{0.001^2 + 0.05^2} = 0.050001 = \mathbf{5.0001}\%$. This is due to the uncertainty of the average force calculated from a 95% confidence interval to be 5% and the uncertainty of x to be 0.1% (given).

As τ is calculated as follows: $\tau = L/(R + R_S)$, the value of τ given the measrued R, Rs, and given L, is the following.

$$\tau = \frac{1.92}{117.2+9.984} = \mathbf{0.01509\ sec}$$

In comparision, the τ actuall value is the known fact of an Rs value of 0, τ actual becomes the following.

$$\tau_{actual} = \frac{1.92}{117.2} = \mathbf{0.01638\ sec}$$

This results in a percent differnce between the two of approximately a **8.2% difference**. However, using LabView, the τ value can be summarized to the time period required for i to go from 0 to 63% of its final (steady state value). This is known as the experimental (measured) time constant (τ). From the plot of *i vs. t* is attached in appendix A, the τ can be seen to be approximately **0.02185 sec**. The difference between this value and the calculated measurement is approximately a **28.6% difference**.

Measruing the voltages to inorder to close and re-open the relay is as follows. The data is put into a tabular format in addition with a 95% confiedence t-distrubtion upper and lower bound average.

Table 2: Voltage (V) measured to close and re-open relay		
Measurement No.	*Voltage-closing (V)*	*Voltage-opening (V)*
1	6.634	2.616
2	6.610	2.738
3	6.839	2.671
4	6.937	2.727
5	6.950	2.749

In order to summarize the data, a 95% confidence interval was used. To perform this, a few values must be calculated first. As n = 5, ν = 4, and in a 95% confidence interval, $\alpha = \frac{1-0.95}{2}$ = 0.025. From the table in appendix B, t = 2.776. This means finding the lower and upper intervals for the average voltage-closing and voltage-opening in the 95% confidence interval will be as follows:

$$\mu = \bar{x} \ \pm t * \frac{s_x}{\sqrt{n}}$$

$$\mu_{voltage\ closing} = 6.794 \ \pm 2.776 * \frac{0.163}{\sqrt{5}}$$
$$\mu_{voltage\ closing} = [\mathbf{6.592}\ , \mathbf{6.996}]\ \boldsymbol{V}$$

$$\mu_{voltage\ opening} = 2.700 \ \pm 2.776 * \frac{0.056}{\sqrt{5}}$$
$$\mu_{voltage\ opening} = [\mathbf{2.630}\ , \mathbf{2.770}]\ \boldsymbol{V}$$

Conclusion/Summary

From the lab experiment of studying the electromechanical measurements, it can be concluded that the inner workings of an electromechanical system, for example a relay, is complex in both the physics and circuitry mechanism. From performing basic analytical, statistical tests, it was calculated that the average force is 0.5554N to open the electromagnetic relay. From the measurements of the time constant, it was found that a 28.6% difference arose when comparing to a simulated value from the aid of LabView; being a measured value of 0.01509s and 0.02185s respectively. Lastly, the voltage required to close and re-open the electromagnetic relay, an average of 6.794V and 2.700V is needed respectively. Statistical tests were extremely helpful in summarizing the data and measurements collected while providing an accurate, yet gauge of uncertainty in a numerical manner. Software such as LabView was also helpful in providing more precise and accurate measurements compared to mathematical equations and the naked eye. In the end, it was a great way to understand and gain knowledge of an electromechanical device, or also known as a relay.

References

A. Palazzolo and M. Adams. "LAB 02-ELECTROMECHANICAL MEASUREMENT LABORATORY INSTRUCTIONS" Texas A&M University, 2020.

Appendix

A) As discussed from the comparing of the measured and predicted τ values, a plot of *i vs. t* is as follows.

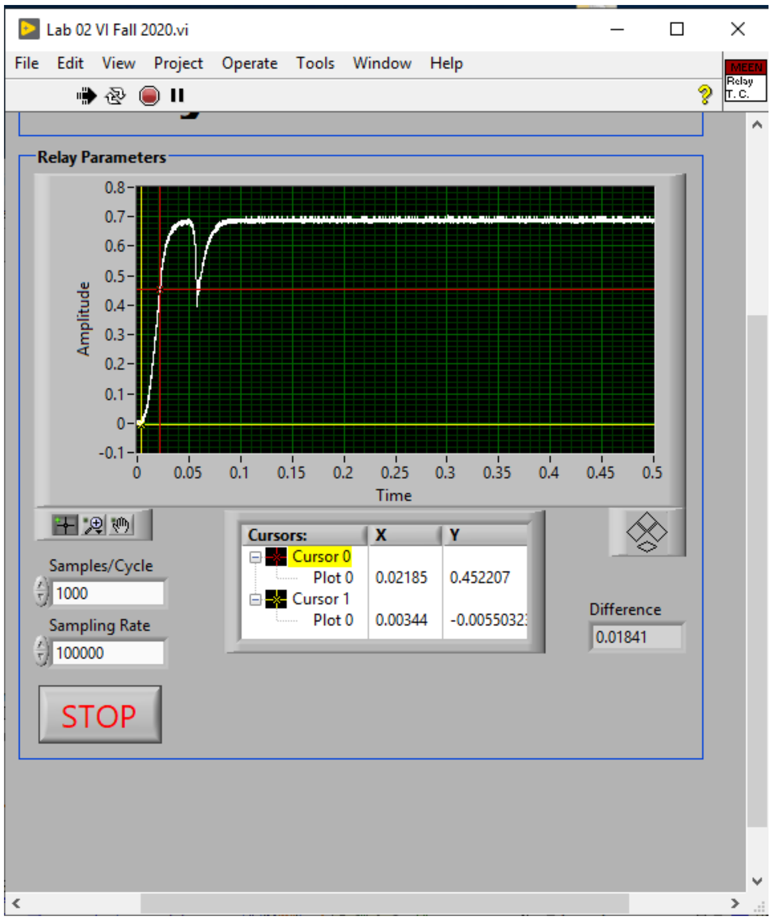
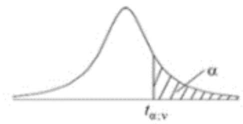


Figure 2: Plot of i vs. t to find τ value

B) Below is a figure (figure 3) to help find the t values from a t-distribution.

Table of the Student's *t*-distribution

The table gives the values of $t_{\alpha;\nu}$ where
$\Pr(T_\nu > t_{\alpha;\nu}) = \alpha$, with ν degrees of freedom



ν \ α	0.1	0.05	0.025	0.01	0.005	0.001	0.0005
1	3.078	6.314	12.076	31.821	63.657	318.310	636.620
2	1.886	2.920	4.303	6.965	9.925	22.326	31.598
3	1.638	2.353	3.182	4.541	5.841	10.213	12.924
4	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	1.319	1.714	2.069	2.500	2.807	3.485	3.767
24	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	1.296	1.671	2.000	2.390	2.660	3.232	3.460
120	1.289	1.658	1.980	2.358	2.617	3.160	3.373
∞	1.282	1.645	1.960	2.326	2.576	3.090	3.291

Figure 3: Table for a t-distribution

C) Below is a figure (figure 4) to help visualize the similar triangle relationship.

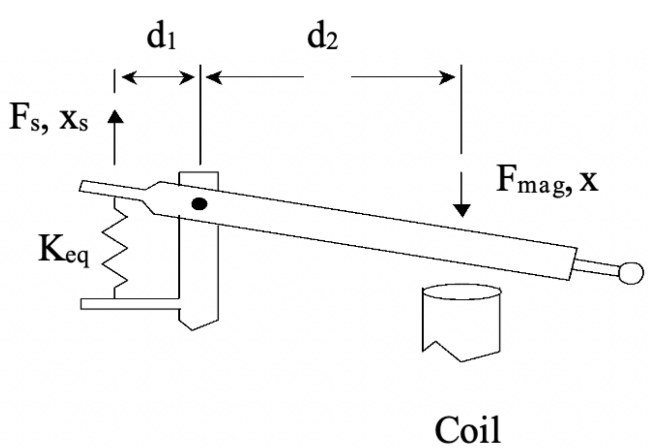


Figure 4: Relationship between x and deflection of spring (A. Palazzolo and M. Adams)