Laboratory Experiment #4
ME 303
11/22/2019

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Measuring the Force of a Punch using a Load cell

Abstract

The purpose of this paper was to experiment with load cells. The chosen experiment was using the load cell to measure the maximum punching force of a group of college students. The load cell was first tested with known masses and a data acquisition system to determine the calibration equation (M=1.78 * 10^6 V+ 677 where M = mass and V = voltage). The load cell was then put into the punching device that was specifically designed for the experiment. The punching force of the college students was then tested using 6 male subjects and 8 female subjects with three trials per subject. The data was analyzed and it was determined that the male test subjects produced a greater punching force than the female test subjects. This is concluded from a male having both the maximum punch force and the average maximum punch with a maximum force of 1437.621 N and an average maximum punch force of 1408.768 N, and the males had a greater average of 917 N and the females had a lesser average of 562 N. Also, every punch displayed the characteristics of an impulse force.

Introduction

There are several methods of measuring an impact force. Some of the sensors that are used are strain gauges, force-resistive resistors, and load cells. A load cell was used to record the max force in a punch in this laboratory experiment [1]. A load cell is a transducer type a sensor that can measure lateral force, such as an impulse force. Impulse is a force acting over a very short time. It converts force into electrical signals that can be recorded. A linear relation exists between the force applied and voltage output and allows for a calibration equation to be developed from known weights.

When recording data, though it is possible to see an output on a voltmeter, it would be impractical since only an instantaneous value would be shown. In this experiment, since the max force applied is what's being analyzed, it is necessary to see the voltage over a time interval. LABVIEW was used to record data during each of the punches. The group decided to record 1000 data points over the span of ten seconds.

To perform calculations for this experiment, two equations were needed. The first equation is Newton's second law equation.

$$F = M * A \tag{1}$$

F is equal to force [N]. M is equal to mass [kg]. A is acceleration due to gravity [m/s^2], which has a numerical value of 9.8 m/s^2. The next equation is the equation for the best linear fit. The equation is:

$$Y = A_1 * X_I + A_0 \quad (2)$$

Y is the dependent variable. A_1 is the slope. X_I is the independent variable. A_0 is the y-intercept.

Experimental Methodology

The first step in the experiment was to set up the load cell. To set up the load cell, wires and banana clips were used to connect the load cell to the National Instruments Data Acquisition Card and the EK DC Precision power supply. The load cell had four separate wires attached to it. The red wire was connected to the positive terminal of the power supply. This supplied power to the sensor itself. The black wire was plugged into the negative terminal of the power supply. The green wire was the positive lead that was plugged into the National Instruments Data Acquisition Card. This green wire was the differential output. It was plugged into port 68 of the card. The last wire, the white wire, was the negative lead that plugged into the data acquisition card. The negative lead was plugged into port 34. The final setup of the sensor can be seen in Figure 1.

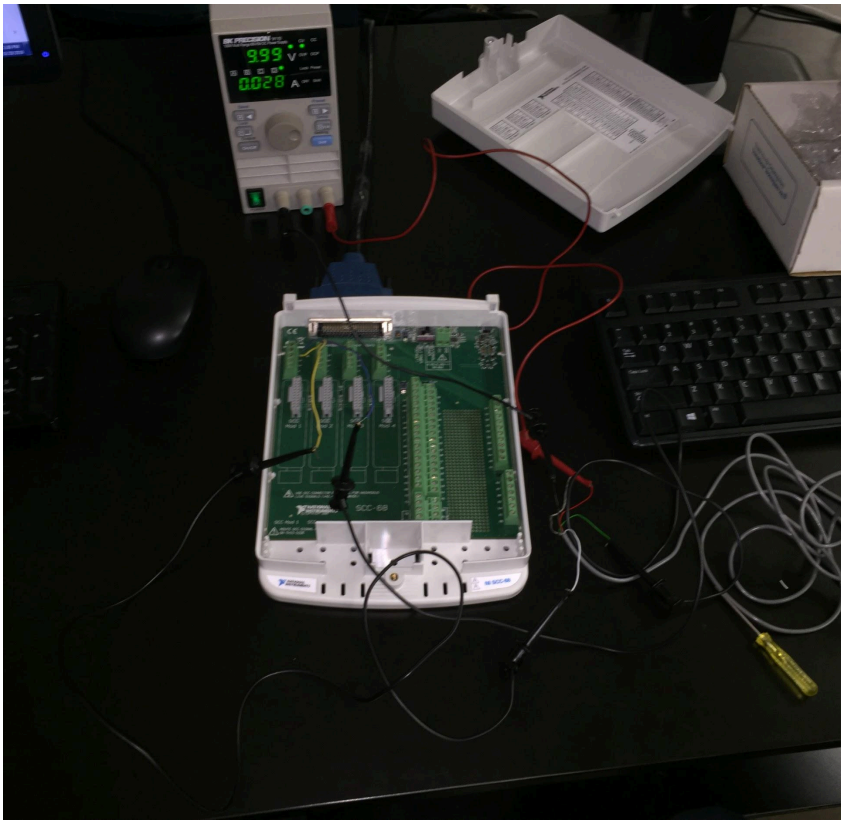

Figure 1: The final setup to record data with the load cell

The next step in the experiment was to calibrate the sensor. To do this, nine different weights were used for the calibration process. Each weight was first measured on a scale. The nine weights with their scale readings were observed and recorded. Next, the masses were then hung from the load cell and data for each mass was collected. From the data collected, voltage vs weight was plotted. A trendline was placed on the data from the calibration. Actual forces values were calculated using the equation from the trendline.

The goal of the experiment was to collect data from a load cell that was being punched. The group designed a device that had the load cell accurately record data from punches. This device can be seen in Figure 5. Figure 6 is a picture of the device. The device was set on the floor. Each person had to punch down towards the floor. To record data, the start button clicked first in LABVIEW. Next, the record button was clicked. The person was then told to punch the device. One thousand data points were collected over a span of ten seconds. Figure 3 and Figure 4 show people punching the device. After each punch, the load cell was checked to make sure that it was properly aligned. Fourteen total people punched the device. This number included six guys and eight girls.

Figure 3: Ronny

Figure 4: Kelly

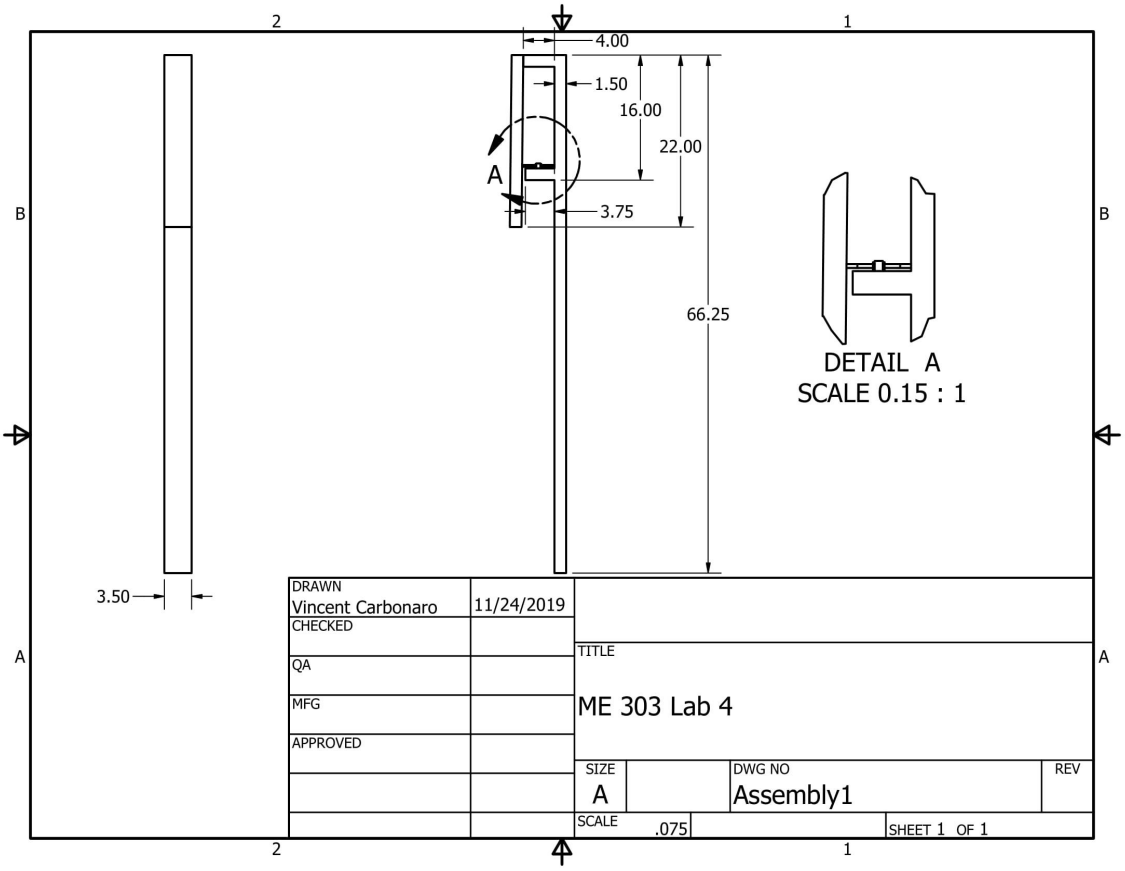

Figure 5: 2D CAD drawing of the punching device

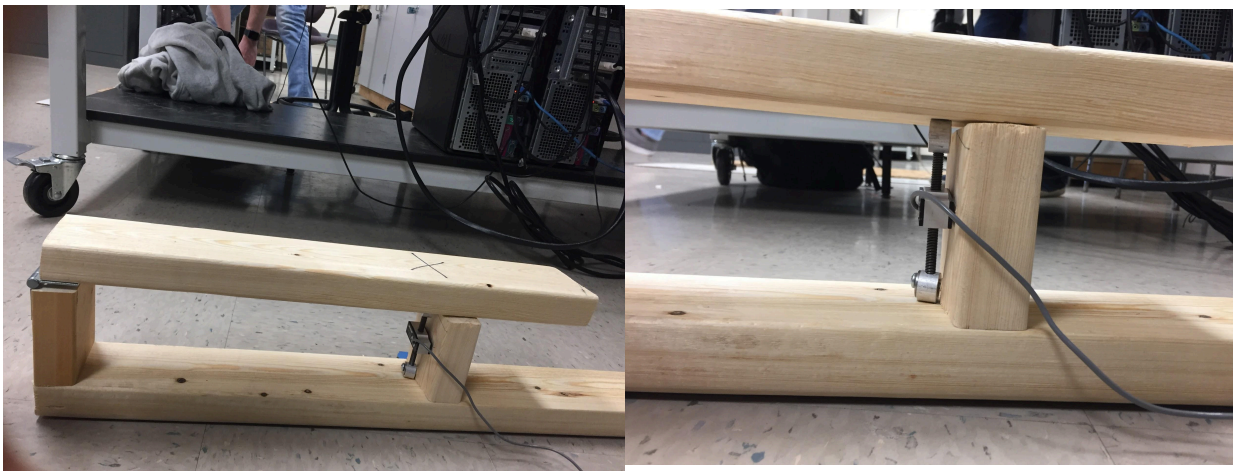

Figure 6: The device used to record the force of the punches

Results and Discussion

Figure 7 is a plot of mass as a function of the average voltage per weight In the case of this experiment, the dependent variable was mass, and voltage is the independent variable. This data obtained using the load cell the data acquisition system and different known masses. The average voltage for each mass can be seen in Table 2.

The voltages were then multiplied by negative -1 and then entered into the graph as seen in table 3 to account for the actual experiment the load cell being in compression. Equation w and excel were then used to create a linear regression on the graph to obtain the calibration equation. The calibration equation was M=1.78 * 10^6 V+ 677 where M = mass and V = voltage. This equation gives the ability to obtain the mass of any voltage reading from the sensor.

Mass (g)	Voltage (V)
200	-0.000273
500	-0.000107
1000	0.000201
1500	0.000463
2000	0.000735

Table 2: Load Cell Voltage per Mass Reading

Mass (g)	Voltage (V)
200	0.000273
500	0.000107
1000	-0.000201
1500	-0.000463
2000	-0.000735

Table 3: Load Cell Negative Voltage per Mass Reading

Figure 7: Mass vs Voltage plot

The data obtained from the data acquisition system during the punching experiment was then analyzed using the calibration equation. The calibration equation ended up being Y = -1.78*10^6 +677. Before the calibration equation was used, the minimum voltage value was obtained from each trial and the average no-load voltage. The minimum voltage was found because the orientation of the sensor measured the force in compression which gave a negative voltage reading. This made it so that the maximum mass would actually be the minimum voltage. The minimum voltage value obtained from each trial and the average no-load voltage was then entered into the calibration equation to obtain the mass in grams. The mass for each trial was then divided by 1000 to obtain the mass in kilograms. Equation 1 was then used to obtain the force in newtons of each trial. The force from each trial was then subtracted by the no-load force to obtain the actual force of the punch. This was done because the punching apparatus exerted a force on the load cell even before a punch was applied. The average punching force was also found for each trial subject. A table with the recorded data can be seen in Table 4. Some of the elements in this table include the name of the person, trial number, the force, and the actual force using the calibration equation.

Name	Max Voltage [V]	Mass [g]	Mass [kg]	Force [N]	Actual Force [N]	Average Punch Force [N]
Zach 1	-0.038335	68913.3	68.9133	676.039	657.376	648.936
Zach 2	-0.040974	73610.72	73.61072	722.121	703.457	
Zach 3	-0.034246	61634.88	61.63488	604.638	585.974	
Vinny 1	-0.07027	125757.6	125.7576	1233.682	1215.018	1157.674
Vinny 2	-0.068016	121745.48	121.74548	1194.323	1175.659	
Vinny 3	-0.062672	112233.16	112.23316	1101.007	1082.343	
Ronny 1	-0.079091	141458.98	141.45898	1387.713	1369.049	1408.768
Ronny 2	-0.083018	148449.04	148.44904	1456.285	1437.621	
Ronny 3	-0.081988	146615.64	146.61564	1438.299	1419.636	

Rachel 1	-0.04854	87078.2	87.0782	854.237	835.573	661.304
Rachel 2	-0.036081	64901.18	64.90118	636.681	618.017	
Rachel 3	-0.031059	55962.02	55.96202	548.987	530.324	
Megan 1	-0.039043	70173.54	70.17354	688.402	669.739	702.153
Megan 2	-0.036757	66104.46	66.10446	648.485	629.821	
Megan 3	-0.046898	84155.44	84.15544	825.565	806.901	
Kelly 1	-0.030383	54758.74	54.75874	537.183	518.519	432.508
Kelly 2	-0.017731	32238.18	32.23818	316.257	297.593	
Kelly 3	-0.028258	50976.24	50.97624	500.077	481.413	
Josh 1	-0.056524	101289.72	101.28972	993.652	974.988	867.051
Josh 2	-0.059614	106789.92	106.78992	1047.609	1028.945	
Josh 3	-0.03489	62781.2	62.7812	615.884	597.220	
Jarad 1	-0.055139	98824.42	98.82442	969.468	950.804	585.037
Jarad 2	-0.022431	40604.18	40.60418	398.327	379.663	
Jarad 3	-0.025007	45189.46	45.18946	443.309	424.645	
Heather 1	-0.042777	76820.06	76.82006	753.605	734.941	616.142
Heather 2	-0.040685	73096.3	73.0963	717.075	698.411	
Heather 3	-0.024459	44214.02	44.21402	433.740	415.076	
Emma 1	-0.02784	50232.2	50.2322	492.778	474.114	383.609
Emma 2	-0.021466	38886.48	38.88648	381.476	362.812	
Emma 3	-0.018665	33900.7	33.9007	332.566	313.902	
Eliza 1	-0.02095	37968	37.968	372.466	353.802	415.643
Eliza 2	-0.028033	50575.74	50.57574	496.148	477.484	
Bret 1	-0.061031	109312.18	109.31218	1072.352	1053.689	831.825
Bret 2	-0.030737	55388.86	55.38886	543.365	524.701	
Bret 3	-0.053208	95387.24	95.38724	935.749	917.085	
Baylee 1	-0.032411	58368.58	58.36858	572.596	553.932	485.348
Baylee 2	-0.027292	49256.76	49.25676	483.209	464.545	
Baylee 3	-0.025747	46506.66	46.50666	456.230	437.566	
Alison 1	-0.045964	82492.92	82.49292	809.256	790.592	797.338
Alison 2	-0.048121	86332.38	86.33238	846.921	828.257	

Alison 3	-0.044966	80716.48	80.71648	791.829	773.165	
No Load 1	-0.00046611	1506.6758	1.5066758	14.780		
No Load 2	-0.0009109	2298.402	2.298402	22.547		
No Load average	-0.000688505	1902.5389	1.9025389	18.664		

Table 4: Punch Force Calculations

The data was also analyzed for the force of the punch over the time of the trial. A trend was established as can be seen in Figures 8 and 9 for reference. The figures shown is the data from test subject Ronny's maximum force trial and test subject Emma's minimum force trial. An overall trend was seen in every subject trial the same as seen in figures 8 and of a steady force due to the block for the first few seconds and then a sudden impulse force that last for about .3 seconds from the force of the punch hitting the block of wood and the sensor. The force increases for about .15 seconds hits its peak and then decreases for about .15 seconds. The first .15 s is the time it takes for the fist to fist come in contact with the block until the punch reaches its full extension against the block and the sensor. The second .15 s is the time it takes for the fist to retract from the block and sensor and leave contact with the block. The other smaller peaks are do to the wooden block bouncing on the sensor due to residual force dying out due to the design of the apparatus.

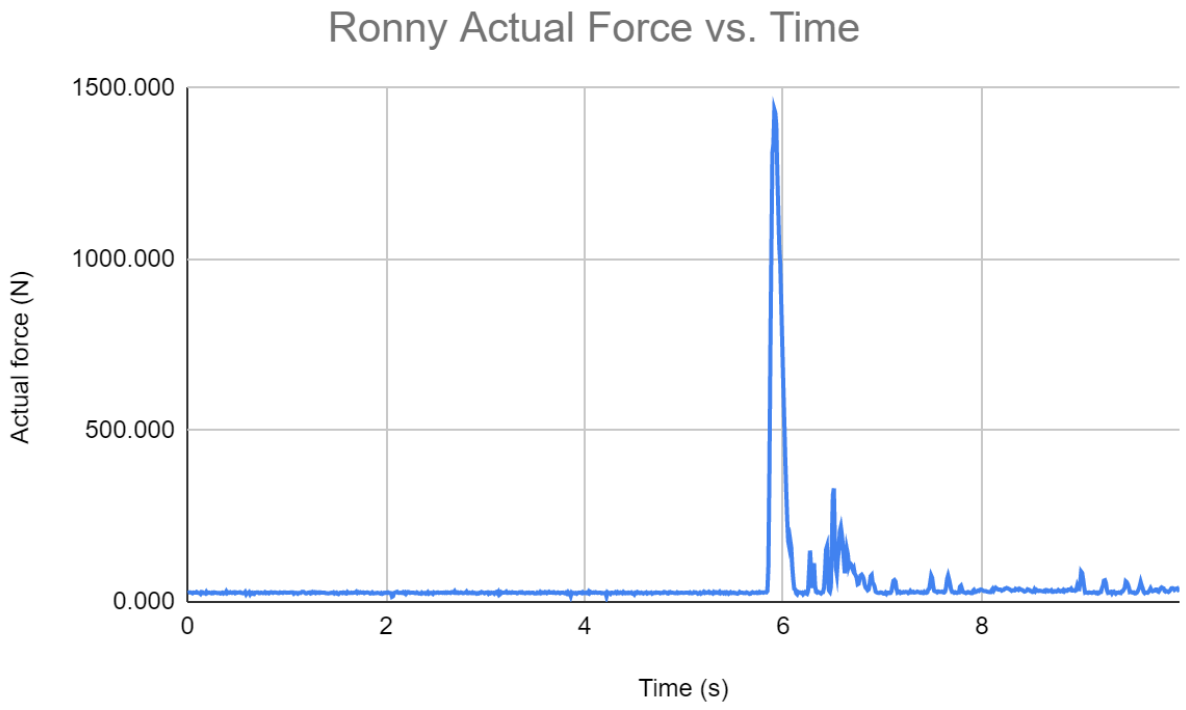

Figure 8: Ronny Actual Force vs. Time plot

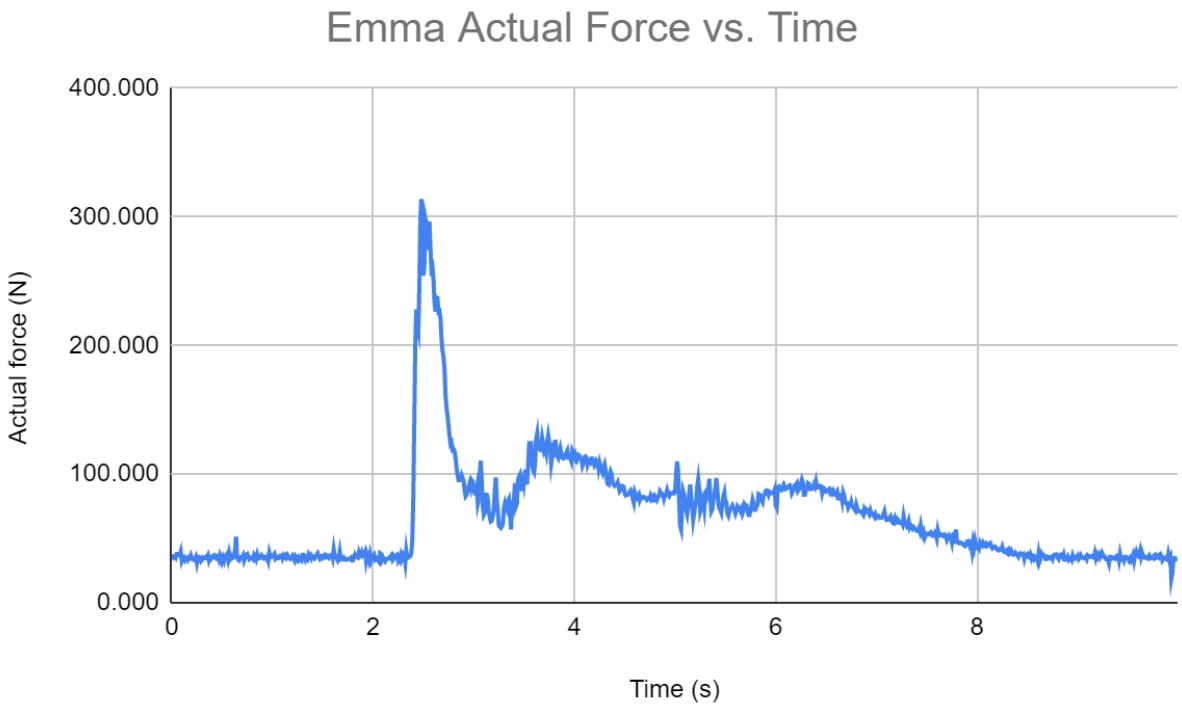

Figure 9: Emma Actual Force vs. Time plot

The data was then analyzed to see who had the maximum force overall, the average maximum force overall, the overall average maximum force of all the trials, and the average maximum force for each gender. The test subject Ronny had both the maximum punch force and the average maximum punch with a maximum force of 1437.621 N and an average maximum punch force of 1408.768 N. The overall average maximum force of all the trials was 721.082 N, the overall average maximum force for the males was 916.548 N, and the overall average maximum force for the males was 561.756 N. All this data can be seen in Table 5.

Max Punch [N]	Max Average [N]	Total Average [N]	Male Average [N]	Female Average [N]
1437.621	1408.768	721.082	916.548	561.756
Ronny	Ronny			

Table 5: Punch Force Average Analysis

There are two main improvements that could be made of this experiment. The first improvement that could be made would be to get more people to punch the device. People from different age groups and athletic abilities could be asked to punch the sensor. Another improvement that could be made is to ask people to punch with both their dominant and non-dominant hands. In the case of this experiment, people only punched the sensor with their

dominant hand. Punching with both hands could give a better understanding of the overall average punching force of an average human.

Conclusion

From the obtained data, it was determined that the male test subjects produced a greater punching force than the female test subjects. This is concluded from a male having both the maximum punch force and the average maximum punch with a maximum force of 1437.621 N and an average maximum punch force of 1408.768 N , and the males had a greater average of 917 N and the females had a lesser average of 562 N. This difference in force can be due to the fact of the difference between male and female anatomy. Also, every punch displayed the characteristics of an impulse force.

References

[1] "Force and Pressure Sensor Technology to Measure Impact Force." ***Tekscan*****, 29 May 2018,**
https://www.tekscan.com/blog/pressure-mapping/force-and-pressure-sensor-technology-measure-impact-force

RECORD OF TIME AND EFFORT

TO COMPLETE THIS LAB REPORT

Total time spent per group member:

Josh: 12 hours, 30 minutes:

Vinny: 12 hours, 30 minutes:

Zach: 12 hours, 30 minutes:

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11/22/2019

1) Tuesday, October 29th, 2019: 2 PM – 4 PM (2 hours) all members

-The load cell calibration experiments were performed and the data was obtained in Jobst 133.

2) Monday, November 4th, 2019: 8 PM – 10 PM (2 hours) all members

-The Punching apparatus material was obtained from Lowes and was assembled at a house off-campus.

3) Tuesday, November 5th, 2019: 2 PM – 4 PM (2 hours) All members

-The Punching experiments were performed and the data was obtained in Jobst 133.

4-1) Friday, November 22nd, 2019: 2 PM – 5:15 PM (3 hours, 15 minutes) Josh

-The ME 303 lab report template was read.

-Analysis of lab data was begun.

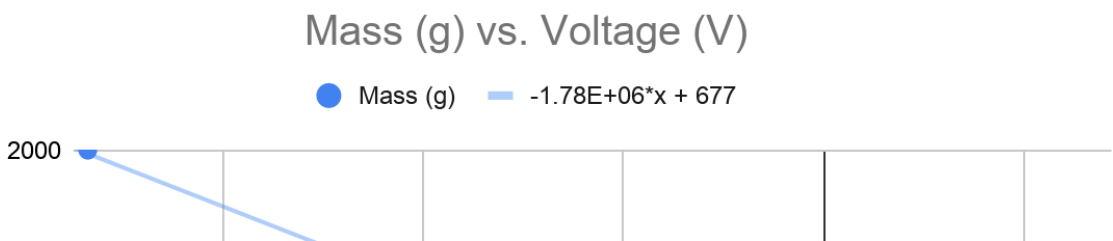
- The report was worked on

4-2) Friday, November 22nd, 2019: 2 PM – 5 PM (3 hours) Vinny

-The ME 303 lab report template was read.

-Analysis of lab data was begun.

- The report was worked on



4-3) Friday, November 22nd, 2019: 2 PM – 5:45 PM (3 hours, 45 minutes) Zach

-The ME 303 lab report template was read.

-Analysis of lab data was begun.

- The report was worked on

5-1) Sunday, November 24th, 2019: 1:15 PM – 4:30 PM (3 hours, 15 minutes)Josh

- The report was worked on and finished

5-2) Sunday, November 24th, 2019: 1 PM – 4:30 PM (3 hours, 30 minutes) Vinny

- The report was worked on and finished

5-3) Sunday, November 24th, 2019: 1:45 PM – 4:30 PM (2 hours, 45 minutes)Zach

- The report was worked on and finished