Strain Gauge Project

Final Testing Documentation

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Test Performed by: Strain Gauge Team

IMPLEMENTATION PLAN

In this final test document, the team used four devices to measure the microstrain of the metal under a certain force. At the same time, the team used the Excel sheet to calculate the actual strain value of the metal under force and compared it with the average value of the data measured multiple times and calculated its error. The calculated error should be less than or close to customer requirements which is 5%.

TESTING PROCEDURES

1 Axial Load Device

For the Axial load part, the team used table clamp to clamp the metal to be tested and vertically downward. The team used two identical hooks to suspend the kettlebell from a metal piece to exert a pulling force of 5.5 kg. Through the computer program, the micro strain data can be measured. Next, the team repeated the same steps 8 times and averaged them. The measured data will be compared with the actual calculated value in the Excel table and the error will be obtained. The range of error should be less than the engineering requirements.

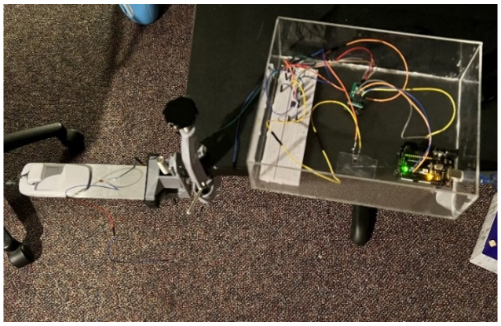

Figure 1: Axial load device

2 Bending Device

For the bending part, the team used a table clamp to clamp one end of the metal to be tested. The 5.5 kg kettlebell is fixed to the other end through a small hole on the fishing line connecting metal. The team released the heavy objects and allowed the metal to bend naturally. Through a computer program, micro-strain data can be read out. The team repeated the same experiment 8 times and averaged it. Then, the average value is compared with the actual value in Excel and the error is calculated. The final error will meet the accuracy in customer requirements.

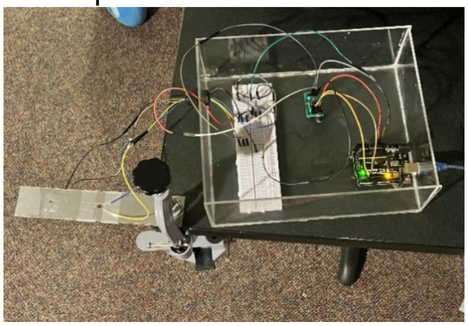

Figure 2: Bending device

3 Torsion Device

For the Torsion part, the team used the table clamp to fix one end of the hollow metal cylinder we machined and make it horizontally. Then we inserted a metal bar that can help apply torsion into the other end of the cylinder and hang a 5.5 kg kettlebell to apply the torsion. The team repeated the same process 8 times to get enough data. Through the computer program, micro-strain data can be read out and we used Excel to calculate the average value and error. The error is around 4% which is in line with the requirements of 5%.

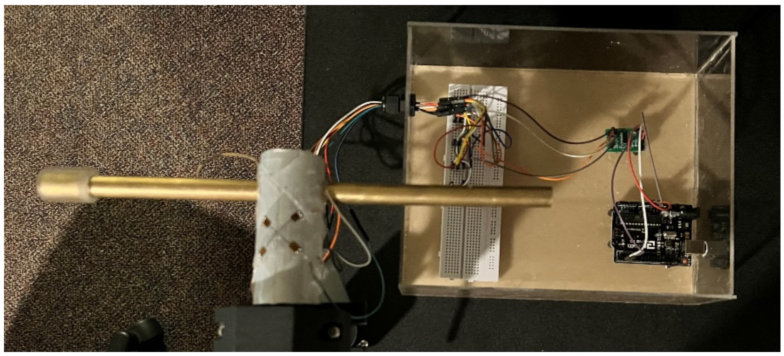

Figure 3: Torsion device

4 Internal Pressure Device

For the internal pressure part, since our device is from Dr. Constantin Ciocanel, so the only test we need to do is the accuracy. This device is We will add pressure to this cylinder and read the micro strain data, this result will be compared with the theoretical value we calculated. This device is hydraulic, and the liquid inside is oil. Since the oil inside will continue to lose, we can only do one more experiment. If we can get the oil added, more data can be got. The results will be shown in the next section.

Figure 4: Internal Pressure device

RESULTS

1 Axial Load Device

For the axial load device testing, the team set the load of 5.5 kg. Through the Excel calculation (Appendix A), the team can get the actual data which is 22.34 microstrain. During the 8 runs of testing, the team can get most of the data lose to actual value. However, because the metal to be tested is very thin, this leads to inevitable bending. Therefore, among all the test results, there are some abnormalities in the data, which also caused the overall error to be very large. But after removing these outliers, the measured data is still very accurate.

Run	Strain
1	23.214
2	50.214
3	76.425
4	22.714
5	21.998
6	107.145
7	87.266
8	23.017
Avg	51.499125
Ref	22.34
Err%	130.52%

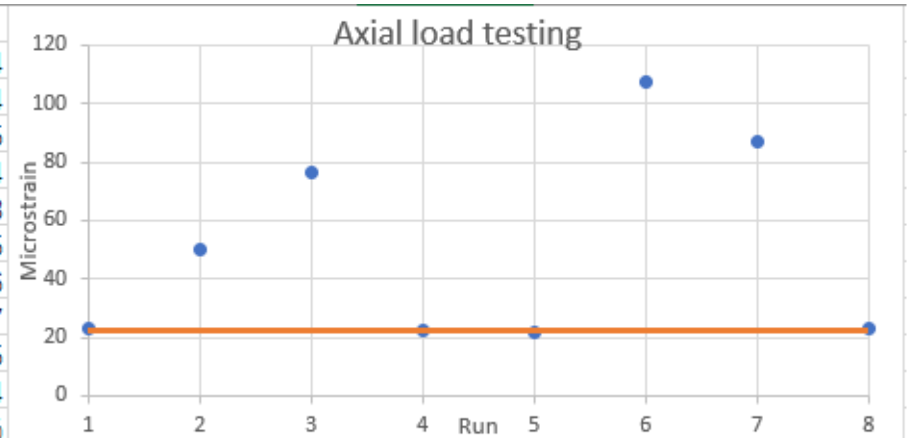

Figure 5: Axial load device testing data

2 Bending Device

For the bending device testing, the load is 5.5kg which mentioned above. Through the calculation shows in the Appendix B. The team known the actual value of the strain is 681.1448 micro strain. Figure 6 shows the data we got in the testing process. The team repeated 8 times so there are 8 points, the orange line is the actual process. From the figure we can see that our measured value is very close to the actual value, with an error of 4.11%. The measurement is accurate and meet our requirements.

Run	Strain
1	667.125
2	624.087
3	642.291
4	678.116
5	653.613
6	635.773
7	636.255
8	687.762
Avg	653.1278
Ref	681.145
Err%	-4.11%

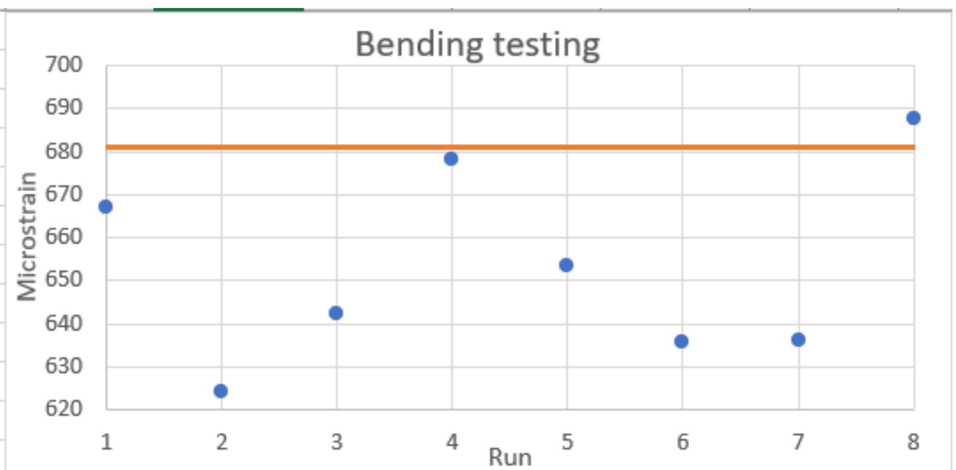

Figure 6: Bending device test data table

3 Torsion Device

For the torsion device testing, the 5.5 kg kettlebell hang on the one end of the brass bar. The forced bar gives a fixed torque to the hollow metal column and its torque distance is 11cm. Through the Excel sheet calculation (Appendix C), the team can get the actual microstrain which is 49.8. The total average value of the 8 times testing is 51.75 which is very close to the actual value and the error can meet the customer requirement which is less than 5%.

Run	Strain
1	51.595
2	58.624
3	49.896
4	54.689
5	46.173
6	57.419
7	52.157
8	43.482
Avg	51.754375
Ref	49.8
Err%	3.92%

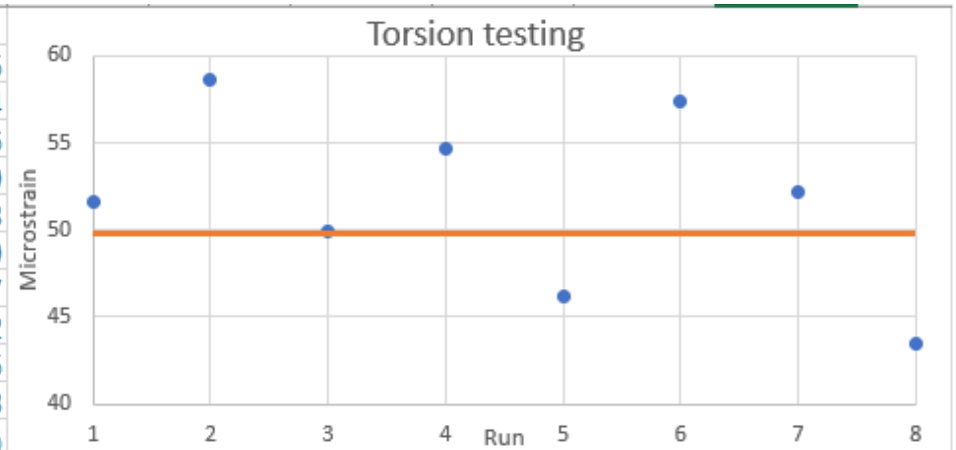

Figure 7: Torsion device test data torsion

4 Internal Pressure Device

The figure below is the distribution of strain gauges, we can see that they can measure strains in the directions of 0°, 30°, 60°, and 90° respectively.

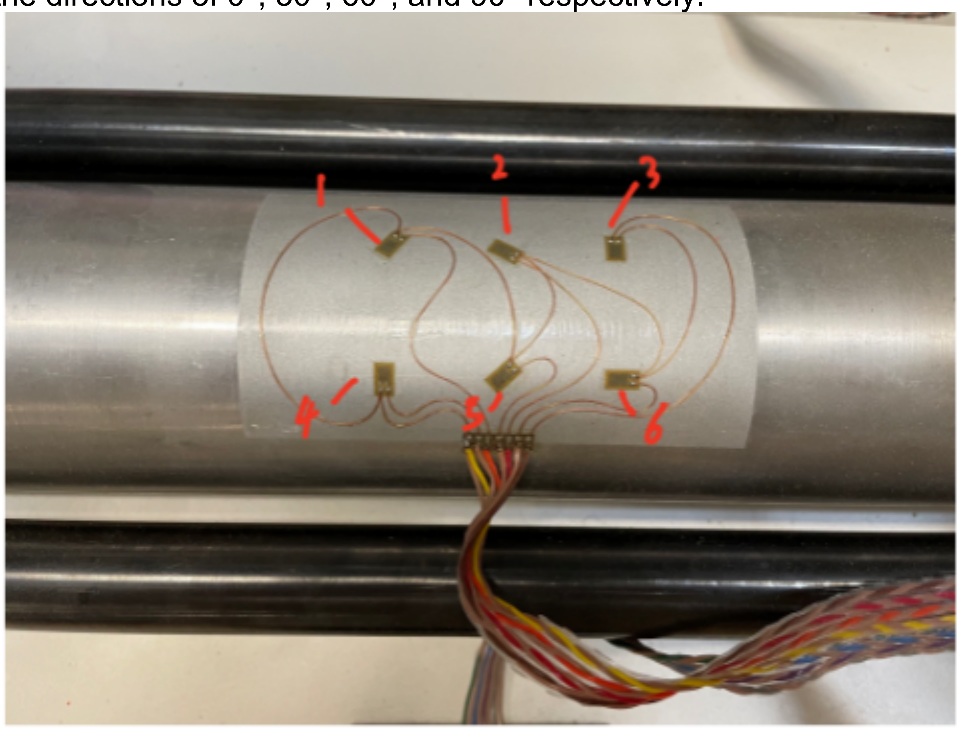

Figure 8: Distribution of strain gauges

And the data we acquired are in the table below. The second row is the initial data, which is the state that no pressure in it. And the third row is the final data, which is the state that we add the certain pressure in it. During this test, the internal pressure we added is 22 bars. So, after doing the subtraction, we can get the actual strain of each direction.

Table 1: Data acquired for internal pressure

Point	1	2	3	4	5	6
Initial	-544.00	-736	-542.00	-688.00	-602.00	9,653.00
Final	-263.00	-612.00	-466.00	-619.00	-396.00	9,339.00
Actual strain	281.00	124.00	76.00	69.00	206.00	-314.00

For the theoretical part, the detailed calculation is in the Appendix D, here we can show you the result.

Table 2: Calculated data

Point	1	2	3	4	5	6
Angle	30	60	90	90	45	0
Theoretical	261.62	130.81	65.41	65.41	196.22	327.03
Actual strain	281.00	124.00	76.00	69.00	206.00	314.00
Error	7.4%	5.2%	16.2%	5.5%	5.0%	4.0%

From the result, the device is very accurate and satisfied our requirement.

Appendix A: Axial load calculation data

Material	6061-T6 Aluminum	
Density	2.78	g/cm³
Length	0.2	m
Width	0.055	m
Height	6.35E-04	m
Cross-sectional	3.49E-05	m^2
Volume	6.99E-06	m^3
Mass	1.94E-02	kg
Fatigue strength	138	Mpa
Modulus of elasticity	68.9	Gpa
Deformation length	0.006	m
Apply force	53.76	N
Stress	1.54E+06	Pa
Strain	2.23E-05	strain
	22.34	microstrain

Appendix B: Bending calculation data

Material	6061-T6 Aluminum	
Density	2.78	g/cm³
Length	0.12	m
Width	0.04	m
Height	0.0032	m
--y	0.0016	m
Cross-sectional Area	0.000128	m^2
Volume	0.00001536	m^3
Mass	0.0427008	kg
Fatigue strength	138	Mpa
Modulus of elasticity	68.9	Gpa
Deformation length	0.006	m
Max F under MOE	440960	N
Max F under FS	17664	N
Force Range		
Load (F)	53.3969091	N
Stress	4.17E+05	N/m^2
Length change	0.0000007265544598	m
	6.054620498	microstrain
Moment of Inertia	0.0000000001092266667	m^4
yield strength	324	Mpa
P range	2.4576	N

Strain at 0		
M0	6.407629092	N*m
tau_0	0.001362289612	
	1362.289612	microstrain
Strain at 1		
M1	3.737783637	N*m
tau_1	0.0007946689404	
	794.6689404	microstrain
Strain at 2		
M2	3.203814546	N*m
tau_2	0.0006811448061	
	681.1448061	microstrain

Appendix C: Torsion calculation data

length of the grip	0.11	m
weight of the suspended object	5.5	Kg
torque	5.93505	N*m
Poisson's ratio	0.33	
E	68	Gpa
Dout	0.04	m
Din	0.038	m
Zp	0.000002330983209	m3
strain	0.00004979984203	
microstrain	49.79984203	

Appendix D: Internal pressure experimental data figure

Material	2024 aluminium alloy					
Density	2.78	g/cm³				
Length	0.375	m				
Outer Diameter	0.0762	m				
Inner Diameter	0.07	m				
Cross-sectional	0.002847665245	m_2				
Volume	0.001067874467	m_3				
Mass	2.968691018	kg				
Fatigue strength	138	Mpa				
Modulus of elasticity	68.9	Gpa				
Pressure	2200000	N/m^2				
Microstrain	327.0284189					
Microstrain	65.40568379	N/m^2				

Microstrain εH	0.00972250789					
Microstrain εL	0.001944501578					
Angle (rad)	0.5236	1.0472	1.5708	1.5708	0.7854	0.0000
Point	1	2	3	4	5	6
Angle	30	60	90	90	45	0
Theoretical	261.623	130.811	65.406	65.406	196.217	327.028