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The Innovation Breakthrough in Digital and Disruptive Era

Design a Data Acquisition System on Deflection Test Equipment

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Abstract. The purpose of performing a deflection test is to determine the behavior of the material when given load variations. Acquisition data is used to read deflection value. Data acquisition is the process of collecting signals derived from changes in physical behavior, in this case read deflection on material test. The sensor used to read the behavior of the material when subjected to load is strain gauge BF 350 AA sensor. Data is captured in real time. Based on testing using a data acquisition system, deflection data was obtained with the smallest difference being 0.032 mm and the largest difference being 1.511 mm. The deflection stress data with the smallest difference is 0.742 N/mm² and the largest difference is 250.816 N/mm². The best deflection strain data acquisition system error rate value is 1.46% and the worst is 2.99%. As for the error rate value of the deflection stress data acquisition system, the best is 1.41% and the worst is 2.98%. Based on the error rate value of the strain-stress produced by the data acquisition system, it can be said that the data acquisition system is designed quite well.

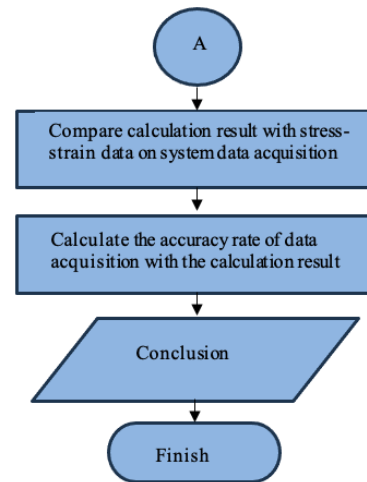
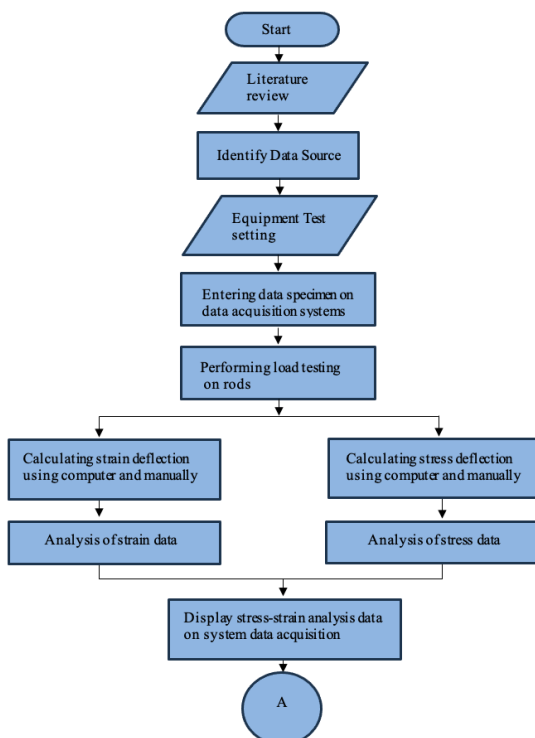
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1 Introduction

The deflection test aims to determine the quality of a material visually [13]. Deflection testing is also used to determine the strength of a material when it is loaded. The greatest deflection stress acceptable when subjected to external loading without a change in shape or defect is called the deflection force [14]. The type of material that is loaded affects how much bending strength can be received by the material [10]. Deflection tests applied to materials that are not easily broken are the best way to determine the strength and brittleness of the material [19].

Data acquisition is the process of sampling signals that measure real-world physical conditions and converting the resulting samples into digital numeric value that can be manipulated by conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer [4][8][18]. Sensor is one component of the data acquisition system that is used to convert a measurement value into a signal, then the signal will be processed by the data acquisition system [11][12]. The processed data will be visualized and stored on the PC. Sensors or transducers produce analog signals that convert a parameter such as pressure, position, or temperature into current voltage[15]. The analog signal obtained cannot be directly read or processed by a computer. Analog signals will be processed and converted into digital signals so that they can be processed by computers [7].

2 Methods



RESULTS AND DISCUSSIONS

A. Cantilever Rod

Cantilever rods are rods that are clamped at one end and free at the other end [2][3]. Basically the cantilever rod looks like a beautiful jump board. The cantilever rod in the loading deflection test will be assigned to the free (non-clamped) end of the rod [20].

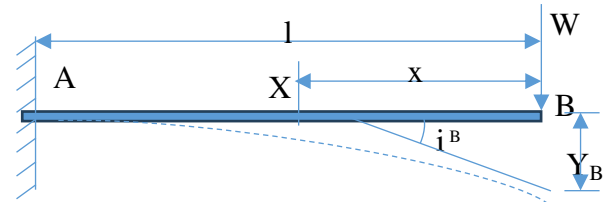


Figure 2. Cantilever Rod with Loads

To calculate the deflection at a given point (B), we can use the equation:

$$y_B = -\frac{Wl^3}{3EI} \quad (1)$$

Where,

W : loads

E : Modulus of elasticity

I : Moment of inertia

l : length

to calculate at a certain point (x), we can use the equation below,

$$y_x = \frac{Wx^2}{6EI}(3L - x)$$

B. Deflection and Stress Data

Based on the test data of the data acquisition system on the deflection test equipment. The cantilever rods used in this study have a length of 1000 mm, a width of 30 mm and a thickness (t),

there are 4 mm, 6 mm, and 8 mm. Data collection was carried out at three different points, there are at points 520 mm (x1), 770 mm (x2), and 980 mm (x3). The ends of the cantilever rods are given loads (F) varying from 350 g, 450 g, and 550 g.

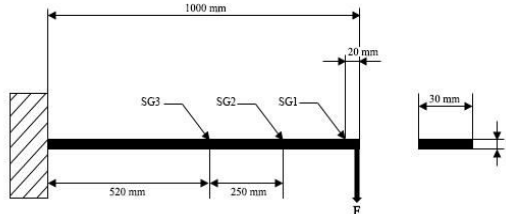


FIGURE 3. Load placement on the cantilever

C. Data acquisition system components

1. Arduino UNO R3.

This Arduino is a simple and most commonly used Arduino. In addition, to program it using USB so that it is easy to connect to a PC [4][5][7][9][22].

2. Strain Gauge Bending Sensor Module Y3

This module is a complete package of strain gauge sensors for deflection tests. It includes an amplifier as a signal amplifier and a strain gauge sensor used to read deflection test results [3][4][15][16].

3. PLX-DAQ Software.

PLX-DAQ is an additional software of parallax microcontroller data acquisition for Microsoft Excel. PLX-DAQ can be used to connect Arduino with Microsoft Excel, so that the output of test result data can be visualized and stored on a PC.

D. Data Acquisition System Accuracy Level.

The accuracy rate of the sensor in retrieving data acquisition system data is calculated using %error [17].

$$\%error = \left| \frac{\text{acquisition data} - \text{manual calculation}}{\text{Manual calculation}} \right| \times 100\%$$

(2)



Figure 4. Layer Design Input of PLX-DAQ Software

RESULTS

TABLE 1. Test Result table of Deflection Test and Stress on Data Acquisition Systems

Deflection Test and Stress on Data Acquisition Systems									
Thickness (mm)	Loads (g)	Repetition	Deflection			Stress (N/mm2)			
			x1	x2	x3	x1	x2	x3	
4	350	1	32,567	22,251	11,221	430,735	3801,129	5491,243	
		2	32,807	22,396	11,341	429,786	3792,439	5481,964	
		3	32,394	11,165	11,165	432,441	3807,294	5513,722	
	450	1	43,688	29,715	15,134	549,731	4979,847	7032,788	
		2	43,491	29,631	15,026	552,32	4998,732	7049,523	
		3	43,255	29,418	14,996	556,462	5027,963	7069,343	
	550	1	54,691	33,179	18,853	672,87	6101,862	8641,188	
		2	54,549	33,099	18,788	679,276	6129,239	8652,931	
		3	54,544	33,091	18,779	680,183	6142,983	8663,896	
6	350	1	9,731	6,613	3,356	128,234	1127,364	1633,312	
		2	9,732	6,615	3,361	128,128	1126,981	1632,137	
		3	9,735	6,62	3,365	127,892	1126,712	1632,019	
	450	1	12,907	8,821	4,47	164,932	1490,512	2099,984	
		2	12,909	8,829	4,477	164,539	1489,396	2098,561	
		3	12,923	8,831	4,483	164,011	1489,199	2098,33	
	550	1	16,201	11,052	5,609	199,829	1808,099	2560,62	
		2	16,194	10,996	5,579	200,198	1810,128	2566,892	
		3	16,19	10,988	5,57	200,967	1815,893	2568,721	
8	350	1	4,088	2,792	1,418	53,294	475,076	687,403	
		2	4,073	2,78	1,416	53,753	475,971	688,27	
		3	4,071	2,779	1,41	53,983	476,126	689,061	
	450	1	5,426	3,698	1,881	69,429	628,747	883,702	
		2	5,439	3,71	1,884	69,194	628,491	883,609	
		3	5,446	3,722	1,889	68,993	628,036	883,004	
	550	1	6,841	4,653	2,365	83,981	765,529	1072,897	
		2	6,837	4,648	2,364	84,383	767,92	1079,154	
		3	6,83	4,645	2,362	84,709	768,203	1082,815	

DISCUSSIONS

1. Accuracy Level At 4 mm Thickness

a. Deflection Data, 350 (g), 4 mm

TABLE 2. Deflection accuracy data, 350 gr loads on a 4 mm specimen

Deflection accuracy on test specimen 4 mm						
Loads (g)	Repetition	Distance	Test value	Manual	Accuracy	Percentage
350	1	x1	32,567	31,908	0,020653128	2,06%
		x2	22,251	21,764	0,02376401	2,23%
		x3	11,221	11,027	0,01759318	1,75%
	2	x1	32,807	31,908	0,028174752	2,81%
		x2	22,396	21,764	0,02903878	2,90%
		x3	11,341	11,027	0,02847556	2,84%
	3	x1	32,394	31,908	0,01523129	1,52%
		x2	22,119	21,764	0,01631134	1,63%
		x3	11,165	11,027	0,012514737	1,25%

b. Stress Data, 350 (g), 4 mm

TABLE 3. Stress accuracy data, 350 gr loads on a 4 mm specimen

Stress Accuracy			
Loads (g)	Repetition		
350	1	x1	
		x2	
		x3	
	2	x1	
		x2	
		x3	
	3	x1	
		x2	
		x3	



c. Deflection Data, 450 (g), 4 mm

TABLE 4. Deflection accuracy data, 450 gr loads on a 4 mm specimen

Deflection accuracy on test specimen 4 mm						
Loads (g)	Repetition	Distance	Test value	Manual	Accuracy	Percentage
450	1	x1	43,688	42,544	0,026889808	2,68%
		x2	29,715	28,994	0,024867214	2,48%
		x3	15,134	14,705	0,02917375	2,91%
	2	x1	43,491	42,544	0,022259308	2,25%
		x2	29,631	28,994	0,021970063	2,19%
		x3	15,026	14,705	0,02182931	2,18%
	3	x1	43,255	42,544	0,01671211	1,67%
		x2	29,418	28,994	0,014623715	1,46%
		x3	14,996	14,705	0,019789187	1,97%

d. Stress Data, 450 (g), 4 mm

TABLE 5. Stress accuracy data, 450 gr loads on a 4 mm specimen

Stress Accuracy on test specimen 4 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
450	1	x1	549,731	540,592	0,016905541	1,69%
		x2	4979,847	4884,639	0,019491307	1,94%
		x3	7032,788	6884,28	0,021572045	2,15%
	2	x1	552,32	540,592	0,021694735	2,16%
		x2	4998,732	4884,639	0,023357509	2,33%
		x3	7049,523	6884,28	0,024002946	2,40%
	3	x1	556,462	540,592	0,029356705	2,93%
		x2	5027,963	4884,639	0,029341779	2,93%
		x3	7069,343	6884,28	0,026881969	2,68%

e. Deflection Data, 550 (g), 4 mm

TABLE 6. Deflection accuracy data, 550 gr loads on a 4 mm specimen

Deflection accuracy on test specimen 4 mm						
Loads (g)	Repetition	Distance	Test value	Manual	Accuracy	Percentage
550	1	x1	54,691	53,18	0,028412937	2,84%
		x2	33,179	32,243	0,029029557	2,90%
		x3	18,853	18,382	0,025622892	2,56%
	2	x1	54,549	53,18	0,02574276	2,57%
		x2	33,099	32,243	0,026548398	2,65%
		x3	18,788	18,382	0,022086824	2,20%
	3	x1	54,544	53,18	0,02564874	2,56%
		x2	33,091	32,243	0,026300282	2,63%
		x3	18,779	18,382	0,021597215	2,15%

f. Stress Data, 550 (g), 4 mm

TABLE 7. Stress accuracy data, 550 gr loads on a 4 mm specimen

Stress Accuracy On Test Specimen 4 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
550	1	x1	672,87	660,642	0,018509268	1,85%
		x2	6101,862	5969,376	0,02219428	2,21%
		x3	8641,188	8413,08	0,027113495	2,71%
	2	x1	679,276	660,642	0,028205897	2,82%
		x2	6129,239	5969,376	0,026780521	2,67%
		x3	8652,931	8413,08	0,028509297	2,85%
	3	x1	680,183	660,642	0,029578804	2,95%
		x2	6142,983	5969,376	0,029082939	2,90%
		x3	8663,896	8413,08	0,029812625	2,98%

2. Accuracy Level At 6 mm Thickness

a. Deflection Data, 350 (g), 6 mm

TABLE 8. Deflection accuracy data, 350 gr loads on a 6 mm specimen

Deflection Accuracy on Test Specimen 6 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
350	1	x1	9,731	9,454	0,029299767	2,92%
		x2	6,613	6,443	0,026385224	2,63%
		x3	3,356	3,267	0,027242118	2,72%
	2	x1	9,732	9,454	0,029405543	2,94%
		x2	6,615	6,443	0,026695639	2,66%
		x3	3,361	3,267	0,028772574	2,87%
	3	x1	9,735	9,454	0,029722869	2,97%
		x2	6,62	6,443	0,027471675	2,74%
		x3	3,365	3,267	0,029996939	2,99%

b. Stress Data, 350 (g), 6 mm

TABLE 9. Stress accuracy data, 350 gr loads on a 6 mm specimen

Stress Accuracy On Test Specimen 6 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
350	1	x1	128,234	124,568	0,029429709	2,94%
		x2	1127,364	1096,05	0,028567988	2,85%
		x3	1633,312	1586,35	0,029606404	2,96%
	2	x1	128,128	124,568	0,028578768	2,85%
		x2	1126,981	1096,05	0,028218552	2,82%
		x3	1632,137	1586,35	0,028865708	2,88%
	3	x1	127,892	124,568	0,026684221	2,66%
		x2	1126,712	1096,05	0,027973125	2,79%
		x3	1632,019	1586,35	0,028791323	2,87%

c. Deflection Data, 450 (g), 6 mm

TABLE 10. Deflection accuracy data, 450 gr loads on a 6 mm specimen

Deflection Accuracy on Test Specimen 6 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
450	1	x1	12,907	12,605	0,023958747	2,39%
		x2	8,821	8,591	0,026772203	2,67%
		x3	4,47	4,357	0,025935277	2,59%
	2	x1	12,909	12,605	0,024117414	2,41%
		x2	8,829	8,591	0,027703411	2,77%
		x3	4,477	4,357	0,027541887	2,75%
	3	x1	12,923	12,605	0,025228084	2,52%
		x2	8,831	8,591	0,027936212	2,79%
		x3	4,483	4,357	0,028918981	2,89%

d. Stress Data, 450 (g), 6 mm

TABLE 11. Stress accuracy data, 450 gr loads on a 6 mm specimen

Stress Accuracy On Test Specimen 6 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
450	1	x1	164,932	160,175	0,029698767	2,96%
		x2	1490,512	1447,3	0,029856975	2,98%
		x3	2099,984	2039,79	0,029511919	2,95%
	2	x1	164,539	160,175	0,02745201	2,72%
		x2	1489,396	1447,3	0,029085884	2,90%
		x3	2098,561	2039,79	0,028814297	2,88%
	3	x1	164,011	160,175	0,023948806	2,39%
		x2	1489,199	1447,3	0,028949769	2,89%
		x3	2098,33	2039,79	0,02870105	2,87%

e. Deflection Data, 550 (g), 6 mm

TABLE 12. Deflection accuracy data, 550 gr loads on a 6 mm specimen

Deflection Accuracy on Test Specimen 6 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
550	1	x1	16,201	15,757	0,028177953	2,81%
		x2	11,052	10,738	0,029241944	2,92%
		x3	5,609	5,446	0,029930224	2,99%
	2	x1	16,194	15,757	0,027733706	2,77%
		x2	10,996	10,738	0,024026821	2,40%
		x3	5,579	5,446	0,024421594	2,44%
	3	x1	16,19	15,757	0,02747985	2,74%
		x2	10,988	10,738	0,023281803	2,32%
		x3	5,57	5,446	0,022769005	2,27%

c. Deflection Data, 450 (g), 8 mm

TABLE 16. Deflection accuracy data, 450 gr loads on a 8 mm specimen

Deflection Accuracy on Test Specimen 8 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
450	1	x1	5,426	5,318	0,020308387	2,03%
		x2	3,698	3,624	0,020419426	2,04%
		x3	1,881	1,838	0,023394995	2,33%
	2	x1	5,439	5,318	0,022752915	2,27%
		x2	3,71	3,624	0,023730684	2,37%
		x3	1,884	1,838	0,025027203	2,50%
	3	x1	5,446	5,318	0,024069199	2,40%
		x2	3,722	3,624	0,027041943	2,70%
		x3	1,889	1,838	0,027747552	2,77%

f. Stress Data, 550 (g), 6 mm

TABLE 13. Stress accuracy data, 550 gr loads on a 6 mm specimen

Stress Accuracy On Test Specimen 6 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
550	1	x1	199,829	195,745	0,020863879	2,08%
		x2	1808,099	1768,7	0,022273371	2,22%
		x3	2560,62	2494,76	0,026397687	2,63%
	2	x1	200,198	195,745	0,022748985	2,27%
		x2	1810,128	1768,7	0,023420538	2,34%
		x3	2566,892	2494,76	0,028911753	2,89%
	3	x1	200,967	195,745	0,026677565	2,66%
		x2	1815,893	1768,7	0,026679987	2,66%
		x3	2568,721	2494,76	0,029644888	2,96%

d. Stress Data, 450 (g), 8 mm

TABLE 17. Stress accuracy data, 450 gr loads on a 8 mm specimen

Stress Accuracy On Test Specimen 8 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
450	1	x1	69,429	67,574	0,027451387	2,74%
		x2	628,747	610,579	0,029755363	2,97%
		x3	883,702	860,535	0,026921624	2,69%
	2	x1	69,194	67,574	0,023973718	2,39%
		x2	628,491	610,579	0,029336089	2,93%
		x3	883,609	860,535	0,026813552	2,68%
	3	x1	68,993	67,574	0,020999201	2,09%
		x2	628,036	610,579	0,028590895	2,85%
		x3	883,004	860,535	0,026110501	2,61%

3. Accuracy Level At 8 mm Thickness

a. Deflection Data, 350 (g), 8 mm

TABLE. Deflection accuracy data, 350 gr loads on a 8 mm specimen

Deflection Accuracy on Test Specimen 8 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
350	1	x1	4,088	3,988	0,025075226	2,50%
		x2	2,792	2,718	0,027225901	2,72%
		x3	1,418	1,378	0,029027576	2,90%
	2	x1	4,073	3,988	0,021313942	2,13%
		x2	2,78	2,718	0,02281089	2,28%
		x3	1,416	1,378	0,027576197	2,75%
	3	x1	4,071	3,988	0,020812437	2,08%
		x2	2,779	2,718	0,022442973	2,24%
		x3	1,41	1,378	0,023222061	2,32%

e. Deflection Data, 550 (g), 8 mm

TABLE 18. Deflection accuracy data, 550 gr loads on a 8 mm specimen

Deflection Accuracy on Test Specimen 8 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
550	1	x1	6,841	6,647	0,029186099	2,91%
		x2	4,653	4,53	0,027152318	2,71%
		x3	2,365	2,297	0,029603831	2,96%
	2	x1	6,837	6,647	0,028584324	2,85%
		x2	4,649	4,53	0,026269316	2,62%
		x3	2,364	2,297	0,029168481	2,91%
	3	x1	6,83	6,647	0,027531217	2,75%
		x2	4,645	4,53	0,025386313	2,53%
		x3	2,362	2,297	0,02829778	2,82%

b. Stress Data, 350 (g), 8 mm

TABLE 15. Stress accuracy data, 350 gr loads on a 8 mm specimen

Stress Accuracy On Test Specimen 8 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
350	1	x1	53,294	52,552	0,014119348	1,41%
		x2	475,076	462,397	0,027420161	2,74%
		x3	687,403	669,24	0,027139741	2,71%
	2	x1	53,753	52,552	0,022853555	2,28%
		x2	475,971	462,397	0,029355727	2,93%
		x3	688,27	669,24	0,02843524	2,84%
	3	x1	53,983	52,552	0,027230172	2,72%
		x2	476,126	462,397	0,029690937	2,96%
		x3	689,061	669,24	0,029617178	2,96%

f. Stress Data, 550 (g), 8 mm

TABLE 19. Stress accuracy data, 550 gr loads on a 8 mm specimen

Stress Accuracy On Test Specimen 8 mm						
Loads (g)	Repetition	Distance	Test Value	Manual	Accuracy	Percentage
550	1	x1	83,981	82,58	0,016965367	1,69%
		x2	765,529	746,172	0,02594174	2,59%
		x3	1072,897	1051,64	0,020218041	2,02%
	2	x1	84,383	82,58	0,021833374	2,18%
		x2	767,92	746,172	0,029146095	2,91%
		x3	1079,154	1051,64	0,026167824	2,61%
	3	x1	84,709	82,58	0,025781061	2,57%
		x2	768,203	746,172	0,029525364	2,95%
		x3	1082,815	1051,64	0,02964907	2,96%

CONCLUSIONS

Based on the test results using a data acquisition system, deflection data was obtained with the smallest difference was 0.032 mm and the largest difference was 1.511 mm. The stress accuracy data, with the smallest difference is 0.742 N/mm² and the largest

difference is 250.816 N/mm². The error value of the best deflection data acquisition system is 1.46% and the worst is 2.99%. As for the error value of the stress data acquisition system, the best is 1.41% and the worst is 2.98%. Based on the error value of the deflection value and stress generated by the data acquisition system, it can be said that the data acquisition system is designed quite well.

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