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EDUCATION AND TVET

Digital Cantilever Beam Apparatus

Roihan Romli[1] and Mohd Azam Mohd Daud[2]
[1] Department of Mechanical Engineering
Politeknik Banting Selangor, Malaysia
Corresponding author: roihan@polibanting.edu.my

Abstract

Strength of Material Course (DJJ30103) has a practical element where students need to conduct experiments and write appropriate report based on the experiments. The beam deflection test takes up to 40 minutes for this practical to complete. In order to overcome this problem, an apparatus has been developed with three objectives: to cut time of use, to obtain the accurate readings and to carry from place to place easily. This apparatus uses a digital dial gauge and equipped with wheels. The apparatus is also equipped with an Open as App application and the barcode is placed at suitable location in the apparatus. The use of this apparatus saves 56.3% of the time compared to existing apparatus. Error reduction achieved up to 30.36%. This situation makes teaching and learning in a classroom smoother and in orderly. The beam deflection apparatus enables students and lecturers of Strength of Material course to complete practical during class hour without taking extra time.
Keywords: Beam deflection, cantilever beam, digital dial gauge.

1. Introduction

Deflection, in structural engineering terms, refers to the movement of a beam or node from its original position due to the forces and loads being applied to the member. It is also known as displacement and can occur from externally applied loads or from the weight of the structure itself, and the force of gravity in which this applies. Deflection can occur in beams, trusses, frames, and basically any other structure. (Skyciv, n.d.)

Strength of Material (DJJ30103) is a discipline core course for Diploma in Mechanical Engineering (DKM) and Diploma in Mechanical Engineering (Manufacturing) (DTP) programs. This course is offered in semester 3. There is a practical element in this course where students have to conduct experiments and write appropriate reports on bending test, beam deflection test, torsion test and shear stress test. Banting Polytechnic Laboratory has only one equipment for the beam deflection test which can take up to 40 minutes to complete. In order to overcome this problem, an equipment called Digital Cantilever Beam apparatus has been developed. This apparatus is used to obtain deflection values on the cantilever beams of different modulus of elasticity. This experiment can help students understand the value of deflection obtained from experimental and theoretical from the calculation.

2. Literature Review

Digital indicators have clear advantages for data collection in process control applications. It can output measurements directly to a printer or SPC program without operator error in reading or recording. The operator simply places the workpiece and presses a button. With a dial indicator, the operator must interpret the position of the indicator to read the measurement, record it and enter the data into the computer. Those are the three steps when an error can occur. If data must be entered into a computer system, digital indicators are the best source. (Dial versus digital indicators, n.d).

The beam under investigation in WP 950 can be supported in different ways. This produces statically determinate and indeterminate systems which are placed under load by different weights. The load application points are movable. Three dial gauges record the resulting deformation. Three articulated supports with integral force gauges indicate the support reactions directly. The articulated supports are height-adjustable, so as to compensate for the influence of the dead-weight of the beam under investigation. A fourth support clamps the beam in place. Five beams of different thicknesses and made of different materials demonstrate the influence of the geometry and of the modulus of elasticity on the deformation of the beam under load. (Gunt Hamburg, 2022).

As a load is applied on a beam, it deflects. The deflection can be observed and measured directly whereas other parameters such as shear force, bending moment and stressed can only calculated. Excessive deflection can cause visible or invisible cracks in beam. Also, excessive deflection perceptible by naked eye give feeling unsafe structure to the occupant of the building causing adverse effect on their health, thus it is extremely importance to have the knowledge of maximum deflection in a beam under the given loading. The maximum deflection beam must not exceed a given limits (S S Rathan, 2011). Figure 1 show a deflection on cantilever beam with uniformly loaded along the beam.

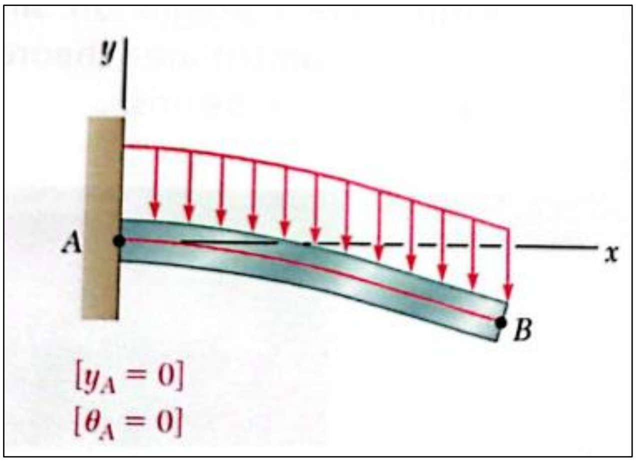

Figure 1: A situation where deflection on the Cantilever Beam with uniformly loaded.
(Ferdinand et al., 2015, p.600)

Cantilever beams are widely used in various walks of life. It is necessary to determine the maximum deflection of the beam subject to load and to determine the strength of the beam for the correct design. The purpose of the Deflection of a Cantilever Beam experiment by Muhammad Dawood Bashir,2019 was to determine the deflection of two cantilever beams. It can be seen from the results that the calculated and measured values are different but the measured values are in perfect agreement with each other i.e. there is a trend in deflection. The high percentage of errors may be due to some type of systematic error in the deflection gauge. There are several other causes of errors as discussed below:

a. While obtaining the formula for deflection, we assume that the beam is of linear, prismatic and other elasticities which is the ideal case. Such an assumption does not occur in actual practice.
b. The load in the hanger is not placed correctly while in theory, it is stated that the load is concentrated which is not suitable for our case. Moreover, we do not place the load exactly at the end of the beam.
c. Errors may be personal in nature i.e. errors in recording readings from deflection gauges and Vernier calipers.

The deflection in the case of Aluminum beams is more than the deflection in Stainless Steel beams. The reason is that steel has more Young's Modulus value than aluminum.

Deflection of beam apparatus was marketed by PA Hilton, a company from Britain. Two reaction piers on apparatus can be moved along the length. The height of each reaction pier is adjustable and displayed digitally. A single steel beam and two load hangers are supplied together with two analogue dial gauges for measuring deflection and slopes. The dial gauge are mounted on movable stands for accurate position along the beam length. However, the apparatus takes 45 minutes to complete. (PA Hilton, 2021).

3. Methodology

This apparatus was selected after a questionnaire related to the problem of practical equipment for DJJ30103 course was distributed to Banting Polytechnic students. From the finding, from 133 respondents of June 2020 session who answered the questionnaire, 97.7% respondents found that the deflection test on the cantilever beam took a long time to complete while 77.4% of respondents informed that the test took more than 30 minutes to complete. 77.1% said the experiment took longer time to complete as there was only one equipment available and 22.9% said the dial gauge was difficult to read accurately. Therefore, this apparatus project was produced to ensure that all students achieve the learning outcomes of this experiment well.

Methodology section will describe all the necessary information that is required to obtain the results of the study. Figure 2 shows a flow chart of the design process which problem identification to product testing.

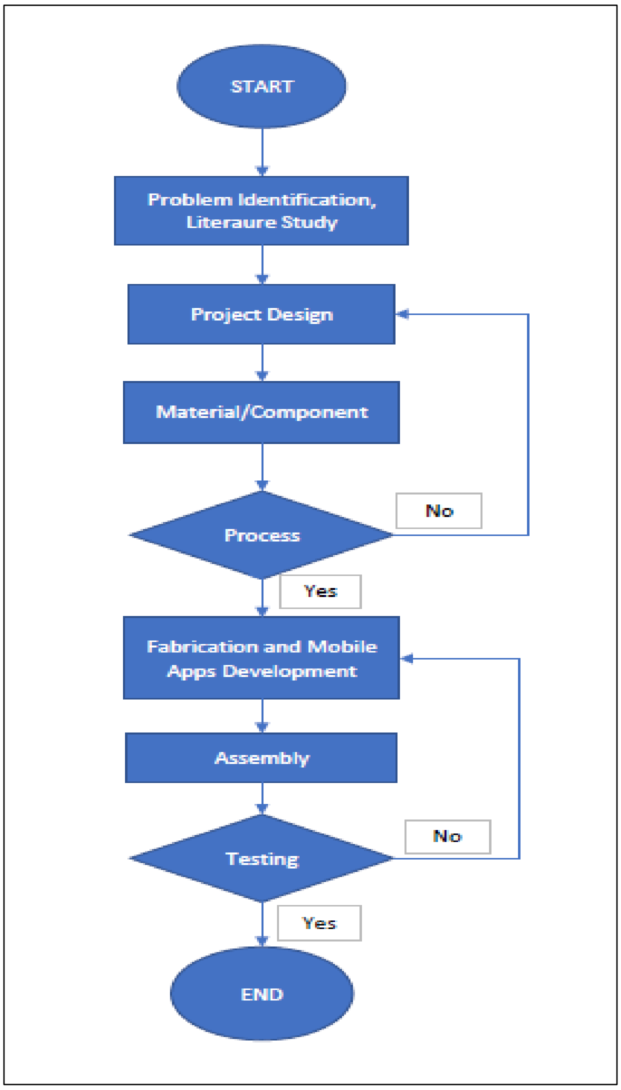

Figure 2: Flow chart of design process

Material selection is very important to ensure the product is lightweight and low cost while maintaining quality. Main body frame uses aluminum dan square hollow mild steel. Metal Inert Gas (MIG) welding is chosen for fabrication and assembly of the hollow mild steel as the main body frame and beam holder. The rivet process is also used to connect the aluminum board to the body frame and gauge roller. CAD software is used to illustrate real objects and can be viewed from various angles including isometric such as Figure 3 with size of frame 125.5cm x 90.5cm x 41.5cm. Figure 4 shows the installation of a digital dial gauge as a dial indicator for which the selection of this gauge can reduce the reading error. The pin on the dial gauge will be placed on the flat surface of the weight rider. After the load is placed, the digital dial gauge will give a deflection reading. Wheels are placed on this apparatus for portability. This apparatus needs to be stored after use as the 3 courses share the same laboratory space.

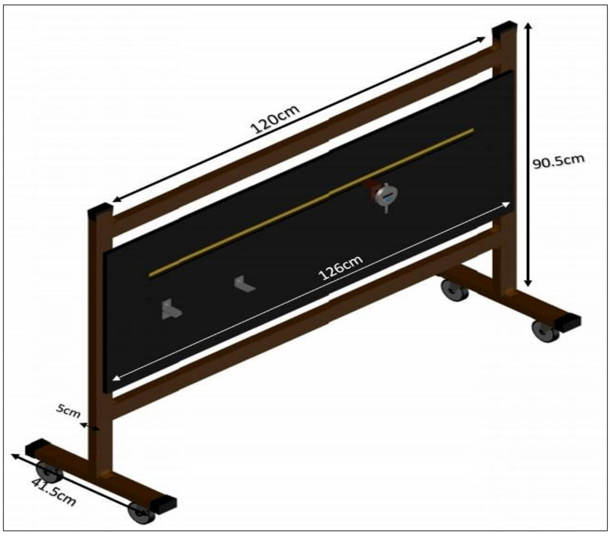

Figure 3: Isometric drawing

Figure 4: Installation of digital dial gauge

Mobile applications are developed with using Open As App. It can be used in both mobile platform which are Google Play Store on Android phone and Appstore on Apple phone. The design on the apps-is created as shown in Figure 5. QR scan codes are also displayed to make it easier for the users to use. The user only needs to enter the value of the young modulus of each material and the length of the specimen.

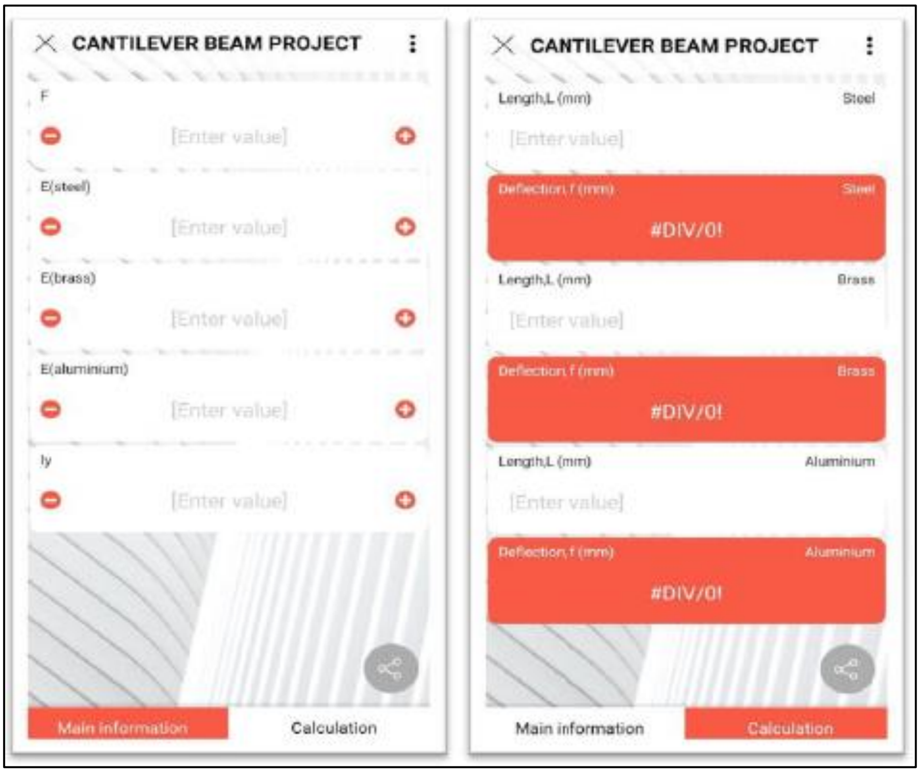

Figure 5: Design on apps software

4. Finding and Analysis

A cantilever beam apparatus was produced with frame dimensions of 125.5cm x 90.5cm which aimed to compare the effect of deflection values obtained from experiments and calculations on cantilever beams of different types of materials and different lengths. Figure 6 shows the digital cantilever beam apparatus that has been produced while Figure 7 shows the application display on the user's mobile. The test was conducted by a group of students who took the strength of material course session 1 2021/2022 at Banting Polytechnic. Students were divided into 6 groups where 3 groups conducted tests using existing apparatus while 3 groups conducted experiments on the apparatus created. The results of the time difference taken to obtain the data are as in Table 1. The average time obtained using the existing apparatus was 39.67 minutes and the time taken to complete the test using the created apparatus, cantilever beam apparatus was 17.33 minutes. This shows the use of this new apparatus saves 56.3% of time compared to the existing apparatus.

Figure 6: Digital cantilever beam apparatus

Figure 7: Open As App interface

Table 1: Time taken from existing apparatus and digital cantilever beam apparatus

Cantilever Beam Apparatus (existing)		Digital Cantilever Beam Apparatus	
Group	Time Taken (mins)	Group	Time Taken (mins)
A	36	C	20
B	44	D	17
C	39	E	15
Average	39.67	Average	17.33

Digital cantilever beam experiment aims to compare the effect of deflection values obtained from experiments and calculations on cantilever beams of different types of materials and different lengths. Table 2 shows the findings of deflection values obtained from theory and experiment. Theoretical readings are from the formula while the deflection readings are from the digital gauge display. By using the error percentage formula, it was found that the difference between the theoretical value and the experimental value was 30.36%. This shows that the use of digital dial gauge is able to reduce reading errors.

Table 2: Time taken from existing apparatus and digital cantilever beam apparatus

Material	Length, L (mm)	Deflection, f (mm) by theoretical	Deflection, f (mm) by experiment	Error (%)
Steel	300	0.625	0.925	48.00
	400	1.481	1.825	23.23
	500	2.894	3.315	14.55
	300	1.353	1.963	45.08

Brass	400	3.207	4.141	29.12
	500	6.264	7.156	14.24
Aluminum	300	1.902	2.789	46.64
	400	4.509	5.722	26.90
	500	8.806	11.051	25.49

Figure 8 shows the feedback from users using a digital cantilever beam apparatus. From the figure, 75.8% strongly agreed that the apparatus would help get readings accurate and fast. From 62 respondents as well, 88.7% strongly agreed the application used helped to obtain computational data quickly as shown in Figure 9.

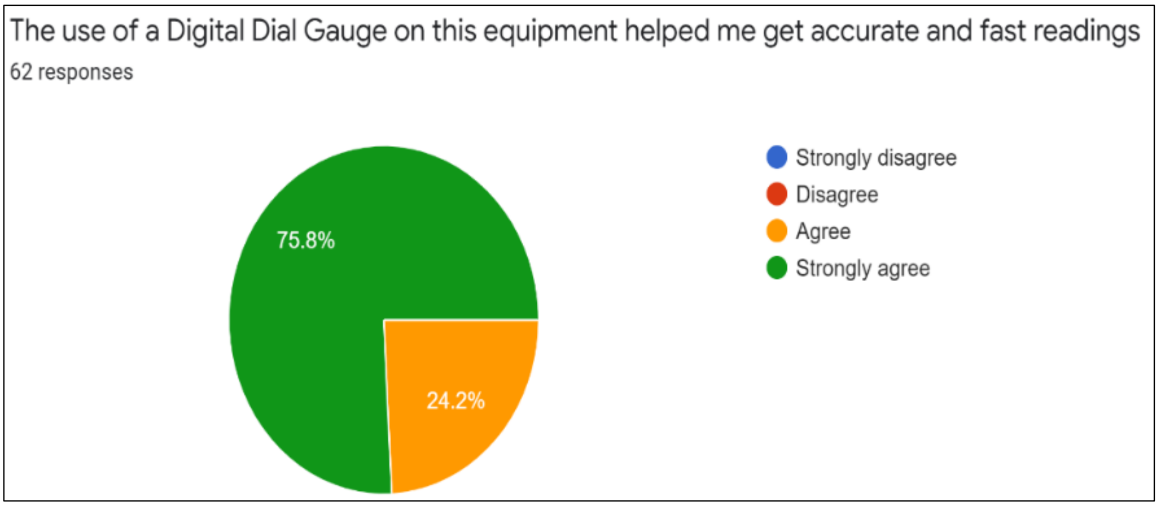

Figure 8: Percentage of apparatus user feedback.

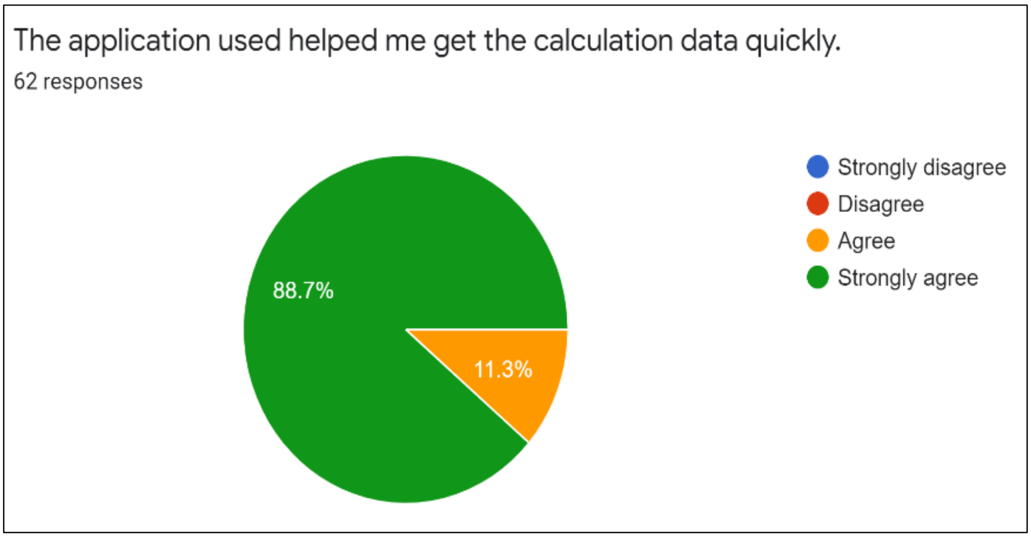

Figure 9: Percentage of application user feedback.

5. Conclusion

Overall, digital cantilever beam apparatus innovation has successfully produced and achieved its objectives. The use of this apparatus shows a time saving of up to 56.3%. In addition, the digital dial gauge shows a reading accuracy compared to the analogue gauge with an error for which the error reduction was 30.36%. This innovation benefits students to complete this bending test practical during class time without taking extra time. The use of mobile applications also greatly helps students in getting a calculation data quickly. This situation makes teaching and learning of the DJJ30103 course smoother and more orderly.

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