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Calibration of Bending and Deflection Forces in Bending Tests Arduino Based

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ABSTRACT: *The bending test is one of several tests that are commonly used to determine the mechanical properties of a material. This research focused on the calibration of force and deflection measuring instruments.*
The method used was three repetitions of force and deflection calibration data collection. The tools used for data collection were a 200 kg capacity crane scale for force calibration and a digital dial indicator for deflection calibration.
From the results of the force calibration carried out, the time required to maintain the measuring instrument shows the zero position at 30 minutes after that it fluctuates although it is very small, the floating reading that occurs at a load of 100 kg is 97.2 kg.The level of accuracy of the force measuring instrument is 97%, there is no hysteresis on the load measuring instrument because the load cell capacity is 1000 kg, however there is an error in the series rising point of 148.4 kg that arises on this measuring instrument nevertheless the equation eliminates this error. It can be said that floating gets bigger at higher extensions.

NOMENCLATURE

Symbol	Description	Unit
y	Higher order polynomial	mm
x	Independent variable	Volt
R^2	Coefficient of determination	%

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I. INTRODUCTION

As technology develops increasingly rapidly, there are many new types of materials where mechanical testing must be carried out to determine the strength of these materials. One of the mechanical tests carried out to test a material is the bending test method.

Bending testing is a process of testing materials by pressing to obtain results of bending strengthdatas. From this test, several mechanical properties can also be observed such as elasticity, yield strength, compression strength, etc. The loading process uses a mandrel or pusher whose dimensions have been determined bypressing the center of the test material or specimen to bend between two supports separated by a predetermined distance. Furthermore, the material experiences deformation with two opposing forces acting at the same time [1-2]

During bending the plastic deformation of metal is linear axis with little or almost no change in surface area. A piece of iron can be bent using a press machine. The process usually uses a die in the form of a V, U, W pattern or other pattern. The metal on the outside of the neutral axis experiences tension while on the other side it experiences pressure [3-4].

In general, bending test equipment has several main parts, such as: frame, press tool, bending point and measuring tool. The frame functions as a barrier to the back force that occurs when carrying out bending tests [5-6].

Calibration of the tool was carried out to increase the accuracy of data collection, especially the force sensor using a 24-bit ADC. Calibration is defined as a series of activities comparing the measurement results of a tool with an appropriate standard tool to determine the magnitude of the measurement correction and its uncertainty. In this sense, the standard equipment used must also be calibrated, proven by a calibration certificate. In this way, the amount of instrument measurement correction can be traced to national standards or international standards with an unbroken chain of calibration activities [7-8].

Several researchers had carried some calibrations of the tools regarding to measuring the certain mechanical properties [8-10]. Pandiatmi et al [10] for instance, utilized a force sensor from a type S load cell, with a capacity of 500 kg. This load cell uses 4 strain gauges with a bridge configuration, each strain gauge has a resistance of 350 ohms where the output impedance is 350 ohms. Measuring instruments that have been calibrated will not have a continuous calibration period, because during their period of use the equipment definitely experiences changes in specifications due to the influence of frequency of use, storage environment, method of use, and so on.

For this reason, during the calibration period the equipment in question needs to be maintained for its traceability by means of maintenance and periodic checks. As a result, that each tool can provide measuring results with the same validity, the measuring tool needs to have traceability either to national or international standards. The way to provide assurance that the equipment used has traceability to national standards is to calibrate the equipment. Moreover, to maintain traceability, it is necessary to maintain the equipment within certain calibration intervals [10].In order to be used, all calibrated equipment must be traceable to national standards or related physical phenomena. In United States for instance, calibrated tools can be tracked at the National Institute of Standards and Technology (NIST) or the national standardization and technology agency if translated into Indonesian. Each country has its own standards to share variations or types of parameters such as pressure, temperature, voltage, resistance, weight, time, and many more [8].

This research focused on calibrating force and deflection measuring instruments. The aim of this research was to compare and match with a calibrated tool. This research was motivated by efforts to develop the learning process of undergraduate students in the Department of Mechanical Engineering particularly in the Engineering Materials course. Test equipment is an educational laboratory facility that is very important in supporting the teaching and learning process. Students often encounter basic materials for machines or equipment that come from metal. These basic materials certainly have special properties to support the performance of these materials. Therefore, the research in calibrating the instrument is important to undergo.

II. EXPERIMENTAL SETUP

Some components that were used in this research were load cells linear potentiometer, test specimen holder, moving frame, boxes and jack (Fig. 1). After the main components of the tool were installed, data collection and analysis were then carried out consisting of taking calibration data of force and deflection.

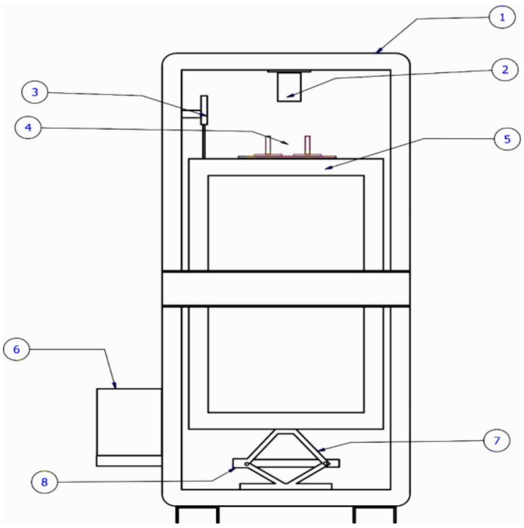

Fig 1. Bending testing machine.

Descriptions:

1. Fixed frame	5. Moving frame
2. Load cells	6. Boxes
3. Linear potentiometer	7. Jack
4. Test specimen holder	8. Electric motor

The physical specifications of load cell, linear potentiometer, box, jack, Arduino, and dial indicator are shown in Fig. 2. Specifically, the characteristics loadcell is detailed in Table 1, 2 and 3.

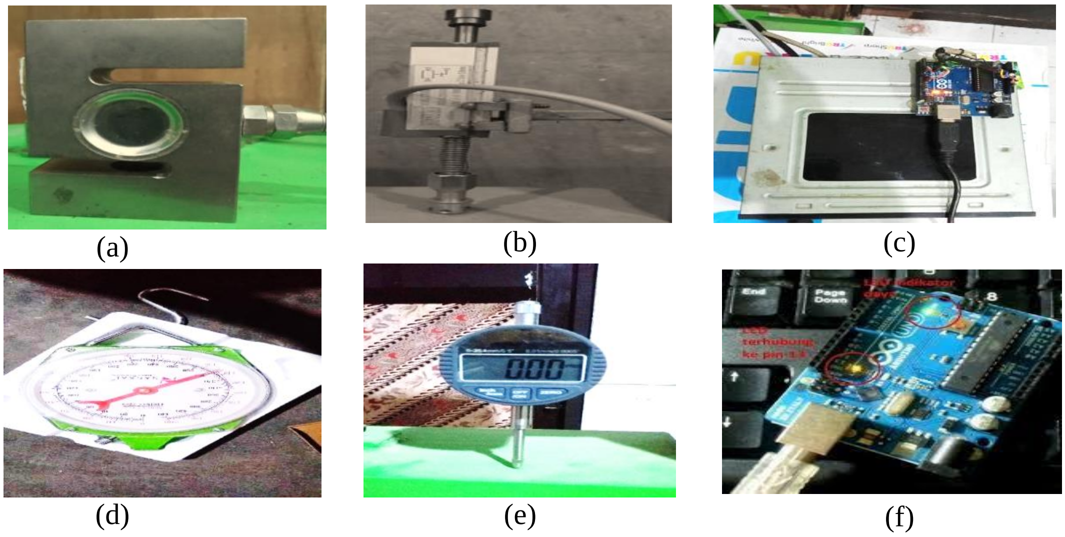

Fig. 2. Load cell, linear potentiometer, box, jack, Arduino, and dial indicator

Table 1. Sensor characteristics.

SensorTypes	Compression/TensionLoadcell (kg)
WeightCapacityMax	1000
MaximumOverload	200

Table 2. Loadcell electrical characteristics.

Components	Values
OutputImpedance	350Ω
SupplyVoltageMin	10VDC
SupplyVoltageMax	15VDC

Table 3. Physical characteristics of load cells

Components	Values
CompensatedTemperatureMin	-10°C
CompensatedTemperatureMax	40 °C
OperatingTemperatureMin	-20°C
OperatingTemperatureMax	80 °C
CableLength	3m
CableGauge	5x22AWG
MaterialAlloySteelIPRating	IP65
ScrewThreadSizeM12Weight	603g

TOOL CALIBRATION

The conditions of the tools that will be calibrated are:

a. Calibration of the force measuring instrument (load cell) using a 200 kg hanging scale (Fig. 3). It is different from what Pandiatmi et al [6] has used to observe. Before calibrating the tool, first take zero observation data with the aim of finding out how long it takes for the tool to show the zero position stably. The length of time for the measuring instrument to show zero is 30 minutes after which it starts to fluctuate by 0.3 kg (3%) because the calibrator also does not show zero. The results of the calibration of the Arduino-based weight measuring instrument with a weighing calibrator from position 0 to 200 kg.

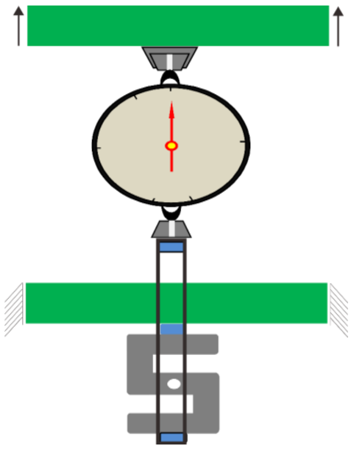

Fig. 3. The force measuring instrument (load cell)

b. Deflection calibration using a dial indicator.
Before calibrating the tool, first take zero observation data with the aim of finding out how long it takes for the tool to show the zero position stably. After observing the zero stability for almost an hour and there were no fluctuations, it means that the zero stability is very stable. The tool used to sense the increase in length of bending test specimens is to use an extenso meter or what is usually called a linear potentiometer. This sensor functions to read linear movement in a straight line and the output from this linear potentiometer is in the form of electric voltage in volts (Fig. 4).

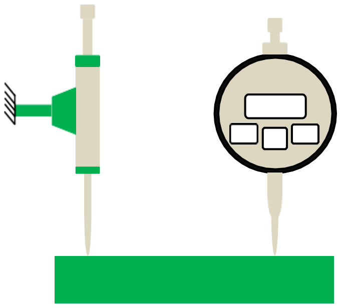

Fig. 4. Deflection calibration

c. Bending force measurement setup.
The measurement setup of deflection and force are shown in Fig. 5 and 6 respectively.

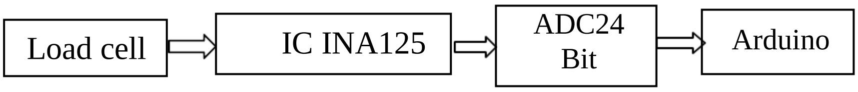

Fig. 5. Deflection measurement setup

Fig. 6. Bending force measurement setup

III. RESULTS AND DISCUSSION

After all the main components of the tool are installed, data collection and analysis is then carried out consisting of taking force calibration data and deflection calibration data.

FORCE SENSOR CALIBRATION

The results of the calibration of the Arduino-based weight measuring instrument with a weighing calibrator from position 0 to 200 kg are as shown in the Fig. 7.

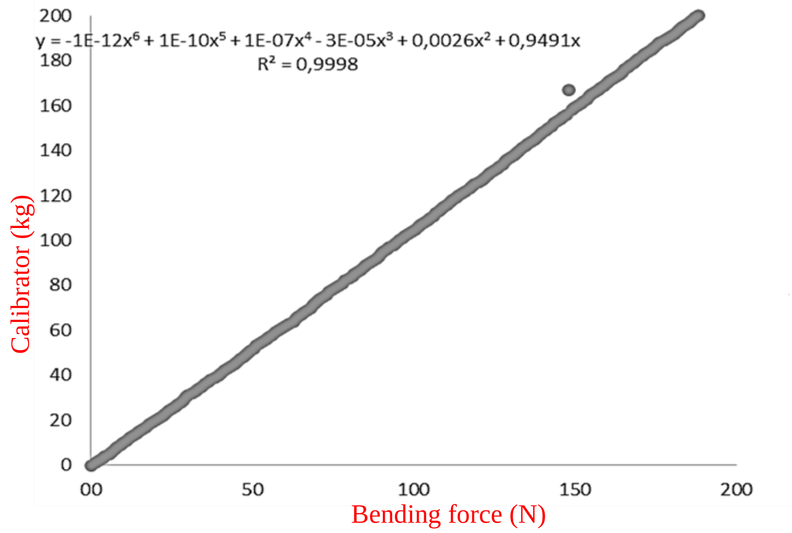

Fig. 7. Force calibration graph from 0-200 kg

The high order trend line polynomial equation is obtained. The results of the force calibration with a load of 0-200 kg are y = -1e-12x6 + 1e-10x5 + 1e-07x4 - 3e-05x3 + 0.0026x2 + 0.9491x. From the force calibration equation with a load of 0-200 kg, the coefficients are searched successively from the rank coefficients lowest to highest and expressed as a constant. These constants, especially the force calibration from 0-200 kg, are used for Arduino programming purposes because when using a bending test machine there tends to be an increase in force. It means it optimizes the result of previous research by Pandiatmi et al [6]. After taking the force calibration data, the result from the hysteresis that occurs when making continuous measurements from two opposite directions isobtained that the highest percentage difference obtained can be seen in Fig. 8 below.

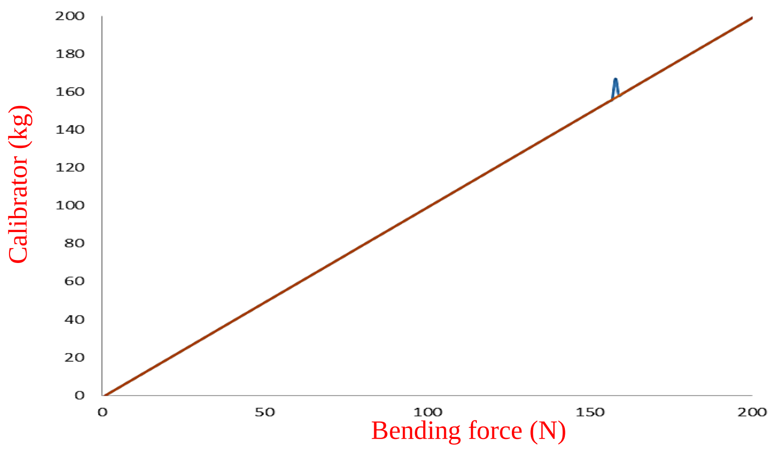

Fig. 8. Hysteresis graph for load measuring instruments

It can be seen that there is no hysteresis on the load measuring instrument because the load cell capacity is 1000 kg while its use is only up to 200 kg, however there is an error in the series rising point of 148.4 kg that arises on this measuring instrument and the equation eliminates this error. Hysteresis in measuring instruments is generally caused by elastic deformation or thermal effects on the components of the measuring instrument mechanism used when calibrating the force of the bending test instrument.Next, data collection was carried out again to determine the accuracy of the careful calibration. shows a comparison of calibration results taken once a day at three times, namely in the morning, afternoon and evening, given the same load, namely 100 kg, with the aim of finding out differences in measurement results for the given load. This force calibration was also carried out three times in repetition to show the correct results. the same or close. It can be seen that the percentage accuracy of the measuring instrument is 97%.

DEFLECTION SENSOR CALIBRATION

Before calibrating the tool, first take zero observation data with the aim of finding out how long it takes for the tool to show the zero position stably. After observing the zero stability for almost an hour and there were no fluctuations, it means that the zero stability is very stable. The tool used to sense the increase in length of bending test specimens is to use an extenso meter or what is usually called a linear potentiometer. This sensor functions to read the movement of a straight line in a linear manner and the output of this linear potentiometer is in the form of electric voltage in volts. The results of the calibration of this tool with the indicator dial calibrator are as shown in Fig. 9.

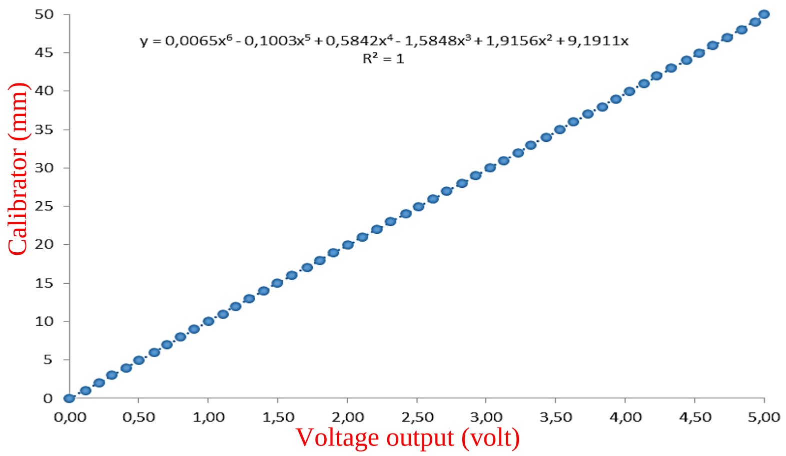

Fig. 9. Deflection calibration graph

Calibration was carried out from position 0 to 50 mm, it is obtained that the high order polynomial equation is the relationship between volts and millimeters, namely y = 0.0065x6 - 0.1003x5 + 0.5842x4 - 1.5848x3 + 1.9156x2 + 9.1911x with level 99.9% confidence or only 0.1%. The equation deviates from determining the increase in length of the output voltage produced by the linear potentiometer sensor. From the polynomial equation, the coefficients are looked for and expressed in constants successively from the lowest to the highest power. This constant position is used for Arduino program therefore the output of this tool will be directly in the form of linear displacement in millimeters.

After taking the deflection calibration data, the next step is to look for the hysteresis that occurs when making continuous measurements from two opposite directions. The results of observations made to find out what the highest percentage difference was obtained can be seen in Fig. 10.

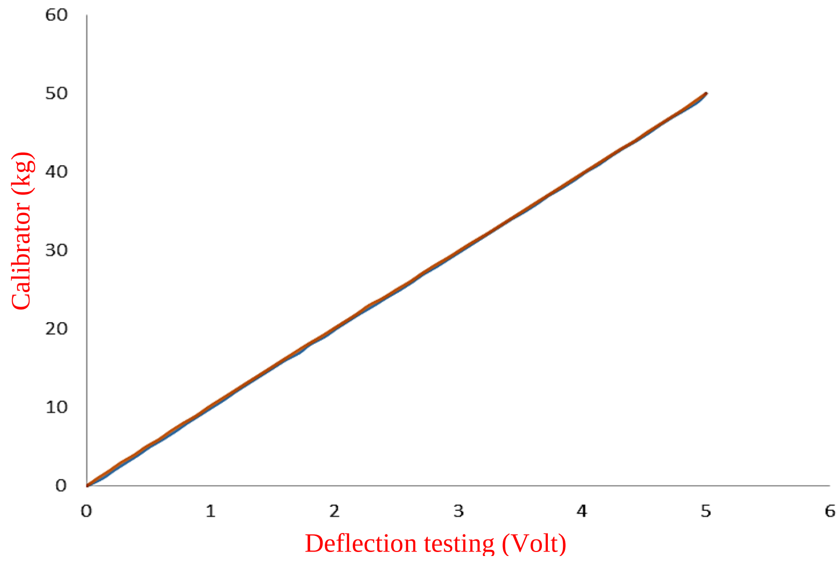

Fig. 10. Hysteresis graph for deflection measuring instruments

There is no hysteresis in this measuring instrument because the system of this measuring instrument uses a linear potentiometer and the effect of deflection is almost non-existent because the system is different from the load cell. Hysteresis in measuring instruments is generally caused by elastic deformation or thermal effects on the components of the measuring instrument mechanism used when calibrating the deflection of the bending test equipment.

From the data from the deflection calibration results, it can be seen that floating occur at a load of 25 mm, namely 2.48 volts, here can be said to be greater floating at higher extensions. As a result, this measuring instrument has a precision level of two numbers after the comma in mm. Floating on measuring instruments is usually caused by the measuring instrument being too sensitive to sense small changes in the sensor.

Next, searching for accuracy is carried out to show a comparison of the calibration results taken a day at three times, namely morning, afternoon and evening, with the aim of finding out the differences in the measurement results given, the load given is the same, namely 25 mm, this force calibration is also carried out three times for repetition. show the same or close results. Therefore, it can be seen that the percentage accuracy of the measuring instrument is 1.56%.

IV. CONCLUSION

From force calibration in bending tests, the time needed is 30 minutes to stabilize the measuring instrument's ability to show the zero position. Floating occurs at a load of 100 kg, namely 97.2 kg, here it can be said that floating is greater at higher loads. The accuracy level of the force calibration measuring instrument is 97%. There was no hysteresis found on the load measuring instrument because the load cell capacity is 1000 kg while its use is only up to 200 kg, however there was an error in the series rising point of 148.4 kg that appeared on this measuring instrument.

From calibration of deflection in bending tests, zero stability is stable significantly on the deflection calibration measuring instrument. The floating does not occur in deflection calibration measuring instruments. The accuracy level of the deflection calibration measuring instrument is 1.56%. There is no hysteresis in this measuring instrument because the system of this measuring instrument uses a linear potentiometer and the effect of deflection is almost non-existent because the system is different from the load cell.

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