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Calibration of 40 Kg Capacity Digital Scale on Automatic Machine Measurement Mass and Dimension Based on Arduino Uno Using CSIRO-NML: 1995 Method

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ABSTRACT

Every measuring instrument is subject to ageing as a result of mechanical, chemical or thermal stress and thus delivers measured values that change over time. This cannot be prevented, but it can be detected at the appropriate time through calibration. Instrument calibration is one of the primary processes used to maintain instrument accuracy. Calibration is the process of configuring an instrument to provide a result for a sample within an acceptable range. Eliminating or minimizing factors that cause inaccurate measurements is a fundamental aspect of instrumentation design. In this research, the load cell 40 kg assembly process is connected to several other supporting components to form a working system such as digital scale, then calibrated. As for the calibration process using the CSIRO-NML: 1995. Calibration results were analyzed using uncertainty analysis types A and B. Measurement uncertainty is the main parameter in this research. Uncertainties of type A and B are carried out to estimate the value of uncertainty in calibration measurements. By knowing the value of measurement uncertainty can be seen reading correction, and instrument limit of performance. Further the calibration results can be issued in a calibration certificate.

KEY WORDS: *digital scale, calibration, CSIRO-NML: 1995 method, uncertainty.*

1.0 INTRODUCTION

The growing number of e-commerce stores in Indonesia, small and medium logistics companies must be able to anticipate a surge in the number of goods shipped per day or per month. In addition to Pos Indonesia as a state company engaged in the delivery of goods and other services, several national logistics companies have sprung up to meet these needs such as TIKI, JNE and others.

Logistics packages are goods that are sent through transportation services. These items can be in the form of a variety of human needs with different sizes and weights so the shipping costs are determined by the weight (mass) and size or dimensions of the goods. Determining the volume of goods is very important if the size of the volume is very large, but the weight (mass) of the goods is very light (Respatindo, 2012). Almost all logistics companies in Indonesia still use conventional and separate methods in determining the volume and mass of logistics packages, namely by measuring logistics packages with meters to obtain volume and then measuring mass using scales. Furthermore, the results of measurement of volume and mass are compared, where the greatest value plays a role in pricing. The techniques used by logistics companies need to be improved to maintain economic sustainability in this field and to face the challenges of globalization that require speed and efficiency.

Based on the above conditions, the authors together with the team created a tool that uses work principles such as machine vision which is named Automatic Measurement Mass and Dimension Machine can be seen in Figure 1. The advantage of this machine is that it can process volume and mass measurements automatically at the same time making it more efficient. Measurement of volume dimensions is done using

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camera and laser images, while mass measurements use sensor load cells.

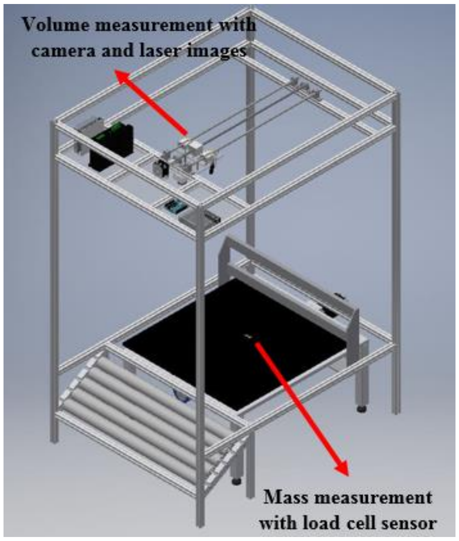

Figure 1: Automatic Machine Measurement Mass and Dimension

Load cell sensor is a force sensor that is widely used in industry, which acts as the main component in designing mass measuring devices. Newly made or long-used equipment usually must be carried out in a calibration process to ensure measurement results are in accordance with national and international standards.

2.0 LITERATURE REVIEW

2.1 Calibration

Calibration is a series of activities that form a relationship between the value indicated by a measuring instrument or a measurement system or a value represented by a measuring material with known values that are related to the magnitude measured in certain conditions (Caciotta, 2008).

From the results of the calibration the conventional truth values obtained from a measuring instrument and uncertainty. Uncertainty is a range in which there are values that may be the value of the measured quantity. A measurement cannot determine the value correctly, which can be done only making estimates (Cox and Harris, 2006).

Measurement uncertainty is the most important thing in the measurement results. Tolerance is the amount of error or deviation that is permitted in the product or work result specified in the design, regulations, standards and so on so that measurement uncertainty is used to determine whether a product meets established tolerance. Sources of uncertainty from a measurement (calibration testing) include standards or measuring instruments, measuring objects, equipment, measurement methods, environment, personnel, and other sources (Meyer, 2007).

Uncertainty combines all errors from known components or contributes to a single range. The ISO Guide classifies the uncertainty components of the measurement in two based on the evaluation method, namely type A and Type B. Type A arises from unexpected quantities based on experimental work and is calculated from a series of repeated observations. Type A is evaluated by the standard statistical method of a set of measurement data (including random errors) and characterized by average (or equivalent) values, estimated variances or standard deviations, linear regression, degrees of freedom, and other statistical characteristics. While type B arises from the magnitude that can be predicted based on the measuring model. Type B is evaluated by methods other than statistics on a set of measurement data (including systematic errors), usually based on scientific determination using relevant information, including: previous measurement data, experience and knowledge, factory specifications, data from certificate calibration, and uncertainty which is determined based on the database (Mulyani, 2009).

2.2 Digital Scales

Digital scales are electronic devices that are used to weigh loads, digital scales come in various sizes and colors and come from various materials. Digital scales are not the same as manual scales because the scales are useful based on the principle of charge cell technology where electronic load cells measure the weight of objects in certain circumstances. After the load is weighed it is transferred to a digital or electronic signal and then shown to a digital form. These scales are available in different models, brands, sizes and models, and usually come with batteries and calibration weights, scales and trays. Digital scales, like every different type of product, vary in price and quality (Furqan, 2016).

2.3 Load Cell

Load cell is a digital weighing sensor that works mechanically consisting of conductors, strain gauges, and wheatstone bridges. Display of load cell can be seen in Figure 2.

Figure 2: Load cell (Furqan, 2016)

Load cell uses a working principle that utilizes a strain gauge as a sensing (sensor). The strain gauge is a passive transducer that changes a mechanical shift into a pressure change. This change is then measured by the Wheatsone bridge where the output voltage is used as a reference load received by the load cell (Nuryanto, 2015).

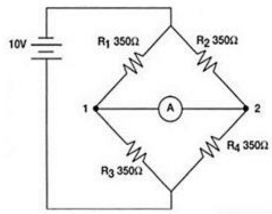

Figure 3: Balanced Wheatstone Bridge (Wahyudi et al., 2017)

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2.4 Modul HX711

HX711 module is an amplifier module commonly used in digital scales as an analog to digital signal conversion module at load cell. Has high precision 24 ADC high gain input designed for various Bridge type sensors. With two channels A and B (fix gain 32) that communicate in multiplex, this module can be programmed to gain 128 or 64 (20*mV* or 40*mV*) (Khakim, 2015). Hx711 is a weighing module that has the working principle of converting readable changes in resistance in changes and converting them into voltage quantities through existing circuits. This module has a simple structure, easy to use, the results are stable and reliable, have high sensitivity, and are able to measure change quickly (Nuryanto, 2015). The Hx711 module is shown in Figure 4.

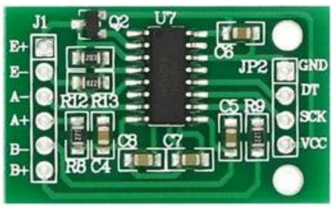

Figure 4: Hx711 Module (Nuryanto, 2015)

2.5 Arduino

Arduino is said to be a platform for open source physical computing. First of all it is necessary to understand that the word "platform" here is a choice of the right words. Arduino is not just a development tool, but it is a combination of sophisticated hardware, programming languages and Integrated Development Environment (IDE).

IDE is a software that is very instrumental in writing programs, compiling into binary code and uploading it into microcontroller memory. There are many projects and tools developed by academics and professionals using Arduino, besides that there are also many supporting modules (sensors, displays, drives, etc.) made by other parties to be able to be connected with Arduino. Arduino evolved into a platform because it is a choice and reference for many practitioners (Sanjaya, 2016).

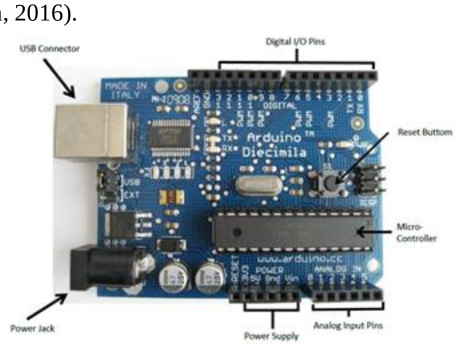

Figure 5: Arduino Board (Sanjaya, 2014)

2.6 Arduino IDE

Integrated Development Environment (IDE), a special program for a computer so that it can make a design or sketch of a program for Arduino boards (Hurisantri, 2016). The appearance of Arduino IDE is shown in Figure 6.

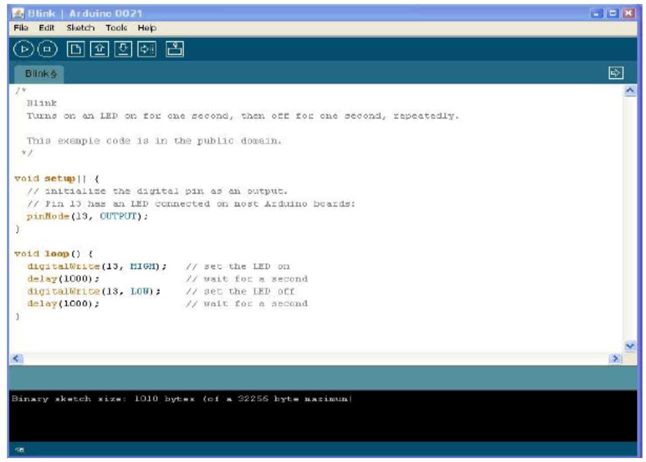

Figure 6: Display of Arduino IDE (Agung, 2014)

3.0 METHODOLOGY

3.1 Design a Mass Measuring Mechanical System

The design model of mass measuring instruments is made using Inventor software which can be seen in Figure 7.

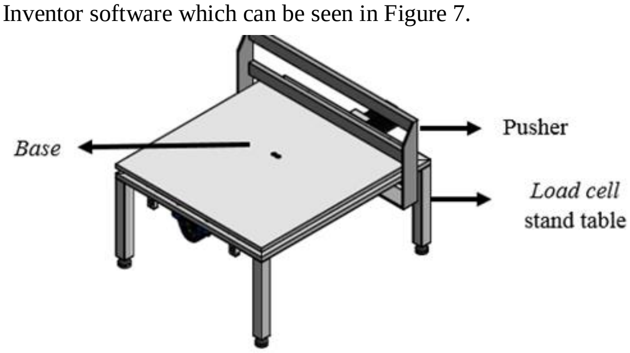

Figure 7. Design of Mass Measuring Instruments

The design of mass measuring devices consists of 3 parts, namely base, load cell holder table, and pusher. Base on this tool uses duralium plate size 50 cm x 50 cm. Base is used as a place to place objects when measuring mass. The second part of this tool is a load cell holder table that functions as a load cell support. The third part is a driver that functions to push objects when the mass measurement is complete. This driver is driven using a DC motor.

3.2 Schematic Electronic Circuit of Mass Measuring Instruments

Electronic circuit scheme is a method of analyzing the work system of each electronic component used. This scheme is intended to facilitate the understanding of component layout and the relationship between one component and other components. Figure 8 is a circuit scheme and layout for detecting object mass using a sensor load cell with a capacity of 50 kg.

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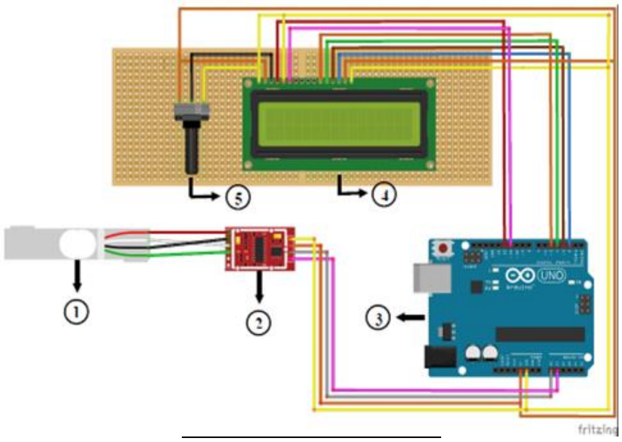


No.	Nama
1	*Loadcell*
2	HX711
3	Arduino Uno
4	LCD
5	Potensiometer 100k

Figure 8: Schematic Electronic Circuit of Mass Measuring Instruments

3.3 Software Design

Software is a system that regulates or instructs programs stored in flash memory programs. The microcontroller cannot work without the software on the instrument used. The microcontroller used in this mass gauge is an Arduino UNO microcontroller. The software is designed so that the microcontroller gets the results of mass measurements from the load cell sensor used. Here is a flow diagram of the system of mass measuring instrument software, can be seen in Figure 9.

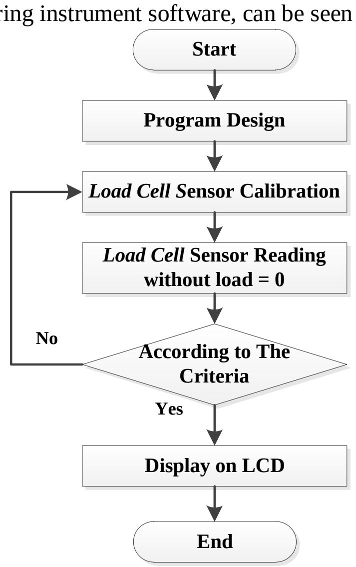


Figure 9: Flowchart of Mass Measurement Software System

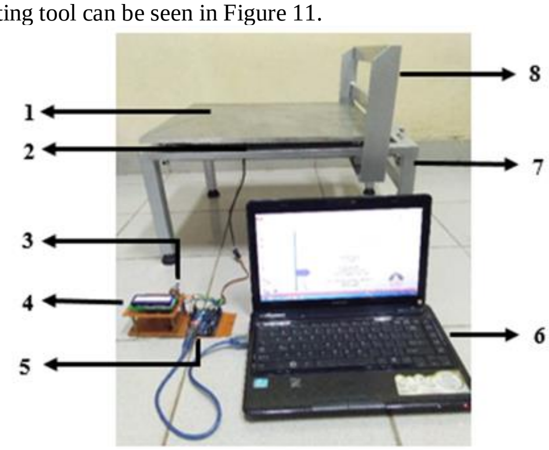
In making the program for mass measuring devices made using Arduino IDE 1.8.5 software. The display of the mass measurement program can be seen in Figure 10. After the program is finished, the program is uploaded so that the program is stored on the Arduino Uno microcontroller. The next step is calibration of the load cell.

Calibration of sensor load cell is done after the program has been uploaded, observe the sensor readings without load and record the reading results. Then measure the mass at a nominal value and record the reading. Compare the average value of the two readings to get the calibration factor value and add that value to the program until the zero load sensor reading is zero. If it is not zero, then look for the value of the calibration factor that is approaching. The next stage the value read by the load cell sensor will be displayed on the LCD screen.

Figure 10: Display of the Mass Measuring Program

3.4 Testing Set Up

In the test set-up, the load cell is placed on the load cell mounting table that is below the base. This research was conducted to obtain the mass value of the load cell sensor readings connected with the HX711 module which functions as an analog signal converter into a digital signal that is distributed with the help of Arduino Uno hardware as data acquisition and Arduino IDE 1.8.5 as a program to record data into the Personal Computer (PC). The test set up and some components of the testing tool can be seen in Figure 11.



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Nomor	Jumlah	Nama
1	1	Base
2	1	Load Cell 50 kg
3	1	Potensiometer 100k
4	1	LCD 16x2
5	1	Arduino Uno
6	1	Laptop/PC
7	1	Load Cell Stand Table
8	1	Pusher

Figure 11: Testing Set Up

3.5 Calibration Testing Procedures

The calibration procedures that will be carried out on the mass measuring instruments that have been made are as follows:

1. Check the scale of the scales if the condition is sturdy and free of vibration.
2. Check the scale of the scale.
3. Make sure there is no dust above.
4. Turn on the scales for about 30 minutes to warm up, before the calibration is done.
5. Select 10 nominal loads in the intervals of 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% of the maximum capacity of the scales.
6. At the time of reading, allow the scales 20 seconds or more to be constant before the results are recorded.
7. Record the measurement results.
8. Evaluate the results of reading the scales with the following formula.
   a. Correction value calculation equation (Darmawan and Titik, 2016).

$$K_i = M_{Si} - (\bar{M}_i - \bar{O}_i) \quad (1)$$

Information:

K_i = Correction value for the measurement point
M_{Si} = Conventional standard mass value for the measurement point-i
$\bar{M}_i$ = Repetitive reading average value with load for measurement point-i
$\bar{O}_i$ = The average value of no-load reading for the measurement point-i

   b. Equations to calculate the uncertainty value of repetition reading (U_1), (Darmawan and Titik, 2016).

$$U_1 = \frac{\sigma_{max}}{\sqrt{n}} \quad (2)$$

Information:

U_1 = Repeat reading uncertainty
σ_{max} = Maximum standard deviation
n = Amount of data retrieval

   c. The standard mass uncertainty calculation equation (U_2), (Darmawan and Titik, 2016).

$$U_2 = \frac{U_{S\,max}}{2} \quad (3)$$

Information :

U_2 = Standard mass uncertainty
$U_{S\,max}$ = The biggest uncertainty of the standard mass used

   d. The equation to calculate the value of uncertainty in the scale reading scale (U_3), (Darmawan dan Titik, 2016).

$$U_3 = \frac{0.5\,R}{\sqrt{3}} \quad (4)$$

Information:

U_3 = Uncertainty about reading scale
R = Resolution (smallest reading scale) of that scale

   e. Equations to calculate the value of uncertainty from the influence of air buoyancy (U_4), (Malengo, 2014).
   The effect of air buoyancy on the scale reading is assumed to have a spring range of 1 ppm.

$$U_4 = \frac{10^{-6}\ x\ Nominal\ Mass}{\sqrt{3}} \quad (5)$$

   f. The calculation equation assesses the uncertainty of standard mass drift (U_5), (Mayr et al.,2013).

$$U_5 = 8\,\%\ x\ MPE \quad (6)$$

Information:

U_5 = Uncertainty of standard mass deviation
MPE = Maximum error value that is still allowed

   g. Calculation equations for combination uncertainty values (U_c), (ISO,2008 ; Kammeyer and Rueger, 2008).

$$U_c = \sqrt{u_1^2\,C_1^{\,2} + u_2^2\,C_2^{\,2} + u_3^2\,C_3^{\,2} + u_4^2\,C_4^{\,2} + u_5^2\,C_5^{\,2}} \quad (7)$$

Information:

U_c = Combination uncertainty
C_i = Sensitivity coefficient

   h. The equation for uncertainty calculation is expanded (U_{95}), (Darmawan dan Titik, 2016).
   Extended extendedness is stretch uncertainty with a confidence level of 95%, with a coverage factor of k = 2

$$U_{95} = k\,U_c \quad (8)$$

Table 1: Calibration of Scale Uncertainty

Component	Unit	Distribution	Divider	Sensitivity Coefficient
Repeatability (U_1)	mg	t-*student*	2^0.5	1
Standard Measuring Instrument (U_2)	mg	Normal	2	1
Resolution (U_3)	mg	*Rectangular*	3^0.5	1
Buoyancy (U_4)	mg	*Rectangular*	3^0.5	1
Drift Standard (U_5)	mg	*Rectangular*	1	1

(Source: Darmawan and Titik, 2016)

3.3 Tools And Materials

The tools and materials used in the manufacture of automatic measuring machine of mass and this dimension can be seen in Table 2.

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Table 2: The tools and materials

No	Tools	Matrials
1	Camera	Logistic packages with different mass and dimension.
2	Laser	
3	Arduino	
4	Motor stepper	
5	Motor Driver	
6	Load Cell	
7	Aluminum Frame	
8	Power Supply	

3.4 Basic Principles of Mass Automatic Gauges on Automatic Measuring Machine of Mass and Dimension.

The working principle of automatic mass measuring instruments at automatic measuring machine of mass and dimension can be seen in the following image:

1. The Object to be measured is placed above the base objects.
2. Ardunio gave orders to the motor driver.
3. Current from the AC is converted to DC power supply for use switch on the motor driver.
4. Motor driver delivers orders to motor 1 to move the sliding shaft that has been associated with a camera and laser.
5. Once the sliding shaft is moving, then the camera and the laser do figure to get the data recording volume, simultaneously load cell do the heavy data retrieval.
6. Data that has been obtained is transferred to matlab software to be processed.
7. Once all of the data obtained, the arduino will give the command to the driver of the motor to drive the motor 2.
8. AC convert to DC using the power supply.

Motor driver delivers orders to motor 2 which is already linked with the axis screw. When the axis of the screw driving then rotate objects already connected by screw axis with bolt system will do the work in the form of the movement pushing objects already measured through roller storage place of entry, then the impeller will be back originally.

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