Virtual Instrumentation for Load Cell – Calibration and Measurements

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Abstract: *The aim of this paper is to present a virtual instrument for load cell. This virtual instrument has been used for calibration of the load cell and for measurements of mass. The paper also presents details on the used load cell. Details on the produced balance that contains this sensor, its mechanical and electrical parts, have been also given in the paper. The paper contains measurement results and a proper discussion.*

Keywords: *load cell, balance, calibration, LabVIEW.*

1. INTRODUCTION

Mass (load), as the main physical quantity and property of every physical body, is present in everyday life. Because of its exceptional importance there is a permanent need for improvement of technologies for its measurement. Consequently, different measurement methods were developed for that purpose, as well as the different constructions of the measuring devices [1-3]. Development of new technologies has enabled the use of semiconductor components in the construction of electronic devices for load measurement with significant precision and accuracy. However, this type of devices does not have full implementation because in systems where is necessary to measure a great load its performance is not satisfying. For that reason, the most reliable systems for measurement of load are load cells with strain gauges [2-5]. They have a large measuring range, which enables construction of different measurement systems depending on the load. The strain gauges are placed on load cell and their resistance is changing linearly whit the deformation of load cell. Therefore, mass (load) can be successfully measured using this solution.

In the study presented in this paper load cell CZL602A was used. It is powered by 9V battery. The load cell output is connected to the analog input of data acquisition card NI-9211, which is connected to a personal computer via USB. Virtual instrument has been made in LABVIEW software [6]. The paper presents the results of calibration of this load cell, as well as measurement of mass according to the determined sensitivity of load cell. Furthermore, it gives the results of absolute and relative deviations of such measurements and a proper discussion.

Measurement setup with load cell and accompanying virtual instrument is suitable for new laboratory exercise and future student work in the laboratory.

2. LOAD CELL CZL602A

Load cell CZL602a belongs to group of resistive sensors for measurement of load [1-3]. Basically, this type of sensor is built from an aluminum load cell that has a gap on its middle part. The photo of the CZL602a load cell is presented in Fig. 1.

Figure 1. *Load cell CZL602a*

The gap enables elastic bending of the load cell. At both ends of the measuring cell there are two M5 threaded bores that allow easy fixing of the load cell. From the upper and the lower side of the gap there are strain gauges that are fixed with some kind of epoxy resin. Strain gauges are arranged so that the two are positioned from the top of the gap and the other two are at the bottom. This arrangement allows connection of the strain gauges in the electrical circuit of the Wheatstone bridge as it is shown in Fig. 2a [3].

When the object is set on the plate, then the load cell will bend. Bending will cause compression and tension of strain gauges in pairs, which leads to a change of their resistance. The change in resistance causes the disbalance of the Wheatstone bridge, as it is shown in Fig. 2b. As a

result of disbalance at the output of the load cell voltage proportional to can be measured [3].
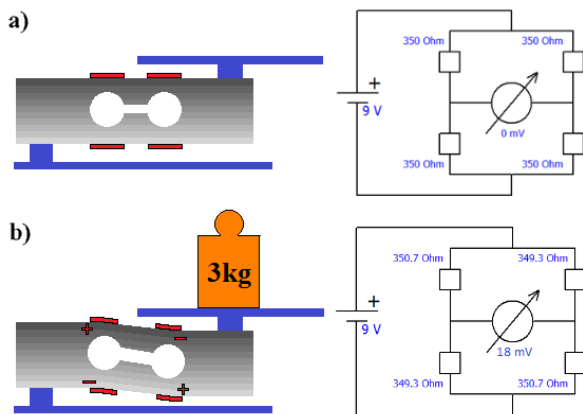

Figure 2. *Display of the measuring cell and the Wheatstone bridge: a) when the measuring cell is not loaded, b) when the measuring cell is loaded*

Some technical data of load cell CZL602a [7], given by the manufacturer, are:

- Rated load (full scale - FS) 3 kg
- Comprehensive error   0.03 % of FS
- Rated output   2±0.02 mV/V
- Nonlinearity   0.03 % of FS
- Repeatability   0.02 % of FS
- Zero Balance   1 % of FS
- Output Resistance   350±5 Ω
- Excitation Voltage   9~12 V.

According to this data, load cell CZL602a output voltage at rated load of 3 kg and chosen supply voltage of 9 V amounts 18 mV. In other words, its sensitivity S is 18 mV/3 kg=6 mV/kg. However, this value needs to be checked because it depends on the voltage (which may vary from taken 9 V) and because sometimes data from the manufacturer may be slightly different from actual data. Therefore, a calibration is needed.

The error of the load cell has been rated at 0.03% of full scale (3 kg), which amounts ±0.9 g.

3. MEASURING SYSTEM

The measuring system created for mass measurements is shown in Fig. 3. The measuring system consists of load cell CZL602a, 9 V battery and NI-9211 data acquisition card manufactured by National Instruments. The load cell is fixed at the one end to the bracket which is lifted from the stand in order to enable the bending of load cell. At the other end, plate has been designed to make it easier to set up an object which mass is measured. The battery is used as power supply. The load cell output is connected to the analog input of the data acquisition card connected to a personal computer (PC) via USB.
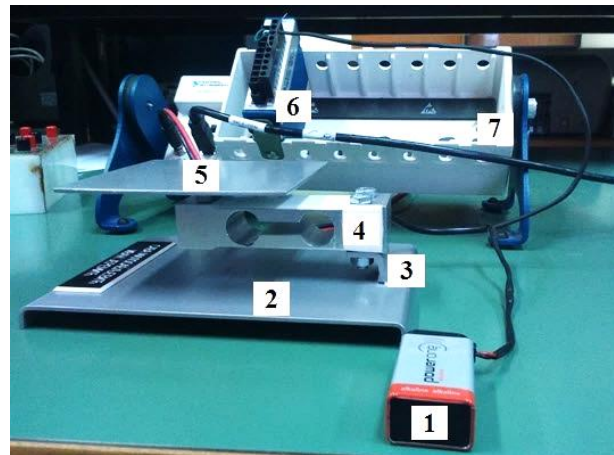

Figure 3. *System for mass measurement: 1 - 9 V battery, 2 - stand, 3 - bracket, 4 - load cell CZL602a, 5 - plate, 6 - data acquisition card NI-9211 7 - chassis*

A virtual instrument has been created in LabVIEW software for measurement of the output voltage of load cell.

4. VIRTUAL INSTRUMENT

Created virtual instrument for calibration and mass measurement contains four tabs [6]. The appearance of its first tab is given in Fig. 4.
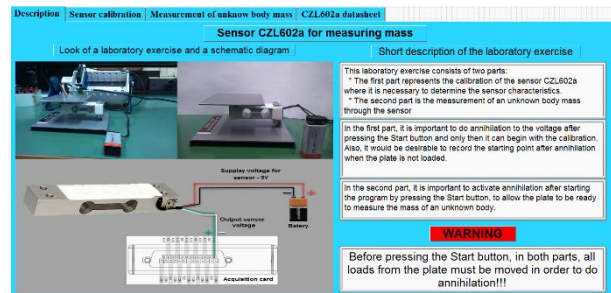

Figure 4. *Display of the first tab of the virtual instrument*

This first tab contains a brief description of measurement setup and electrical scheme of the measurement system. The second tab is designed to perform a calibration of load cell CZL602a. Calibration is performed by measurement of the output voltage U of load cell for different values of known mass m. In this way is obtained characteristic of the load cell as set of points (m, U). The third tab is designed for measurement of an unknown mass according to the predetermined characteristic $m=f(U)$. By applying linear interpolation, for measured voltage U' it is possible to determine unknown mass m' of an object using the existing $m=f(U)$ characteristic. Also, within this tab it is possible to print a report of measurement in PDF format. In the last tab, the datasheet of the CZL602a sensor is given as an additional information to the user.

4.1. CALIBRATION AND MEASUREMENTS

As in most systems, before the start of the measurement, it is necessary to know its

characteristic (dependence of output quantity on input quantity). This characteristic of load cell with strain gauges represents dependence of the output voltage of load cell on the load itself. As it has been explained in Section 2, it is important to perform a calibration in order to determine this characteristic. Tab entitled "Sensor calibration", which is shown in Fig. 5, is made for this purpose.
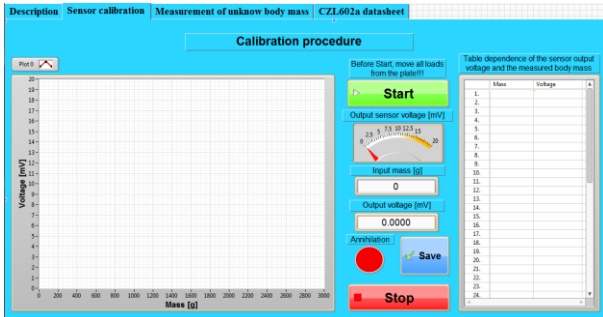

Figure 5. *Display of tab for calibration*

The calibration procedure is implemented as follows. The calibration starts with no load by clicking on the "Start" button. A certain output voltage different from zero will be measured. This is the result of the imperfection of the system, as well as the existence of a certain mass of the plate, which initially bends the load cell. In order to eliminate this problem, it is possible to annul this voltage in the software. After the annulment, it is necessary to record initial values in the table. At the same time the starting point in the graph will be plotted. After the starting point is recorded, it is possible to gradually bend the load cell with different mass and save obtained values in the table. Simultaneously, new point of the characteristic will appear in the graph. Every following load putted on the plate need to be greater than the previous, until the rated load is reached. When the calibration is finished, by click on the button "Stop" this part of virtual instrument will be stopped and then it is possible to move on the next tab for measurement of unknown mass.

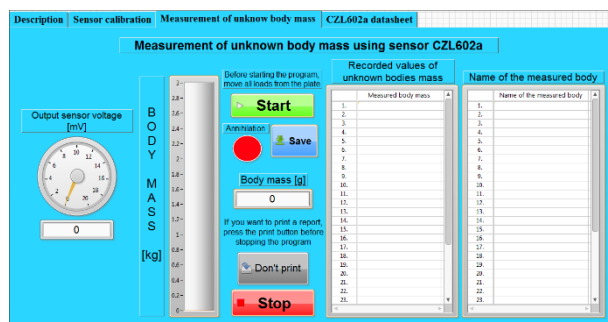The appearance of the tab for measurement of unknown mass is given in Fig. 6.

Figure 6. *Display of tab for measurement of unknown mass*

As in calibration, in this part of the program the output voltage should be annulled immediately after starting the program on the "Start" button

(load cell is unloaded). It is necessary to take care that all loadings from the plate are removed before the start of the program in order to ensure that the annulment is valid.

On this tab it is possible to read the unknown mass placed on the plate, as well as the output voltage of load cell. To save measured mass, it is necessary to click on the button "Save". Then, the mass of the body will be automatically saved in the table of recorded values of the unknown mass. It is possible to insert the name of the measured mass (object). When the mass measurement is finished, it is possible to print a measurement report in PDF format by clicking the button "Don't print". Then the button name will be changed to "Print". This option must be set before stopping the program by clicking "Stop" button. This report contains the following: theoretical basis, results of calibration of load cell with graphs and tables and table of measured masses and their names. This makes calibration and mass measurements with sensor CZL602A complete and program stops.

5. MEASUREMENT RESULTS

Numerical data on calibration of load cell are given in Table 1. Also, these data are presented graphically in Fig. 7. It has been performed for different loads up to 1.8 kg.

Table 1. Measurement results of load cell calibration

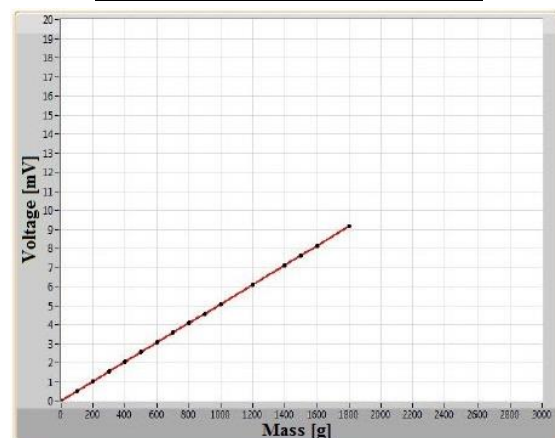| No.	m [g]	U [mV]
1	0	0
2	100	0.507
3	200	1.016
4	300	1.525
5	400	2.032
6	500	2.543
7	600	3.054
8	700	3.562
9	800	4.072
10	900	4.578
11	1000	5.087
12	1200	6.105
13	1400	7.120
14	1500	7.625
15	1600	8.137
16	1800	9.159

Figure 7. *Graphical representation of calibration results*

From Fig. 7 is evident that the characteristic of load cell is linear. According to these results, a coefficient *k*, which is a ratio of measured voltage *U* and set mass *m*, can be determined for each measurement:

$$k_i = \frac{U_i}{m_i}; i = 1, 2, \ldots, 16. \tag{1}$$

The mean value of this coefficient can be used as a sensitivity *S* of load cell and it can be calculated as follows:

$$S = \frac{\sum_{i=1}^{16} k_i}{16} = 5.085 \left[\frac{mV}{kg}\right] \tag{2}$$

This value is significantly different from the one calculated in Section 2 (6 mV/kg), which shows the significance of the performed calibration.
Further measurements of mass have been made with known masses in order to check the deviations of the measurement results. The results obtained are given in Table 2.

Table 2. Results of measurement of mass and absolute and relative deviations

m [g]	*m'* [g]	Δ*m*=*m'*−*m* [g]	δ*m*=*100*Δ*m/m* [%]
100	100.548	0.548	0.548
250	250.010	0.010	0.004
500	500.120	0.120	0.024
1000	999.746	−0.254	−0.025
1500	1498.126	−1.874	−0.125
1800	1799.318	−0.682	−0.038

From the results given in this table, it can be seen that the obtained absolute deviation Δ*m* is higher than the error of load cell given in Section 2 (0.9 g) only in one measurement. Also, the relative deviations δ*m* are low. These values are acceptable for this type of load cell and performed measurements.

6. CONCLUSION

Load cells with strain gauges, in combination with other equipment, are an integral part of almost every device for mass measurement. Their measurement accuracy is increased with the use of new technologies.

The aim of the research presented in this paper is to show one solution for measurement of mass which is based on the load cell. It has been shown how this load cell can be calibrated and how it can be further used for measurements according to the obtained sensitivity. For that purpose, an application has been made in LABVIEV software. It has been used to record all measurement data of

interest during the calibration of load cell and during the measurement of mass.

The paper presents all the results obtained, as well as a proper discussion.

Presented measurement setup opens the possibility to students to get acquainted with knowledge on load cells, mass measurement and virtual instrumentation.

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