Calibration of a pressure transducer

The aim of the measurement

The aim of this measurement training is to learn the calibration of a pressure transducer. Calibration is a process when the output signal of the sensor is compared to the value measured by an accurate device, and the relationship between the measured and the accurate value is determined.

Description of the measurement rig

The pressure transducer is connected to an air reservoir L, and the pressure in the reservoir is measured by a manometer filled with water. The pressure transducer is connected to the reservoir and has an electric current output. This way the pressure measured by the manometer and the output current of the pressure transducer can be related.

The scheme of the measurement rig is shown in Figure 1. The pressure transducer (N) receives its electrical power from the power supply (T). The pressure transducer and the manometer are connected to the reservoir tank via a T-junction.

The height of the water column (h) of the manometer can be read from the mm scale attached to the glass pipe. The height has to be read at the horizontal tangent of the curved water surface (the meniscus).

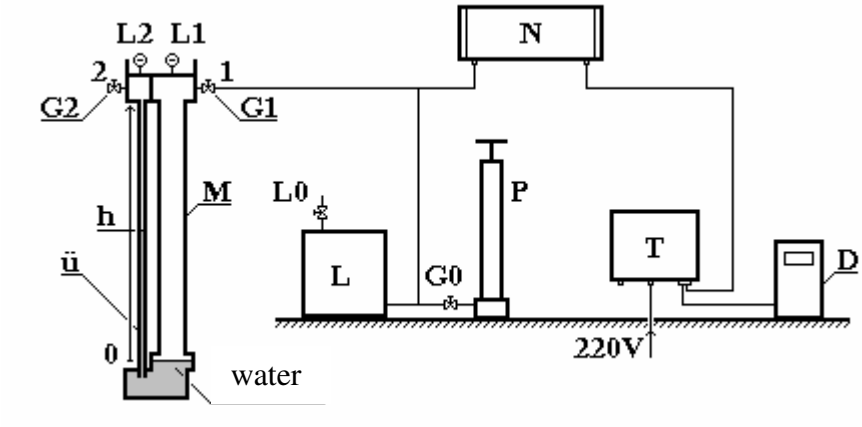

Figure 1. Scheme of the measurement rig

The output signal of the pressure transducer can be measured by a digital multimeter (D). As the output of the sensor varies between 4 mA and 20 mA, so the digital multimeter should be used in the 20 mA setting.

Description of the measurement process

Before the beginning of the measurement make sure that the measurement rig is built up as shown in Figure 1. Open the L0 throttle valve, and if needed set the mm scale placed next to the glass tube of the manometer to have its 0 mm point at the meniscus of the water surface. Close the L0 valve.

Attach a hand pump (P) to the valve denoted by G0, and pump air into the reservoir tank until the height of the water column in the manometer reaches at least 95 cm but less than 100 cm. The pressure transducer used for the calibration is capable of measuring pressures in the [0 Pa; 10000 Pa] range which means somewhat more than 1 m water column. The pump should be operated with small but fast pushes, because this way the oscillation of the water column in the manometer is reduced. After the desired water column height is reached close valve G0, and detach the pump. For a short time make sure that the measurement rig is not leaking, by watching the height of the water column. If it does not change, then the measurement process can be started.

15 measurement points are needed. By gently opening/closing valve L0 set the pressure in the reservoir to have approximately equidistantly placed pressures during the calibration. Read the corresponding (h_j, l_j) value pairs and write them to a table as in Table 1.

The height of the water column (h_j) should be written down with 1 mm accuracy while the output current of the pressure transducer should be written down as the display of the digital multimeter (with 0.01 mA accuracy).

After the measurement, fill out the other columns of the table in the report. The pressure at the reservoir can be calculated from the height of the water column of the manometer with the following formula: $\Delta p_j = \rho g h_j$, where $\rho=\rho_{water}$ = 1000 kg/m^3 where the height of the water column in the manometer (h_j) is meant in meter.

j	h_j [mm]	I_j [mA]	$\Delta p_j=\rho g h_j$ [Pa]	I_j^2 [mA^2]	$\Delta p_j I_j$ [Pa*mA]
1.					
…	…	…	…	…	…
15.					
		Σ	Σ	Σ	Σ

Table 1.

Calculation of the parameters of the fitted line using the method of least squares

After the calibration process and calculating the pressures, the output current (I [mA]) and the pressure acting on the sensor (Δp [Pa]) values are paired. From the measured (Δp_j, I_j) pairs the parameters of the regression line have to be calculated:

$$\Delta p = aI + b$$

This will be done using the method of least squares. For this, at first the difference of the regression line and the measured pressure has to be calculated at each calibration point:

$$\varepsilon_j = \Delta p_j - aI_j - b$$

Make the sum of its square over the measure points and denote it by D.

$$D(a,b) = \sum_{j=1}^{n} \varepsilon_j^{\,2} = \sum_{j=1}^{n} \Delta p_j - aI_j - b$$

Find the values for the *a* and *b* parameters for whose D is the smallest. To find them, one has to calculate the derivatives of D:

$$\frac{\partial D}{\partial a} = 0, \qquad \frac{\partial D}{\partial b} = 0$$

After the derivation we obtain:

$$a\sum_{j=1}^{n} I_j^{\,2} + b\sum_{j=1}^{n} I_j = \sum_{j=1}^{n} \Delta p_j I_j$$

$$a\sum_{j=1}^{n} I_j + bn = \sum_{j=1}^{n} \Delta p_j$$

Yielding:

$$a = \frac{\left(\sum_{j=1}^{n} \Delta p_j I_j\right) - \frac{1}{n}\left(\sum_{j=1}^{n} \Delta p_j\right)\left(\sum_{j=1}^{n} I_j\right)}{\left(\sum_{j=1}^{n} I_j^{\,2}\right) - \frac{1}{n}\left(\sum_{j=1}^{n} I_j\right)^2}$$

$$b = \frac{1}{n}\sum_{j=1}^{n} \Delta p_j - \frac{a}{n}\sum_{j=1}^{n} I_j$$

The report of the measurement should contain:

i) the measured values, the calculated pressure, the calculation of the parameters of the regression line in table 1

ii) the equation of the regression line

iii) the type and serial number of the used equipment (pressure transducer, power supply, digital multimeter).

iv) a mm scale paper on which the measured values (the pressure against the output current of the sensor) and the regression line are plotted. The regression line output to be drawn by calculating two points of it, using the formula.