Calibration Equipment for a Pressure Sensor on the Basis of a Conductive Elastomer

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Abstract-The equipment described in this paper has been developed on the basis of the requirement for a calibration pressure sensor based on the use of a conductive elastomer. The testing procedure is described. Our calibration system enables the sensor to be loaded by a square constant static mechanical pressure with a regulable value or by a dynamic pressure step function.

I. Introduction

The basic structure of the pressure sensor is illustrated in Fig. 1. A foil of conductive elastomer [1] forms the basis of the sensor. The electrodes are made of gold-plated Cu foil on a polymer carrier. The top foil prevents damage to the protective coat of the sensor.

covering antistatic layer
upper electrode, CUFLEX, th. 0,05 mm
composite elastomer, CS 57 - 7 RSC, th. 0,5 mm
lower electrode, CUFLEX, th. 0,05 mm
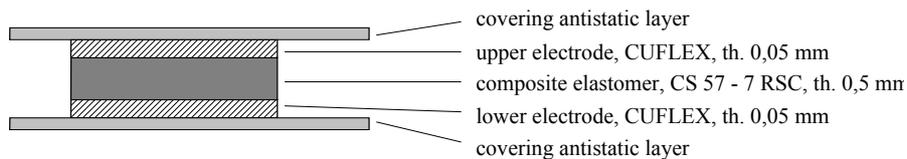covering antistatic layer

Figure 1. Sensor element (cross-section)

The instantaneous value of the calibration pressure and the ohmic resistance value of the elastomer sensor are scanned during the calibration process. The recording in the storage oscilloscope assesses the values statically or dynamically. The dependence of the sensor resistance on the actuating pressure in the steady state or the time characteristic of the sensor, i.e., the time response of the sensor to a step change in pressure, are the results of the measurement.

II. Calibration equipment

The pneumatic pressure chamber forms the core of this calibration equipment. It is supplied with compressed air from the pneumatic equipment. Mechanical pressure is provided by an elastomer membrane, which separates the pneumatic pressure chamber from the measuring chamber space (Fig. 2.) The mechanical pressure is in principle constant throughout, and its magnitude matches the air pressure in the pneumatic pressure chamber.

referential pressure sensor
pressure chamber
elastomer membrane
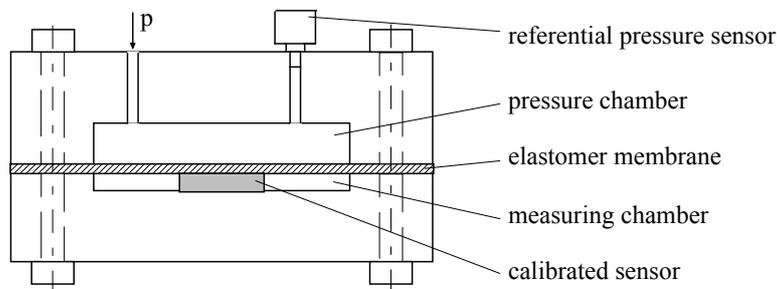measuring chamber
calibrated sensor

Figure 2. Pressure chamber - cross-section

The general layout of the calibration equipment is illustrated in Fig. 3. The pneumatic device supplies compressed air with adjustable pressure in the range from 0 to 1 MPa. The output of the equipment is

handled by magnetic valves, which enable pressure changes in the pneumatic chamber from 0 to the working pressure and back within a few of tens of seconds.
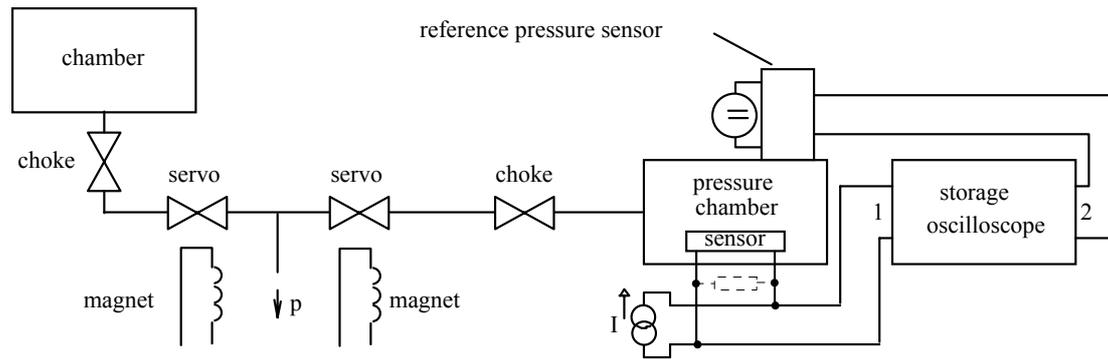

Figure 3. Calibration equipment

The resistance of the sensor is scanned by means of a voltage drop on the sensor, which is supplied with a constant current. In working conditions with small pressures, when the resistance value of this sensor is very high, the linear function U= f(R) can be distorted by inserting a parallel resistance, in order to keep the indicated voltage low.

The referential pressure sensor scans the air pressure in the pneumatic chamber with the voltage output in the range from 0 to 10 V at pressure from 0 to 1,6 MPa. The producer guarantees the 0,1 % accuracy rating of the sensor.

The voltage drop on the sensor and the output voltage of the reference pressure sensor are indicated and registered by a storage oscilloscope or by digital voltmeter.

III. Experimental results

A sensor with a structure according to the Fig. 1 and with the surface of 1 cm^2 was measured. The static calibration of the sensor was provided the calibration arrangement described above in the quasi-static mode. Very small air flows were set for filling and emptying the pressure chamber using a throttle-valve, so that the pressure increase and also the pressure drop in the chamber take between 5 and 10 seconds. The pressure course and also the sensor resistance were scanned discretely in large numbers of samples. Between one and two thousand samples were recorded while the pressure chamber was being filled and emptied. An example of the measured dependence of the sensor resistance and the pressure in the chamber for continuous, approximately exponential fall in pressure with a time response of approximately 2 s, is displayed in Fig. 4.
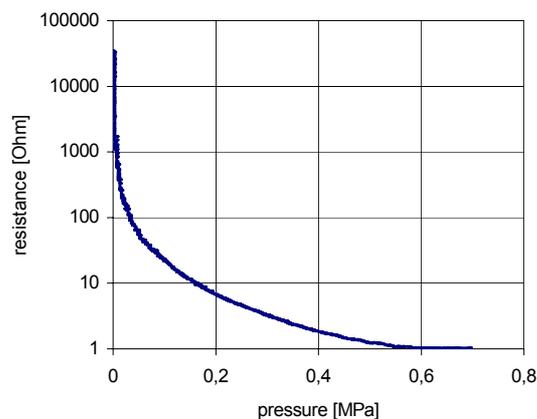

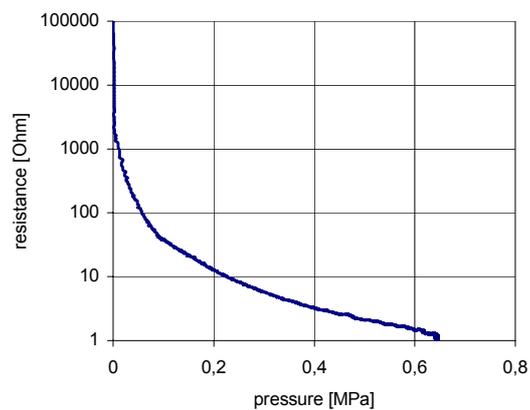Figure 4. The transducer resistivity – pressure decrease

Figure 5. The transducer resistivity – pressure increase

The dependence of the sensor resistance is displayed for an approximately linear pressure increase lasting about 10 s in Fig. 5. This dependence, which was measured at discrete points, with time approximately 15 s to stabilization for damping the transient process, is shown in Fig.6.
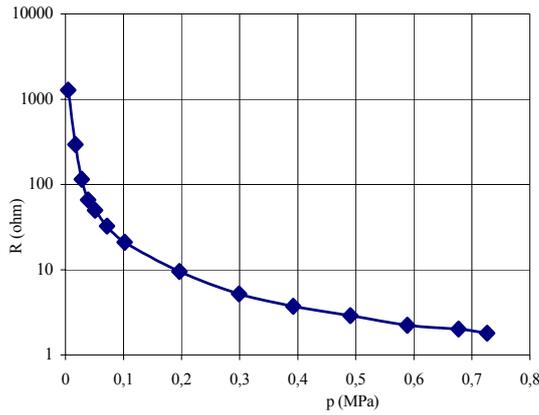
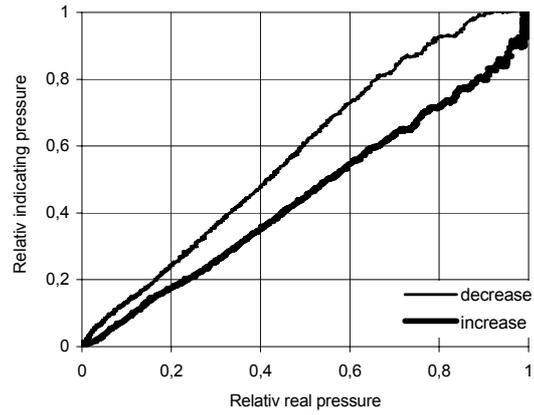Figure 6. Static calibration curve of the sensor

Figure 7. The approximation on the real pressure

The measured dependencies show a change in the resistance of the sensor of several orders. The highest response speed of the dependence of the resistance on pressure is in the range of low pressures, and the change in resistance is markedly lower at higher pressure and low resistance.

To facilitate the description of the response and to simplify the plotting of the dynamic effect, a backward transformation was searched that will enable the pressure to be determined according to the sensor resistance. The logarithmic function provides an approximation, because the dependence of the resistance matches it to a great extent. The function of the approximation provided by the resistance logarithm was formulised as a multinominal in the form

$$P = A(\log R_0 - \log R)^4 + B(\log R_0 - \log R) \qquad (1)$$

The dependencies of the pressure, assumed according to the approximation, on the real pressure in the chamber are shown in Fig. 7. The courses correspond to slow pressure changes; the rise time and pressure drop took 5-10 s. Curve A matches the pressure increase, while curve B matches the pressure fall. The dependencies are linear in both cases, and correspond to the continual proportion. A comparison of these curves shows that the course of the rise and drop in pressure are unequal, due to the small hysteresis of the sensor.

Similar processes were also observed during fast changes in pressure in the chamber. The course of this statically reduced dependence is displayed in Fig. 8 for a pressure increase lasting 50 ms. The course of this dependence, which is distinctly non-linear, documents the difference between the dynamic transfer characteristic of the sensor and the static transfer characteristic.
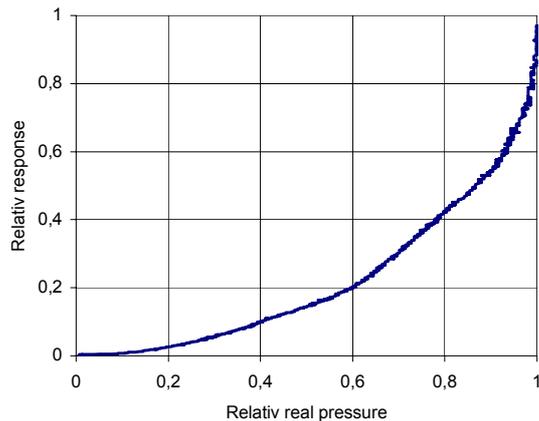

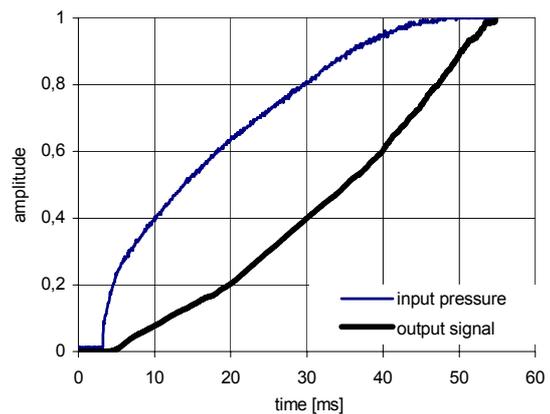Figure 8. The approximation on the real pressure
increase 50 ms

Figure 9. The pressure change response

The dynamic response of the sensor was observed by means of the response of the sensor to an impulse actuating signal in the time domain. It is not possible to measure the required impulse or the performance of the transient system directly, because an actuating signal, represented by the time changes in pressure in the chamber, represented by the time changes in the pressure in the chamber, cannot be generated in the required form. Therefore a comparison method using an actuating signal spectrum and its response was employed to determine the dynamic response. This method assumes a

linear system, in which the system response G(jω) can be expressed in the spectral range by multiplying the actuating signal spectra F(jω) by the transfer function H(jω).

$$G(j\omega) = H(j\omega)F(j\omega) \qquad (2)$$

If the driving signal f(t) and its response g(t) are known, and if their nonzero Fourier picture F(jω) and G(jω), then the transfer function H(jω) can be expressed as the term H(jω)= G(jω)/ F(jω). Then the system pulse response can be expressed using the backward Fourier transform of the transfer function H(jω).

$$h(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} H(j\omega) e^{j\omega t} \, d\omega \qquad (3)$$

The pressure change response, which is also the driving signal displayed in Fig. 9, was used to determine the dynamic response of the sensor. The calculated frequency characteristic and the transient response are displayed in Fig. 10 and Fig. 11. These system performances correspond to an ordinary low-pass filter with a cut-off frequency 6 Hz and time constants 3 and 30ms.
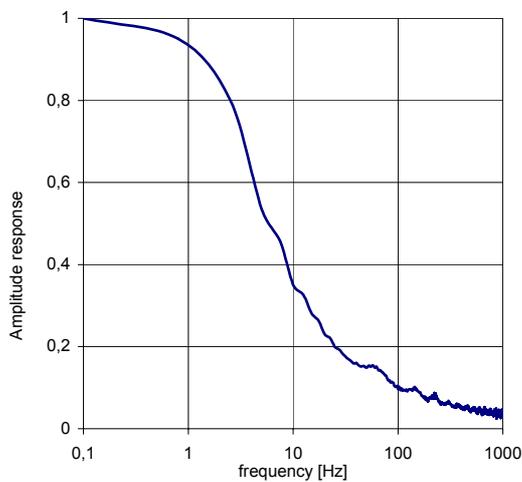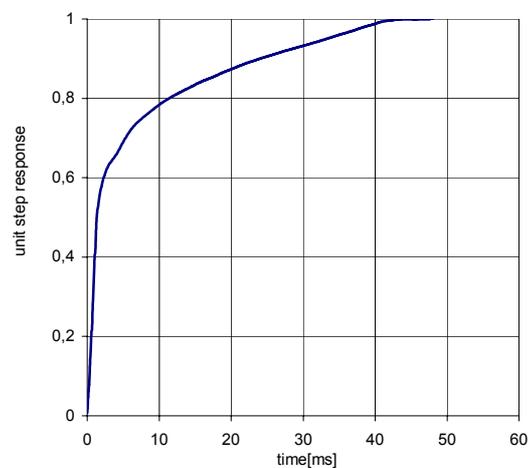
Figure 10. The amplitude response of the transducer

Figure 11. The transient response of the transducer

IV. Conclusions

The calibration system described in this paper enables the sensor to be loaded by a square constant static mechanical pressure with a regulable value, or by a dynamic pressure step function. The equipment enables the sensor to be calibrated and its time response to be assessed.

Acknowledgments

References

[1] *Technical documentation of the conductive composite elastomer CS 57-7 RSC*, Yokohama Rubber Co.Ltd.Japan - 1980

[2]Volf, J. - Papežová, S. - Vlček, J. - Holý, S.: *Transducer for Pressure Distribution Measurement and its Practical Tests*. In: World Multiconference on Systemics, Cybernetics and Informatics. USA Orlando (Florida) : International Institute of Informatics and Systemics, 2001,vol. II, ISBN 980-07-7555-2.