ELECTRICAL MEASUREMENT OF PRESSURES IN ROMANIA

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Abstract - *The paper illustrates more than 30 years of author's experience as a measureman in the field of pressure measurements, both for industry and/or for environment. In a world where engineering acquires more and more complexity as a science, going beyond strictly specialized fields, the application of mechatronic principles results in the optimum utilization of materials in their elastic limits and ingenious association of tensometric sensors and corresponding electronics, in order to achieve high sensitivity transducers with multiple applications.*

Keywords - Pressure membrane/diaphragm, strain gauges (SG), electrical measurement, intelligent transducer.

1. INTRODUCTION

Congratulating the new topics entitled "Measurement of electrical and non-electrical quantities" this paper illustrates the electrical measurement of pressures in Romania. A series of applications for modern control requires the measurement of some mechanical quantities (pressure, force, torque, vibration, displacement, and so on). Compared with other methods, the electrical ones offer some advantages: high accuracy, flexibility and simplicity, transmission at distance of results, possibility to record the time history, PC interpretation of experimental data.

A special accent was put on transducers, highlighting the flow of energy conversion: ***non-electric quantity - specific deformation ε - resistance variation - voltage variation*** that characterizes the tensometric measurement. The basic circuit for the electric measurement of non-electric quantities is the well-known Wheatstone bridge [3]. Several personal strain gauged transducers are presented in this work, whose performances are comparable to those achieved by reputed firms all over the world, being used in a wide range of adverse dynamic conditions.

2. STATE-OF-THE-ART IN THE FIELD OF PRESSURE MEASUREMENT IN ROMANIA

The following Romanian contributions in the field of pressure measurements have been presented at the **N**ational **S**ymposia of **T**ensometry (Strain Gauge Techniques):

- cells for soil pressure measurements (Hann, NST I, Iassy, vol. 3, p. 205, 1977);
- stress and strain states determination for pumps (Posea, NST II, Cluj, vol. 2, p. 193, 1980);
- pressure measuring between skies and snow (Sperchez, NST III, Timisoara, vol. 1, p. 137, 1983);
- contact pressure determination in a rolling mill (Ilca, NST III, Timisoara, vol. 2, p. 135, 1983);
- manometers with thin deposited strain gauges (Devenyi, NST IV, Brasov, vol. 1, p. 59, 1986);
- diaphragms for force/pressure measurements (Sandu, NST IV, Brasov, vol. 1, p. 209, 1986);
- ball bearings pressure determination (Diaconescu, NST IV, Brasov, vol. 4, p. 85, 1986).

The author's principal and original contributions in this multidisciplinary field are the following:

- pressure variation measurements by using strain gauge transducers [5];
- dynamic measuring in fuel oil feeding pipes from thermo power stations, where the "heart" of the system is the strain gauged pressure transducer, having the components shown in Fig. 1 [6];

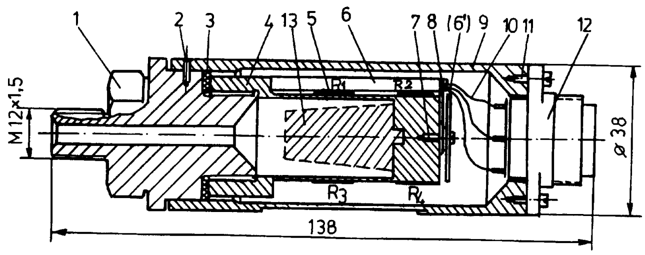

Fig.1 – Pressure transducer: 1 - connecting piece; 2, 7, 11 - screws; 3 - gasket; 4 - elastic element; 5 - strain gauge; 6 - connecting plate; 8 - terminal; 9 - case; 10 - wire; 12 - connector.

- high pressure measurements on reciprocating compressors [1];
- stress determinations in various elements of pumping installations [2];
- strain gauge force transducers for dynamic measurements in energetics [11];
- metrological check procedure for the pressure transducers in Romanian trisonic wind tunnel within our National Institute for Aerospace Research [12];
- capacitive transducer for determining the fluids compressibility [13];
- increasing methods of strain gauged force transducer sensitivity [14];
- structural optimization for intelligent transducer diaphragms [15].

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A separate chapter is devoted to the optimization of the profiled membrane shape for strain gauged pressure transducers, a lot of personal works in this respect being presented in reputed international conferences [4, 7-9].

3. OPTIMIZATION OF THE PROFILED MEMBRANE SHAPE FOR S. G. PRESSURE TRANSDUCERS

Shape optimization of such circular membranes in order to increase their tensometrical sensitivity is possible using FEM (the **f**inite **e**lement **m**ethod) as method of research. Starting from a chosen shape and preliminary dimensions established by analytical computation on simple models, a first discretization for the elastic element and FEM analysis are made. The results are examined and, if necessary, the initial dimensions are modified and FEM computation is made again. After several statical analysis the transducer elastic element reaches its optimum shape - a good example of novelty.

The most important criteria for geometrical optimization of the transducer elastic elements are the following [10]:

- strain gauges bonded on the places and on the directions with strains closer to the maximum ones;
- half from the strain gauges connected in Wheatstone bridge to be extended (R_2 and R_4 from Fig. 2), another half to be shortened (R_1 and R_3 from Fig. 2), so the strains ε read on the measuring apparatus to be as great as possible, all strain gauges being active;
- the fundamental frequency of the transducer to be much greater than the frequency of the parasitic vibration from the environment, to avoid the resonance;
- the overall dimensions within the imposed limits.

A personal example of "profiling" tensometrical membranes is shown in reference [8]. Improving the constant thickness plate to the profiled membrane, the sensitivity of the force/pressure transducer is increased, without the getting higher the maximum stress σ_{max}. The profiled membrane with thickness variation along the radius is an elastic element with small height. This transducer is easy to manufacture, sturdy, low and economic: only four strain gauges, utilized to measure force and pressure as well. Extended variants using 8 or 16 strain gauges are presented in Fig. 2 too.

4. COMBINED PRESSURE AND FORCE TRANSDUCER

It is a good idea to achieve a complex transducer, starting from the property of the circular plates to sense both pressure **p** (force distributed on the whole surface) and concentrated force **F** (in the plate center). So, the unique multifunctional transducer presented in Fig. 3 has a simple construction (circular membrane with a central protuberance) and a "double" functionality: the four strain gauges emplaced on the opposite face to the pressure application sense both the pressure and the pressing force. Two strain gauges (1 and 3) are bonded on the radial direction, at the extremities, and the other two strain gauges (2 and 4) are bonded on the tangential direction, in the middle of the same radius. Studying the stress and strain states within this multifunctional transducer, depending on force **F**, respectively pressure **p**, on elasticity modulus **E** and on geometrical dimensions (**a** - radius and **h** - plate thickness), the strain gauge sensitivities ε_F and ε_p respectively are computed using the formulae noted in Fig. 3.

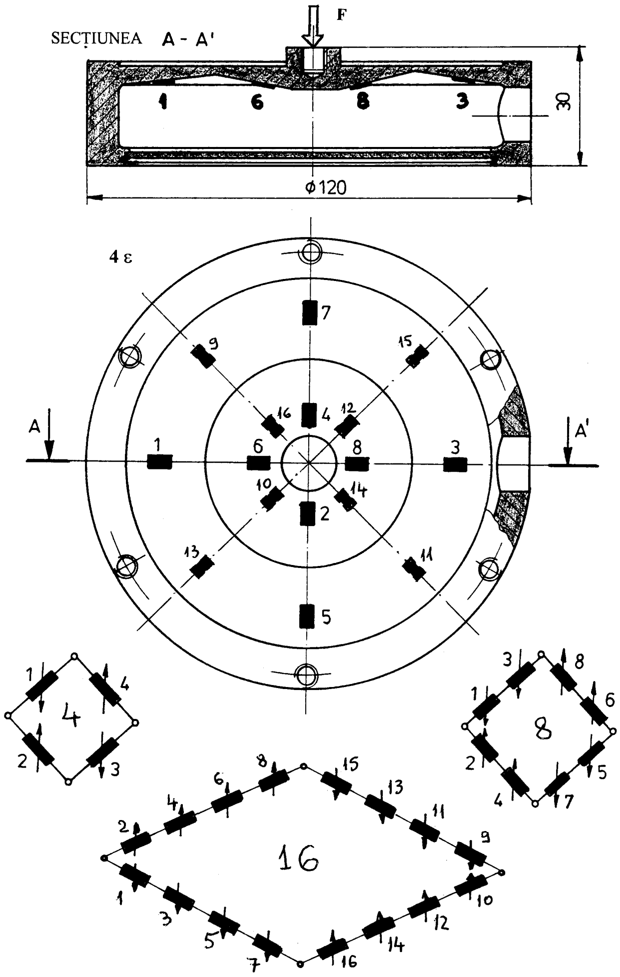
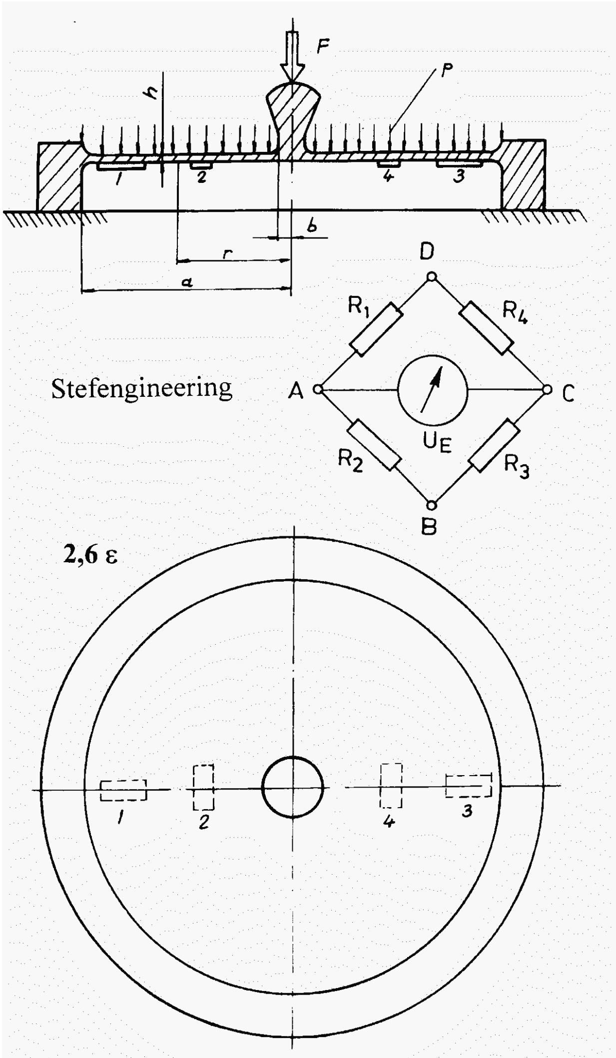


Fig. 2 Strain gauge emplacement on a profiled membrane utilized as pressure/force transducer.

Special application: Adapting the trisonic wind tunnel for terrestrial vehicle models testing raises numerous and interesting metrological/instrumentation problems. Blow-downs acting on high speed models placed on a special moving belt impose the optimum combination between the pressing force (the belt weight) and the suction pressure (to maintain the proper belt position). Control loop measurement of the pressure differences (8 atm) between the two faces of the moving belt active part is made by two independent transducers:

- classical pressure transducer on the upper face;
- (com)pression transducer on the lower face, summing the aerodynamic pressure and the pressing force of the moving belt.

The appropriate sensors calibration permits the separate evaluation of pressure and force contribution. Finally, the global signal in the strain gauged measurement system is a precise measure of the composed loading: force and pressure, i.e. (com)pression.



$$\varepsilon_p = 0.865 \frac{p \cdot a^2}{E \cdot h^2} \qquad \varepsilon_F = 0.950 \frac{F}{E \cdot h^2}$$

Fig.3 – Membrane shaped strain gauge pressure and/or force transducer.

5. INTELLIGENT TRANSDUCER DIAPHRAGMS

A recent application consists in structural optimization for intelligent transducer diaphragms [15]. The optimized diaphragms (membranes) utilized as smart mechatronic devices are intelligent due to the efficient utilizing of the semiconductors, the advanced technologies being applied simultaneously to elastic microstructures and computer components.

Smart transducers are devices with built-in intelligence; they have a great potential for many functional enhancements like outputting multiple variables from a single transducer (e.g. pressure, force, temperature), choosing of optimal sensitivity, remote programmability, system interoperability at the sensor level. Following the analogical sensing, analog-to-digital conversion (ADC) and digital signal processing (DSP), software is the key element to pass from the classical diaphragms to the intelligent ones.

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