Laboratory Experiments Made on Corrugated Metallic Capsules, for Selecting Optimal Sensitive Elements in Pressure Transducers Used in Modern Mechatronics Systems

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Abstract: *This work focuses on laboratory experiments and researches carried out in laboratory environments, in order to obtain the "useful deformations" of the behaviour of corrugated metallic capsules – which are very imported for optimal dimensioning of sensible elements of low pressure transducers. This research provides real information needed in the construction of precision transducers for low pressure, having corrugated metallic capsules as sensitive elements.*

Keywords*: low pressures, sensitive elements, corrugated capsules, transducers for low pressures*

1. Introduction

A team of specialists made efforts to create a low pressure measuring device with high accuracy class (0.25%), which falls into the category of standard measuring devices which can check less precise measuring devices, in safe and efficient way.
The authors studied the comparative performance of different transducers with pressure sensor type "corrugated capsule", having incorporate systems of mechanical compensation of errors due to temperature variations, designing and developing a performance constructive solution with competitive and important advantages, such as: stability and better accuracy, sensitivity and high reliability, operating within tolerable error in the range 5°C ... 55°C.
There have been studied and experimented several corrugated metallic capsules (having minimum geometric dimension) that falling within the rigid centre displacement of 1 mm in the range of maximum 1000 mbar (including subdomains 0 ... 40 mbar, 0 ... 80 mbar, 0 ... 100 mbar, 0 ... 160 mbar, 0 ... 200 mbar), based on experimental observation that efficient use of inductive coils into an inductive transducer occurs for a displacement of 1 mm of ferromagnetic core (linear hysteresis area).

2. Innovative equipment developed for conducting practical experiments on different types of corrugated metallic capsules

The accumulated experience in several years of research and development has led to the development and creation of an special innovative equipment for experiments (named „MCDR-MM-01") used when carrying out experiments, and it was designed, assembled and used for precision determinations, according to internal norms and the procedures in accredited laboratories.
The special innovative equipment - MCDR-MM-01 for measuring the useful deformation of corrugated metallic capsules, working at low pressures, has the following components:
- a precision manometer with a maximum of 100 mbar range,
- an instrumental air source,
- a subassembly for mounting watertight capsule,
- a subassembly for reading (showing) deformation of the capsule made up from a micro-meter that ensures a proper visualization of the corresponding deformation for a certain work pressure and a signalling device for instantaneous contact between the prod (feeler pin of micrometric

screw) and the superior membrane of the corrugated metallic capsule (which is tested about maximal deformation obtained on upper surface),
- a digital thermometer for indicating temperature inside the laboratory,
- a barometer – for checking atmosphere pressure.

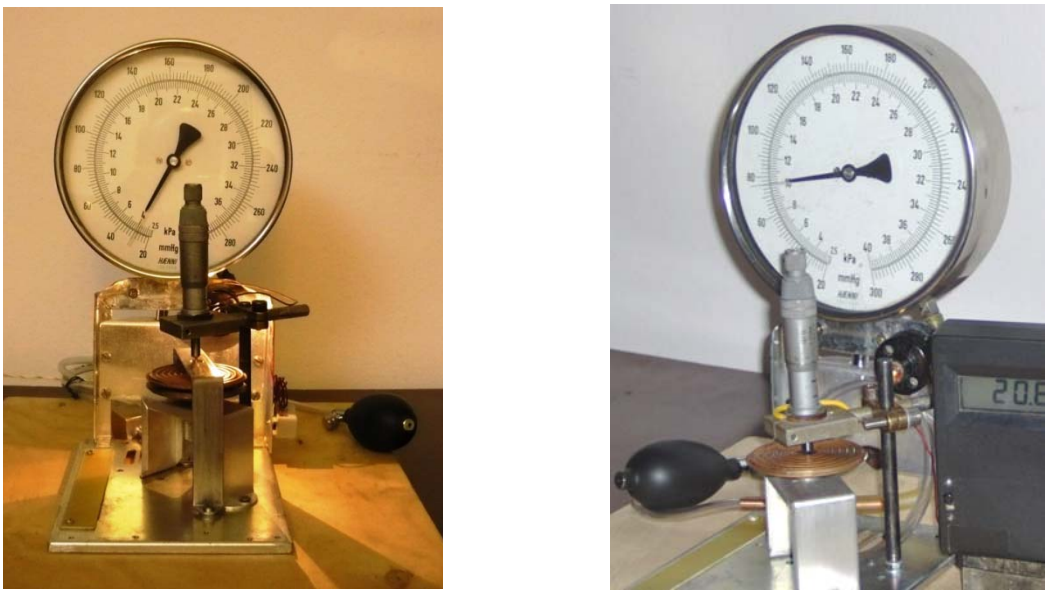

Fig. 1. MCDR-MM-01 - The equipment for measuring the deformations of corrugated capsules, when into these capsules are applied low pressures

With the support of MCDR-MM-01 equipment was made more substrings measurements on several types of corrugated capsules in order to determine the best solution of a curled capsule that can provide useful deformation desired, according to pre-calculations made in the design stage for executed a sensitive element with corrugated capsule for a high efficient inductive transducer.
We measured useful deformations for 40 corrugated capsules, but following the centralization of the results obtained, it was found that the optimal output parameters are supplied of the following measures:
- measuring the deformations corresponds to some points of applied low pressures, for corrugated copper-beryllium capsules, having a diameter of 60 mm, a radius of the tightened centre of 6 mm, with 6 sinusoidal corrugations, with height of the first 5 undulations of 1.1 mm, and thickness variables – the row of values in: {0.2; 0.22; 0.25} [mm] – there have been obtained some pairs of values ("p - $w_{capsule}$") recorded in the following tables, then we used these results to draw characteristics "pressures - deformations" of the corrugated capsule ("p - $w_{capsule}$"), in order to examine graphic the differences resulting and make the right decision for stage of practical execution of a precision transducers for low pressure.

Table 1 - contains the values of the pressure needed to displace the rigid centre of the measuring capsule (having a thickness 0.2[mm]) with a "useful deformations" ("offset") of 0.94 mm, and fig.2 depicts the characteristics "pressures–deformations" for corrugated metallic capsule, within the domain 0... 40 mbar;

TABLE 1: Values for "pressures–deformations" into domain 0...40 mbar

p [pressure][bar]	0	0.01	0.02	0.03	0.04
$w_{capsule}$ [mm]	0	0.24	0.46	0.70	0.94

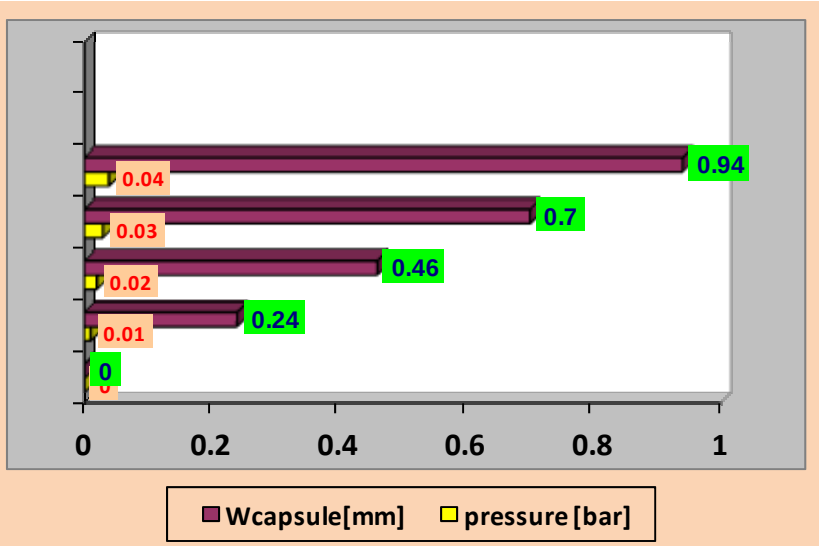

Fig. 2. The characteristics "pressures–deformations" for low pressure applied on corrugated metallic capsule, within the domain 0... 40 mbar

Table 2 contains the values of the pressure needed to displace the rigid centre of the measuring capsule with a "useful deformations" ("offset") of 1.46 mm, and fig. 3 depicts the characteristics "pressures–deformations" for corrugated metallic capsule, within the domain 0... 60 mbar;

TABLE 2: Values for "pressures–deformations" into domain 0...60 mbar

p [pressure][bar]	0	0.01	0.02	0.03	0.04	0.05	0.06
$w_{capsule}$[mm]	0	0.24	0.48	0.74	0.98	1.22	1.46

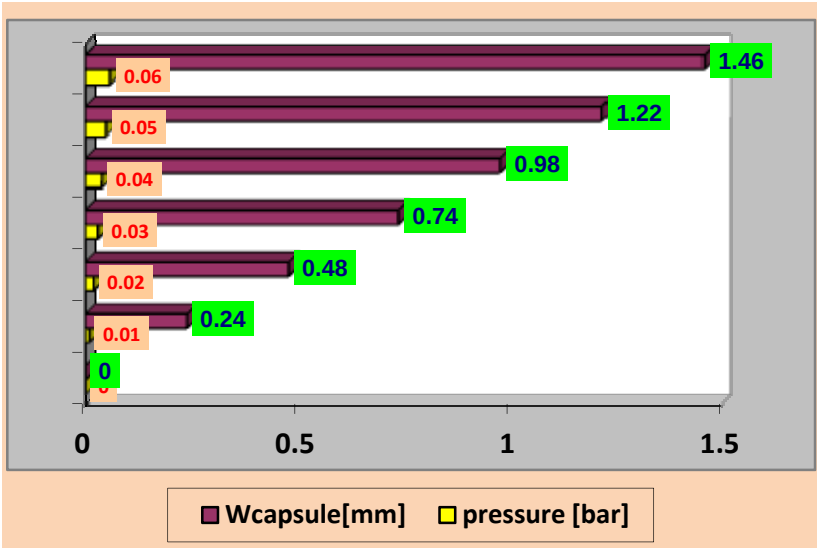

Fig. 3. The characteristics "pressures–deformations" for low pressure applied on corrugated metallic capsule, within the domain 0... 60 mbar

Table 3 contains the values of the pressure needed to displace the rigid centre of the measuring capsule with a "useful deformations" ("offset") of 1.66 mm, and fig. 4 depicts the characteristics "pressures–deformations" for corrugated metallic membrane/ capsule, within the domain 0...100 mbar;

TABLE 3: Values for "pressures–deformations" into domain 0...100 mbar

P [bar]	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1
$w_{cp} = w_{capsule}$	0	0.16	0.34	0.5	0.66	0.84	1	1.16	1.32	1.5	1.66

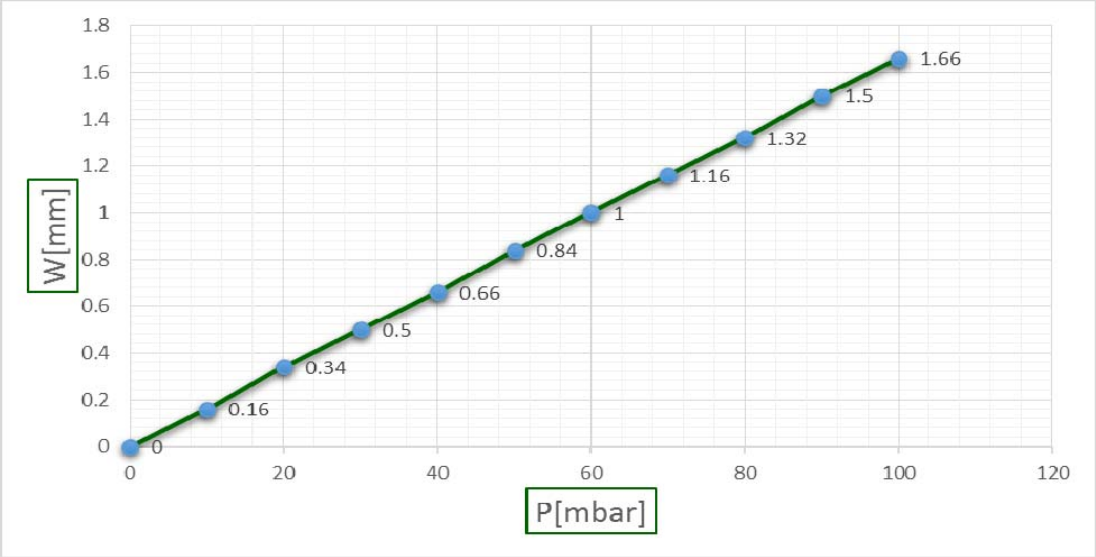

Fig. 4. The characteristics "pressures–deformations" for low pressure applied on corrugated metallic membrane/ capsule, within the domain 0... 100 mbar

Table 4 and fig. 5 contain the values obtained after the experiments took place.
The pressure check was of 100 mbar of a measuring capsule with a 60 mm diameter, a rigid centre radius of 6 mm, with 6 sinusoidal corrugations, wave height of 1.9 mm, with rising and falling pressure.

TABLE 4: Different values measured for low pressure into range 0 ... 100 mbar (for increasing pressure and for decreasing pressure)

Pressure [bar] (Pressure rising)	**Capsule arrow** "Useful deformations"**[mm]**	**Pressure [bar]** (Pressure decreasing)	**Capsule arrow** "Useful deformations" **[mm]**
0	0	0.1	1.66
0.01	0.16	0.09	1.49
0.02	0.34	0.08	1.32
0.03	0.5	0.07	1.16
0.04	0.66	0.06	1
0.05	0.84	0.05	0.83
0.06	1	0.04	0.65
0.07	1.16	0.03	0.48
0.08	1.32	0.02	0.33
0.09	1.5	0.01	0.16
0.1	**1.66**	**0**	**0**

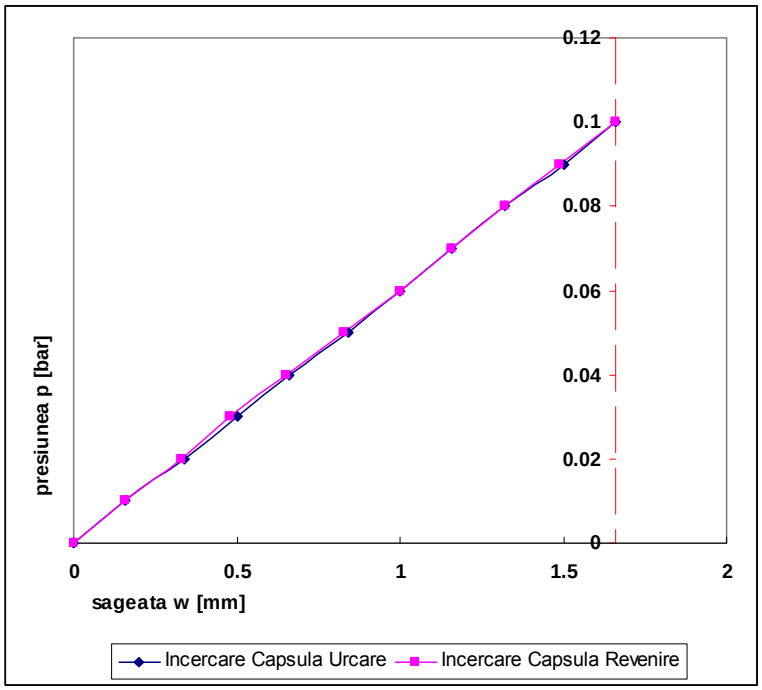

Fig. 5 Values measured for "pressure rising" and "pressure decreasing" for a pressure domain 0 ... 0.1 bar

3. Conclusions

After conducting practical experiments on corrugated metallic capsules, with different wall thicknesses, it was desirable a dedicated application software, which can offer an accurate simulation of the behaviour at low pressure applied into corrugated metallic capsules, to compare theoretical and practical results, and finally obtain valuable results, proved technically and mathematically.
This paper focused on laboratory experiments generated results for optimal dimensioning of sensible elements of low pressure transducers. To ensure valuable results, experiments were conducted in rigorously controlled laboratory conditions, with always controlled temperature and maintained at values mentioned in modern standards.
By creating an original device for measuring "useful deformations", real data could be recorded extremely accurately, which subsequently had directed efforts to correct conception of an inductive transducer for low pressures.

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