FLEXIBLE AREAL TRANSDUCER FOR PARAPLEGICS

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Abstract: For necessities to determine the pressure distribution on lightly curved solid and pliable areas, the special flexible areal pressure transducer has been developed. The whole design is being adapted to this purpose. As, the sensitive measuring layer is used the special semiconductive elastomer, type: CS 57-7-RSC. This one proportional changes its resistance, due to the acting pressure's force. As many as, 7500 sensors can be situated on the sensing area, as large as 300 x 400 mm, in matrix arrangement. The output signal processing is realized by means of PC, which controls the electronic circuits, too. The designed electronics concept enables to reach an extra-ordinary top parameters in the dynamic transducer's mode, it means: snap-frequency 250 Hz; and sample-frequency 2,5 MHz (what ranges, this measuring system, on one of the top places in the world). SW-equipment enables the measurement in static mode, too. Then, the results are gained in real time.

Keywords: transducer, pressure, elastomer; measurement in Biology & Medicine

1   INTRODUCTION

Mainly for medicine purposes, to design the sitting profiles for paraplegics; and to realize the preventative feed-back element of the pathological press-through places generation on the human body („bedsores"), the flexible pressure areal transducer has been developed. Having mentioned properties, this measuring system can be used in any other branches, too:

- in medicine (e.g.: orthopaedics; rehabilitation; prothesis and orthesis-development; bio--feed-back etc.);
- for the anatomy sitting and leaning profiles design, especially in car and air-craft industry (by „crash-test", air-back tests - being high demands on the dynamic mode of the transducer);
- in robotics (e.g.: for the stability and the robot-balancing point determination further for the grasp-force determination; the pattern recognition etc.);
- in any other industrial applications where is needed to know the pressure distribution on loaded area;
- in the sport medicine and methodology.

2   PRINCIPLE AND TRANSDUCER ARRANGEMENT

With respect on the fact to be known the pressure distribution between the patient's body and usually the uneven pliable area, the flexible transducer has to be used. Having been held - the enough flexibility of the whole transducer, the special flexible elastomer (type: CS 57-7-RSC-Japan) has been used. From the view-point principle, it deals about the semiconductive layer (only 0,5 mm thick), which proportionally changes its electrical resistor, if the load is applicated. The other (mechanical, temperature, etc.) properties and the reliability against the influences of surroundings are guaranteed by producer in [3]. For the defined arrangement of the electro-
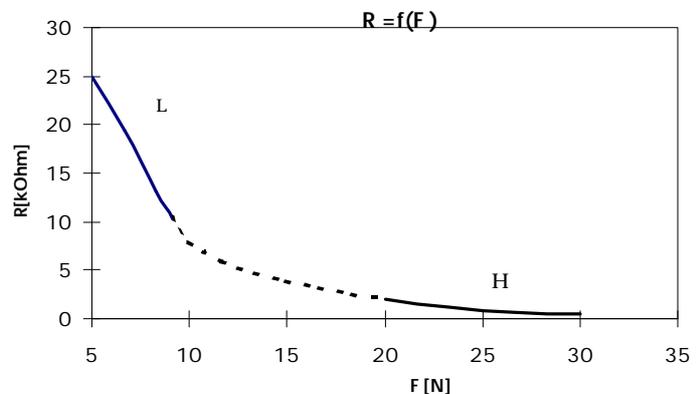

Fig. 1 Dependency El. Resistor vs. Acting Force

des, the dependency El. Resistor vs. Acting Force can be seen in fig.1. Especially for the child-patient, or where is demanded to measure only the low loads, the high-sensitivity part of this curve „L" is used. The „H" part then, for paraplegics and mainly for the long-term patients, or for the cases where the high loads or lower sensitivity is supposed.

By the construction of the transducer - see fig. 2, the core creates this elastomer situated between two areal electrodes. Being held accuracy the system of the parallel belts is produced with the techniques for the flexible printed circuits on both of these electrodes. The polyimide substrate guarantees to get enough flexibility of the electrodes. For the better chemical stability and for the guaranteed conductivity, the surface of Cu-electrodes is gilded. To get enough the mechanical transducer's independence, the electrodes outputs with the sufficient length are divided into the sessions. Thickness of electrode is only 0,05 mm. The upper electrode has 75 column-belts; and the upper electrode has 100 row-belts. Being perpendicular electrodes arrangement, we receive 7500 sensing elements in the cross-section points. To be set, the base sensitivity of these sensors, it means that the right combination of the grid-resolution and the part of the dependency R=f(F) from fig. 1. has to be chosen. For the paraplegics, the transducer has been realized with the grid-resolution 4 mm (3 mm - electrode width; and 1 mm - air-gap width); so that the dimensions of one sensor: 3 x 3 mm. The sensitivity can be further adapted, either by using the various cover layers, and either by electronic way. The upper cover layer - material silicone rubber th. 1.5 mm - has the damping effect and it causes the starting insensitivity. Besides that, this layer is used as the protective layer against the influences of surroundings e.g.: moisture, dust etc. Of course, it´s demanded no-health-troubles to cause, too. Being followed, the reliable acting forces transfer, there is placed the wool-layer between the cover layer and the upper electrode. Besides that, this layer (2rows-thick approx. 1 mm) enables the slip by the transducer bending.
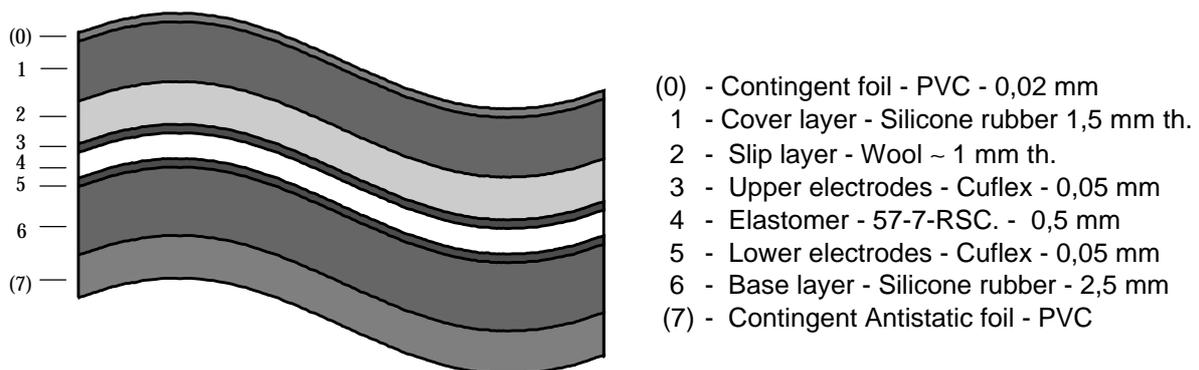

(0) - Contingent foil - PVC - 0,02 mm
 1 - Cover layer - Silicone rubber 1,5 mm th.
 2 - Slip layer - Wool ~ 1 mm th.
 3 - Upper electrodes - Cuflex - 0,05 mm
 4 - Elastomer - 57-7-RSC. - 0,5 mm
 5 - Lower electrodes - Cuflex - 0,05 mm
 6 - Base layer - Silicone rubber - 2,5 mm
(7) - Contingent Antistatic foil - PVC

Fig. 2 Transducer-Arrangement

The task of the Ground base layer is not only to ensure the flexibility of the whole transducer, but at any rate partly to damp and to decrease the prospective local shock - loads or overloads. The used material is Silicone rubber th. - 2,5 mm. This layer and the upper cover layer can be modified in agreement with demands not only from the point - view of the thickness and the materials (with similar properties; with any other stiffness etc.); but with the added demands, too. E.g. : for child's -patients, to be demanded - the impermeable foil (realized with common PVC - th. 0,02 mm); especially in arrid surroundings - the ground antistatic foil etc. It can be said, that the constructional arrangement of the transducer allows to realize almost any other pressure range on the sensing area as large as 300 x 400 mm, of course if we don't exceed the maximum load-limit for elastomer 1,4 MPa (any other elastomer - parameters - see [3]).

2.1   Output Signal Processing

The analoque - output signal processing can be schematically seen in fig. 3.

Step by step, each of sensing elements is connected to the excitation voltage (+5 V_{ss}) by means of Row-Multiplexor (100 rows) and Column - MUX (75 columns), so that the scaning of the sensing transducer´s area in Matrix Arrangement is realized. No - activated electrodes are grounded. The couple CMOS-unipolar transistors are used as switches. (Their activity is controled with micro-processor; and all logical controling functions are programmed in PLA-memories). An analogue level of the output signal can be adapted, either by means of the output resistors - used R = 47 Ω at present (these ones are connected in series with sensors being realized voltage divider), and either by means of the amplifier. Its output is connected to the 8-bit A/D converter - supplying the I/O peripheral card -

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circuits of PC. The mentioned electronic components are solved as the peripheral unit for PC-with SMD technology. Due to the fact, having been realized - the high sampling frequency (2.5 MHz); the coaxial cable has to be used by connection of the output transducer´s circuits with the PC-card.

The evaluation is provided on PC - with respect to the used SW-equipment (as e.g. : 2D-half tone view on the monitor, or the pressure-profile cuts of the activated loaded area etc.).
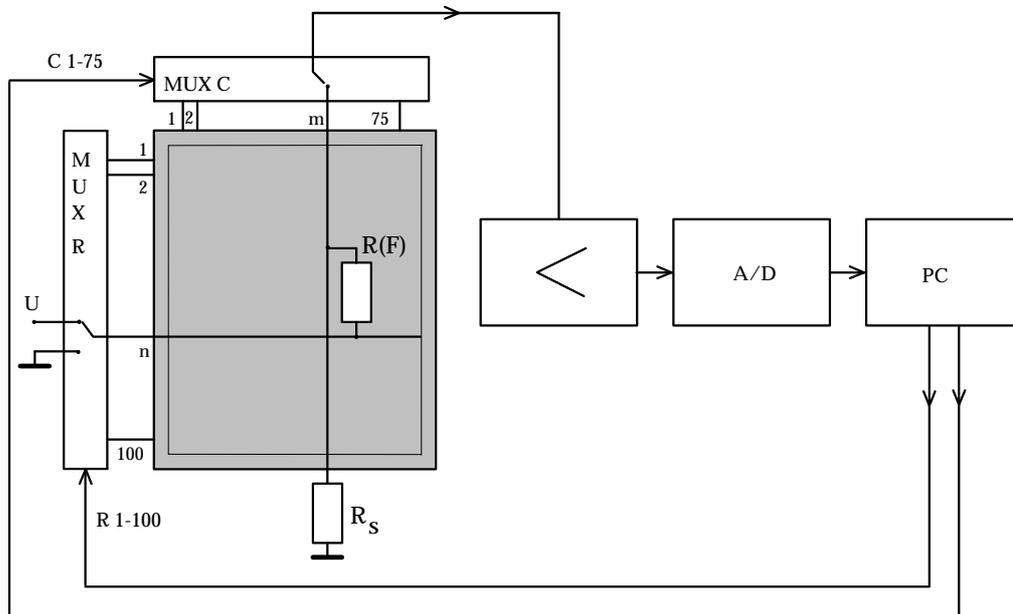

Fig. 3 Block diagram: Measurement Areal Pressure Distribution System - Output Signal Processing

Main technical features:

Patient Mass	to 120 kg
Rated Preassure Range	5 - 80 kPa
Permissible Overload	1.4 Mpa
Transducer Activated Area	400 x 300 mm
Transducer Over All Dimensions	750 x 650 mm
Sensing Elements Number	7500 pcs
Transducer Supply Voltages	+ 5V; + 12 V
Transducer Analogue Output	to 1V
Digital Output	256 levels
Sampling Frequency	2.5 MHz
Demands on PC	min. 386; 486

3   PRACTICAL RESULTS TESTS

The original demand has been only to construct the sensor „on-off" (as bio-feedback) for handicapped people - forced to be long term lying - to be protected the pathological press-trough places generation (so called „bedsores"). The better situation would be to use the proportional sensor - to be followed the critical overloaded places development. Such transducer could be used for the testing of the sitting profiles (e.g.: wheelchairs) for immobile persons, too. The experiments have been directed to verify and to test the transducer´s properties for these purposes. Therefore in this paper, the attention will be concentrated only on the special problems concerning:

- the reliable pattern recognition of the defined loaded area;
- the mutual sensitivity in the separated points of the loaded area;
- the cover layer influence on the pressure distribution homogeneity under the equally loaded calibrating area;
- the long term transducer's stability - in the static mode

Special attention has been concentrated to ensure the reliable transfer the acting forces on the sensors, especially for the larger areas than $A > 9$ cm^2 . From the fig. 4, can be seen the unhomogeneous pressure distribution by the equally loaded test in the application on the flat calibrating areas

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(e.g.: triangle against horizontal plane). This defect has been born, if no-slip layer (see - fig. 2 - No. 2) is used. To be prevented, the unhomogenize pressure distribution in the (followed) tested area the experiments have been done. Having been followed the Quality Sensitivity among the activated sensors under the Loaded Area, the number of the various materials and theirs combinations for upper cover layers have been tested. The materials have been numbered (e.g.: 01 - silicone rubber th. 1 mm; 02 - silicone rubber 1.5 mm; 07 - black rubber 2 mm; 17 - foam rubber 3 mm; 18 - cotton 3 rows; 23 - wool 2 rows).

The homogeneity improvement can be seen in fig. 5; when this slip layer in combination with the upper cover layer - so called „sandwich" has been attacked with low - („lo"), and high - („hi") equally loading tests. (No better results have been reached for the single or triple cover layer, to this time. The theoretically projected 3-rows hexagonal texture for cover layer hasn´t been tested till yet).
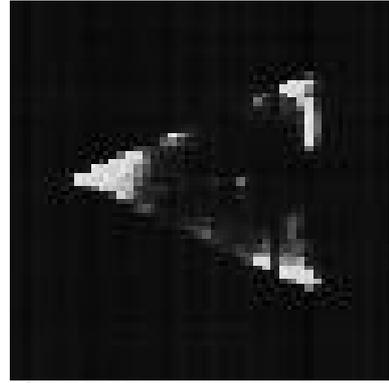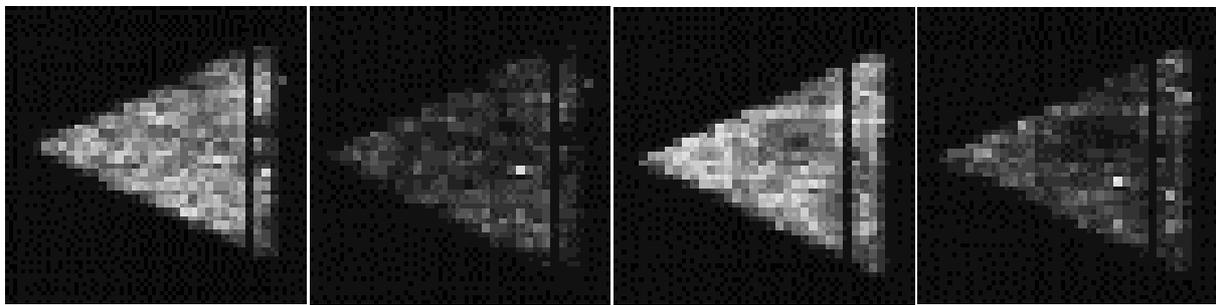

Fig. 4. Unhomogeneous pressure distribution

a) b) c) d)

Fig. 5 Homogenization of the pressure distribution on calibrating area by means of „sandwich" cover layer.

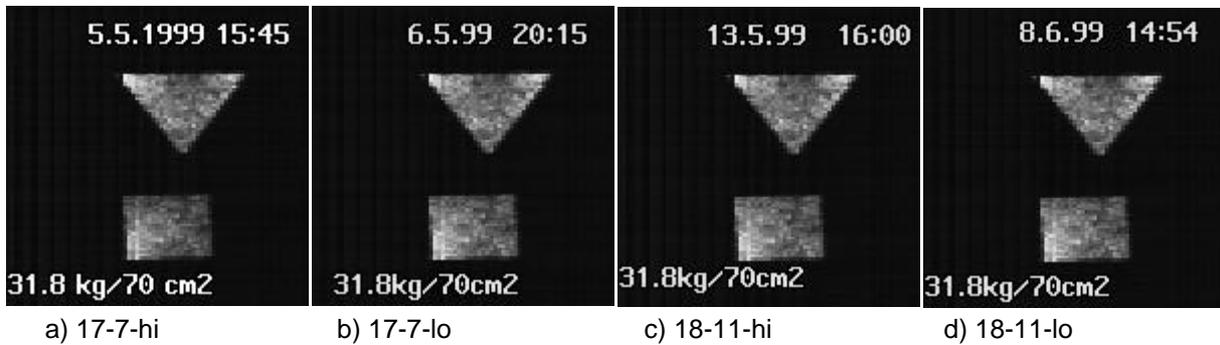a) 17-7-hi b) 17-7-lo c) 18-11-hi d) 18-11-lo

Fig. 6 Long-term stability test

This equally loading test has been applied for the Long - Term Stability Test, too. The results see fig. 6.

At first point of view, no significant changes can be seen. „The greatest changes" have been caught only in first hours. The optimal combination of cover layers ("sandwich") and the percentage evaluation of the sensitivity changes among the individual sensors in the various stages are subject of the further investigation. It can be said on the base the other measurements (reproducibility; hysteresis etc. - which are not given in this paper), that this transducer is possible to use as the Relative Transducer. To be reached the quality of the absolute transducer, it would be necessary to realize „the floating calibration", it means to correct the Load v.s. Time Dependency with respect to the Instantaneous Value of the Loading Etalon.

Note: The dark strip in figures is one disconnected Sensors Column - to be caught a better contrast in the followed loaded area.

The practical transducer applications - see fig. 7 and 8. - an areal pressure distribution on sitting profiles.
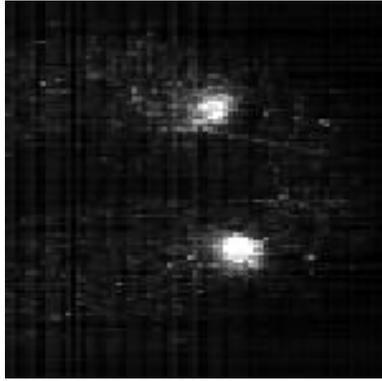
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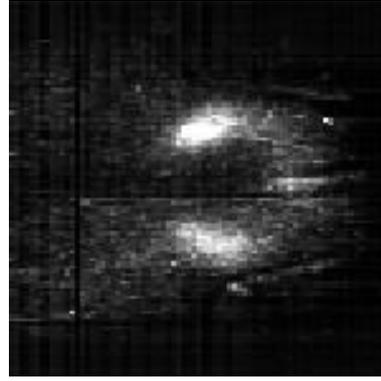**Fig. 7** Pressure distribution - child 55 kg with local overloading.

Fig. 8 Pressure distribution - man 85 kg

4   CONCLUSION

The task in modern medicine is not only to realize the treatment, but to predict and prevent the disease generation, too. Being the effective means for this purpose, the non-invasive methods are developed. Therefore getting in front of the interests at present, the technical means and methods - which enable to have been caught the pathological symptoms - signalling the same beginning of the starting disease´s stage. The advantages are quite clear: the starting treatment in time is - then more effective; from the view-point of costs - more economy (the medicamentes, the medical interventions, the medical helps etc.); the prospective earlier patient´s „come-back" into the normal life, the working process etc.; from the view-point of patient alone, the much better situation not only what concerns of the physical and psychical pains, but mainly without the prospective lasting defects etc. Our small contribution, to be spred these non-invasive methods, is then above mentioned Flexible Transducer for Paraplegics, which enables to be caught the pressure distribution between the patient´s body and the contacted surface - even, if this one is the lightly curved pliable area.

ACKNOWLEDGEMENTS

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