SINGLE ELECTRO-PNEUMATIC CELL SENSOR FOR THE DETECTION OF PRESSURE ULCERS

Cristina-Luminița TUINEA-BOBE[1], Patrick LEMOINE[2], Claudine GHEIN[3], Adrian RUSU[4]

În ultimii zece ani, problema ulcerului de decubit a devenit foarte importantă nu doar pentru aria medicală, dar şi pentru aria inginerească, care a început să fie implicată în necesitatea de a predetecta dezvoltarea acestui tip de escară. Un model îmbunătăţit al dispozitivului electro-pneumatic realizat la INSA-Lyon este prezentat în această lucrare. Noul design al senzorului de presiune satisface specificaţiile necesare detecţiei presiunii la interfaţă. În lucrare sunt prezentate rezultatele măsurărilor făcute cu senzorul electro-pneumatic precum şi planurile pentru dezvoltări viitoare.

In the last ten years, the problem of pressure ulcer become very important, not just for the medical field also for the engineering field, which start to be involve in the necessity to early detect the development of this kind of injuries. An improved INSA Lyon electro-pneumatic sensor cell is presented in this paper. The new design of the pressure sensor satisfies best the specifications needed for the detection of the interface pressure. In this paper, the results of the measurements with the electro-pneumatic sensor designed are presented and also the future work.

Keywords: pressure ulcer, electro-pneumatical sensors, copper-kapton

1. Introduction

A pressure ulcer is damage that occurs on the skin and underlying tissue [1]. Pressure ulcers are caused by three main influences:

1 – the pressure applied by the body weight on the skin;

2 – the shear as effect of the movement of the different layers of the skin relative to each other (e.g. when the patient moves its body from and to a wheelchair);

3 – the friction – rubbing the skin against textile materials [2].

Pressure ulcers can have a fast evolution with very serious consequences. That is the reason, why the early detection of pressure ulcers is crucial. The costs

[1] PhD student, The Nanotechnology and Integrated BioEngineering Center (NIBEC), University of Ulster, United Kingdom
[2] Lecturer, The Nanotechnology and Integrated BioEngineering Center (NIBEC), University of Ulster, United Kingdom
[3] Reader, Institut national de sciences appliquées (INSA) Lyon, France
[4] Prof., Universitatea POLITEHNICA of Bucharest, Romania (UPB)

of the treatment for this kind of injuries are very high: approximate 2-3 billion Euro of the UK health budget (4% of total budget) [3]. Without medical care, pressure ulcer which can develop within as little as one hour can become very serious. The injury does not affect just the skin but also bones, muscle and ligaments. These kinds of wounds are very painful and need a long time to heal, requiring a long time in the hospital. Sometimes pressure ulcers can cause infection in tissues and bones and blood poisoning which can cause death [4].

To date, pressure ulcers are prevented by moving the patient from time to time, requiring the help of a nurse. Some medical interventions however, require the total immobilization of the patient so movement is impossible. Further research is needed to early detect pressure ulcers prior to their occurrence.

Because of the factors involved in the occurrence of pressure ulcers not just one parameter is involved in pressure ulcer early detection.

If you are laying in a bed for long time the temperature of the body skin which is in permanent contact with the clothes and sheets increases, and also makes the body to sweat. These factors involve a big insensitivity of the pressure sensor to the variation of temperature and humidity [5]. The most important parameter, which must be measured at the same time as the pressure, is the shear.

The measurement of the interface pressure is constrain by many factors, but to characterise in the best way the measurement, the literature establish nine parameters which are crucial:

1. the sensor surface;
2. the thickness of the sensor;
3. the elasticity of the sensor;
4. the sensor hysteresis;
5. the sensor creep;
6. the number of sensors;
7. the precision;
8. the resolution;
9. the price [6].

Limitations of the existing pressure ulcers detection devices are presented in the table I, problems related with the physical construction or the measured parameters.

Table 1

Limitations of the pressure devices

System	Limitation
Talley SA500 (EP)	only 5mm Hg accuracy
X sensor, ROHO (C)	hammocking
FSA and TEKSCAN (R)	hammocking
INSA (EP)	accuracy
ST&D (PE)	only dP/dt

In this paper we present an improvement of existing sensor of INSA Lyon. The focus was in increasing the flexibility and the stretchability of the sensor but also, at the end of this paper, some solutions for the problems encountered will be presented.

2. Improve the existing INSA – Lyon device

The INSA device is based on a pneumatic cushion, including 32 electrical cells, made of flexible copper circuit and covered with rubber. The prototype has proven a poor accuracy for low pressure values. Especially in the initial phase of testing, searching for a comfortable seating position to be achieved, considerable bigger errors were found for healthy subjects compared to disabled persons [7].

The big errors of this device can be caused of the bed open contact due to the sticky rubber (try to find a new material to replace the existing one) or because of the bending surface of the device, which measures a higher pressure than that applied (found a solution to prevent the bending of the surface). In this moment, the INSA Lyon device was improved by adding a new rigid layer, which prevents the bending problem, but in this moment we do not measure anymore the interface pressure directly.

The main steps in the fabrication of the sensor are:

- choose the material for the envelope;
- outline of the electrode array;
- design of the electrodes in CircuitCAM;
- fabrication of the electrodes on LPKF ProtoMat M60;
- fabrication of the sensor cell;
- contacts design.

First step, in the development of the sensor, is to choose the material for the envelope, and to do the project for the outline of the electrodes (ground electrode and the active electrodes). The material use as envelope is Plymounth R136 6/100, a thin material with very good elastically proprieties.

For the ground electrode must be done the project, in the program CIRCUITCAM, and this electrode must have the next proprieties: offer big elasticity to the entire system and cover as well as possible the surface of the active electrodes which are round (fig. 1).

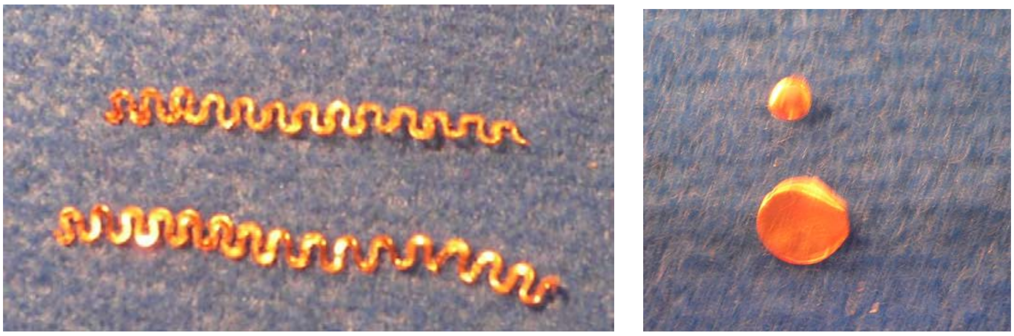

Fig. 1. The electrodes: left - the ground electrode, right - the active electrodes

The electrodes are made on the gravure device with numerical command named ProtoMat M60 fabricate by LPKF (fig. 2).

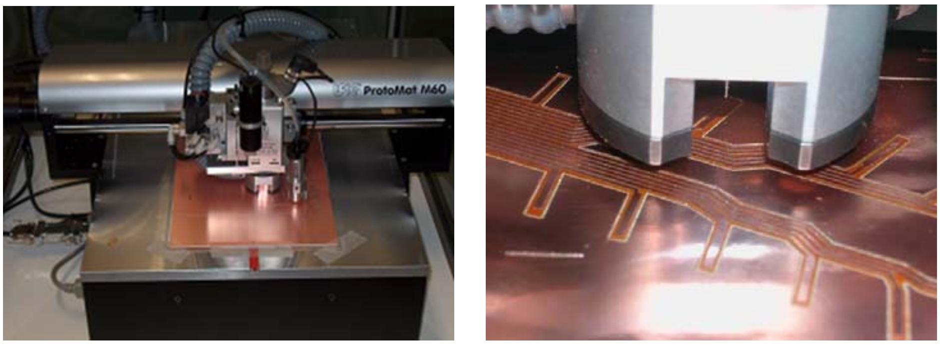

Fig. 2. ProtoMat M60 LPKF

The precision of the device is:

- vertical (z) 4 µm;
- horizontal (x-y) 8 µm.

According with the projected shape, surface and the cutting type are necessarily different tools. For the electrode fabrication is used a universal tool of 0.2 – 0.5 mm. The model is made on Copper – Kapton with the next thicknesses: 35µm copper and 50µm Kapton.

After the electrodes practical fabrication is made the glue cleaning of this in ethylic alcohol.

The envelope shape must be performed after the choose shape. The X shape for the ground electrode (fig. 3) is done by welding the parts made on the gravure device. A thin metallic isolated wire is also welded with the electrodes. The electrodes are cleaned in a cold chemical bath which is useful also for the anticorrosive treatment. The time necessarily for this clean is 3 minutes and after this a powerful rinse in water is made to remove the chemical product.

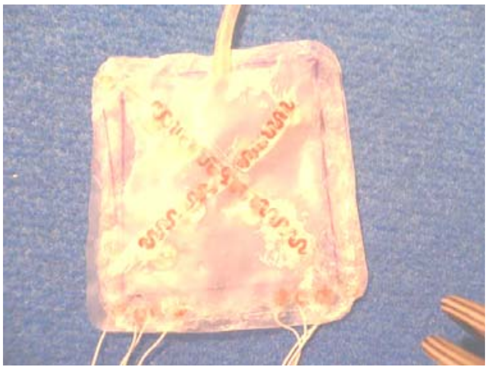

Fig. 3. The ground electrodes fixed on the envelope

The active electrodes are holed in the middle to pass the supply wires and are cleaned and very well dried. After the wire welding is performed (0.08mm) a new cleaning in CIF AR17 for one minute is made. After the electrodes are dray, a thin layer of glue Cyanofix is applied, on the plastic surface of the envelope and the electrodes are fixed.

After the fixation of the ground electrodes the round electrodes are glued on the marked places, after the wires pass trough the envelope surface.

The line which must be followed by the supply wires must be created and the connection with the exterior must be done in the most flexible way. A solution was fined and applied for this case. The supply wires were processed as springs and flattened on the envelope (fig. 4.).

For the electrical alimentation of the electrodes, 8 small round electrodes (fig. 4) was placed on the exterior board of the envelope, to transfer the contact from the thin wires use like contact on the envelope surface to less thin wires to the exterior. The chosen wires are metallic wire isolated with plastic. For the ground electrode the same procedure was followed, supply trough one round small electrode.

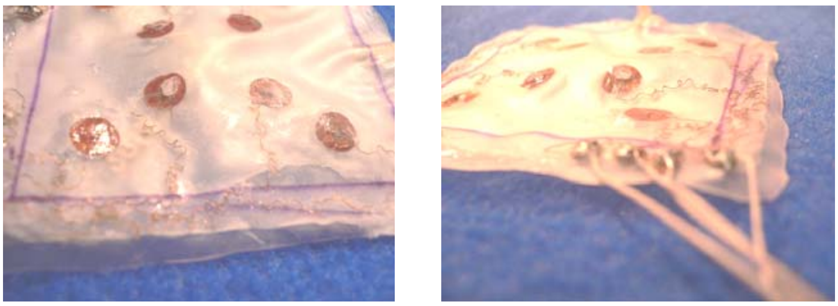

Fig. 4. The supply for the active electrodes

The best position for the inflating tube is to be chosen also for the sensor cell. For an easier air supply, this will be done just trough one tube, to can use for measurements the Talley device. The best constructive solution, for the air supply, is the air distribution trough 4 or 8 inflating tubes, but the technological solution is too hard to fabricate with the existing materials, and also to measure the pressure just with one Talley device.

After the exterior contacts are glued on the envelope, is performed the stick of the two envelopes, one to another, and to fix the air tube in the right position. The tightness of the sensor cell check is performed applying liquid soap, on the borders of the cell and everywhere were can be lost some air.

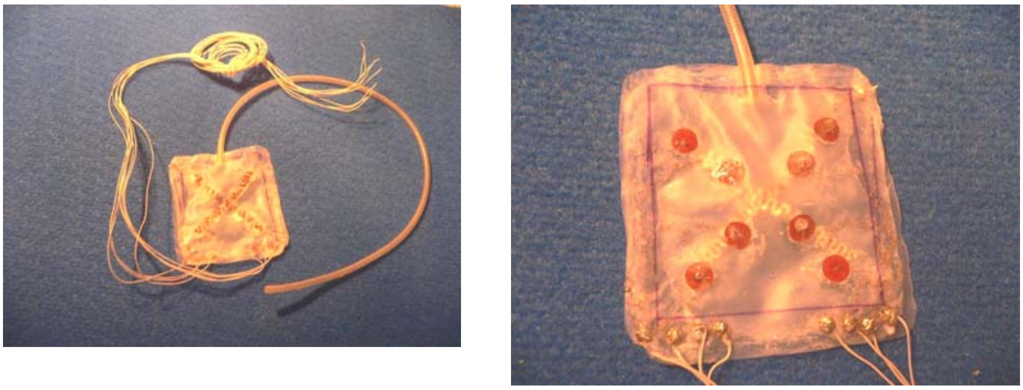

Fig. 5. The single pressure cell sensor

3. Tests and results obtained for the single electro-pneumatic cell

The tests were performed in two cases: the first one using weights and as measurement display and air supply the Talley device (fig. 6), and second with the physical model. To can do the tests must be connected the coupling for the air to the sensor tube. The electrical alimentation is done trough a Jack coupling. The sensor cell is connected to the Talley device and for the measurements the next steps must be followed:

- place the left button in the position DOWN;
- the cell sensor is inflated turning off the air valve of the inflating rubber balloon;
- the air valve is turned on after the complete inflating of the sensor cell;
- a pressure is applied, and the pressure level can be read in the moment in which the red LED is lighting (the value is folded), this show we have contact between the mass electrode and the rounds electrodes;
- the pressure is read on the screen of the device.

Fig. 6. Talley device

The first set of measurements is made with weights under and equal with 200g. The results are showed in the table II.

Table II

Results obtained for the measurements made with different weights

The weight (g)	200	100	50	20	10
Pressure level (mmHg)	2.1	1	2.5	1.8	1.3
	8.2	3	3.1	1.2	1.3
	6.6	6.3	3.3	1.6	1.4
	7.1	6.3	3.3	1.2	1.3
	7.0	4.1	2.9	1.2	1.3
	6.9	4.5	3.9	1.2	1.3
	8	5.3	3.6	1.2	1.3
	6.8	5.9	3.7	1.2	1.3
	4.2	3.8	2.5	1.2	1.4
	7	3.4	3.9	1.3	1.3
	5.8	6.4	3.2	1.8	1.5
	6.2	4.2	3.7	1.3	1.4

The second set of measurements was performed with the physical model. The physical model is fabricated from thin rubber very well stretched on a Plexiglas support equipped with an inflating tube.

The physical model is fixed on top of the cell sensor taking care to not stroke the air alimentation tub of the sensor cell and fixed in that position with two hooks on a flat surface. To avoid the brake of the Plexiglas must be use on top of the physical model a rigid plaque for protection.

The physical model is inflated until a convenient pressure level; the inflating tube is obturated (closed) with a hook. The Talley device is connected to the sensor cell and this is inflated. When the red LED is lighting we have the pressure.

Fig. 7. The physical model

The results obtained for the measurements made with the physical model are shown in fig. 8.

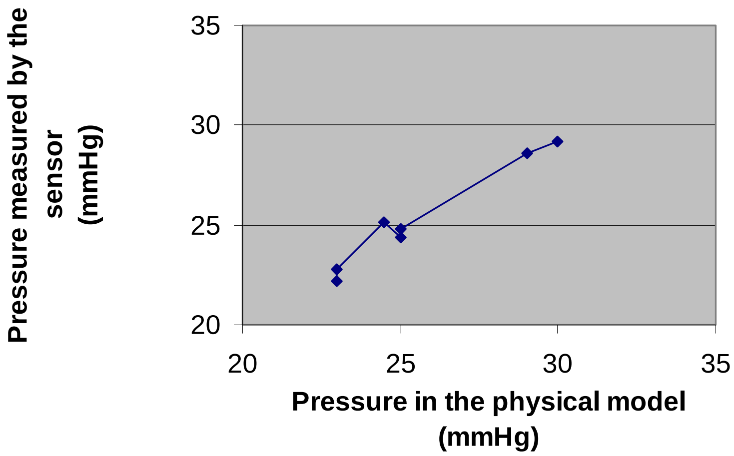

Fig. 8. The results obtained for the measurements made with the physical model

Conclusion for the sensor cell fabrication:
- good stability and repeatability;
- the minimal pressure value measured is 1.2 mmHg;
- the maximal pressure value is 8.2 mmHg;
- find new glue, which offers a better flexibility to the system;
- find solution for the shear measurements in the electro-pneumatic case;
- use a new material for electrodes (Au or Pt).

4. Future work

Due to the materials problems indentified for the previous design some crucial changes in the design but as well on the device layout must be performed. The specifications for the future sensor are:
- low stiffness to follow the skin contours;
- no drift (temperature, humidity, creep, hysteresis)
- accuracy for low pressure (<kPa values);
- accuracy for low shear (<kPa values);
- independent measurements of shear and pressure;
- no hammocking (no influence of tensile/ bending stresses);
- lateral resolution (not crucial - cm);
- low cost.

The solution is investigated in the area of Flextronics. As materials for the electrodes (the copper can not be used for medical devices in UK because of the toxicity issues) we look at the qualities of gold and as material for envelope we investigate from mechanical and biocompatibility point of view some polymers.

Also a new measurement method has to be employed and its errors have to be identified. The new device will use the piezoresistive or the capacitive method [8].

Currently a comparative study is performed in which the method with the most satisfying parameters will be identified. Results to date indicate higher accuracy of the capacitive method added to its case of implementation.

5. Conclusions

A new design for an electro-pneumatic sensor was created and its results presented. Comparatively with the previous design, the single electro-pneumatic cell showed a good repeatability and good stability for low pressure. The device measures strictly the interface pressure.

Due to the medical background of the application a new solution for the detection of pressure ulcers was envisaged [9]. The future sensor will use a flexible system formed from a polymer and gold and will employ a piezoresistive or a capacitive measurement method.

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