THE METHOD OF HUMAN FREQUENCY BREATHING MEASUREMENT BY TEXTRONIC SESNORS

Janusz ZIĘBA; Michał FRYDRYSIAK
Technical University of Lodz, Faculty of Material Technology and Textile Design, Department of Clothing and Textronics, Lodz, Poland
michal.frydrysiak@p.lodz.pl

Abstract
In this paper authors presented three kind of textile sensor implementated in textronic shirt to breath frequency measurement. Sensors have a textile structure, since they were made from piezoelectric, optical waveguide and electroconductive materials. The construction of three textile sensors will be presented in paper. Sensors were placed in a measuring shirt. The knitting method and cotton yarns used to production close fit shirt. It was used Stoll flat knitting machines. During the manufacture production take into account individual dimensions of user. The characteristics of the sensors and the curves of input voltages of the sensors have been presented. The correctness of operation of the sensors was verified by the measurements obtained by means of a professional spirometer.
Key words: textronic, measurement, sensor, respiratory rhythm, optical fibres, piezoelectric fibres, electroconductive fibres

1. Introduction

The measurement of breathing rhythm is one of very important physiological indices. In the work three prototypes of textronic sensors for measuring respiratory frequency. The sensors have a textile structure, since, they are made from optical, piezoelectric or electroconductive fibres. This type of interactive structures, hybrids of textile products with electronic elements, demonstrating the feature of auto-adaptation, have been called textronic products [10]. The respiratory rhythm is generally measured by multifunctional medical measuring instruments measuring a number of the man's physiological indices but it can also be measured by a separate measuring system. Following the present-day tendency of manufacturing textronic clothing equipped with measuring systems measuring the man's physiological indices, prototypes of textile sensors measuring respiratory frequency were developed. Since clothing is in direct contact with the human body, an attempt was made to build a textile clothing interface; such that adds a new function to clothing – apart from functionality and aesthetics, interactive adaptation to external stimuli [3]. The most important function of the prototype sensors discussed is monitoring the man's health. Dangerous situations related to the professional activity of soldiers, policemen, fire fighters, rescuers as well as ordinary people, e.g. undergoing convalescence in their homes, create an environment for the potential application of a sensor of respiratory frequency. The basis for the realization of this function is the broadly understood monitoring of working conditions and health condition. During a respiratory cycle the volume of the chest changes due to an increase in the three main dimensions: anteroposterior, transverse and vertical, Figure 1. In correct conditions the expiration is a passive phase of breathing [2].

The main muscle participating in inhalation is the diaphragm separating the rib cage from the abdominal cavity. Other respiration muscles are of minor importance and are set in motion during a greater physical effort. Inhalation is an active phase of external respiration. The originally expanded chest and lungs return to their “initial” sizes owing to the phenomenon of elastic strain [1].

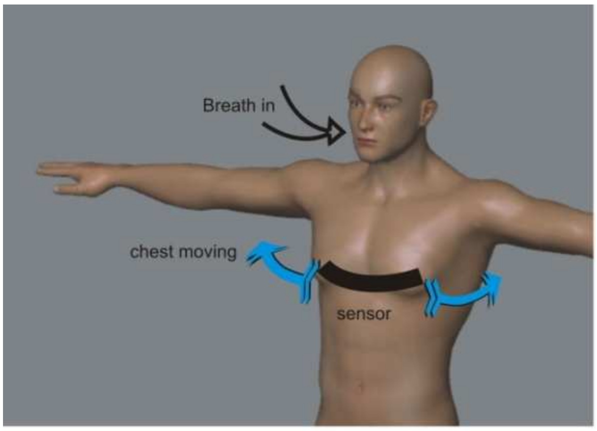

Figure 1. Distortion of the chest during the breathing process

2. Textile Sensors

In Clothing technology and Textronic Department was conducted the research on different textile sensors to breath frequency measurement. Sensors have a textile structure, since they were made from piezoelectric, optical waveguide and electroconductive materials. Sensors were placed in a measuring shirt. The example of finished prototype presents table1.

Table 1. The photos of textile breath frequency sensors

Piezoelectric sensor	Fibre optic sensor	Electroconductive fibre sensors
		
	SENSORS	

2.1 Piezoelectric sensor

A piezoelectric sensor consists of four layers, as shown in Figure 2. The first layer (1) is an inner electrode made from a semiconducting polymer, the second (2) is a coating of vinylidene polyfluoride (PVDF). The third layer (3) is a copper conductor, laid in a tortuous manner, connected with one of the two conductors. Element (4) is an insulation.

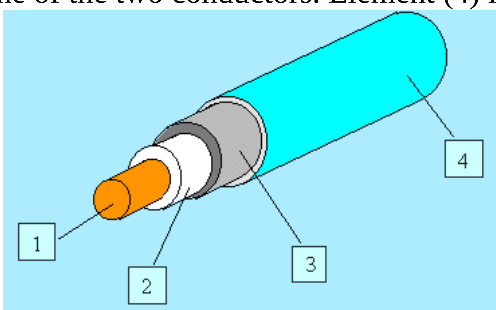

Figure 2. Diagram of the structure of a piezopolymer sensor

Figure 3. Prototype of a textronic shirt with a piezoelectric sensor

Since the diaphragm moves while breathing, a piezocable sensor has been placed in the belt at the waist (1) of the measuring shirt, Figure 3, in which a pocket into which a casing (2) of the electronic sensor has been put. The movement of the diaphragm causes the deformation of the piezocable and then the generation of electric charges. 9

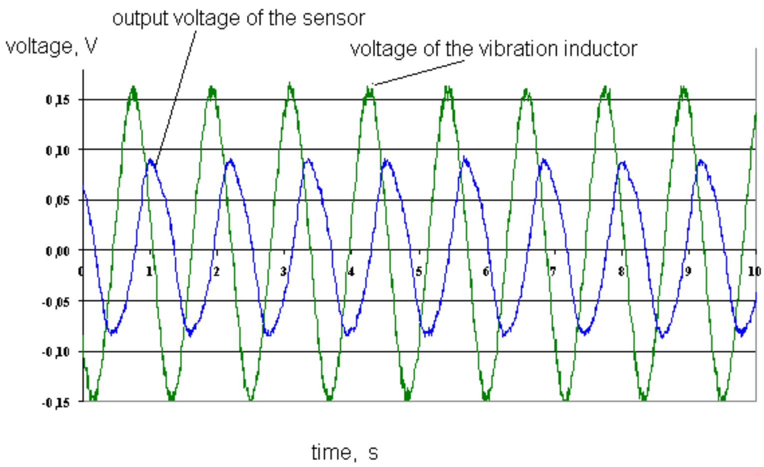

Figure 4. Supply voltage and the output voltage of the sensor

2.2 Fiber optic sensor

For measuring the breathing frequency, optical fibres can be used, Fig. 5. Optical fibres carry the light determined by the stream Φ; if the fibre is deformed then the light carried will be subjected to modulation.

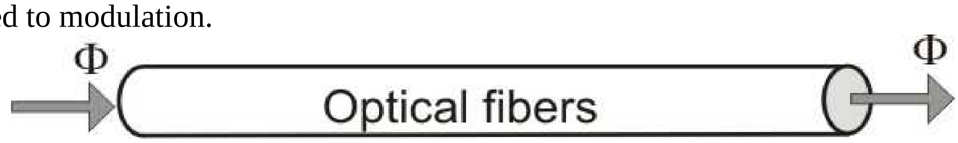

Figure 5. Optical fibre [4]

There are different constructions of fibre optic sensors. One of the solutions of a fibre optic sensor made by the authors [3], [5], [6] is a sensor in which optical fibres move towards one another in a sliding manner. Another construction is a sensor, described herein, in which an optical fibre of a tortuous shape is placed in the jacket. During breathing the human body is deformation with a specific frequency. A rhythmic distortion of the man's body, along with a textronic shirt, causes modulation of the light transmitted through the optical fibre. The beginning of the optical fibre is illuminated by a LED, whereas the end of the optical fibreilluminates a photodiode. The photodiode is on the input of amplifire. On the out put of amplifire is the breathing wave. By measuring pulses during one minute the respiratory frequency is determined. There are three possibilities for placing an optical fibre in the jacket: lengthwise, crosswise and obliquely relative to the fabric column. It results from the investigations that the optical fibre with a sensor placed obliquely relative to the fabric columns was characterized by the greatest sensitivity. The characteristics of the sensor were determined on a tensile testing machine Instron, as shown in Figure 6.

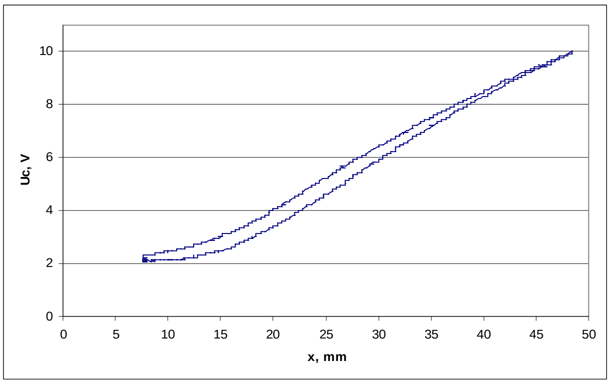

Figure 6. Sensor characteristics

The sensor was subjected to periodic elongation on a mechatronic stand, Figure 9, with frequencies corresponding to the respiratory rhythm frequency. The selected curves of the distortion and the output voltage are shown in Figure 8.

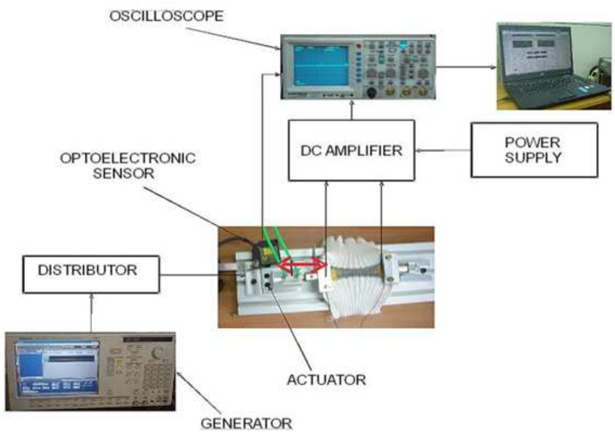

Figure 7. Mechatronic measuring position

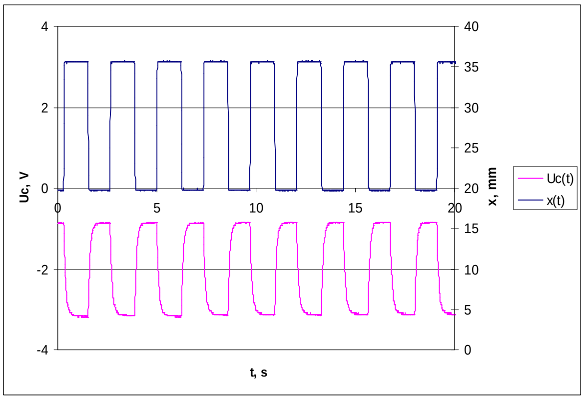

Figure 8. Deformation of the sensor and the output voltage of the sensor

The curves of the distortion of the sensor and the output voltage of the sensor testify to its correct operation, since voltage follows up the changes in the deformation. The correctness of the operation of the sensor was tested after it had been placed in a shirt (blouse). The blouse, adhering closely to the body, underwent deformations, along with the optical fibre during the subject's breathing. The operation of the sensor was tested on a female patient, Figure 11; at the same time, her lung capacity was measured by means of a professional spirometer of the SpiroLab make, Figure9, and the respiratory rhythm frequency, Figure 10.

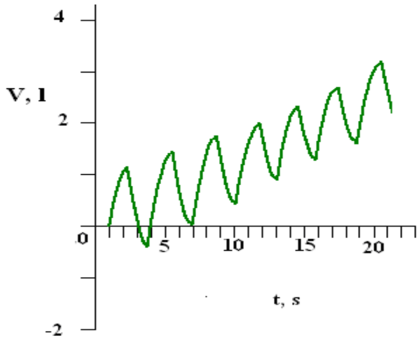

Figure 9. Volume of the exhaled air

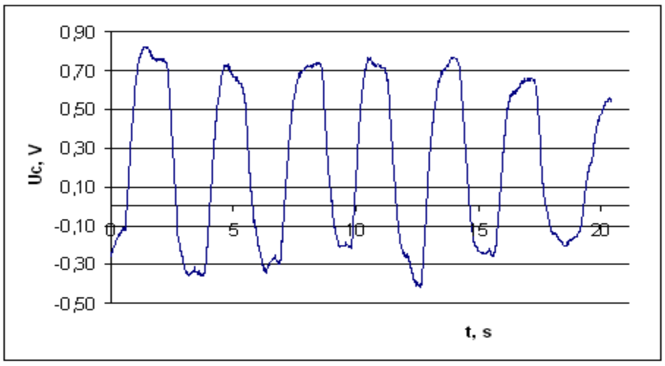

Figure 10. Curse of the voltage of the fibre optic sensor during deep breath

The number of pluses at the sensor output was equal to the number of pulses recorded by the spirometer, which testifies to the correct operation of the fibre optic sensor.

2.3 Electroconductive fiber sensor

Electroconductive fibres, figure 11, have sensory properties, since the distortion of the fibre is accompanied by a change in the resistance R. The resistance depends on the fibre, while that of the yarn depends on its geometrical dimensions and the conductivity **γ**. This property was used in the construction of the sensor for measuring the breathing rhythm frequency, placed in a shirt.

Figure 11. Electroconductive fibre [5]

The textronic shirt, made using knitting techniques, contains three strips made from electroconductive yarn. The distortion of the chest causes a change in the resistance of electroconductive strips, which had been connected at the amplifier input [7], [9]. The measuring diagram is shown in Figure 12. The recorded curves of the voltage at the three outputs of the sensor are shown in Figure 13. At the end of each of the sensory strips, in the textronic shirt, there were metal press studs, used for connecting the clothing product with the direct current amplifier and the recording device. The breathing rhythm frequency of a volunteer was recorded by means of a textronic shirt.

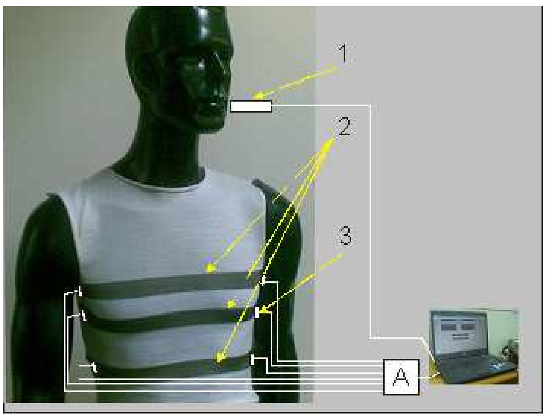

Figure 12. Simplified diagram of a measuring stand consisting of a textronic shirt with 3 sensory strips – 2; electric measuring connectors – 3; spirometer – 1; direct current amplifier – A, along with a recording device

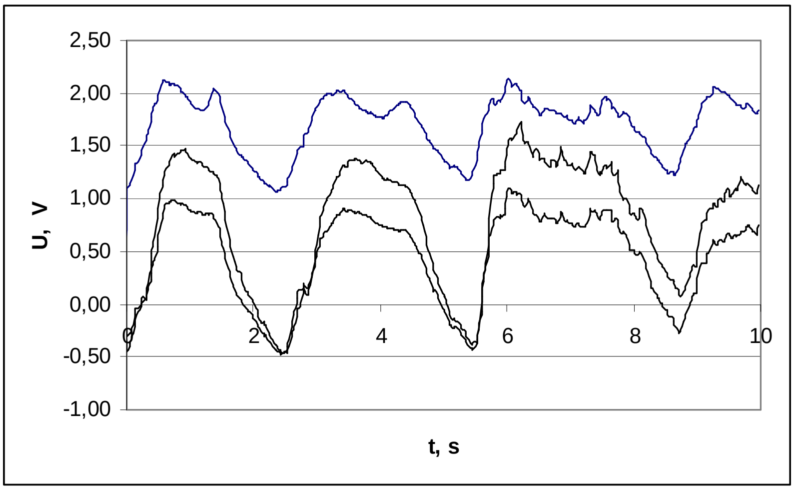

Figure 13. Curves of voltages of the sensors made from electroconductive knitted fabric
The output of the three sensors show the same variation as the respiratory rhythm of the person under study

3. Conclusion

The described textronic sensors integrated with clothing allow measuring the breathing rhythm frequency and can be placed on different types of apparel (a shirt or a blouse). Their advantage is that they do not interfere with the human body and their textile form does not cause discomfort of use. All the three types of the sensors meet the requirements of textronic constructions and are characterized by correct operation.

4. Acknowledgement

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