M. Zimniewska,
M. Michalak*,
I. Krucińska*,
B. Wiecek**

Institute of Natural Fibres
ul. Wojska Polskiego 71b, 60-630 Poznań, Poland,

Technical University of Łódź,
***Department of Textile Metrology,**

****Technical University of Łódź,**
Institute of Electronics,
ul. Żeromskiego 116, 90-543 Łódź, Poland

Electrostatical and Thermal Properties of the Surface of Clothing Made from Flax and Polyester Fibres

Abstract
The study presented in this paper is a continuation of earlier research on the effect of clothes on the electromiographic parameters of muscles. It is assumed that the changes observed in the EMG recording of the forearm muscles tested could be caused by a rise in skin temperature under the fabric, and also by an electrostatic field generated due to the accumulation of electrostatic charges on the surface of the clothes. The tests conducted allowed the determination of temperature distribution and the determination of the electrostatic field potential caused by charges accumulated on the surface of the clothes. The distribution of temperature was tested by the touch-less method, specifically by a thermo-vision camera. The tests discussed were conducted directly on the fabric in use. The tests were conducted on 100% flax (linen) and 100% polyester (PES) men's shirts.

Key words: *clothing comfort, flax, linen, polyester, electrostatic properties, thermovision.*

Introduction

Comfort is a key parameter in clothing. Much attention is paid to it both in everyday life and in research. It is known that the structure of the fabric, composition and dimensions as well as the geometry of the product affect the comfort of use, i.e. hygienic and thermal properties. Apparel made of natural fibres guarantee perfect comfort, which cannot always be said of synthetic fibres. The question arises of whether the clothes that we wear every day are always responsible for comfort in particular conditions, or indeed have any effect on the physiology of the human body.

At the Institute of Natural Fibres, in co-operation with the Academy of Medicine in Poznań [1], research has been conducted on the effect of clothes made of synthetic and natural fibres temporarily covering the muscles of a forearm on the action of the motor units of those muscles in rest and exercise conditions. Additionally, the conductivity of motor fibres in nerve branches connecting the muscles tested was investigated. The electromiographic parameters of muscles were tested by EMG Neurorapid RunTime 10/20 apparatus, using surface electrodes.

The tests allowed the following conclusions to be drawn:

- The temporary covering of tested forearm muscles with a synthetic fabric changes the pattern of motor unit activity. This is shown by low-frequency spontaneous activity of muscle fibres during rest, or by reduced high-frequency activity during exercise. The presence of these phenomena is correlated with slight alternation in the nerve fibre conductivity of branches connecting the muscles mentioned above. This is not, however, a pathology.
- Covering the arm with a natural fabric causes none of the effects mentioned in conclusion 1.
- The cause for the changes observed might be an electrostatic field formed in the skin-cloth area as a result of the accumulation of electrostatic charges and a temperature growth in the case of clothes made of synthetic fabrics.

The changes observed in conclusion 1 are the cause of increased tendency to fatigue when wearing clothes made of synthetic fibres. Therefore, further research was conducted to analyse in detail the electrostatic field formed by charges accumulating on the surface of clothes and the temperature distribution during the wearing of clothes.

Materials

Clothes made of synthetic and natural fibres were tested. Flax represented natural fibres, because it is a domestic fibre. The synthetic fibres were represented by polyester because it is the most commonly used fibre in clothing industry. The fabrics (plain weaves, thickness 0.4 mm) were tested in the form of men's shirts made of the fibres mentioned above. The shirts were identically designed, with long sleeves, had the same geometry and were of a size suitable for the user. The characteristics of selected physical parameters of the fabrics used for manufacturing the clothes tested are presented in the form of graphs in Figures 1-4.

The time-constant is a measured time, in ms, in which the electrostatic charges collected on the surface of the fabric were discharged by 67%. The limits of time-constant measurement were as follows: the upper value of potential difference of time-constant was 150 V, the lower 50V. The conditions of testing were as follows: air humidity 50%, temperature 20°C.

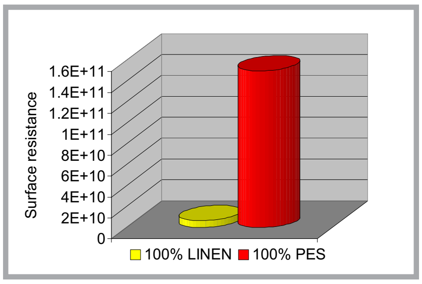

***Figure 1.** Surface resistance of linen and polyester fabrics in Ω, measured according to Polish Standard PN-91/P-04871.*

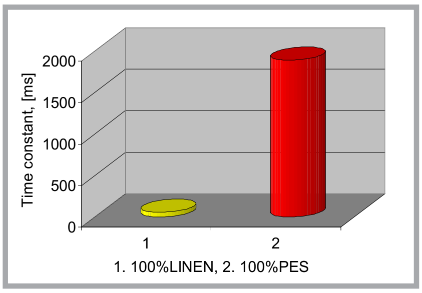

***Figure 2.** Time-constant of disappearance of electrostatic charges for 100% linen and 100% PET fabrics.*

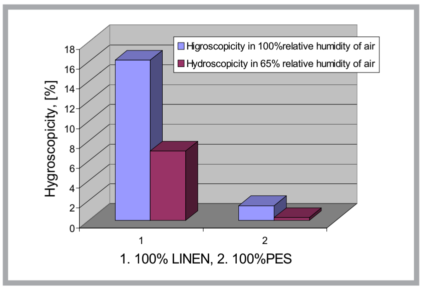

***Figure 3.** Hygroscopicity of linen and polyester fabrics in different conditions of relative air humidity, measured according to Polish Standard PN-80/P-04635.*

The low surface resistance and low value of time-constant of electrostatic discharge for the linen fabrics shows that linen, unlike polyester, does not collect electrostatic charges on the surface. A person wearing polyester clothes is permanently exposed to the effect of electrostatic field and flashovers when approaching conducting objects. This is caused by PES's great affinity for collecting electrostatic charges. The higher hygroscopicity of linen fabrics in comparison with polyester fabrics may also (together with surface resistance and time constant) be a factor influencing the ability of polyester fabric to store electric charges. On the other hand, the lower heat resistance of polyester fabrics does not stand in any direct relation to the results obtained.

Methods of Testing

During the tests, the potential difference of electrostatic field formed by the charges accumulated and the temperature distribution on the surface of linen and polyester clothes was registered. The clothes were worn by a volunteer. The man stayed in fixed air temperature and relative humidity conditions. He did no exercise, ate only fruits and drank only mineral water (different kinds of food can influence the metabolism and changes in body temperature). His last supper before tests was non-copious and easily digestible, as was his breakfast on the day the tests started. For the first two hours of the test, the man wore a polyester shirt, and then a linen one for a further two hours. He wore no undershirt. His other clothes were made of natural fibres (cotton). The tests were repeated many times in the same conditions at a temperature of 22°C, and a relative air humidity of 40%.

Testing accumulation of electrostatic charges

The tests of the degree to which electrostatic charges were accumulated were made by measuring the potential difference of an electrostatic field at a fixed distance from the shirt the volunteer wore. The magnitude and sign of the electrostatic field depends on the mark and magnitude of a charge forming this field, i.e. charges collected on the surface of the shirt and a distance from the source of the field. The measurements were done by a rotation meter from HAUG Company. The detector of this meter has a rotating disc provided with segments of holes. The charges generate an alternated electric signal, which is directed to the electronic unit of the apparatus. The meter gives readings of values of an electrostatic field in the position of the detector. The meter can measure the potential difference from 100 V to 100 kV in several measurement ranges.

In the case of the electrified surface, the value determining the electrostatic field is the surface density of electrostatic charges. To avoid the error connected with the geometry of the object tested and the position of the meter in electrostatic field, no density of electrostatic charges was measured. Instead, the size and sign of potential difference of the electrostatic field was determined.

In measurements of electrostatic fields, the distance between detector and the object is very important. The change of distance causes the change of an electrostatic potential difference value at the same density of the charge. The measurements were made at the distance of 15 mm between the detector and shirt surface. To ensure the stability of measurement conditions, the meter was fixed on a mount.

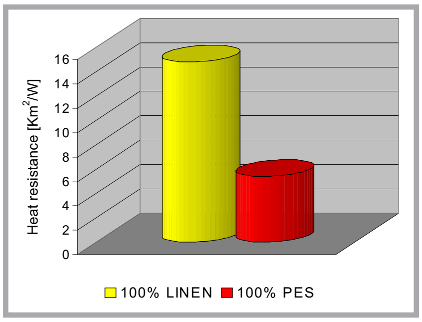

***Figure 4.** Heat resistance of linen and polyester fabrics (Operation Instruction of Alambetta Apparatus).*

Testing temperature distribution

The temperature measurements were carried out by a thermovision method. In this method, the distribution of the temperature is visualised by a non-contact method on the surface of a tested object by measuring of infra-red radiation. The thermovision method involves the observation and recording of radiation distribution and transformation of this radiation into a visible light range. Infrared radiation is an electromagnetic radiation with the wave

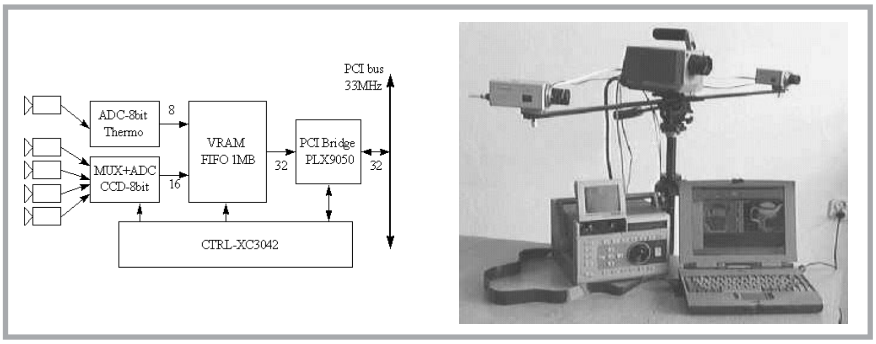

***Figure 5.** Block diagram and system set-up.*

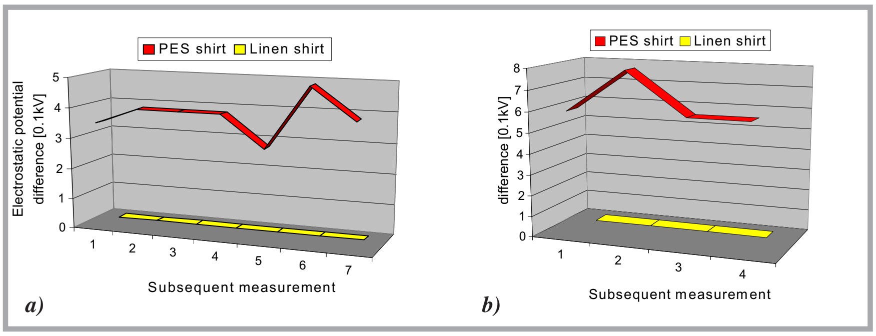

***Figure 6.** The electrostatic potential difference on the surface of cloth tested as a function of time: a) static conditions, b) dynamic conditions.*

range from 0.78 μm to 1000 μm. Practically, the method uses detectors which measure within two main wavelength ranges: 2-5 μm (the so-called medium-wave infrared radiation) and 8-14 μm (long-wave infrared radiation). Sometimes it uses detectors measuring the wavelengths of 14-30 μm. The resolution of the measuring system was 0.01°C, which allowed us to determine unquestionable temperature differences within the range of a few °C, irrespective of the real level of temperature.

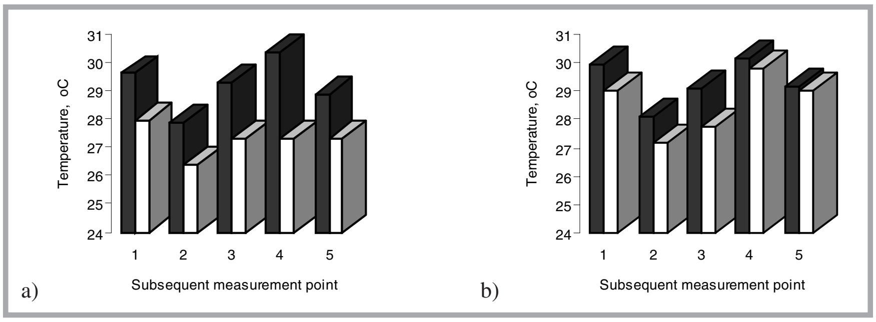

Figure 7. The distribution of temperature measured at 5 different points of the volunteer's body wearing polyester and linen shirts: a) in static conditions, b) n dynamic conditions. Column 1 shows average temperature of breast; 2 - temperature on the pocket; 3 - temperature of arm, 4 - temperature of armpit; 5 - average temperature of torso. ■ - 100% PES, □ - 100% LINEN.

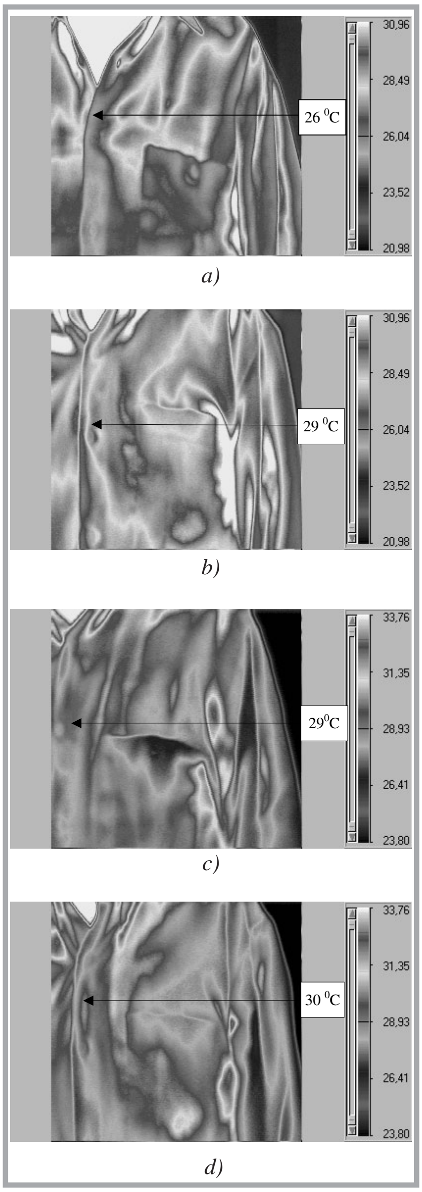

Figure 8. Temperature distribution recorded with the thermovision camera during the tests and the temperature at one point of the diagram.
a) The linen shirt, static conditions.
b) The PES shirt, static conditions.
c) The linen shirt, dynamic conditions.
d) The PES shirt, dynamic conditions.

System architecture

An infrared camera and a computer system with dedicated software for various applications were used in the investigations (Figure 5). The system allows thermal and visual images to be captured in parallel, in real-time into the operational memory in the computer. The interface is prepared in the form of a Peripheral Component Interconnect (PCI) plug-in card which offers high performance and a 32-bit data transfer rate. An optional burst mode provides accelerated throughput of data across the bus of 132 MB/s. There are systems available for thermal and optical image processing, but most of them work separately for each channel, often off-line, without powerful tools for processing thermal and visual images in parallel. The system presented in this work is one of the first which provides enough data transfer throughput to capture and process images in real-time. The software for this system was developed by the authors.

Results

The electrostatic potential difference on the surface of the cloth tested on a function of time in static and dynamic conditions is presented in Figure 6, whereas the distribution of temperature measured at 5 different points of the volunteer's body wearing polyester and linen shirts also in static and dynamic conditions is shown in Figure 7. The measurements obtained revealed a great difference in the potential difference of electrostatic fields. In the case of the linen shirt, the level of electrostatic field potential difference was very low, close to 0 in both static (no exercise) and dynamic conditions (after 10 throws of the arms). The tests of the polyester shirt showed that electrostatic charges are accumulated on the shirt surface when worn in static conditions (no exercise). The electrostatic potential difference increases considerably in dynamic conditions (after 10 throws of the arms). The measurements were conducted every 20 minutes. The measurements were repeated many times, and high repeatability of measurements was observed. Figure 8 show the temperature distribution recorded with the thermovision camera during the tests, and the temperature at one point of the thermogram, as an example.

Conclusions

- The electrostatic charges accumulate on the surface of the fabric when the polyester shirt was worn. No generation of electrostatic charges on the linen shirt was observed. The potential difference of electrostatic field at a distance of 15 mm from the polyester shirt was 600 V in dynamic conditions, and is higher than that in static conditions (about 400 V).
- The differences in temperature between linen and polyester clothes are visible thanks to the thermovision camera.
- The results obtained by the tests carried out allow us to assume that the electrostatic charges stored on the shirt's surface, as well as the increase in the shirt's temperature noted after wearing polyester shirts, may be the reason for the changes in the electromiographic muscle parameters.

References

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