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# Comfort-Related Properties of Workwear for Employees With Motor Disabilities

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**Abstract**

Activisation is very important for motor disabled persons and helps them to integrate with the whole of society. Physically disabled persons face many occupation related obstacles at work, mainly connected with the presence of architectonic barriers and the occupational environment. An important part of the employment process of locomotor disabled workers is the adjustment of work stations to the worker's needs, providing workwear, rooms and work plant surrounding adaptation. Analysis of workwear available on the market shows that commercial offers do not cover workwear dedicated especially for physically disabled persons. The main goal of workwear design and construction is to provide complex comfort for the user, whose needs and expectations differ from able-bodied employees. In this study the general assumptions of textile material selection for workwear dedicated for locomotor disabled employees are presented, together with the results of tests carried out for selected textile materials.

**Keywords**

workers with motor disabilities, workwear, functional comfort.

## 1. Introduction

The human mainly performs two types of movements with the help of the musculoskeletal system: manipulative - with the help of the upper limbs, and locomotive - with the help of the lower limbs. Activities consisting of manipulative and locomotive movements are called motor activities and the disabilities of the motor organ resulting from damage or disease of the components of this system - motor disabilities [1].

People with motor disabilities resulting from lower limb disfunction, while maintaining the ability of the upper limbs, can perform both mental and physical work, which can be done in a sitting position. In such a position, the following are most often performed [1]: office work, repetitive activities on production lines, with machines (adapted for sitting work), and packing individual products into collective packaging.

People with motor disabilities most often find employment in sheltered workshops, but also such forms of employing of the disabled as in the teleworking system and homework - most often performed in their own apartment, are also reported [2]. Professional work integrates disabled people with the non-disabled part of society [3-5].

In the Research on Economic Activity of the Population, an increase in the professional activity of disabled people has been observed in recent years. Studies conducted in Poland in the third quarter of 2020 stated that the employment rate of disabled people of working age was 29.5%, while the unemployment rate of disabled people of working age was 4.5% [6].

People with disabilities face many barriers in their professional career, mainly architectural - related to the work environment and their own limitations [7-10]. A barrier to the professional activation of people with disabilities may be an employer who is afraid of additional formalities and obligations related to the employment of a disabled person, as well as costs resulting from lower productivity, the limited mobility of a disabled employee, adjusting work positions, and providing preventive care [11-14]. It is necessary to adapt the premises and surroundings of the workplace to the needs of disabled people and to equip workstations according to the needs resulting from the disability – for example, by using personalised wheelchair seats to prevent skin lesions (bedsores) [15-19].

The most important goal in the field of clothing design and material selection is to provide overall comfort to a user with a motor disability, whose needs and expectations are different compared to a mobility-abled person.

The variety of work environments allows for the classification of working conditions in terms of the functional properties of clothing required and the materials used to protect the user or the production process against specific factors [20].

When performing light and medium-heavy work, it is required to use clothes and materials:

– protecting against normal damage and soiling,
– facilitating the hygiene of production,
– facilitating the maintenance of asepsis.

In the case of heavy work, it is required to use clothing and materials that protect against the intense impact of:

– destruction,
– destruction and staining with hard-to-wash, non-toxic substances,
– destruction and dampness.

In scientific publications, a lot of information on multifunctional textiles can be found, including those designed for workwear and protective clothing, the functionalisation of textiles and modification of textile structures, as well as shaping special functions in terms of improving the comfort of use, ensuring protection or developing test methods [18-23].

The problem of preserving the quality of textiles and usage properties is of great practical importance. Protective clothing requires barrier properties (protection against heat and flame, dirt resistance, protection against heat shock), appropriate physiological parameters (breathability, thermal insulation properties) and wearing comfort without restricting movement. These properties are achieved through the structure of the yarns and fabrics combined with the choice of fibers, special finishing of the fabrics, and the design of the garment [21-24]. In the case of special clothing, antibacterial properties are of great importance [25].

In the field of physiological comfort, research works were carried out involving the analysis of the parameters of materials designed for selected clothing applications. The analysis and evaluation was based on determined indicators characterising physiological comfort in relation to garments made of knitted and woven materials in appropriate material systems, in order to use them for garments with the assumed properties [26-29].

With reference to the information contained in Art. 2377 of the Polish Labor Code - "workwear is a protective clothing or clothing that replaces the employee's own clothing in conditions where there are no harmful factors. It must be adapted to the activities performed and the requirements of the technological process" [30].

Analysis of workwear available on the market showed that the commercial offer does not include workwear intended for people with motor disabilities.

The development of appropriate functional and safe clothing that will be able to meet specific needs as well as both safety and ergonomic requirements at the workplace during the performance of the occupational activities of people who are permanently immobilised in a sitting position may overcome the barriers preventing employers from employing people with motor disabilities.

The paper presents general assumptions regarding the selection of materials for workwear for people with motor disabilities as well as the results of research carried out on the materials selected.

## 2. Materials and methods

The characteristics of fabrics selected from the currently available offer of manufacturers' with certificates in the field of workwear and protective clothing, are presented in Table 1. The range of surface mass of these fabrics 175-276 $gm^{-2}$ is suitable for work clothing for light and medium-heavy work characterised by normal damage and soiling of workwear.

The basis for determining the model-design and technological changes to be introduced in the workwear model was the analysis of a two-piece garment consisting of a jacket and trousers, which was focused on for the assessment of available workwear in terms of functionalisation and possibility of use for people with motor disabilities.

The selection of workwear depends on the type of work performed and professional activities. The functions of the garment related to its intended use can also be realised by using optimal material variants and appropriate design measures conditioned by the position during work.

A review of the requirements for flat textile materials intended for workwear was carried out in relation to the requirements of standards for workwear, based on own previous experience in the field of research on clothing for people with disabilities [31,32].

General assumptions were made regarding the selection of materials for workwear for people with motor disabilities, stating, that the materials used:

- should meet the requirements of Standard PN-P-84525:1998 Workwear. Work suits [33];
- should be durable, both mechanically and during use;
- should not contain rough, hard elements that cause skin irritation;
- intended for garment elements in direct contact with the user's body should provide thermal comfort and meet biophysical requirements depending on the function of the garment.

The fabrics, suitable for workwear clothing, underwent testing in accordance with PN-P-84525: 1998.

The fabrics selected were subjected to physico-mechanical and chemical tests in accredited laboratories of the Łukasiewicz-Textile Research Institute for the following parameters:

- abrasion resistance according to PN-EN ISO 12947-2:2017-02, under a load of 12kPa [34],
- water vapour resistance, water vapour permeability according to PN-EN ISO 11092:2014-11 [35],
- tear strength according to PN-EN ISO 13937-2:2002 [36],
- air permeability according to PN-EN ISO 9237:1998 [37],
- pH of water extract according to PN-EN ISO 3071:2007 [38],
- formaldehyde content according to PN-EN ISO 14184-1:2011 [39],
- pesticide residue content according to PB/19/1999 8th edition, dated 2019.07.01 [40],
- aromatic amines content according to PN-EN ISO 14362-1:2017-04 and PN-EN ISO 14362-3:2017-04 [41, 42].

One of the aspects of the negative impact of textile materials on humans is the emission of harmful, carcinogenic or mutagenic substances into the environment. Possible harmful effects of

| Fabric marking | Raw materials composition % | Weave | Surface mass $g \times m^{-2}$ |
|---|---|---|---|
| 1 | PES 65/CO35 | twill 2/1 S | 243 |
| 2 | PES 65/CO35 | twill 2/1 S | 204 |
| 3 | CO 100 | twill 3/1 S | 276 |
| 4 | PES 65/CO35 | twill 3/1 Z | 228 |
| 5 | CO 100 | plain | 183 |
| 6 | PES 65/CO35 | twill 2/1 S | 175 |

*PES – polyester fibres, CO – cotton fibres*

*Table 1. Fabric characteristics*

*Fig. 1. Alambeta device of the Sensora company, Czech Republic*

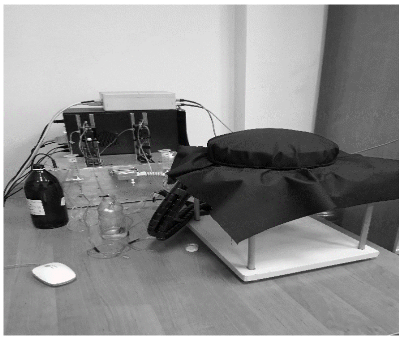

*Fig. 2. Setup for measurement and evaluation of thermodynamic parameters in a system simulating a real human body - material/textile system*

hazardous substances on the user's body may occur as a result of direct or indirect contact with human skin and the entry of harmful substances into the body due to dissolution in sweat and migration to the body [43-45].

Assessment of the thermophysiological properties was carried out on the basis of the results of tests performed on an Alambeta device [46] and on a test stand for thermodynamic processes in the human body - material / textile structure system.

The Alambeta device was developed by the company Sensora (Czech Republic) and is a measuring device that uses the two-plate method of measurement (Figure 1) [46]. The test consists in measuring the amount of heat flowing through the test sample, placed between two plates - the upper one heated to a temperature close to that of human skin, and the lower one at ambient temperature.

The Alambeta device is used for measurement of:

- thermal conductivity, $\lambda$ [$Wm^{-1}K^{-1}$]
- thermal diffusivity, a [$m^2s^{-1}$]
- thermal absorptivity, b [$Wm^{-2}s^{1/2}K^{-1}$]
- thermal resistance, r [$Km^2W^{-1}$]
- thickness, h [mm]
- ratio of maximum heat flow density to stationary heat flow density, p [-]
- maximun heat flow density, $q_{max}$ [$Wm^{-2}$]

The main advantages of the device are as follows:

- short measurement time, maximum 5 min,
- measurement of the so far only subjectively determined parameter of "warm-cold" sensation at the moment of contact of the fabric with human skin,
- the device can be used both in laboratories and in conditions of use.

The laboratory setup designed and manufactured at the Łukasiewicz-Textile Research Institute (Figure 2) enables the measurement and evaluation of thermodynamic parameters in a system simulating a real human body - a material/ textile system.

This setup, in a complex way, allows for simulation and recording as a function of time of phenomena occurring at the interface of the measuring head and material/textile system in conditions corresponding to actual conditions of a sitting/lying human body - textile structure and human body - clothing/clothing systems. The unique design of blocks and individual elements of the setup guarantee the release of water ("sweat") in a way similar to human sweat glands as well as the emission of heat by conduction, radiation and convection in proportions similar to real ones. The setup designed allows for high precision, repeatability and conditions reproducibility of the measurement methodology developed.

The system of data acquisition with a computer and software enables the control and recording of the following parameters as a function of time:

- the amount of "sweat" released per unit area and time,
- the total amount of "sweat" released by the simulator,
- relative humidity and temperature at three points of the measuring head,
- pressure of the measuring head on the textile system tested,
- temperature of the measuring head,
- ambient temperature and humidity,
- power per unit area,
- power and energy fed into the simulator.

The measurements were carried out at a constant temperature of the measuring head of 35°C, corresponding to the temperature of human skin under normal conditions. The test was carried out after heating, with the temperature of the measuring head stabilised at 35°C, and the simulation of "sweat" release at 5 ml/$hcm^2$ switched on The amount of "sweat" released corresponds to the amount of sweat secreted by the human skin during light exercise.

## 3. Results

The graphs present the results of selected parameter tests included in the PN-P-

84525:1998 standard, determining the mechanical and usable durability of fabrics as well as the parameters of physiological comfort, in line with general assumptions regarding the selection of materials for workwear clothing for people with motor disabilities.

When analysing the test results presented in Fig. 3-6, it should be stated that fabric 1 is characterised by very high mechanical and usable durability along with a high level of air permeability and relatively low water vapor resistance. Therefore, among the fabrics that meet the requirements of the PN-P-84525:1998 standard, it will be an optimal material for the construction of both work jackets and trousers. In both cases, it is required to ensure the physiological comfort of the user, taking into account the special needs related to the limited mobility of the lower body part. Moreover, fabric 1 will provide optimal usage durability (high abrasion resistance) as well as mechanical performance (high tear resistance).

Fabric 6, similar to the fabric 1, has a high level of air permeability and relatively low water vapor resistance, but its mechanical characteristics are much lower due to the lower surface mass of the fabric. Fabric 6 can find application in the design of workwear for people with motor disabilities, in relation to textile products not directly exposed to an intense mechanical impact.

Based on the results of physicomechanical and ecological cleanliness, it should be concluded that the parameters of the fabrics meet the requirements for materials designed for workwear contained in PN-P-84525:1998.

The results of tests carried out on the Alambeta device are shown in Fig. 7-9. The mean values of 10 measurements of parameters and standard deviations were summarised.

From the point of view of the application of clothing for people with motor disabilities, thermal resistance is an important feature, i.e. the material resistance to heat exchanged due to the

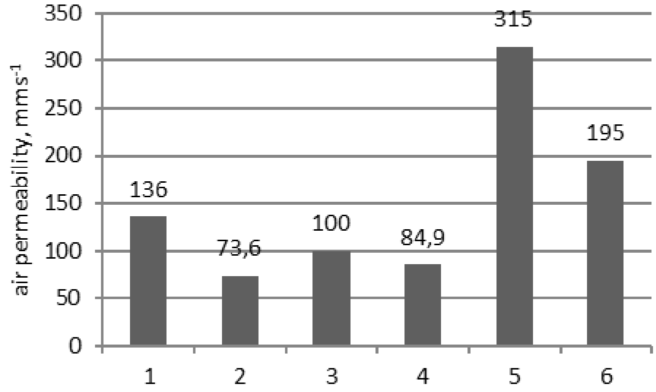


*Fig. 3. Average values of air permeability of fabrics tested*

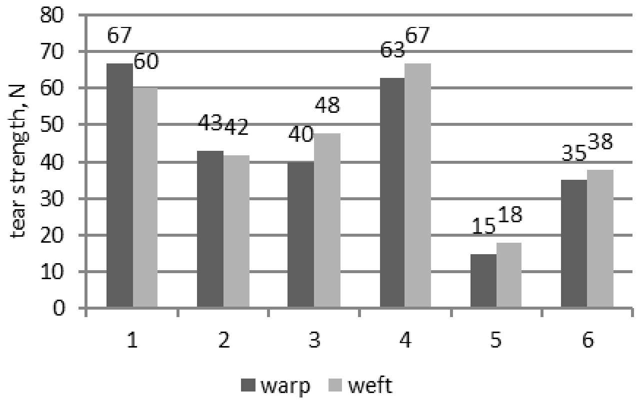


*Fig. 4. Average values of tear strength of fabrics tested*

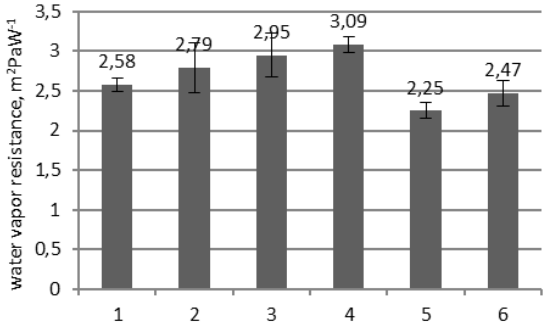


*Fig. 5. Average values of water vapour resistance of fabrics tested*

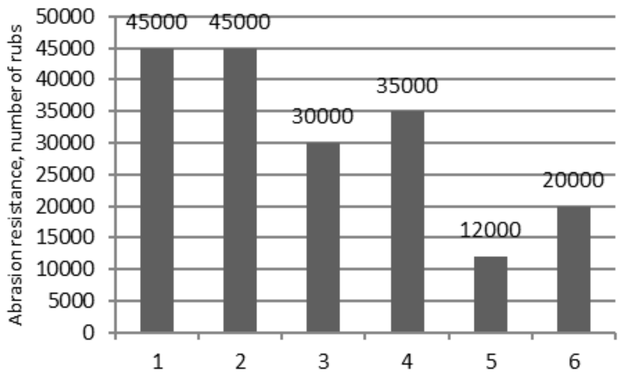


*Fig. 6. Abrasion resistance of fabrics tested*

existing temperature differences on both its sides. Fabrics 2 and 6 have the lowest thermal resistance and, at the same time, the lowest thickness. The thermal conductivity of the fabrics tested, i.e. the material's ability to conduct heat, is at a similar level. Fabric 1 has the highest conductivity, while fabric 5 has the lowest one.

Figures 10-11 present the results of tests carried out on a test setup for thermodynamic processes in a system simulating a real human body - a material/textile system.

Based on the research results, it should be concluded that the most favorable parameters of physiological comfort are shown by fabrics 5 and 6, with an surface mass up to 200 $gm^{-2}$, and by fabrics 1 and 2, with an surface mass over 200 $gm^{-2}$. The highest values of the average power density and the lowest values of underclothing humidity testify to a greater ability to exchange heat with the environment and transport water vapour, which in the case of people with motor disabilities using wheelchairs is extremely important.

Taking into account the results of all tests of physicomechanical, chemical and thermo-physiological parameters conducted, fabrics 1, 2 and 6 were selected for use in workwear clothing for people with motor disabilities.

The development of an appropriate structure of clothing can, equal to the material, determine the comfort of use, and by using appropriate slack and ergonomic elements in design solutions, its functionality can be increased. In the case of workwear and protective clothing, there are greater structural clearances than in typical all-day clothing, paying particular attention to the working position. The functionalisation of working clothes through structural and model changes is possible thanks to procedures taking into account the body structure and silhouette of the user together with the position and range of movements resulting from the specificity of the work performed.

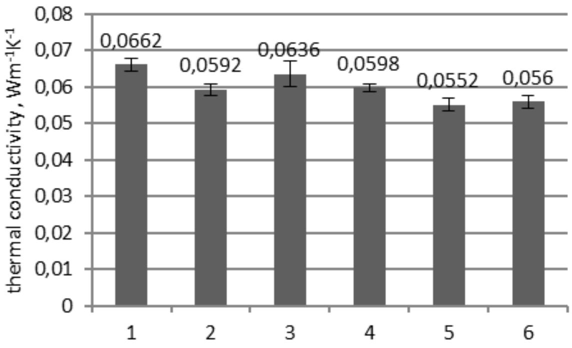


*Figure 7. Thermal conductivity of fabrics tested*

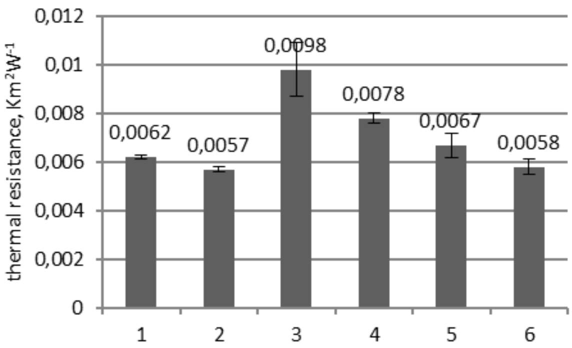


*Fig. 8. Thermal resistance of fabrics tested*

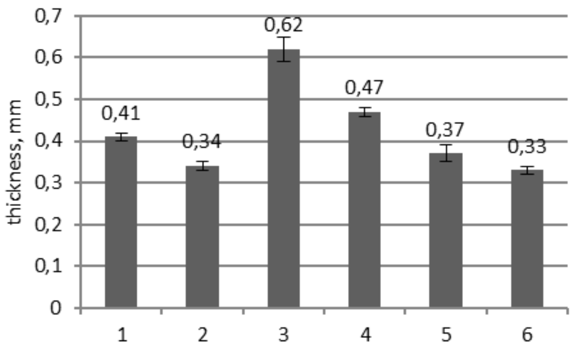


*Fig. 9. Thickness of fabrics tested*

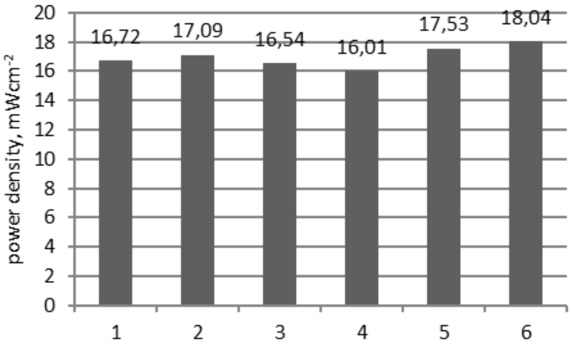


*Fig. 10. Medium power density*

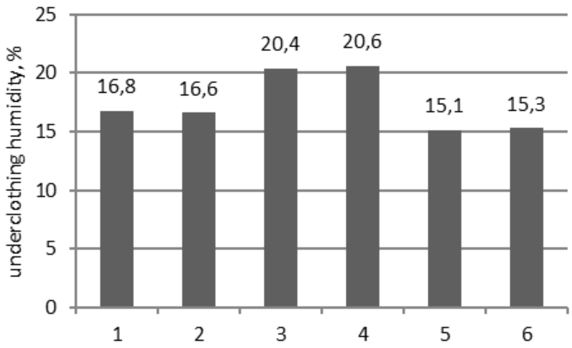


*Fig. 11. Average underclothing humidity*

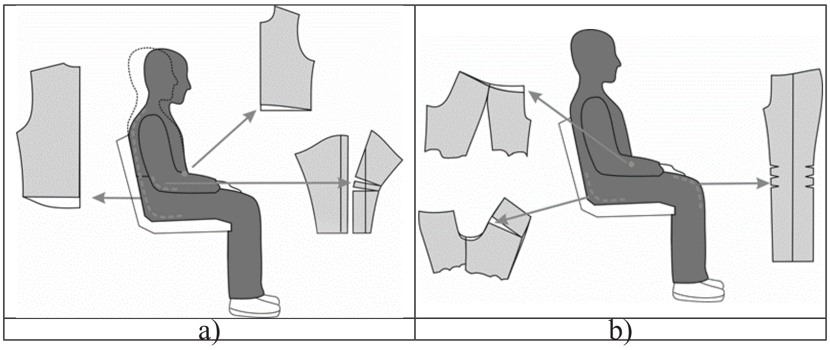


*Fig. 12. Ergonomics taken into account in the construction by modeling and shaping the convexity. a) jacket, b) trousers*

Design assumptions related to the selection of materials were the basis for the development of workwear designs for users with motor disabilities. In the design of non-standard clothing the following were taken into acount:

- adjusting the dimensions and shapes of the clothing segments to the body dimensions and positions most frequently used;
- identification of sensitive areas on the figure;
- structural adaptation to the individual needs of specific users;
- design considering functions of the clothing related to movement restrictions and deformations of the body, to facilitate the operation and assistance of caregivers;
- convenience and design attractiveness improving the self-esteem of users;
- reducing manipulation difficulties when dressing and undressing;
- improving the function of clothing through the technology of garment manufacturing; flat or elastic seams with stitches adapted to the structure of materials, positioned so as not to subject pressure in contact with the wheelchair.

In the design of clothing, ergonomics was taken into account by remodeling and profiling the places where the greatest stresses and pressures occur, i.e. in the area of the bend of the knees and elbows and also in the buttocks area to shape their convexity (Fig. 12), because in a prolonged sitting position the human body is subject to various stresses.

## 4. Summary

People with motor disabilities are, in most cases, permanently immobilised and use wheelchairs. In the case of professional activation of this social group, it is extremely important to provide them with the best possible working conditions, especially work clothes. Prolonged immobilisation in the sitting position, resulting from disfunction of the lower limbs, may lead to disturbances in the exchange of heat and water vapour with the environment at the point of contact with the seat surface. That is why it is so important to ensure overall comfort in terms of clothing construction and material selection for these people. The test results of fabrics designed for workwear for employees with motor disabilities presented in the paper showed that fabrics 1, 2 and 6 meet the requirements of Standard PN-P-84525:1998, which will provide the highest degree of comfort for employees with motor disabilities.

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