Evaluation of clothing fit

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Abstract. This paper focuses on analysis of clothing appearance and fit. Clothing fit ensures human body comfort in terms of microclimate, movements and the body well-being. Garments produced in serial production developed according sizing chart, which is suited to the individual measurements by indifference intervals only. Some, more elaborated systems use drop values. The fit is good for people whose size meets the middle of the table. If the measured values reach the end of the interval, fit is at risk. This is especially important for garments with integrated additional features. Clothing appearance and fit assessment methods are currently well developed - it is possible to assess the individual's 3D look and the distance from the body of the garment. Such an analysis can be done either through virtual simulation or by scanning a real person and/or sample. However, none of aforementioned methods assess the individual's senses in clothing. Therefore, a system is proposed which allows evaluating the analysis of clothing pressure.

1. Introduction

Nowadays different textile materials are developed – tendencies in the market are to produce textiles with smart applications. Smart applications in terms of garment include not only textile properties – it is complex system within human body and environment [1]. Clothing can increase the ability of body to function in different environments. Although all clothing is functional, the functional clothing design focuses on garments with special purposes. In order to meet all the determined functional and comfort requirements for clothing, patternmaking is one of the most significant steps. Pattern should be suitable for users’ body type and its specifics, as well as for the specifics of the garment itself. Clothing is produced according to certain size charts (considering few main measurements – body height, bust, waist and hip horizontal girth) [2]. However, the figure of each individual is very different; therefore, it is hard to meet the classification due to the various proportions, which are rarely taken into account when designing clothes for production.

For a textile to meet the set requirements in terms of functionality and comfort, one of the most important and crucial factors is a pattern corresponding to human figure and the specific features of the particular garment [3]. Clothing is produced based on figure types [4], [5]. The main pre-condition for standardization and figure type indifference intervals is to serve as wide target group as possible so

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as to ensure that one size covers as large part of the population as possible. However, the figure of each individual is different, and even though it may be analyzed statistically, it is difficult to classify it due to different proportions (drop type), which in patternmaking for mass production are hardly ever taken into account.

Clothing designed for a specific function such as winter sportswear (providing protection against wind, moisture, and cold, pleasant microclimate, etc.) loses its functionality, if the pattern does not correspond to the specific features of the body – the interlining between the outer fabric and the lining of the garment becomes tightened, thus causing loss of air gap, which, in turn, results in considerable decrease in thermal protective properties of the garment. Moreover, discomfort is caused also by limited range of mobility [3].

Target of the research is to create a prototype for a system to experimentally determine the extent to which clothing clings to the wearer's body (or other clothing layers), how the clothing fit affects the wearer's comfort and ensures that garment meets all the functional requirements. Sensors elaborated in textile system can be used to analyze and determine these questions, also 3D prototyping and ease evaluation is useful.

2. Materials and methods

The fit of clothing and clothing systems greatly affect the provision of general garment performance, functionality, comfort, and mobility [3]. Clothing is an essential human need with several functions. The choice of clothing depends on several complex criteria, such as personal desires and needs, which are user dependent and therefore subjective. Lately more and more attention is focused on the concept and awareness of comfort, and the possibility to express the level of comfort by means of specific characteristics.

Thermophysiological comfort can be evaluated by performing the guarded-hotplate test (as referred to in ISO 11092) and by means of different thermal manikins (as referred to in ISO 15831) [6], [7]. Ergonomic comfort parameters can be defined by using a 3-D body scanning method to determine the air gap and its distribution between the clothing and human body [3]. Furthermore, different CAD/CAM systems [8] may be used in patternmaking, and virtual fitting when analyzing the respective color-coded bars regarding the fit [5].

Since the clothing covers a three-dimensional figure, the fit is hard to define due to the specific geometry of the human body, different characteristics of the material, and other complex factors (fashion, perception, purpose of wearing the specific garment, etc.). When designing garments in a 2-D environment, ease allowances are determined by linear body measures. However, they may not always correctly represent the fitness of the garment for the human figure [4], [5].

The 3-D scanner registers specific characteristics of human body and clothing proportions in three dimensions, which also allows determining deficiencies of 2-D patterns. Thus, it is possible to analyze the required ease allowances and the distance between the clothing and the human body. The air gap amount and the overall air gap distribution between the clothing and the human body are quantified in order to quantitatively characterize a three-dimensional garment fit.

2.1. Measurements

Measurements of subjects were obtained using two methods, for the contact method using measuring tape and anthropometer (device), for the noncontact method using 3D anthropometrical scanner Vitus Smart XXL® (©Human Solutions GmbH and VITRONIC GmbH) with data processing system AnthroScan. A human body surface reproduction dot cloud is created from the coordinate readings, which is to be used as a virtual mannequin or only the coordinates themselves can be used. A virtual reproduction of the human body for this research is used as virtual try-on object within the same pattern jacket for 6 different persons from point of view of drop values, although the size by sizing system is the same for each person – see values of total morphological parameters for each person used in the research in Table 1.

For the pattern size 40 as basic size is used. The intervals of main dimensions required are bust girth 90-94 cm, waist girth 74-78 cm and hip girth 98.5 – 101.5 cm. According to sizing system used in patternmaking method, indifference intervals for bust and waist measurements are 4 cm and 3 cm for hip girth, all involved test-persons are in size 40 at least in interval of bust girth.

Table 1. Measurement table for test-persons [cm]

#	Body height	Bust girth	Waist girth	Hip girth
1.	171.1	93.7	72.3	102.5
2.	180.6	90.5	66.8	96.7
3.	167.5	92.6	65.8	96.2
4.	166.7	93.0	75.9	99.0
5.	173.1	92.3	75.9	100.9
6.	156.8	91.2	77.4	99.4

2.2. Virtual try-on

For the virtual try-on and ease assessment, Lectra Modaris 3D Fit system is used. This system is useful for garment imitation – the systems allows performing a virtual fitting, evaluate the external appearance, shape, set, proportions of the garment (the garment is created in 3D by joining patterns constructed in a plane, creating an imitation of the garment with the intention to ascertain the conformity of the outer appearance to the expectations).

System allows choose material from built-in data by searching most important parameters. Model for simulation is one ply fleece jacket with zipper closure ('figure 1'). Fabric used is fleece interlock, Cotton 94%/ Elastane 6%, thickness 0.8 mm with good drape. For virtual prototyping side panels are gathered to 90 % and sleeves are gathered to 80 %.

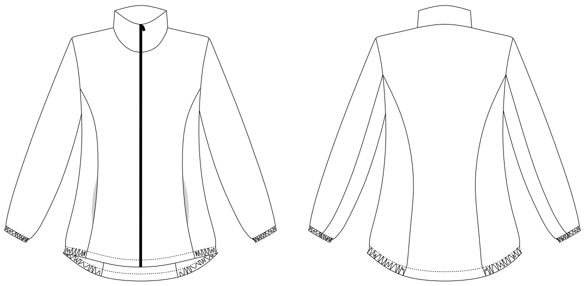

Figure 1. Jacket technical drawing.

3. Results

The results of virtual prototyping allow assess ease, fit and appearance of the model. As the chosen test-persons are different – three of them match the size only by bust girth, three of them fits into indifference intervals.

3.1. Assessment of fit

Fit assessment visually by appearance of simulated jacket displayed in Table 2.

Table 2. Fit of the virtual jacket to the test-person virtual scanatars

#	Front view	Right side	Back view	Left side
1.				

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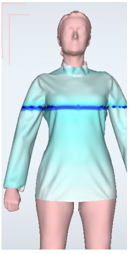
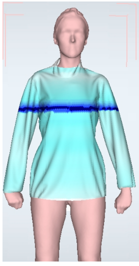
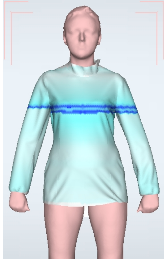
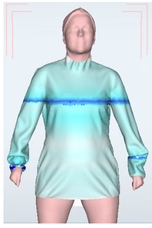
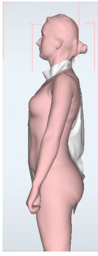
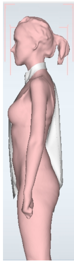
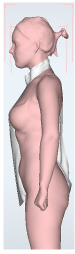
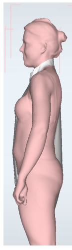
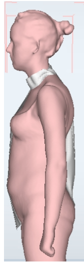
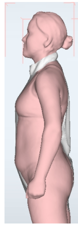
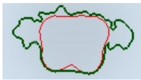
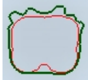
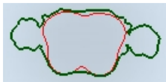
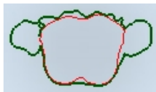
Table 2. Fit of the virtual jacket to the test-person virtual scanatars

#	Front view	Right side	Back view	Left side
2.				
3.				
4.				
5.				
6.				

Last three test-persons fit in the sizing table more proper (in terms of total morphological values) than first three and the appearance of the jacket is smooth and appropriate to the body. To evaluate ease of garment colour analysis is used where dark blue shows too loose garment and bright red is too tight garment. White shows appropriate fit, light blue loosened fabric and yellow – stretched fabric. Analysis of ease and fit in Table 3 is given.

Gaps between jacket and body shows spatial ease – one for free movements, other describe bad fit. As all six test-persons fit in sizing chart, ill fit is caused only if person's measurements are supreme or infima values in the indifference interval. For example, first test-person's bust circumference tends to reach supreme value – therefore folds around bust transversal plane are rather small. In addition, some folds are caused by posture and dedicated for free movement. Second person's jacket's appearance analysis shows large gaps between body and jacket – this is caused by smaller bust circumference.

Table 3. Analysis of ease and fit

#	1.	2.	3.	4.	5.	6.
Ease shadow						
Medial cut of jacket (white)						
Transverse (bust level)						

Beside fit and comfort analysis individual peculiarities of a person can be assessed – third person's most prominent bust point is lower than axilla points – therefore transversal analysis shows jacket cut without sleeves, while sixth person is asymmetrical – therefore transverse cut also is not symmetrical.

3.2. System of textile based sensors

The aforementioned methods to be used to identify factors affecting comfort are widely applied and developed so as to allow obtaining results and draw conclusions arising out of them, which are more approximate to the real situation. The proposal as the result of this research is to develop a prototype for a grid system of sensors, which shall be used to experimentally determine to what extent the garment fits to the wearer and the pattern of the garment (in terms of compliance with the specific characteristics of wearer's body) affects wearing comfort and ensures compliance with the relevant functional requirements. Textile based capacitive force sensors shall be integrated into the prototype for the system of sensors to be developed. Furthermore, it is planned to keep developing this idea by integrating heat and moisture sensors.

The capacitive force sensors can be used to determine the pressure between two surfaces. These sensors use the principle as follows: there is a three-dimensional fabric (spacer fabric) arranged between two electrically conductive layers. With the supply of voltage by applying force/ pressure, the distance of both electrically conductive layers is reduced, whereas the electric charge increases, such outcome being expressed as capacity [9], [10]. A set of sensors matrix will be designed in order to increase pressure influence in desired areas and more precise pressure identification. Data will be obtained by cable communication indoors, laboratory tests, or by means of Internet of Things outdoors.

The pressure caused as a result of the interaction between the human body and the clothing, and/or additional elements is, to a great extent, attributable to the fit of clothing, the characterizing indicators being the comfort, freedom of movement, weight, firmness of the fabric, etc. The skin is extremely sensitive to different mechanical stimuli, and the studies show that if the clothing pressure on the human body exceeds 30 mmHg, a person ought to feel discomfort [11]. Increased clothing pressure may indicate to incorrect fit of clothing and reduced performance.

4. Discussion and conclusions

Non-fitting or ill-fitting functional clothing can reduce and/or lose ones' functionality – for example, the insulation [12] between the top and the lining of the garment is tightened/flattened losing the air interlayer, thus the product's heating ability is significantly reduced, discomfort could be also caused by the limited movement ability.

The research will boost further the use of design systems in apparel industry and trade, and reduce the number of trial and error experiments by producers when selecting garment sizes for special target groups. The approach supports the Sustainable Development Goals, i.e. – the need for sustainable development - provides a comprehensive approach bringing together economic and environmental considerations in ways that mutually reinforce each other. As functional clothing is expensive and material consuming process – the improvement and enhancement of the design process and adjusting the design to end user is to be boosted within this research result.

The result of this research will improve the development and operational process in functional clothing industry. The result of the research will show solutions on multi task and multidisciplinary approach – including benefits for textile producers, pattern makers and end users. In the terms of 3D prototyping and ill-fitting detection, research gives advices on improvement of patterns. Research tasks performed within it give opportunity to make conclusions regarding causes of pattern alterations, their depiction in computer simulation, measuring possibilities and thereby the prevention of the causes of such alterations thus easing the work of pattern maker. In addition, smart solutions of ill-fitting detection are suggested.

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