ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

VIRTUAL PROTOTYPING OF PROTECTIVE CLOTHING FOR OVERSIZED SUBJECTS

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Abstract: *The paper presents the virtual prototyping of protective clothing for oversized female and male subjects, highlighting the importance of personalization and its competitive advantages. Customisation of protective clothing for oversized subjects offered the possibility to individualise the products to each wearer with different conformation and specific work activities. Customized protective clothing involves the dimensional and conformational aspects of the body, respectively the product size as well as the quality-linked functionality criterion, aspects regarding its wearability and protection tested in accredited laboratories, the effects over the individual comfort. The research implementation involved 3D body scanning for analysis and determination of anthropometric measurements and conformation, 3D CAD technology for automatic rapid design of patterns in Made to measure system, modeling and simulation of product in the virtual environment on customized mannequin, highlighting the body-product correspondence. New technologies in the context of Industry 4.0 are the seeds for disruptive innovation in the clothing industry, by increasing the digital capacity and flexibility to satisfy the customer requests and implement more dedicated services.*

Key words: *virtual, design, protective clothing, simulation, oversize*

1. INTRODUCTION

The textile and clothing industry is a traditional and important part of the European manufacturing industry, having great impact on the economy and social well-being of numerous regions of EU.

In 2019, the entire EU-27 T&C industry represented a turnover of €162 billion. According to Euratex, 160.000 textile & clothing companies, of which 99.8% are SMEs employed 1.5 million people. To keep up with the evolution of the textile-clothing industry, which follows the three strategic directions established by the European Platform for the Future of Textiles and Clothing, the textile industry must increase its competitiveness and benefit from a qualified human resource, adapted and ready to implement the new technologies to obtain smart, advanced, multifunctional, personalized textile products for both T&C and related industries [1, 2]. Recently, the European Commission launched the new Industrial Strategy for a globally competitive, green and digital Europe that will help deliver on three key priorities: maintaining European industry's global competitiveness and a level playing field, at home and globally, making Europe climate-neutral by

2050 and shaping Europe's digital future [3].

Design and creativity, quality fashion products, technical goods of high added-value, smart and technical textiles have been identified as major competitive advantages of the EU T&C industry. Technical textiles represent a key sector regarding the impact on economic growth, sustainable development and employment. The textile, clothing and fashion industry is in a continuous movement, characterized by an increased mobility of production factors, rapid delocalization, fragmentation and higher specialization of the activities in the value chains of products and services. The turbulent business environment and COVID 19 pandemic are forcing textile and clothing companies to adapt their production lines and increase their efficiency In order to face these challenges, companies must improve their internal organization and create a network/cluster of co-operations with external organizations [4-6].

Protective clothing creates barriers against external factors during the professional activity of workers and professionals. The properties of this type of clothing must be balanced in order to assure the level of protection, reduced weight and comfort during usage without impact on work performance.

The current paper presents the virtual prototyping of protective clothing for oversized female and male subjects, highlighting the importance of personalization and its competitive advantages, from the idea to the prototype. Customized protective clothing involves the dimensional and conformational aspects of the body, respectively the product size as well as the quality-linked functionality criterion, aspects regarding its wearability and protection.

2. 3D BODY SCANNING AND MORPHOLOGICAL ANALYSIS OF THE OVERSIZED SUBJECTS

In the study, the subjects were scanned using the body scanner 3D VITUS XXL and the measurement protocols and virtual bodies/parameterized virtual mannequins were generated (fig. 1). The anthropometric data was the basis for designing the personalized patterns in Made-to-Measure system.

The selected female subject had the following main body dimensions extracted from the measurement protocol:

- Body height (Ic) 172 cm;
- Bust circumference (Pb) 129 cm;
- Waist circumference (Pt) 122 cm;
- Hip circumference (Ps) 120 cm.

These values reveal that the bust circumference is 1 cm larger than the superior limit value of 128 cm mentioned in the standard SR 13545 - Clothing. Women’s Body Measurement and Garment Sizes [7]. The maximum standard circumference of the bust has a value of 128 cm.

The selected male subject has the following main body dimensions extracted from the measurement protocol:

- Body height (Ic) 190.5 cm;
- Bust circumference (Pb) 143 cm;
- Waist circumference (Pt) 143 cm;
- Hip circumference (Ps) 166 cm.

The data extracted from the anthropometric standard reveal that the body dimensions are outside the standard SR 13544 - Clothing. Men’s Body Measurement and Garment Sizes [8]. In this standard, the maximum chest circumference is 132 cm, and the maximum waist circumference is 128 cm.

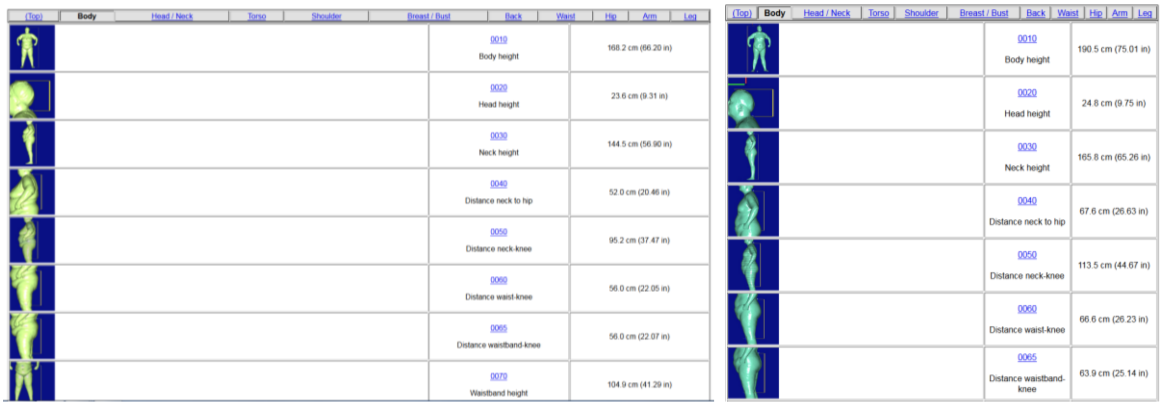

Fig. 1. Measurement protocol for studied subjects

3. CUSTOMISATION OF THE SELECTED PROTECTIVE CLOTHING

In the study, different types of protective clothing were analysed and selected for female and male subjects and then were customized by the innovative technological design and production solutions. The Overalls suit with chest and waist pants for women has been developed according to the technical specification.

The protective clothing consists in the blouse, chest trousers and waist support pants. The overalls suit with chest pants and waist pants is worn by the operative personnel in the repair, maintenance and inspection activities of water pipes. The protective clothing for women was manufactured from fabric 35% PES, 64% TENCEL and 1% AS (antistatic), in blue colour with the weight of 205 g/m^2.

The model of protective clothing selected for the male subject is the Unique costume with two trousers for the Jardarmerie (service uniform), developed according to the technical specification. The unique costume consists of a blouse and two trousers and is worn by the military units as service uniform. The costume was manufactured from fabric containing 86% cotton mixed with 14% polyester, ripstop, dark blue color with the weight of 229 g/m^2.

Physical-mechanical and physical-chemical characteristics of the fabric were determined in the accredited laboratories (table 1) and the data were used for textile material characterization in the 3D simulation.

Table 1. *Physical-mechanical and physical-chemical characteristics of fabric used for male EIP (selection)*

Characteristic	Values obtained in the accredited laboratories	Reference document
Weight (g/m^2)	229	SR EN 12127:2003
Weave	Diagonal 2/1 with ripstop form 2 filaments	SR 6431:2012
Warp density (threads/10 cm)	480	SR EN 1049-2/2000
Weft density (threads/10 cm)	260	SR EN 1049-2/2000
Tensile strength warp (N)	1426	SR EN ISO 13934-2013
Tensile strength weft (N)	690	SR EN ISO 13934-2013
Tear strength warp (N)	83.8	SR EN ISO 13937- 1:2001/AC:2006
Tear strength weft (N)	97.8	SR EN ISO 13937- 1:2001/AC:2006

Colour fastness to	perspiration acid alkaline	4-5 4-5	SR EN ISO 1 05-E 04:2013
	rubbing dry wet	4 4	SR EN ISO 105-X12:2003

The pattern design for the selected protective clothing was implemented using Gemini Pattern Editor's Made-to-Measure module.

The fitting of customised patterns, designed according to individual body dimensions, was accomplished by modelling 2D/3D patterns and simulating protective clothing on the parameterized mannequin, using Optitex PDS software for visualization and modelling. The virtual prototyping system involves transferring and fitting protective clothing to virtual mannequin with various shapes and postures. In this sense, the protective clothing must be treated as elastic models and their deformation is controlled by the laws of dynamics [9,10].

The patterns designed in 2D were transposed in 3D environment in order to develop the virtual prototype of customized protective clothing. The following methodological steps were applied:

• dimensioning the virtual mannequin to the anthropometric dimensions obtained from 3D body scanning;

• adding stitching lines and guide points to the 2D patterns (fig. 2 for female subject and fig. 3 for male subject);

• introducing the data regarding the textile materials used for the manufacturing of protective clothing (fibrous composition, weight, drape, shrinkage etc.);

• 3D simulation of the clothing on the virtual mannequins (fig. 4 for female subject and fig. 5 for male subject);

• checking and modifying the 2D patterns to ensure the optimal fitting.

Fig. 2. *The 2D patterns of the customized Overalls sit with seam lines and required characteristics of the textile material*

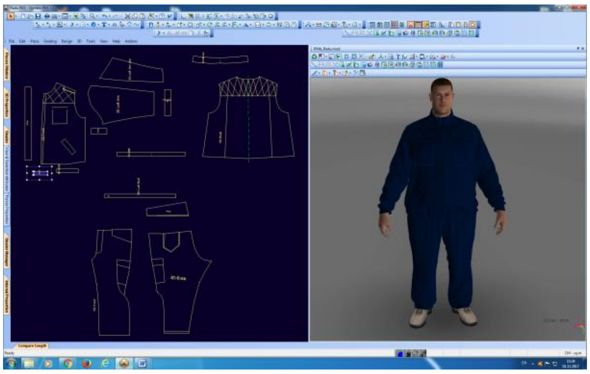

Fig. 3.*The 2D patterns of the customized protective clothing, with seam lines and required characteristics of the textile material*

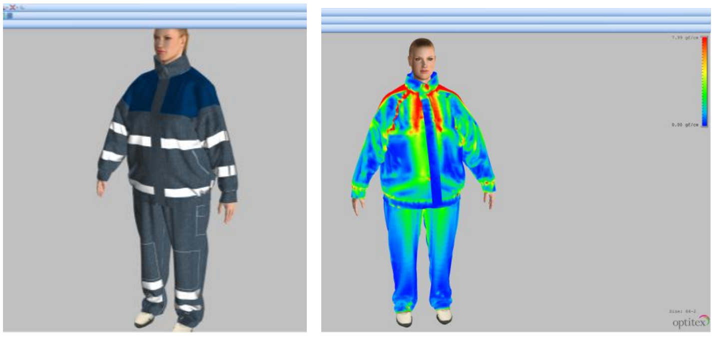

Fig. 4. *Virtual try-on and verification of the customized protective clothing for women*

Fig. 5. *Virtual try-on and verification of the customized protective clothing for men*

For checking the body-product correspondence, the Tension Map function was applied, which renders the degree of ease/adjustment of the products on the bodies (fig. 4 and 5). For the female subject, the software reveals the information that the jacket corresponds dimensionally. Also, the chest and waist trousers fit on the waist line and are slightly wide on the hips line. The degree of ease is justified by the semi-rigid silhouette of the protective clothing. This information is useful for the pattern designer which could return to 2D patterns and introduce necessary corrections.

For the male subject, the jacket product corresponds dimensionally too. Also, the trouser fits on the waist line and is slightly wide on the hips line. The case is similar with the protective clothing for female subject.

4. CONCLUSIONS

Customisation of protective clothing for oversized subjects offered the possibility to individualise the products to each wearer with different conformation and specific work activities. The research implementation allowed the direct involvement of the clothing manufacturing companies in the design of the customised protective clothing. The industrial partners participation represent also their first contact with the 3D body scanning for analysis and determination of anthropometric measurements, 3D CAD technology for automatic rapid design of patterns and simulation software for virtual prototyping. These new technologies in the context of Industry 4.0 are the seeds for disruptive innovation in the clothing industry, by increasing the digital capacity and flexibility to satisfy the customer requests and implement more dedicated services.

ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI - UEFISCDI, project number PN-III-P2-2.1-CI-2017-0046 and project number PN-III-P2-2.1-CI-2018-0912, within PNCDI III. Also, this work was carried out through the Nucleu Programme, with the support of MCID, project no. 4N/08.02.2019, PN 19 17 02 01, project title: “Advanced multifunctional logistics, communications and protection systems to improve the safety, operability and efficiency of emergency workers – SiMaLogPro”.

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