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Improvement of Workwear Clothing for Army

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Abstract. The two main tasks of combat clothes are soldier's physical protection and freedom of movements [1]. This requirement shall be made with the provision of protective clothing appearance and fit, as well as a suitable choice of material [2]. The aim of the research described in an article is to find out what issues the potential end user meets with during product using (field uniform trousers and jackets) and how it would be possible to avoid it. To reach the aim, end user were interviewed using survey, prospective users were measured by non-contact Human Body 3D scanning combat clothing prototypes (field uniforms) constructive and technological solutions and properties of fabrics were analysed during research.

1. Introduction

Interest of human complex protection from various influencing factors while doing work is more and more growing. One of those protection remedies is workwear clothing. Increasing demands, influence on the labour garment improvement process in order to reach the required level of end-user protection.

2. Materials and Methods

In order to provide soldiers with the clothing, which are appropriate to requirements, researchers split the research in phases.

2.1. The end-user survey

The end-user survey was selected as one of the qualitative research methods. The survey provides an opportunity to find out the user experience wearing combat uniforms and its weaknesses, thus enabling researchers to improve it.

2.2. Human Body 3D scanning

Prospective users were measured by non-contact Human Body 3D scanning (Vitus Smart XXL), which will serve as the basis of anthropometrical data for creation of new generation workwear prototypes.

2.3. Testing of fabrics properties

Properties of fabrics were analysed during research - tensile strength and elongation, tearing strength, Martindale abrasion resistance, pilling resistance, rigidity, thermal and water vapour resistance were determined and carried articles connectivity testing.

2.4. Testing of constructive and technological solutions

The analysis of the field uniform’s trouser crotch connection has been carried out, by determining the tensile strength and elongation of the trouser crotch connection.

3. Results
Interim results achieved allowed to estimate the main imperfections of existing protective clothing (field uniform trousers and jackets) - lack of durability and thus loss of defences and even usability. It was observed gaps in human body measurements, which affect the fit of clothing, quality of textile materials, as well as constructive and technological solutions of components. Factors are different and improvement solutions should be complex throughout the research.

3.1. Results of Survey
The total number of respondents participating in the survey is 122. The survey identified three main problems – size discrepancy to the user, quality of the material and the constructive technological solution. For example, as shown in Figure 1, approximately 72% of the respondents say that material strength should be increased, while 62% believe that the material must be more flexible.

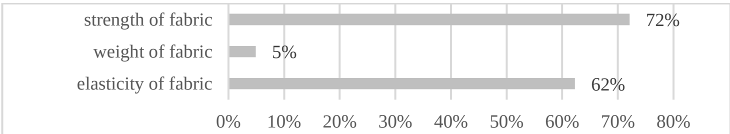

Figure 1. Preferred changes in the materials of field uniforms

Asked about what defects the respondents have observed in their field uniforms (Figure 2), 80% of them indicated that they have observed loss of colour, 75% observed wearing and 72% - tear. All of the above-mentioned defects indicate the material properties that are inappropriate to the conditions of use. Similarly, 34% of the respondents noted that they have observed broken seams which could be a sign of fragile connections in the places where the most strength can be detected during wearing, as well as week threads (Figure 2).

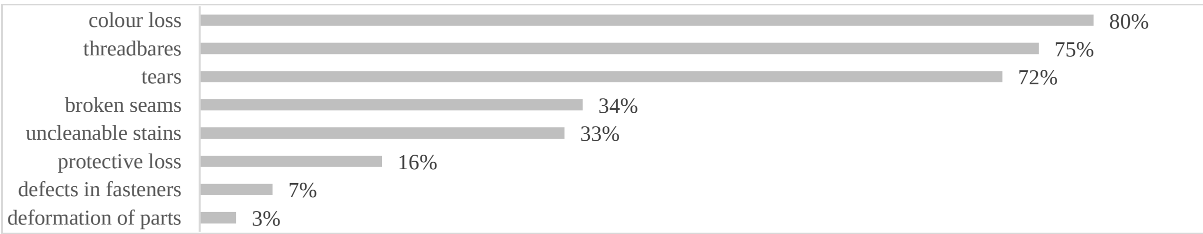

Figure 2. Defects detected in field uniforms

Additional information about the defects leads to the conclusion that most of the defects (tears and broken seams) are directly in the trouser crotch area. This was indicated by 66% of the respondents.

3.2. Results of 3DBody Scanning
One of the reasons for clothing defects might be their non-compliance to the body size of the person.

3.2.1. Size selection
In the framework of soldier 3D scanning process, 150 uniform wearers were asked to indicate the sizes of wearable products. 87% of the tested persons were able to indicate the trouser sizes. Still, types of the size labels were different – 87% indicated only letters (XS-3XL), and 11% of them, due to having doubts, indicated two markings (e.g. L/M), 6% mentioned two-dimensional numeric labels (e.g. 92/182) and only 7% indicated the manufacturer's introduced and used two-dimensional marking with letters (e.g. L/REG).

3.2.2. Cloth compliance according to the primary measure of waist cloths - waist circumference
In order to check the compliance of the set sizes to the measurements of each person's body, trouser sizes, that have been acquired after a 3D scanning of wearer waist circumferences, have been checked

according to the producer's measurement tables. The comparison shows that only 51% of the trouser sizes corresponds to the waist circumference, 31% of the respondents have indicated a smaller size, but 18% - a larger size. (Figure 3).

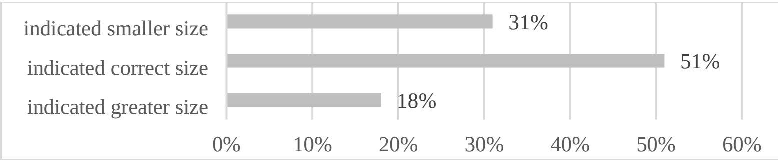

Figure 3. Size conformity to the wearer according to the waist circumference

3.2.3. Cloth compliance according to the secondary measure of waist cloths –leg inner length

The producer's ready-made trousers are labelled considering the waist circumference as the primary measurement and by dividing them into 7 sizes (XS-3XL), while the second measurement is body height. The leg length (for the lapped seam and bound seam) is divided into 7 lengths (2XSH-2XLO), which provides 49 combination possibilities of body sizes.

This means, that the length of the lapped seam and the bound seam will be determined by the test person's inclusion in one of the body height intervals. Anthropometric studies have observed that the leg length or leg proportion towards the body height of individuals who fit in the same body height range may differ, e.g. extra levant, levant, normal length, long-legged and extra long-legged types.

When aligning trouser/leg length intervals of the manufacturers' tables, that are determined by the body height, with leg length measurements (Table 1), after a more personal investigation of leg lengths in any of the body height groups, it can be seen that not all wearers are included in those set intervals, although the average rates are close to the one set by the manufacturers.

Table 1. Proportion of leg length in relation to a body height

Label	Body height	Trouser/leg length	Trouser/leg length range	Leg length incidence according to body measures
2XSH	164	*75*	3 (73,5-76,5)	Δ=7 (**71**-77), average = 75
XSH	170	*78*	3 (76,5-79,5)	Δ=9 (**72-81**) , average = 77
SHO	176	*80*	2 (79,0-81,0)	Δ=8 (**74**-82) , average = 79
REG	182	*82*	2 (81,0-83,0)	Δ=11 (**77-88**) , average = 82
LON	188	*85*	3 (83,5-86,5)	Δ=11 (**78-89**) , average = 84
XLO	194	*88*	3 (86,5-89,5)	Δ=5 (86-**91**) , average = 88

The distinction of the specific research group has been done according to body measures and tables provided by the manufacturers. Thereby the appropriate markings for leg length (the other side of the two-dimensional label) has been set. First, marking according to the body height has been determined, then according to the measurement of the leg's inner length (Table 2).

Table 2. Example for disparity of size labelling

Trouser size (recorded)	Body height	Range according to body height	Leg inner length (body measurement)	Range according to leg inner length
XXL/**REG**	181.0	**REG (179-185)**	79.6	**SHO (80)**

After comparing, it has been observed that in 72% of all the cases the labels do not match or the labels are affected by the fact, whether the body height or the leg inner length has been taken as the main

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measurement. It can be seen also visually - when aligning the representations of people belonging to one body height range, the leg ratio difference can be observed.

3.3. Results of Fabric Property Testing

Two fabrics were used for testing – fabric sample No. 1 issued by the NAF and fabric sample No. 2 issued by the fabric manufacturing company. According to the oral confirmation of the manufacturing company, the fabric No. 1 has been produced, taking fabric No. 2 as a sample, which is then printed according to the needs of the Latvian NAF.

The structural and geometric characteristics of the fabric No. 2 have been compared with characteristics of fabric No. 1. The fibre content and the fabric type of both fabrics correspond to the set requirements of NAF.

When comparing the mechanical and technical characteristics of both fabrics, the following characteristics have been determined according to the standards: ultimate tensile strength and longitudinal and transversal elongation [3], tear resistance [4], air permeability [5], bending rigidity [6], abrasion resistance [7], water vapour resistance [8], thermal resistance [8] and the fabric surface wetting [9].

Table 3. Comparison of mechanical and technical characteristics

Characteristic		Fabric No. 2	Fabric No.1
Tensile strength	longitudinal	1106±111N	1260±126N
	transversal	552±55N	547±55N
Elongation	longitudinal	22.2%	15.5%
	transversal	11.7%	12.7%
Tearing strength	Transverse	27N	19N
	tissue	20N	15N
Air permeability, Pressure 100Pa		60mm/s	30mm/s
Bending rigidity	longitudinal	17 μNm	18 μNm
	transversal	23 μNm	49 μNm
Abrasion resistance		30 000 cycles (12 kPa)	30 000 cycles (12kPa)
The surface wetting		1 point	4 points
Thermal resistance		< 0.02 m^2Pa/W	< 0.02 m^2Pa/W
Water vapour resistance		3.4 m^2K/W	4.2 m^2K/W

The values of tensile strength in transversal direction are very low, which means that the fabric is not suitable for cloths to be worn at aggressive conditions under physical activities (Table 3). The values of relative elongation provide information on the fabric's maximum capacity to prolong until breaking, and therefore provides an indication of the possible free movement during wearing. The values of the certain relative elongation indicates the low elongation capability of both fabrics (Table 3). According the recommendations of the EURATEX confederation [10], the value of this capability should be between 12.5% and 55% in each direction.

The resulting values of tear strength tests (Table 3) are lower than the ones indicated in the fabric catalogue, where the values given for manufacturing this type of clothing can be considered satisfactory. Air permeability of fabric No. 1 is very low (Table 3). Such air permeability is not allowed for clothing that is worn under strong physical activities during summer.

When testing the longitudinal and transversal bending rigidity of both fabrics [6], it has been indicated that the bending rigidity of fabric No. 1 in transverse direction is more than 2 times higher than that of fabric No.2 (Table 3). This indicator is too large for the fabric of such clothes.

The abrasion resistance indicated in the characterization of fabric No. 2 of the manufacturing company is equal 25 000 cycles, which indicates a short wearing time.

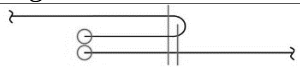
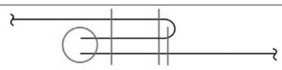
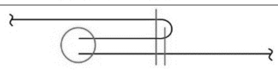
When testing the surface wetting of both fabrics, the results were different (Table 3). The surface of fabric No. 2 strongly moistens and its resistance to soaking can be evaluated with 1 point, while the surface of fabric No. 1 is almost water repellent and can be evaluated with 4 points.

The vapour resistance of fabric No. 2 corresponds to the one set out in the technical specification, but vapour resistance of fabric No. 1 is higher than set out. This allows us to conclude that during physical activities within warm weather conditions the lower layer of the cloths will accumulate a higher level of humidity, due to which the fabric will "stick" to the body, will not resist the extra tension and tear.

3.4. Results on testing trouser crotch connections

Analysis of the field uniform trouser crotch connection has been carried out according to the standard [11], by determining the ultimate tensile strength and the elongation of the trouser crotch connection. Samples of three connection types (different construction) with different connection parameters were developed out of fabrics No. 1 and No. 2. The first connection type (Table 4) corresponds to the one that has been used for connecting the trouser crotch of NAF field uniforms.

Table 4. Types and parameters of trouser crotch connections

No.	Cutting scheme of the connection	Parameters
1		3 stitches/cm
		4 stitches /cm
2		3 stitches /cm
		4 stitches /cm
3		3 stitches /cm
		4 stitches /cm

As shown in Table 5, the 1st connection, that has been used for connecting the trouser crotch of NAF field uniforms shows low values of tensile strength at 3 stitches/cm and a bit higher at 4 stitches/cm. Also the 3rd connection, that, by its construction, is only a little different from the 1st connection, indicates a lower value than the 2nd connection.

Table 5. Test results of connection ultimate tensile strength and elongation

Type	Number of stitches cm	Ultimate tensile strength, N		Elongation, %	
		No.2	No.1	No.2	No.1
1st connection	3	343	383	12,1	13,5
	4	443	409	12,8	13,3
2nd connection	3	437	476	12,9	13,2
	4	470	490	13,2	13,5
3rd connection	3	332	327	12,0	12,4
	4	385	429	12,1	13,2

When comparing the tensile strength of the 3rd connection with the one of the 1st and 2nd connections (Table 5), it can be seen that 2nd connection is the strongest one due to its construction. Also, there are differences in the connections that have been created using different number of stitches per centimetre. The trend shows that the tensile strength value is higher for samples that are stitched with a seam that consists of 4 stitches per centimetre, instead of three as in the original field uniform trousers.

Overall, the judgment on the connection strength is undermined by the fact that according to the fabrics property tests, materials are not suitable for manufacturing field uniforms due to the low ultimate tensile strength and low elongation capabilities.

4. Conclusions and Discussions

The significant size discrepancy to the wearers' actual body measures shows the need to revise the overall size ratio, however, it should be taken into account that body acquisition and exploration of a much broader audience is necessary, since the audience of 150 persons measured in the research is not wide enough and it cannot provide a statistically significant reflection of the target populations' (army of national guard) anthropometric characteristics.

After analysing the material test results, it can be concluded that it is necessary to develop a new NAF technical specification that should contain such additional characteristics as the warp and weft density, elongation at the breaking point, tearing strength, abrasion resistance. The minimum tensile strength in the transverse direction should be increased.

After analysing the strength of field uniform connections, it has been determined that another (stronger) type of connection must be used for connecting the trouser crotch; use of the 2nd connection type is recommended, since it showed the highest ultimate tensile strength values if compared to connections No. 1 and No. 3. It is recommended to use 4 stitches per centimetre for the trouser crotch connection seam, which increases both the ultimate tensile strength of the connection and the prolongation capability.

5. References

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