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SUBSTANTIATION OF PARAMETERS OF CLOTHES DESIGN FOR EMPLOYEES OF PIPELINE COMPANIES

Purpose. *This article suggests the improvement of the quality indicators of clothes for employees of pipeline companies due to substantiation of parameters of garments design.*

Methodology. *The general methodology of the systematic approach to the design of special clothes is used. To conduct anthropometric measurements and calculate dynamic growth to the measure, a standardized method is used.*

Results. *According to the study of dynamic growth, substantiated of parameters of clothes design for employees of pipeline companies. As a result of the study, constructive means of providing dynamic correspondence of clothes to human movements were recommended.*

Scientific novelty. *Based on the study of dynamic growth to the measure of an employee while performing professional movements, the recommendations for making changes to jacket's and jump suit's garments design were worked out.*

Practical value. *The operation conditions of this type of clothes were studied, including the labor routine of employees of pipeline companies, nature of activity, basic and additional movements and poses.*

Keywords: *clothes for employees of pipeline companies, dynamic growth, design parameters.*

Introduction. The main functions of the gas pipeline system of Ukraine are: natural gas supply to domestic consumers and natural gas transit through Ukraine to Western and Central Europe. The efficiency of the system depends on the level of equipment's service quality provided by experts in operation and maintenance of gas equipment for various purposes. During the performance of professional duties, an employee of a pipeline company uses a variety of tools and devices for measurement, diagnostics, installation of gas equipment, repair of gas stoves, water heaters, gas cylinder units with condensed gas, domestic gas installations, equipment adjustment, etc. [1]. Therewith an employee is provided with individual protective gear, including clothes. Timeliness of the topic is that the current range of clothes for employees of pipeline companies does not meet operational requirements due to imperfect technological and design approaches of products, which is the absence of reasonable recommendations on technological and design parameters of clothes.

For a long time, the subject of designing special clothes including ergonomic properties is discussed by scientists from Ukraine and other countries worldwide, including famous works of A. Mychko, M. Kolosnichenko, Masaki Onishi, Tadashi Odashima, Zhiwei Luo, Shigeyuki Hosoe, James Anderson, Catherine M. White, Z. Chubarova, E. Surzhenko, that are dedicated to scientific bases of designing highly-effective variation of special clothes for various scope of human activity [2-5]. Those were considered as specific studies, which dealt with functional parts of clothes, selection of materials during package assembling, without taking into account the movements' characteristics during clothes usage. We are considering the use of clothes in the "human-production environment" system, so the study is directional in accordance with the operating conditions and materials' performance while performing professional movements.

Objectives. To solve the abovementioned problems, the general methodology of the systematic approach to the design of special clothes is used. To conduct anthropometric measurements and calculate dynamic growth to the measure, a standardized method is used. An important aspect of the research is to provide improved ergonomic properties, which consist of anthropometric, hygiene, psychological and physiological indicators.

Researches results. For design of ergonomic clothes the objective information about size of the body is important not only in statics, but also in dynamics. Anthropometric quality indicators of clothes include static and dynamic correspondence of clothes to human body [6]. Static correspondence suggests the correspondence of clothes to a form of human body, as well as the degree of correspondence of clothes design to

figure size. Dynamic correspondence takes into account customization of a particular product to the performance of all types of movements foreseen by operation conditions (free lifting and movement of arms, freedom of product movement when lifting arms, when leaning, etc.) [7]. Dynamic effects are used more widely to determine the volume of functional widening while designing protective, special and sports clothes. It is important to consider this while designing clothes which should not only provide protection from dangerous and harmful production factors, but also comfort during working process [8,9].

In order to substantiate parameters of clothes design for employees of pipeline companies the conditions of its operation, including labour routine, the nature of movements in accordance with the duties, were analyzed. Analysis of employees' movements allowed to reduce the most typical poses that are different from the basic anthropometric provisions. During the research, the following was determined: a list of basic and additional movements of an employee, places of measurement of figure size measure in dynamics, movements with maximum values of dynamic growth to the measure. To obtain numeric and qualitative information that will describe changes of body size in motion, comprehensive anthropometric researches were made. The measurements program included determination of dynamic measures and corresponding static ones. The research was made with five parallel researches. Characteristics of the test person: male, engineer of the 4th category on operation and repair of in-house gas equipment, working experience — 22 years, age — 40 years old, with the following size/height parameters: height – 182 cm, chest circumference – 88 cm, waist circumference – 76 cm [10]. The main criterion for choosing the test person was a long-term working experience in the company, which allowed to use the obtained results for the development of recommendations on the clothes design parameters and configuration of patterns on typical sizes of male figures. During dynamic measurements, the following problems were resolved: identification of a set of basic and additional movements of an employee of pipeline company, choice of figure measuring points in dynamics, designation of necessary anthropometric points in accordance with the methods of measurement set forth in ISO 7250-1:2008 Basic human body measurements for technological design - Part 1: Body measurement definitions and landmarks [11], and immediate measurement in positions at which the largest dynamic growth to the measure is seen.

During the research, five parallel researches were made, with the help of whichX_j^1, X_j^2, X_j^3, X_j^4, X_j^5were determined. For each "j"-type of movement, the research the calculation of arithmetic mean, calculation of ordinal error mean square (estimation of parallel research error) and verification of homogeneity of variance by Cochran's Q test G_T were performed.

Verification of homogeneity of variance performed by Cochran's Q test G_T

$$G_P = \frac{S^2_{u\max}}{\sum_{u=1}^{N} S^2_u}, \qquad (1)$$

$S^2_{\text{u max}}$ –maximum calculated dispersion.

The fulfillment of the condition $G_P < G_{table}(q, f_1, f_2)$ is checked. In case the condition is fulfilled, then the process is deemed to be repeatable.In case the condition is not fulfilled, it is necessary to increase the number of parallel researches, or to increase the accuracy of variables control, or to change the control method in general.

Tabulated value of Cochran's Q test G_T is determined by reference data [12] and depends on *q*parameters–significance value($q = 0,05$), f_1 – numbers of degrees of freedom of each estimate of ordinal dispersion ($f_1=m-1$), $f2$ – number of independent estimates of dispersion.

During measurement of measure in statics, value of Cochran's Q test: q=0,95, m=5, andf_1=4, G_{table}=0,192, with 95% probability.

After verification of homogeneity of variance, standard deviation was determined, random error volume by Student's test was calculated, absolute error volume (when measuring with the help of measuring tape $\Delta X_{j_{np}}$ = 0,01 cm)and ratio error volume were calculated. Calculation example is given in Table 1.

Table 1**. Mathematical expressions and calculation example of statistical data processing figures (as exemplified by Movement No. 1)**

Name of statistical processing figure	Figure formula	Calculated value for Movement No. 1					
		Designation of changing measures*					
		Wb	Wl	Ssh	Uag	Al	Swf
Arithmetic mean of the figure	$X_j^S = \sum_{m=1}^{m} X_j^m / m$ m – quantity of parallel researches; X_j^m – measure volume.	38,82	43,42	51,54	118,02	66,64	27,38
Ordinal error mean square	$S_j^2 = \frac{1}{m-1} \cdot \sum_{m=1}^{m} \left(X_j^m - X_j \right)^2$	0,727	0,217	0,253	0,027	0,103	0,217
Standard deviation volume	$\overline{S}_y = \sqrt{\frac{\sum_{m=1}^{m} \left(X_j - \overline{X}_j \right)^2}{m \cdot (m-1)}}$	0,3813	0,2083	0,2249	0,0735	0,1435	0,2083
Random error volume by Student's test	$\Delta X_{random} = \overline{S}_y \cdot t_T$ t_T – tabulated value of Student's test, for five researches $t_T = 2,8$	1,068	0,583	0,630	0,206	0,402	0,583
Absoluteerrorvolume	$\Delta X_{gen} = \Delta X_{j_{random}}^2 + \Delta X_{j_{np}}^2$, $\Delta X_{j\ random}^2$ – random error volume	8,457	0,754	1,024	0,012	0,1699	0,754
Ratioerror	$\varepsilon = \frac{\Delta X_j^{gen}}{X_j} \cdot 100\%$	2,178	1,735	1,987	0,009	0,255	2,752

*Width of back, *Wb;* Center back waist length, *Wl;* Slash shoulder height of back, *Ssh;* Side waist to floor, *Vag;* Arm length, *Al;* Knee girth, *Swf*[10,11]

The difference in volume of measuring dynamic and static measures is a dynamic effect or dynamic growth. Its volume can be measured in centimeters (absolute value) or in percent (relative value) and is calculated by two formulas (2) and (3):

$$d_j^a = X_j^D - X_j^S, \qquad (2)$$

d_j^a absolute dynamic growth of "j" person;

X_j^D measure value in dynamics of "j" person;

X_j^S measure value in statics of "j" person;

$$d_j^R = \frac{d_j^a}{X_j^c} \cdot 100\% \qquad (3)$$

d_j^R relative dynamic growth of "j" person [12].

The values obtained are given in Table 2.

Table 2. **Dynamic growth to the measure while performing typical movementsof employees of pipeline companies**

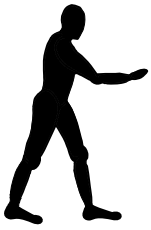
Schematic illustration of movements of employees while doing work	Characteristics of dynamic pose of corresponding movement	Designation of changing measures	Measure volume, cm		Volumes to wards dynamic growth	Dynamicgrowth volumetomeasure, %
			In statics	In dynamics		
			X_c	X^c_d	d^R_{medium}	
1	2	3	4	5	6	7
	MovementNo.1 (j=1) Legsapart, corpus isslightlytiltedforward, handslaidforward andbentatelbowata nobtuseangle	Width of back	36,1	38,82	7,5346	7,54±2,178
		Center back waist length	42,6	43,42	1,9249	1,93±1,735
		Slash shoulder height of back	51	51,54	1,0588	1,06±1,987
		Side waist to floor	117,5	118,02	0,4426	0,44±0,009
		Arm length	66,5	66,64	0,2105	0,21±0,255
		Shoulder girdle	27,4	27,38	-0,073	-0,07±2,752

Table 2 continuation

1	2	3	4	5	6	7
	Movement No.2 (j=2) Fullbodyframetilt, kneess lightly bent, hands put down or bent at elbow.Single support leg	Width of back	36,1	48,44	34,183	34,18±1,295
		Center back waist length	42,6	45,10	5,8685	5,87±0,003
		Slash shoulder height of back	51	54,52	6,902	**6,90±1,382**
		Side waist to floor	117,5	118,74	1,0553	1,06±0,014
	Movement No.3(j=3) Knee bending with one knee lean. Bending angle is 45º.Hands slightly laid forward and bent at the elbow	Width of back	36,1	50,28	39,28	**39,28±0,023**
		Center back waist length	42,6	43,80	2,8169	2,82±0,234
		Slash shoulder height of back	51	54,22	6,3137	6,31±0,021
		Side waist to floor	117,5	120,86	2,8596	2,86±0,269
		Arm length	66,5	69,04	3,8195	**3,82±0,913**
		Knee girth	38	44,34	16,684	**16,68±3,313**
		Waist girth	79	79,36	0,4557	0,46±0,174
	Movement No.4(j=4) Sitting position: legs bent at knees at 80-90º. Hands laid forward	Width of back	36,1	47,4	31,302	31,30±0,041
		Center back waist length	51	51,38	0,7451	0,75±0,009
		Slash shoulder height of back	42,6	43,52	2,1596	2,16±0,692
		Side waist to floor	117,5	118,62	0,9532	0,95±0,194
		Arm length	66,5	66,4	-0,15	-0,15±0,656
		Knee girth	38	41,48	9,1579	9,18±0,484
		Waist girth	79	79,24	0,3038	0,30±0,022

Table 2 continuation

1	2	3	4	5	6	7
	Movement No.5(j=5) Back lying: straight legs, slightly raised body frame, hands laid forward and bent at elbow at 100º.	Width of back	36,1	41,08	13,795	13,79±0,011
	Movement No.6(j=6) Stairs climbing: one leg is straight and the other one is bent at 90º, hands laid for ward and slightly bentatel bow	Width of back	36,1	49,1	36,01	36,01±0,003

Provision ofdynamic correspondence of system “human-work clothes” for use in environment is one of the relative objectives of designing clothes for employees of pipeline companies. Therefore, to create high-quality designs it is important to make experimental researches on changing employee’s body measure in terms of dynamic loads. Dynamic growth are determined bythe change of human’s measure volume while performing the specified movements. The maximum dynamic growth volumes are given in Table 3.

Dynamic growth to measures, which are typical for defined movements, are crucial for calculating widening while designing clothes. The established dynamic growth as a result of ergonomic researches, allow to determine rational widening and constructive means of dynamic compliance for shoulder and belt clothes for employees, and can be recommended for use while designing range of special clothes that meet requirements while in operation.

The next stage of work was the calculation of absolute values of dynamic growth to the measure, based on their maximum in percentages, the results of calculation sare given in Table 3.

Table 3. **Maximum dynamic growth volume**

Name of measure, designation	Absolute dynamic growth volume, cm	Dynamic growth volume, %
1.Width of back, *Wb*	4,99	39,28±0,023
2. Center back waist length, *Wl*	2,6	6,10±1,955
3. Slash shoulder height of back, *Ssh*	3,52	6,90±1,382
4.Side waist to floor, *Vag*	3,36	2,86±0,269
5.Arm length, *Al*	2,54	3,82±0,913
6. Knee girth, *Swf*	6,34	16,68±3,313

The obtained values allowed to make changes in clothing design for the employees of pipeline companies (jackets and jump suits), in particular, Figure 1 provides the schemes of configuration of back patterns of male jacket including the increase in its width in the process of exploitation to the absolute value of the dynamic growth with the total value of about 5 cm, which is divided into two symmetrical pleats of 2.5 cm each. This figure shows the position options of an additional adjustable part in the form of a pleat on the jackets’ back details.

Similarly, recommendations for constructive means of providing the dynamic correspondence of clothes to movements of an employee of pipeline company during the performance of professional duties were suggested.

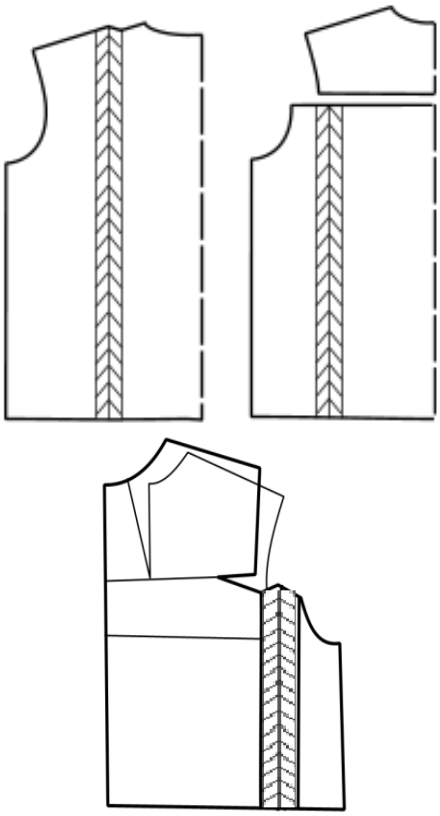


Fig. 1. The illustration of recommendations on changing male jackets' back design with pleats of 2,5 cm in width each

Conclusion. According to the study of dynamic growth, the recommendations for making changes in design of garments, jacket, jump suit and clothes ensemble for employees of pipeline companies were worked out. As a result of the study, constructive means of providing dynamic correspondence of clothes to human movements were recommended.

Study of types and methods of work of employees of pipeline companies allowed to select six movements of different purpose and difficulty category that lead to maximum movement of upper and lower extremities, corpus, which significantly influences the dynamic correspondence of clothes indicators. This set of movements allowed to investigate to the greatest possible extent the changes in human body's measures while designing shoulder and belt clothes for employees of pipeline companies.

Based on the chosen movements of an employee of pipeline companywhich could characterize changes of human body size during labour activity, the measurement of working person instatics and dynamics was made, followed by processing of results using mathematical statistics methods.

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ОБҐРУНТУВАННЯ ПАРАМЕТРІВ КОНСТРУКЦІЇ ОДЯГУ ДЛЯ ПРАЦІВНИКІВ ГАЗОТРАНСПОРТНИХ КОМПАНІЙ

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Мета. *В статті запропоновано покращення показників якості одягу для працівників газотранспортних компаній за рахунок обґрунтування параметрів конструкції деталей.*

Методика. *Для вирішення поставлених завдань використано загальну методологію системного підходу до проектування спеціального одягу. Для проведення антропометричних вимірювань та розрахунку динамічних приростів до розмірних ознак, використано стандартизовану методику.*

Результати. *За результатами дослідження динамічних приростів обґрунтовано параметри конструкції одягу для працівників газотранспортних компаній.*

Наукова новизна. *За результатами дослідження динамічних приростів до розмірних ознак працівника при виконанні професійних рухів розроблено рекомендації щодо внесення змін в конструкції деталей куртки та напівкомбінезона комплекту одягу. Як*

ОБОСНОВАНИЕ ПАРАМЕТРОВ КОНСТРУКЦИИ ОДЕЖДЫ ДЛЯ РАБОЧИХ ГАЗОТРАНСПОРТНЫХ КОМПАНИЙ

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Цель. *В статье обосновано улучшение показателей качества одежды для рабочих газотранспортных компаний за счет обоснования параметров конструкции деталей.*

Методика. *Для решения поставленных заданий использовано общую методологию системного подхода к проектированию специальной одежды. Для проведения антропометрических измерений и расчета динамических приращений к размерным признакам применена стандартная методика.*

Результаты. *Исходя из результатов исследования динамических приращений, обоснованы параметры конструкции одежды для рабочих газотранспортных компаний. Как результат исследований были рекомендованы конструктивные средства обеспечения динамического соответствия одежды движениям человека.*

Научная новизна. *Исходя из результатов исследования динамических приращений к размерным признакам рабочего во время*

результат досліджень були рекомендовані конструктивні засоби забезпечення динамічної відповідності одягу рухам людини.

Практична значимість. *Вивчено умови експлуатації даного виду одягу, зокрема режим праці працівників газотранспортних компаній, характер діяльності, основні та додаткові рухи та пози.*

Ключові слова: *одяг для працівників газотранспортних компаній, динамічні прирости, параметри конструкції.*

выполнения профессиональных движений, разработаны рекомендации по внесению изменений в конструкции деталей куртки и полукомбинезона комплекта одежды.

Практическая значимость. *Изучены условия эксплуатации данного вида одежды, а именно, режим работы рабочих газотранспортных компаний, характер деятельности, основные и дополнительные движения и позы*

Ключевые слова: *одежда для рабочих газотранспортных компаний, динамические приросты, параметры конструкции.*