Проведеними дослідженнями впливу бази даних на процеси формування універсальної конструкції встановлено механізм інтерактивного застосування кластерів розмірних ознак. Доведено, що типологічний ряд конструктивного розміру характеризує умовну типову фігуру молодіжного типу. Завдяки цьому стало можливим визначення рухомості конструктивних зон відповідно до морфологічних особливостей будови тіла на стадіях побудови основи конструкції. Експериментальними дослідженнями підтверджено, що межі функціональних ділянок у групуванні конструктивних зон підпорядковані мінливості приростів основних конструктивних точок. Це призводить до поліваріантності контурів тазової ділянки для формування властивостей співрозмірності штанів. Зокрема, встановлено, що завдяки ідентифікації подібності конструкцій за коефіцієнтом масштабування, адекватність бази даних підвищується шляхом координації інформаційної бази для побудови конструктивних зон. Це дозволяє стверджувати про достовірність механізму формування кластерів антропометричної бази даних та практичну привабливість запропонованої технології інтерактивного конструювання. Показано, що дисперсія приростів забезпечує деконструкцію замкненого контуру деталі в точках зміни функціональних ділянок, що є перевагами дослідження. Показано перспективність розширення діапазону морфологічних типів за віковою ознакою біодинаміки функціональних рухів.

Таким чином, є підстави стверджувати про можливість спрямованого регулювання процесів формування універсальної конструкції шляхом використання комплексної бази даних, яка поєднує кластери розмірних ознак, приростів і номенклатуру конструктивних зон

Ключові слова: кластер, розмірні ознаки, універсальна конструкція, конструктивні зони, прирости, морфологічне поле

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SIMULATION MODEL OF THE MORPHOLOGICAL FIELD OF DATA FOR CONSTRUCTING A UNIVERSAL DESIGN OF TROUSERS

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1. Introduction

Implementing the strategic direction towards advancing the garment industry in terms of entering new markets is aimed at the effective combination of metrological quality of a structure and the high adaptive capability of a finished article to functional operation requirements. Researchers and designers all over the world strive to achieve a more versatile process for the automated resize of clothes based on body sizes [1–4].

A wide range of methods for ensuring the versatility of a design is selected and combined in the clusters of databases, whose key module is the platform for a finished article functionality [5, 6].

Techno-economic advantages of using virtual objects in 2D and 3D modeling of clothes of any product range predetermined the application of universal structures as an alternative to structures on an actual body [7].

The mechanism of morphological transformation of a body's spatial characteristic in regulating the properties of operational and aesthetic quality of a article is algorithmic in character. Accordingly, it is a relevant task to undertake a study aimed at further improvement of the metrological effectiveness of applying the principle of unification of structural zones when forming a typological series of structural elements.

2. Literature review and problem statement

The advancement of computer technologies in the field of garment production based on kinect-systems that create a virtual model of clothes requires formalization of the anthropometric database of consumers' body figures. Paper [8] reports results of research into a 3D body surface scanning technology using the machine Anthroscan 3D VITUS Smart. It is shown that 3D scanning produces a larger number of measurements over a considerably shorter time. However, the anthropometric functions of changes in a article shape were left unaddressed. An option for integrating the anthropometric sections into a 3D classification of clothing could be a process of 3D-illustration of the virtual design of articles, used in work [9]. However, applying a changeable design platform as a 3D whiteboard in order to draw the virtual models of trousers does not provide information about accuracy in the automated alignment of a body figure contours by the garment. The structural size representativeness in the classifications of anthropological standards was theoretically substantiated in study [10]. The iterative model of mass settings is based on the method of «consumer satisfaction effectiveness» indexes. However, it should be noted that paper [11] lacks the conditions for selective population surveys in terms of their application in the sampling clusters. This means that the authors did not determine how the composition of a biological age period manifests itself in the stability of morphological attributes in specialized and addressed groups. A variant of accounting for the influence of specialized and addressed groups on empirical formulae of design calculation is to determine a representative structural size.

Study [12] reports results from using a MCDM model to ensure conformity of clothing to a consumer body shape size. It is shown that the size specification based on standard sizes and styles, GSS, appears controversial for a consumer. The reason for this is the objective difficulties in typical scenarios for selling clothes due to the complexity of a mathematical notation of size validation. An option for varying the starting anthropometric base in discrete quantities of the morphological structure of a population is the use of virtual 3D human models on the basis of data on anthropometry [13]. Applying the clustering of a body shapes confirms the static nature of anthropometric data in the parametric model of mannequins. The above allows us to argue that it is advisable to conduct a research aimed at preserving the variability of standard body figures within a typological series of a structural size.

An approach to using 3D virtual modeling for an individual body shape is reported in paper [14]. The authors defined a basis for design patterns in a part contour's structural points in order to improve the functional properties of trousers. However, the poly-variance in the displacements of structural points within a structural size was not confirmed by analytical estimates of variance within the range of variability in the coefficients for grading the discrete models of typical body shapes. Accordingly, it is appropriate to undertake a research into the influence of morphological patterns in the size-based attributes of the system of anthropometric planes on the coordination of structural zones in the design of belt articles.

3. The aim and objectives of the study

The aim of this study is to determine the clusters within a database for the processes of interactive design of competitive belt articles, aimed at specializing the size-based series and forming the structure of structural zones in a universal design with improved functional properties.

To accomplish the aim, the following tasks have been set:

– to determine the influence of morphological types of gender-age group on formation of a typological series of size-based attributes of a conditional structural size;

– to establish patterns in the formation of functional properties of structural zones interrelated with the size-based attributes of the morphological type of a body figure;

– to analytically substantiate the morphological field of parameters for structural zones based on the attributes of the morphologic type of a body figure in order to scale the universal design of trousers.

4. Materials and methods to study the morphological types of gender and age groups for the universal design of trousers

4. 1. The mechanism of identifying the functionality of trouser structural zones

Our morphological analysis of structural elements in the graphic construction of a design for basic components of classical trousers is based on the unified method of designing clothes of the CMEA (UMDC CMEA) procedure [15], underlying which is the principle of universality of structural zones in a grid of anthropometric planes of the lower part of a human body.

The typological analysis of size-based attributes for constructing the base of a trousers design was carried out using the following size standards:

1) OST 17-326-81 (women);
2) OST 17-916-89 (teen girls);
3) OST 17-325-86 (men);
4) GOST 17-917-86 (teen boys).

Classical methods for constructing a design of trousers are matched by 19 size-based attributes: 4 – main; 11 – subordinate; 4 – control.

AutoCAD 2014 software was employed to build the base of structures of the same size, implying the registration of structural zones for determining the lines of section deployment: pelvic, middle, and bottom.

The drawings of experimental structures for typical body figures were combined as follows: women's – universal; men's – universal, for determining the magnitudes of deviations in coordinates Δx, Δy. The equivalence of gains at main structural points was examined based on the estimated gradation coefficients.

Applying the morphological field mechanism to form a database coordinates the transmission of anthropometric information to the signal structure of morphological properties of size-based attributes. Indivisible structural elements of a flat structure are a point, a straight line, an arc. The structure is described using the following scheme: parametrical design module → structural module → structural zone → geometric module of the functional section → component.

4. 2. Procedure for determining the indicators of functional properties of the structural zones of trousers

The main indicators of the functional properties of trousers, which were determined in our experiment, were the following [14]: size-based attributes (T), basic structural points (BSP) of structural segments (SS), variance in coordinates: gradation (D), gains (Δx, Δy).

The indirect estimation of influence of size-based attributes on variability of structural zones was carried out based on the results from grouping the size-based attributes into a typological series on the basis of similarity criteria for gender-age groups in the classifications of standard body figures. The constant and varying elements in the reliability of deviations of structural belts in the grid of anthropometric planes were determined from a discrete model of a universal standard body shape the size of 158-84.

We determined a conditional structural size in line with the following procedure. Analytical synchronization of standard body shapes takes into consideration the impact of the following complexes of anthropological examination [16]: basic – age-specific affiliation to a youth group (14–22 years), special – belonging to the group of mobile communications in online mode. According to studies [6, 17], customers as collaborators of design development under an automated mode are employed in verifying the prototype models creation.

A universal social type, in terms of communicative function, is in the active dynamic phase of life, has the similar status of behavior, established stable shape and body size. The size of 158-84 represents gender- and age-based belonging to the current classifications of typical body figures.

In order to reproduce the size-based attributes of age-related belonging in the sample, we traced the tendencies of intergroup and intragroup variability in the classifications of standard European-type body figures.

To select the structural size, we selected the size-based attributes of a fullness characteristic: hip girth (T_{19}), waist girth (T_{18}) (Table 1).

Table 1

Synchronized classifications of standard European-type body figures for the manufacture of belt clothing the structural size of 158-84

Size-based attribute	Women	Girls	Men	Boys	$\bar{X}$	S
T_{18}, cm min	63	63	70	64	65	1.39
T_{18}, cm max	66	72	76	76	72.5	4.09
T_{19}, cm min	88	88	88	89	88.25	0.25
T_{19}, cm max	92	92	92	90	91.5	2.0

A bottom range limit (min) characterizes the intragroup variability in the fullness component of the morphologic structure of the body; the upper range limit (max) characterizes the intergroup variability inn gender and age.

Representativeness of the morphologic types of a conditional body figure was investigated by a statistical method of intergroup and intragroup variance under two parameters: the arithmetic mean $\bar{X}$, the mean quadratic deviation S:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n}\frac{X_i - \bar{X}}{n}, \tag{1}$$

$$S = \sum_{i=1}^{n}\sqrt{\frac{\left(X_i - \bar{X}\right)^2}{n}}, \tag{2}$$

where X_i is the magnitude of the i-th size-based attribute; n is the totality of size-based attributes.

To construct a typological series of size-based attributes, 19 size-based attributes for building a trouser structure were used [12]: T_1, T_7, T_8, T_{12}, T_{15}, T_{16}, T_{18}, T_{19}, T_{21}, T_{22}, T_{25}, T_{26}, T_{27}, T_{46}, T_{51}, T_{23}, T_{49}, T_{50}.

To determine the gradation coefficients of size-based attributes (D_i) and gains Δx_j, Δy_j, we used a standard procedure of proportional calculations in our design.

4. 3. Analytical substantiation of the morphological field of structural zones in the design of trousers

In practical design, a geometric object is a flat component whose contours (according to GOST 4.45-86) should correspond to sections that cover the lower part of the body in terms of static and ergonomic compliance and which ensure the functionality of a article. Empirical comprehension of the algorithm for constructing trousers confirms the independence of the basic scheme of a design (Fig. 1) on gender and size-based attributes in the grid of anthropometric planes, which is described by the set of size-based attributes, SAs. The morphological field of SA defines boundaries between the structural zones, SZs, for the specified design category (a type of design with three structural holes: 1 – waist, 2 – lower limbs) [14, 18].

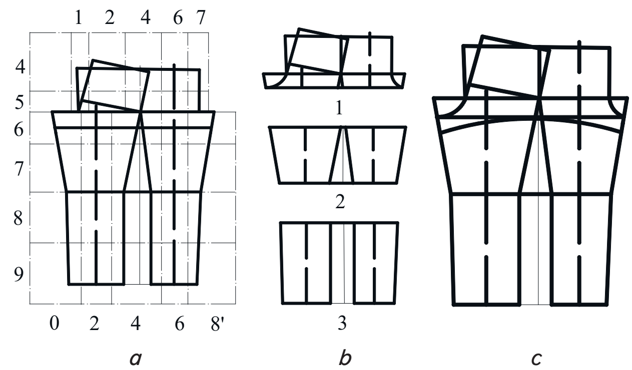


Fig. 1. Principal diagram of trousers design: *a* — grid of anthropometric planes; *b* — modules of functional sections based on a combination of structural zones: 1 — pelvic; 2 — middle; 3 — lower; *c* — types of design decomposition

Based on the functionality attributes, three groups of structural elements were identified in the design construction:

– basic ones determine the number of typical decompositions into components that cover part of a body;

– auxiliary ones define the parameters of structural zones along the lines of structural belts;

– combined ones characterize a contact between elements at the points that connect a flat contour of the geometric module of a component's part in technological operations. This approach makes it possible to apply the boundaries of structural zones in order to establish the functional sections in a body cover according to the requirements of dynamic conformity [3, 19] (Fig. 2).

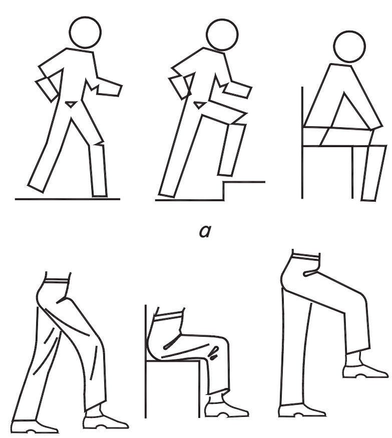


Fig. 2. Changes in the system «human — article» in dynamics: *a* — ergonomic schemes; *b* — position of the bottom of the trousers in statics and dynamics

The number of observations for simulation modeling is defined as the product of the number of structural zones in geometric modules and the number of basic structural points, BSPs, in the design construction: $i_{num} = \overline{1.60}$; Cd=2; SA=19; SZ=11; GM=6; BSP=22.

To ensure a flat contour line layout, it is advisable to use graphical techniques to connect BSP, which bring a plot to a straight line or to the arc of a circle [20].

The empirical curves of the midline contour in the design of trousers can be replaced with corresponding lines of conical cross-sections, which are implemented by the method of radius (Fig. 3).

A feature in the design of the rear part of trousers is to determine the rear balance Δ_r by making a forced turn at the assigned magnitude (Fig. 4), which is primarily a function of the following size-based attributes T_i [21]:

$$\delta_r = f\left(T_{18}, T_{19}, T_{22}, T_{51}\right). \qquad (3)$$

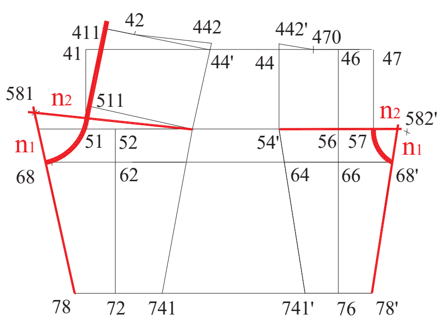


Fig. 3. Approximation of curved elements of trousers components contours: I — middle line of the rear part of trousers; II — middle line of the front part of trousers

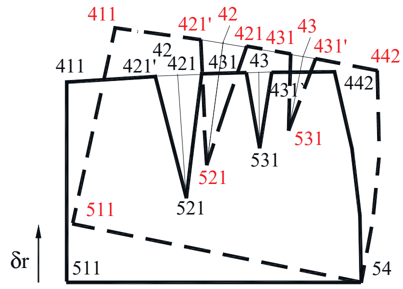


Fig. 4. Schematic of determining the turn of an upper rear pelvic part of trousers

The estimation method of determining Δ_r takes into consideration the difference between T_{19} and T_{18}:

$$\delta_r est = \frac{T_{19} - T_{18}}{4}. \qquad (4)$$

For the criterial evaluation of the gender influence of T_{19} and T_{18}, we performed a regression analysis of compliance between Δ_r and the sizes of standard body figures. The analysis was conducted by forming an anthropometric database using the arithmetic mean $\bar{X}$ and variance S in line with OST 17-325-86 and OST 17-326-81 (Table 2).

The linear dependence of magnitude Δ_r and the size of a typical body figure (Fig. 5) confirms the possibility of combining a structure of the rear pelvic section for men's (group 1) and women's (group 2) trousers into the middle one (group 3).

Table 2

Anthropometric database to determine the magnitude of Δ_r for standard body figures of fullness II for two basic heights

Size-based attributes	Magnitude of size attributes													
	OST 17-325-86 Height 170/176					$\bar{X}$	S	OST 17-326-81 Height 158/164						
$0.5T_{16}$	44.0	46.0	48.0	50.0	52.0	48.0	2.0	44.0	46.0	48.0	50.0	52.0	48.0	2.0
$0.5T_{18}$	38.0	40.0	42.0	44.0	46.0	42.0	2.0	34.4	36.5	38.6	40.7	42.8	38.6	2.1
								33.8	35.9	38.0	40.1	42.2	38.0	
$0.5T_{19}$	47.0	48.5	50.0	51.5	53.0	50.0	2.0	48.0	50.0	52.0	54.0	56.0	52.0	2.0
	47.4	48.9	50.4	51.9	53.7	50.4								
$0.5(T_{19}–T_{18})$	9.0	8.5	8.0	7.5	7.0	8.0	0.5	13.6	13.5	13.4	13.3	13.2	13.4	0.1
	9.4	8.9	8.4	7.9	7.4	8.4		14.2	14.1	14.0	13.9	13.8	14.1	
Δ_r	4.5	4.25	4.0	3.75	3.5	4.0	0.25	6.8	6.75	6.7	6.65	6.6	6.7	0.05
	4.7	4.45	4.2	3.95	3.7	4.2		7.1	7.05	7.0	6.95	6.9	7.0	

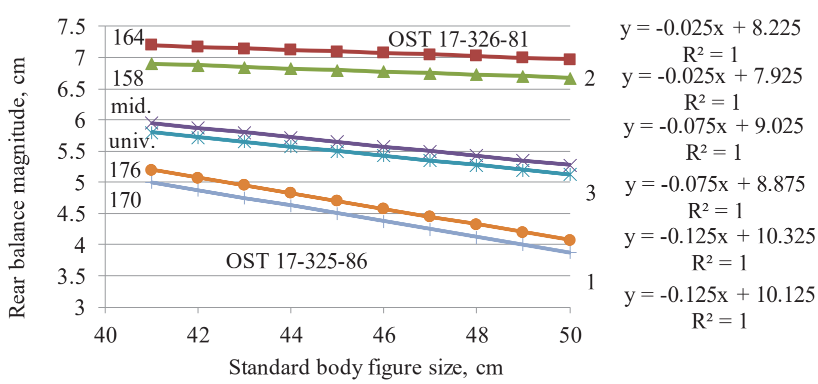


Fig. 5. Dependence of the rear balance magnitude on size of a standard body figure

The normalized parametric series Δ_r (5.5; 5.35; 5.2; 5.05; 4.9) takes into consideration a gradation coefficient D_{22}=0.15 cm for the unified structure of a typical section of trousers the size of 96 and characterizes the linear variability of the balance in the range of sizes 42–46 within a «unisex» segment.

The morphological field of structural elements in the lower part of trousers is characterized by displacements schemes with respect to verticals of a side seam and the midlines of front and rear parts (Fig. 6).

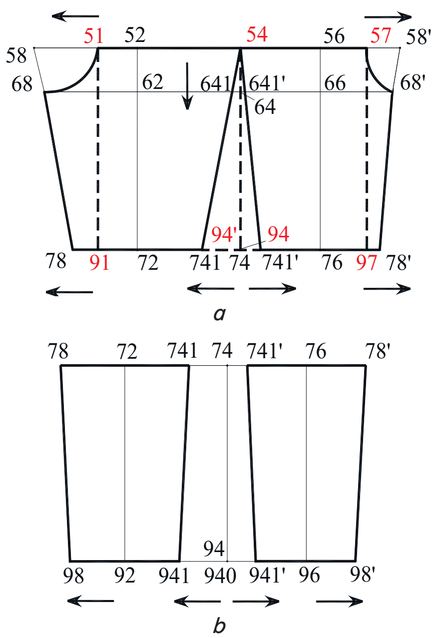


Fig. 6. Schematic of interactive restructuring of structural zones in the lower part of trousers: *a* — middle section module; *b* — lower section module

5. Results of research into changes in the parametric indicators of structural zones of trousers

Taking into consideration recommendations [23], the interpretation of anthropometric information on the morphological patterns of size-based attributes for the lower part of a body was performed for the structural size of 158-84 (Table 3).

SAs T_{18}, T_{19} in most classifications of standard body figures for belt articles are the basic ones.

The results from a graphical study of variance in the gains of subordinate size-based attributes Δx, Δy along the lines of anthropometric planes depending on gender are shown in Fig. 7.

It should be noted that a deviation in the size-based attribute T_{19} over the range of 0.1–0.4 cm for the selected four gender-age groups is consistent with the condition for normalizing a article's width control measurement for the conditional morphological type of a youth group. The deviation magnitude arithmetic mean $\Delta X_{T_{19}} = 0.325$ cm is within the boundary deviation from the rated size of a article, ±1.0 cm (DSTU GOST 25295:2005).

A deviation of SA T_{18} over the range of 0.4–5.5 cm and $\Delta X_{T_{18}} = 2.8$ cm corresponds to the condition for maintaining an inter-fullness interval of ±6.0 cm and belongs in the typological series of SA 158-84 of the conditional morphological type.

The deviations of subordinate SAs both within a Δy group, from 0.4 to 1.0 cm, and within a Δx group, from 0.325 to 1.85 cm, have confirmed the expediency of using a combined anthropometric base on terms of a gender attribute: women and men. The deviation of SA T_{26} of $\Delta Y_{T_{26}} = 1.0$ cm coincides with the boundary deviation from the rated size, ±1.0 cm (DSTU GOST 25295:2005).

A scaling method [22] was used to investigate deviations of the size-based attributes in the coordinates of basic structural points.

The mathematical apparatus of scaling, aimed at testing the designs of trousers for different gender-age groups, is described by scaling coefficients:

$$k_x = \frac{\sum_{i=1}^{n} a_i}{n}, \quad k_y = \frac{\sum_{i=1}^{n} d_i}{m}, \qquad (5)$$

where

$$a = \frac{x_i}{x_0}$$

– scaling coefficient along the X axis for the i-th structural point;

$$d = \frac{y_i}{y_0}$$

– scaling coefficient along the Y axis for the i-th structural point; $n(m)$ – number of structural points lying in the direction of the $X(Y)$ scaling axis.

Table 3

Systematization of deviations in the size-based attributes of the lower part of a body based on principle of unification of gender-age groups. Size 158-84

Deviations of SAs along the lines of anthropometric planes Δx, Δy		UMDC CMEA-based designation of a size attribute	Gender						Range
			women			men			
			Age group based on a size standard						
			Δ_1	Δ_2	$\bar{X}\delta_w$	Δ_3	Δ_4	$\bar{X}\delta_m$	$\bar{X}$ type
Basic size attributes	Δy	T_1	0	0	0	0	0	0	0
	Δx	T_{16}	0	0	0	0	0	0	0
	Δx	T_{18}	1.8	2.4	2.6	5.6	0.4	3.0	2.8
	Δx	T_{19}	0.1	0.3	0.2	0.5	0.4	0.45	0.325
Subordinate Δy	Δy	T_7	0.1	1.0	0.55	1.4	0.5	0.95	0.75
	Δy_d	T_8	0.36	0.14	0.25	0.46	0.64	0.55	0.4
	Δy	T_9	0.4	0.6	0.5	1.4	1.2	1.3	0.9
	Δy	T_{12}	0.8	0.5	0.65	0.9	1.3	1.1	0.875
	Δy	T_{25}	0.1	0.3	0.2	2.2	0.1	1.15	0.675
	Δy	T_{26}	0.2	1.5	0.85	1.8	0.5	1.15	1.0
	Δy	T_{27}	0.3	0.5	0.4	1.2	1.0	1.1	0.75
	Δy_d	T_{49}	1.0	–	0.5	1.1	–	0.55	0.525
Subordinate Δx	Δx	T_{15}	0.3	0.1	0.2	0.2	0.7	0.35	0.325
	Δx	T_{21}	1.6	2.1	1.85	2.4	1.3	1.85	1.85
	Δx	T_{22}	0.5	0.8	0.7	0.1	0.2	0.15	0.4
	Δx	T_{46}	0.3	0.3	0.3	0.4	0.35	0.375	0.337
	Δx_d	T_{50}	0	–	0	0	–	0	0
	Δx	T_{51}	1.0	0.6	0.8	0.5	1.0	0.75	0.775
	Δx_d	T_{23}	0.3	0.2	0.25	0.1	0.1	0.1	0.175

Note: index Δx_d, Δy_d denote a control SA

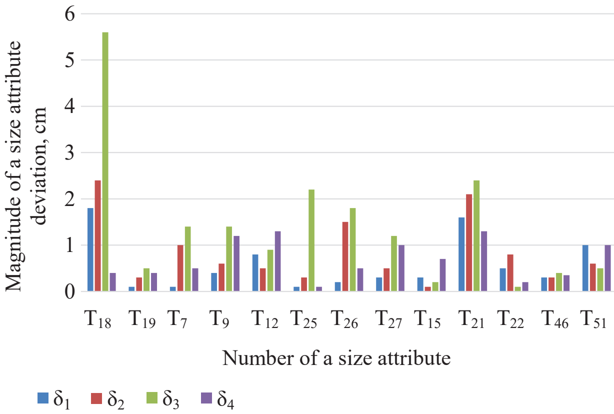


Fig. 7. Diagram of observations of anthropometric information to identify the morphologic age of a consumer

tude (formula 3): men /41-51/=0.65·(T_7–T_{12})–3.0; women /41-51/=0.65·(T_7–T_{12})–2.0.

Differences in the constant regression coefficient for women's and men's body figures may be excluded since the youth group shows a tendency towards an increase in the length of a lower part of the body: T_7, T_9, T_2, T_{27}.

The pelvic area became shorter and narrower in the frontal plane, confirming the appropriateness of the group arrangement of gains in the structural zones of the pelvic, middle, and lower sections of a trousers design by calculating the magnitudes of gradation coefficients in order to determine the coordinates of BSP displacements.

The results from our analytical study of the estimated gradation coefficients (Δx, Δy) for the BSP of a structure's base are given in Table 5.

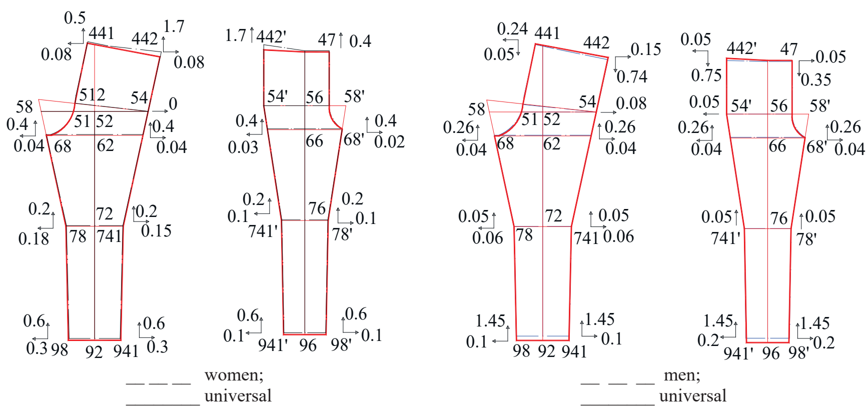
The results from studying the three bases of trousers designs (women's, men's, universal), built in AutoCAD, by determining the deviations in the BSP coordinates of the combined structures of the rear and front parts are shown in Fig. 8.

The displacement directions show that we obeyed the rules for passing the starting gradation axes for trousers.

Specifically, the rear part – p. 52, horizontal – hip line/51-54/, vertical – fold line/52-72/; front part – p. 56, horizontal – hip line/54′-57/, vertical – fold line/56-76/.

Based on the sequence of control over the magnitudes of SA deviations Δx_i, Δy_i within the structural zones (according to Fig. 8), we have separated the size-based attributes (Table 4) that correspond to the levels of horizontals and verticals of anthropometric planes (shown in Fig. 1).

It should be noted that the pelvic section is characterized by SAs related to the dynamic comfort of belt arrangement and the balance magni-



a *b*

Fig. 8. Schematic of interactive trousers design for a standard body figure: *a* — women; *b* — men

Table 4

Size-based attributes that correspond to the levels of horizontals and verticals of anthropometric planes in the trousers design

Functional section	Anthropometric plane	Gains	Size attributes
Pelvic	horizontal 4, 5, 6	Δy	T_7, T_8, T_{12}, T_{26}
	vertical 1, 2, 4, 6, 7	Δx	T_{18}, T_{19}, T_{21}, T_{22}
Middle	horizontal 6, 7, 8	Δy	T_{26}, T_{12}, T_9, T_{49}, T_{23}
	vertical 1, 2, 4, 6, 7, 8, 8′	Δx	T_{18}, T_{19}, T_{21}, T_{22}, T_{50}
Lower	horizontal 7, 8, 9	Δy	P_1, T_7, T_{26}
	vertical 1, 2, 4, 6, 8, 8′	Δx	T_{21}, T_{22}, T_{50}, T_{51}

Table 5

Estimated gradation coefficients for the base of a trousers design. Size 158-84

Gradation point	Rear part						Gradation point	Front part					
	Δx_m	Δy_m	Δx_w	Δy_w	Δx_u	Δy_u		Δx_m	Δy_m	Δx_w	Δy_w	Δx_u	Δy_u
51	0	0	0	0	0	–	57	–	–	–	–	–	–
58	0.36	–	0.465	–	0.105	–	56	0.2484	–	0.322	–	0.0736	–
52	0.157	–	0.203	–	0.046	–	54′	0.675	–	0.85	–	0.175	–
68	0.36	–	0.465	–	0.105	–	741′	0.4097	1.915	0.2633	1.565	0.1464	0.35
78	0.02	1.898	0.0495	1.565	0.0285	0.333	76	0.2484	1.915	0.322	1.565	0.0736	0.35
72	0.157	1.898	0.203	1.565	0.046	0.333	941′	0.30515	0.585	0.3619	0.75	0.05675	0.165
98	0.157	0.585	0.203	1.565	0.046	0.333	96	0.2484	0.585	0.322	0.75	0.0736	0.165
92	0.157	0.585	0.203	1.565	0.046	0.333	98′	0.2196	0.585	0.512	0.75	0.2924	0.165
941	0.336	3.7	0.2825	3.6025	0.0535	0.0475	78′	0.102	1.8975	0.061	1.365	0.041	0.5325
741	0.4235	3.7	0.434	3.6025	0.0535	0.0975	68′	0.36	–	0.465	–	0.105	–
54	0.6750	–	0.575	–	0.1	–	47	–	0.5525	–	0.75	–	0.1975

Note: Δx_m, Δy_m – *men;* Δx_w, Δy_w – *women;* Δx_u, Δy_u – *universal*

The variance Δx, Δy in the eponymous points is explained by the variance of deviations within a typological series of size-based attributes (Fig. 7).

Since the morphological field of a structure within the contours of a component includes the closed information system related to elements of SA, BSP, D, Δx, Δy, the adequacy of experimental structures in terms of similarity criteria was tested by a scaling technique relative to a conditional body figure based on gender belonging. The matrix of scaling coefficients k_{si} is given in Table 6.

Table 6

Scaling coefficients matrix for the elements of a morphological field for a universal design of trousers

Array of scaling field	Scaling direction	Scaling coefficient			
		$k_s x_1$	$k_s x_2$	$k_s y_1$	$k_s y_2$
SA	conditional – women	1.46	–	0.93	–
	conditional – men	–	1.07	–	1.085
BSP	conditional – women	0.96	–	0.99	–
	conditional – men	–	1.034	–	1.033
D	conditional – women	1.42	–	0.93	–
	conditional – men	–	1.034	–	1.085
Δx, Δy	conditional – women	0.93	–	0.987	–
	conditional – men	–	1.085	–	1.014

Note: x – experimental; y – estimated; index 1 – women, 2 – men

The typological variability of the morphological field in terms of gender belonging should be noted. This is true of SA and D for an experimental size of a body figure, which are characterized by the poly-variance of pelvic section contours.

Based on the results of research into the estimated projected measurements of the pelvic part of a body (Fig. 9), we determined variability ranges of the magnitudes of darts at the waist.

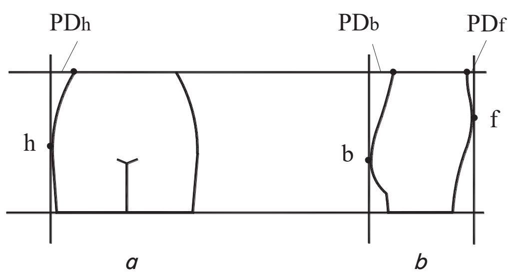


Fig. 9. Schematic for determining the projection measurements of deflections in the pelvic section of a female body: *a* — front view; *B* — side view

The projection spread of darts ΣPD for the examined typological series of size 158-84 is given in Table 7.

The results from graphical analysis of dart magnitudes for the typological series of size 158-84 are shown in Fig. 10.

As shown by Fig. 9, the groups of the overall spread of waist darts BS are almost close to Δt T_i. A scale ratio for Wd via dt and ΣPD (women: $k_{s1}=1.21$, men: $k_{s2}=1.41$, universal: $k_s=1.31$) confirms the equivalence of spreads in the experimental (ΣWd) and standard (dt) darts. The variance in the range of 0.2 cm for dt–ΣWd corresponds to the following characteristic [24]: the shape of buttocks is semispherical, hip bulge is small, a flat-type abdomen; and it does not depend, within the typological series of size 158-84, on gender.

Table 7

Group analysis of waist darts spread magnitudes

Standard SAs				Estimated PD			
Designations	women	men	conditional	Designations	women	men	conditional
T_{55}	20.29	24.3	22.3	PD_h	4.47	2.595	3.535
ΔT_{55}	2.01	2.0	2.0	CD_h	5.41	3.66	4.63
T_{56}	29.3	29.49	29.4	PD_b	4.95	5.15	5.05
ΔT_{56}	0.1	0.1	0.1	CD_b	5.99	7.26	6.62
T_{111}	21.64	21.88	21.76	PD_f	2.05	–0.37	0.64
ΔT_{111}	0.12	0.12	0.12	CD_f	2.48	–0.52	0.84
T_{112}	4.95	5.15	5.05	ΣPD	11.47	7.375	9.225
ΔT_{112}	0.1	0.1	0.1	ΣCD	13.88	10.04	12.09
T_{95}	14.64	17.5	16.07	–	–	–	–
ΔT_{95}	1.43	1.43	1.43	–	–	–	–

Note: PD – measured on a figure; CD – calculated by projection dimensions

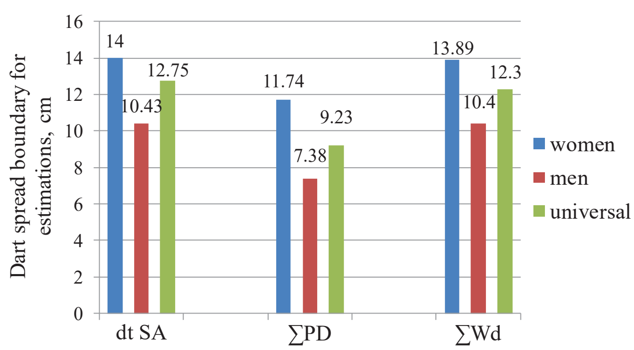


Fig. 10. Graphical interpretation of waist dart magnitudes for a typological series of size 158-84

Investigation of a deformation load action on convenience of a article when in motion determines the importance of the type of a dynamic posture for indicators of ergonomic properties [25] and the distribution of deformation of elongation over structural zones (Fig. 11, Table 8).

The distribution of elongation deformations over structural zones confirms the presence of the most active load at CZ4, due to the protrusion of buttocks and the dynamic effect of changing the distance from the line of girth waist to a dart under buttocks $T_{49}d$. Elongation Δl along the width at section /52-53/ is 0.73 cm, along the length at section /42-52/ is 0.54 cm. This difference in Δl is predetermined by the different stretching properties of warp and weft threads.

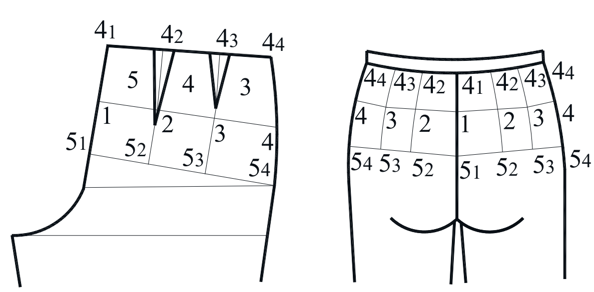
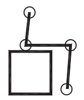
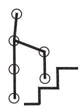
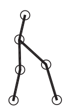
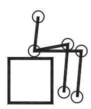
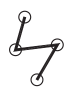


Fig. 11. Schematic of elongation deformation distribution over the structural zones of trousers

Table 8

Value of Δl depending on the type of a dynamic posture

No. of entry	Type of dynamic posture	Title of section in structural zone, cm									
		4_1–5_1	4_2–5_2	4_3–5_3	4_4–5_4	4_1–4_2	4_2–4_3	4_3–4_4	5_1–5_2	5_2–5_3	5_3–5_4
1		0.19	0.54	0.02	–7.99	0.2	0.19	0.01	0.35	0.63	0.24
2		0.01	0.32	0.01	–0.54	0.3	0.29	0.02	0.01	0.21	0.02
3		0.41	0.5	0.06	–9.31	0.44	0.35	0.02	0.5	0.73	0.26
4		0.02	0.22	0.12	–6.98	0.25	0.25	0.05	0.64	0.64	0.35
5		0.07	0.12	0.21	–7.32	0.14	0.28	0.15	0.35	0.45	0.28
6		0.03	0.42	0.2	–8.26	0.3	0.24	0.43	0.21	0.45	0.42
7		0.09	0.38	0.23	–5.98	0.27	0.36	0.25	0.26	0.71	0.28

In this sense, of special interest is the group arrangement of gains in the structural zones of the structural size of trousers. In contrast to studies [15, 26], the arrangement is performed by calculating gradation coefficients for the coordinates of BSP displacements, the interpretation of which is shown in Fig. 7. The variance of Δx, Δy deviations indicates the complexity of identification of structural zones according to the analytical-graphical method [15].

To identify the universal design of trousers, we used a simulation model of the morphological field of a component's contour (SA, BSP, D, Δx, Δy) based on the criterion of similarity (Table 6). Scaling of deviation arrays shows the gender-based poly-variance of pelvic section contours.

The comparison of magnitudes of balance in the spread of waist darts, defined in different ways, indicates the equivalence of geometric parameters. This agrees with the practical data from papers [12, 13, 27].

However, in contrast to the research results reported in [28, 29], the data acquired on the impact of size-based attributes and the set of movements on the process of section deformation make it possible to assert the following:

– the principal regulator of construction process is not so much the formation of a typological series of size-based characteristics, but the coordinating effect of BSP gains;

– a significant impact on the universal design is exerted by the continuity in the transitions of systems: a typological series of size-based attributes → mesh frame of anthropometric planes → structural zones – universal design;

– the possibilities of trousers construction are expanded through the use of scaling of structural zones in the front and rear parts.

Such conclusions can be considered appropriate. From a practical point of view, we can reasonably approach the coordination of information in the process of forming a database. From a theoretical point of view, they make it possible to show the mechanism of gains in the processes of modular design, which are certain advantages of this research. However, it should be noted that the experimental magnitudes of displacements (Fig. 8) indicate a poly-variant effect of size-based attributes on changing the boundaries of structure sections. This is evident, first of all, in the differences between the contours of a waist line of the pelvic section and the bottom line of the bottom section of trousers. This difference imposes certain restrictions on the use of the derived schemes.

A potentially interesting direction of further studies into the range of morphological types according to the age attribute of motion biodynamics would make it possible to

6. Discussion of results of studying the influence of elements in a morphologic structure of a belt article on the structure quality

In determining the effectiveness of coordination of a typological series of size-based attributes, as it follows from the results obtained (Table 3, Fig. 1), it is natural to retain the condition for normalizing control measurements of width and length of an article. This is predetermined by the synergy between key size-based attributes (T_1, T_{16}) and a set of subordinate attributes of a conditional morphological type. It should be noted that the number of size attributes for building a structure in line with an unified method of designing clothes of the CMEA procedure corresponds to the specialization of structural sections in the grid of anthropometric planes. Clearly, the mechanism of concentration of structural zones is a factor regulating the boundaries of functional sections for static and dynamic compliance by maintaining an inter-fullness interval. The deviation of T_{18} within the range of 0.4–5.6 cm and $\Delta X_{T_{18}} = 2.8$ cm confirms that the conditional morphologic type belongs to the standard size of 158-84. However, at the same time, the mechanism for applying size-based attributes in standard calculations of basic structural segments does not provide communication between modules of graphical construction of an article's components, as indicated in [20].

investigate the kinematics of structural zones, which should be taken into consideration in the silhouette transformation of trousers design.

7. Conclusions

1. Our research has established patterns in the formation of a typological series of size-based attributes for constructing the base of trousers design, which imply the application of age-related and a specialized complex of anthropological studies. Given this, it can be argued that the conditional morphological type of a body figure 158-84 adequately reproduces the standard dimensions of four gender-age groups: women and teenage girls, men and teenage boys. The magnitude of a waist girth significantly affects the poly-variance of changing the deviations in the design of the pelvic section. The size variability is manifested in the formation of typological series of magnitudes for the rear balance and waist darts.

2. Special features in the formation of functional properties of the universal design of trousers imply the application of interconnection between a frame model of structural zones of anthropometric planes and size attributes, established by scaling the overall increments. We have proven identity of design bases: scaling coefficients are within the range of 0.93–1.085.

3. Effectiveness of using modification types of pelvic sections of design base for the unified series of rear balance and waist darts indicates a possibility of interactive graphical restructuring of structural sections at the stage of silhouette modification using the technique for transforming structural gains.

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