

*The influence of modeling effect of the structural zones of a corset for everyday purposes on ensuring its comfort was studied. It was established that the design structure of a corset varies significantly, depending on the magnitude of the modeling effect on different torso sections. At the same time, the mechanism of application of zonal anthropometric correction of a torso varies depending on the comfort of materials. It was proved that morphological parameters of the women's torso zones affect the methods and parameters of the formation of the typical segmentation of a corset.*

*Due to this, it became possible to substantiate analytically the ergonomic parameters of modeling effect in the «corset – torso» system for interactive designing the silhouette structures. Experimental studies proved the dispersion of the points of structural zones in the ranges of morphological types. It was shown that the rational variant of the combination of technological modules ensures a dimensional transformation of corset zones by means of grouping. In particular, the prospects of adaptation of the combined shape of a corset to the individual figure type were revealed.*

*This makes it possible to assert the possibility of adaptive regulation of the feeling of comfort in a corset by combining zonal-modular models of anthropometric features and transformation of modeling effects in technological modules.*

*It was shown that the technological module of a bustier cup provides the polyvariance of the breast volume through vertical and horizontal segmentation. The technological module of a belt-corset, in addition to the properties of the basic fabrics, takes into consideration frame elements. This results in fixing the desired modeling effect.*

*Thus, there are some grounds to argue that the introduction of a new type of corset design will increase the productivity of design works. The practical comfort of the proposed technological solutions will ensure the reduction of the number of corset types and sizes, which in terms of comfort are universal for adjacent sizes*

*Keywords: comfort of a corset, modeling effect, design zone, morphological type, adaptive method*

# DEVELOPMENT OF AN ADAPTIVE METHOD FOR REGULATING CORSET COMFORT BASED ON THE PARAMETERS OF DESIGN ZONES IDENTIFICATION

**A. Slavinska**

Doctor of Technical Sciences, Professor\*

E-mail: tksv@khnu.km.ua

**O. Syrotenko**

PhD, Associate Professor\*

E-mail: syrotenko@email.ua

**V. Mytsa**

PhD, Associate Professor\*

E-mail: mitsa\_vv@ukr.net

**O. Dombrovska**

PhD, Associate Professor\*

E-mail: p\_dombrovska@ukr.net

\*Department Technology and Design of Garments  
Khmelnytskyi National University  
Instytuts'ka str., 11, Khmelnytskyi, Ukraine, 29016

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## 1. Introduction

A wide range of the methods of 3-D imaging in traditional processes of the shape formation of clothing from flat parts is based on 3D modeling methods. They imply using graphical software products from a 3D model of a person's figure to designing a product and its sweep [1–3].

One of the tendencies in fashion trends of aesthetic perception of the shapes of a female body is the use of different variants of adjustment of the breasts and torso shape with the help of corset items [4]. Corset items for cosmetic purposes are aimed at performing not only hygienic function, but also providing modeling effect on a torso using a set of functional elements from the position of shape fixing [5]. Corset items for medical purposes are aimed at the prevention and treatment of diseases and injuries of the muscular-skeletal system [6].

Exploration of designs and functions by manifestations of positive emotions through aesthetic and functional attri-

butes is based on qualitative analysis of interviews on the physical self-comfort of a person [7].

Gender differences in the motivation of the positive perception of social identity at the level of psychogenic need of women to use a corset determine the controlling effect in the creation of a unique image [8].

The algorithm of manipulative actions in transformed clothing is based on the concept of argumentation of aesthetic values in the preservation of functional properties [9]. Accordingly, the research aimed at enhancing the comfort of a corset by means of regulating modeling effects on body sections should be considered relevant.

## 2. Literature review and problem statement

Paper [10] presents the results of the research into the methodology of using the sweep method and the convex 3D

method to restore the shape of a virtual body using a computerized system to generate rigid images of a product. The variant of generating graphic 3D models of mannequins with typical shapes with subsequent anthropometric adjustment by means of proportional transformations in the grid of geodesic parallels is presented in article [11]. However, the issue of adaptation of a rigid mannequin shell to the action of the modeling effect during torso tightening by a corset to parameters of pressure in the zones of tight fitting for the «body-dress» system remained beyond consideration. The reason for this may be a fundamental impossibility of applying the typical design of underwear corset items to simulate a silhouette shape.

The criterial approach to designing a corset item for special purposes was proposed in [12]. An option of ensuring a level distribution of pressure for torso tightening may be the separation of functional zones for studying the tension points, which was outlined in [13]. However, a change of dart intakes in torso tightening areas was considered only in relation to a side seam. This suggests that it is advisable to conduct a study of zonal changes in the torso deformation. The study on the identification of the features of the volume-space shape of women's dresses in 2D drawings of a structure was partially implemented in [14]. Since the technology of the generation of silhouette parameters is based on variable parameters of air layers, it does not make it possible to apply the principle of «reference» points to identify the comfort of negative allowances in horizontal planes.

The method for the construction of a corset sweep according to research into the deformation of soft and hard shells was considered in [15]. The technological rationality of segmentation of three basic corset zones, which are swept as cylindrical or conical surfaces, into geometric modules was proved experimentally. The breast area is swept as spherical. The technical and economic advantages of using a general-modular model of the transformation of wedding clothing are studied in [16]. However, the parameters of the deformation of structural zones within silhouette allowances were not reasoned. Thus, it is advisable to conduct research into the silhouette deformation of a corset based on the coordination of potential energy of stretching and folding in corset segmentation zones.

### 3. The aim and objectives of the study

The aim of this study is to form a zonal-modular model of the polyvariant design of an everyday corset based on plane sweeps of the tightened surface of the body torso.

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

- to determine the impact of morphological types of the female torso structure on the choice of the variant of tightening to ensure the comfort of a corset;
- to develop the procedure of forming a database of negative allowances to take into consideration the deformation characteristics of the basic materials;
- to develop varied parameters of the size transformation of structural zones of a corset for correction of a female torso.

## 4. Materials and methods to study the functional properties of a corset

### 4.1. The procedure of identification of compositional dominants of functional properties of structural zones of a corset

The compositional aspect of the special function of an everyday corset involves fixing erotic zones by forming separate sections of the female body's torso due to the deformation of soft tissues. The bra zone accentuates the shape and the position of breasts. The zones of a half-corset reduce the belly bulge and outline the areas of hips and buttocks.

The historical aspect of modeling a female figure by a corset is demonstrated by the procedure of location of silhouette lines of the contour shape formation in the system of five horizontal lines (breast line I, breast line III, breast line IV, a waistline, a thigh line) [17].

The graphic editor of the Auto CAD system provides the construction of frontal and horizontal projections using the dimensional features of current standards. 36 dimensional features are used to construct a technical sketch of a female figure of size 158-88-96. The silhouette lines in the contour of a modeled figure were determined by scaling horizontal and vertical segments [18].

As can be seen from Fig. 1, silhouette lines of corsets of the XX and XXI centuries in geometric symbols of a shape fix the constant position of the waistline and the variable position of the neckline and hip lines.

To determine the main points of fixation and the outline of a geometric symbol of modern female corsets using the RAY command, the fixation points were joined by beam-lines (Fig. 2).

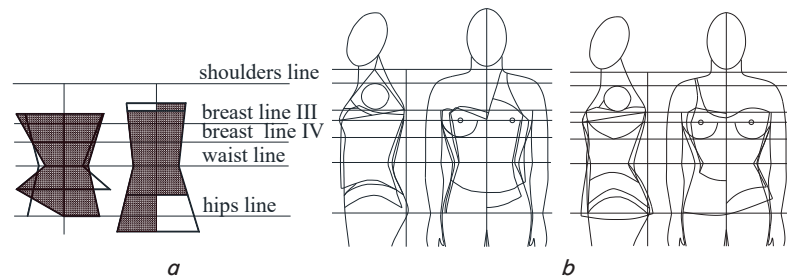


Fig. 1. Formation of zones of silhouette lines of a modern corset: a – erotic zones; b – functional zones

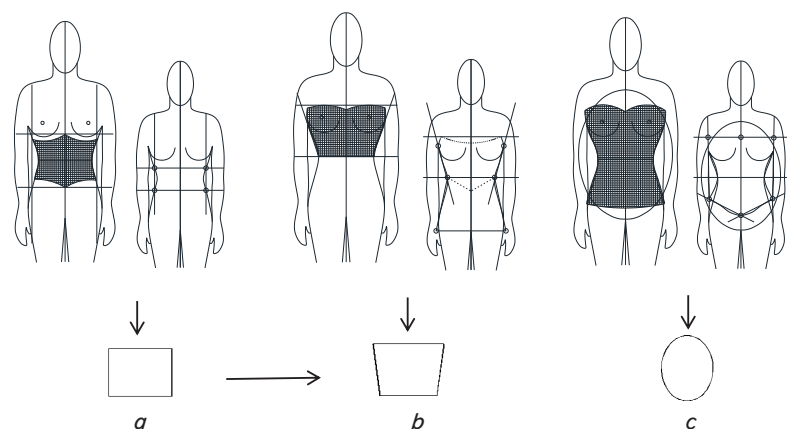


Fig. 2. Graphic interpretation of joining geometric symbols of a corset shape: a – rectangular; b – trapezoidal; c – oval

Four fixation points ensure the construction of a rectangular corset shape, eight points – a trapezoidal shape (four of which are for the length to the waist), six points – an oval shape. Geometric symbols of the corset shape are subordinated to the functional purpose of the torso modeling zones. Extrapolation of a torso of both rectangular and trapezium into an oval shape ensures the combinability of zones by the level of tightening.

The lack of proportionality and physiological comfort of corset zones for those who practice buying clothes through the network of Internet stores are often caused by the mismatch of negative allowances of a corset with the bra cups size. The possibility of transformation of a corset into adjacent sizes is ensured by a polyvariant design of two separate technological modules – a bustier (bra) and a belt-corset. Since a bustier emphasizes the existence of an erotic taboo for the breast shape, the technological module of belt-corset acts as a compositional dominant for tightening the torso sections.

**4. 2. A mechanism of studying the shape of the parts' contours by means of anthropometric identification**

The volume-spatial body shape is quite a complex object and at the same values of dimensional characteristics in different people, the sizes of separate body sections may differ, and the proportional structure of a body will have its own characteristics. The outer shape of a female body primarily depends on the skeleton, location, and distribution of fat deposits. The fat location and amount cause different magnitudes of tightening of a female figure by a corset. Three main types of body structure are separated according to constitutional classifications:

- 1) the type with a normal (conventionally uniform) distribution of tissues and masses;
- 2) the type of the upper distribution (upper part of a torso, specifically, breasts);
- 3) the type of the lower distribution (the largest volume is in the lower part, specifically, in the hips and abdomen sections).

The visual perception of the torso massiveness is assessed by grouping widths, in particular, narrow build, medium build, broad build types.

The metric index of the dimensional sizes of a figure (height, the girth of the breast, waist, hips) is used to evaluate fat deposits. Indices of proportions of curves in the

profile and horizontal planes characterize the upper and the lower torso types [19].

The consolidated matrix of indexing the proportions of a female body in the ranges of ratios is shown in Table 1.

A special anthropometric program for researching the modeling effect of a corset takes into consideration the anatomical features: the torso shape facing front and in profile, size of the breasts, and the posture. It also takes into consideration the morphological features – fat layer thickness ( $F$ ) and its elasticity ( $E$ ) at the waist levels ( $F_w, E_w$ ), hips ( $F_h, E_h$ ), and the girth of the fourth ( $F_{GbIV}, E_{GbIV}$ ).

The model of the organization of the numeric series of the sample volume for a special anthropological program for studying the tightening should take into consideration the segmentation of variability of morphological types by the feature of the narrow age interval. The numeric series of the sample volume is converging and uniform based on the feature of arithmetic progression in the sequence of numbers [20].

Calculation of the sample size for medical research in self-comfort is based on the magnitude of the minimum arithmetic progression:  $d_{min}=10$ , which is the supporting base for ensuring the objectivity of results of computer diagnostics.

Thus, the sample size of 10 people ensures the representativeness of grouping of subordinate dimensional features for the main structural size by the principle of intra-group variability minimization.

**4. 3. Algorithm of application of the zonal-modular model to determine the comfort of the modeling effect of a corset**

The study of the impact of modeling effect of a corset on the degree of the body surface deformation is to study the character of changes in human body size in a corset compared to dimensions of standard measurements. The researchers used a group of women aged 20 to 24 who do not have muscular-skeletal pathologies and chronic diseases according to the results of computer diagnostics in the laboratory of medical and biological examinations [21].

To determine the figure type, we used the leading dimensional features for corset products:  $H, Gb_{III}, Gb_{IV}, Gw, Gh$  using the standard measurement procedure. The confidence boundaries of the sample volume are assessed according to the parameters of the distribution of statistical data probabilities (Table 2).

Table 1

Matrix of indexing the proportions of a female body for figure types

Description type	Range of relations in calculations of indices				Conditional type
Indices of proportions of dimensional sizes	$M=Gb_{II}/H$	$K_1=Gb_{III}/H$	$K_2=Gw/H$	$K_3=Gh/H$	
Narrow build	<0.56	<0.556	<0.435	<0.582	N
Medium build	$0.594 \pm 0.038$	$0.514 \pm 0.038$	$0.475 \pm 0.040$	$0.633 \pm 0.051$	M
Broad build	>0.633	>0.633	>0.515	>0.684	B
Indices of proportions in the profile plane	$K_{bw}=d_{svb}/d_{svw}$	$K_{bl,b}=PD_{bl}/d_{svh}$	$K_{t1}=PD_{bl}/d_{svbIII}$	$K_{t11}=PD_{bl}/d_{svh}$	
Narrow build	<1.4	$\leq 0.026$	<1.4	0.026	N
Medium build	1.4	$0.029 \pm 0.03$	1.4	$0.029 \pm 0.03$	M
Broad build	>1.4	>0.029	>1.4	>0.029	B
Indices of proportions in the horizontal plane	$K_{wb}=d_w/d_{bIII}$	$K_{wh}=d_w/d_h$	$K_{bl,f}=PD_f/d_{svw}$	$K_b=C_{bII}-C_{bI}$	
Narrow build	<0.8	<0.8	<0.8	4.5	N
Medium build	$0.85 \pm 0.05$	$0.85 \pm 0.05$	$0.85 \pm 0.05$	4.0	M
Broad build	>0.9	>0.9	>0.9	3.5	B

Table 2

The values of statistical indicators of leading size features

Statistic indicator	Leading size feature, cm				
	<i>H</i>	<i>Gb<sub>III</sub></i>	<i>Gb<sub>IV</sub></i>	<i>Gω</i>	<i>Gh</i>
Minimum	158	87.93	74	66	92
Maximum	164	89.96	78	73.06	96
Class interval	6	2.03	4	7.06	4
Arithmetic mean	160.4	88.57	76.15	70.0	94.8
Mode	158	89	75	69.5	96
Median	158	88.45	76.25	70.98	96
Root mean square deviation	3.098	0.697	1.2	2.745	1.932
Variance	9.6	0.486	1.441	7.536	3.733
Asymmetry	0.484	0.77	-0.357	-0.32	-1.035
Excess	-2.276	-0.179	-0.36	-1.87	-1.22
Standard error	0.979	0.22	0.379	0.868	0.61
Calculation	10	10	10	10	10
Reliability level (95.0 %)	2.216	0.498	0.858	1.96	1.382

To study a change in the magnitudes of size features during corset tightening on the base waistline, three variants of magnitudes of modeling effect were selected: minimum – 1–2 %, medium – 3–5 %, maximum – 6–10 %.

A digital model of a typical mannequin of the 158-88-96 size, which can be converted into a frame model of layers of horizontal cross-sections in the zones, was selected as a graphic model of the research object. It is advisable to represent a graphic model of breasts by an ellipsoid (Fig. 3) using the recommendations of [22]. To study the deformation ability of corset fabrics to tighten, we selected the

standard procedure of studying viscous-elastic and strength characteristics in the «loading-unloading – rest» cycle. In accordance with the operational requirements for preservation of shape and durability, we selected deformations of stretching and rigidity, taking into account weaving and raw composition. The characteristics of fabrics are presented in Table 3.

The bioenergy impact of fabrics on human health taking into consideration the level of deformation capacity was assessed according to the procedure of electron point diagnostics PSI Vector LIA COR [23].

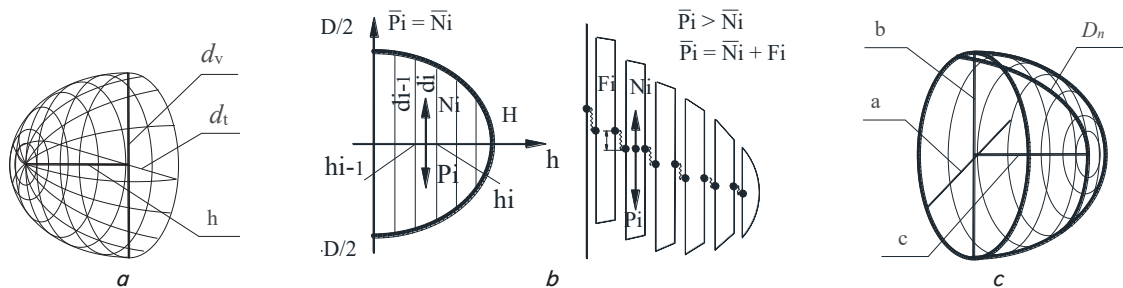


Fig. 3. Schematic of an ellipsoid as a prototype of the breast shape: a – geometric model; b – physical model; c – calculation model of breast volume (a – half the transverse diameter of the breast; b – half the vertical diameter of the breast; c – breast depth)

Table 3

Characteristics of materials

No. b/o	Condition- nal design- ation	Fabric	Width of material, cm	Density, number of threads per 10 cm		Surface density, g/m <sup>2</sup>	Thickness, mm (ISO 5084:1996)	Weaving	Raw material composition, %
				<i>T<sub>o</sub></i>	<i>T<sub>y</sub></i>				
1	CL	Calico	150	240	180	128	0.2	linen	Cotton
2	SD	Silk dress fabric	150	650	306	78.4	0.13	linen	AC-60, PE-40
3	SC	Dress fabric (crepe satin)	150	336	220	141.8	0.3	satin 5/3	AC-60, PE-40
4	ST1	Satin fabric	150	320	260	214	0.34	satin 5/3	PA-60, PE-20, IEA-20
5	ST2	Satin fabric	150	360	320	171.6	0.39	satin 5/3	PA-50, PE-30, IEA-20
6	BR	Brocade	120	273	283	196	0.52	plain large-patterned	Cotton-70, PE-30

Note: *T<sub>o</sub>* – density on base; *T<sub>y</sub>* – density on weft

**5. Results of studying the transformation parameters of the modeling effect of a corset**

**5.1. Determining conditional morphological types of a female torso structure to ensure functional properties of structural zones of a corset**

Statistical assessment of the leading size features within confidence boundaries of the sample volume (Table 2) proves the reliability of the anthropometric database for research into the comfort of a corset in the process of torso tightening.

The generalized type of the women of the experimental group according to fat deposits corresponds to the narrow build type (Table 4).

The research [20] analytically proved a significant impact on the magnitude of maximum modeling effect of a corset on the waistline of size features  $Gb_{IV}$  and  $Gw$  ( $r_{xy}=0.982$ ).

The influence of morphological features of a torso facing front and in profile (Table 5) determines the figure in the simulation zones and affects the choice of tightening option for studying the comfort.

The variability of the figure types in the characteristics of torso areas proves the appropriateness of using the detachable technological modules of a corset: for zone 1 – a bustier (bra), for zone 2 – a corset belt.

Since the magnitudes of the bend relative to the waistline differ for the upper and the lower parts of a torso, the recommended magnitudes of waist darts should take into

consideration the morphological characteristics of a figure in the static state (Table 6).

The variant of the typical figure of an electronic mannequin: 158–88–96:  $\delta_{tb}=0.35\delta t$ ,  $\delta_{ef}=0.3\delta t$ ,  $\delta_{ts}=0.36\delta t$  was selected as the compromise magnitude of distribution of waste darts  $\delta t$ .

Fig. 4 shows the results of the zones generation by horizontal cross-sections of the mannequin surface.

Table 4

Characteristics of the female figure type by proportionality coefficients

Number of subject	Proportionality coefficients								Generalized figure type
	$M=Gb_{II}/H$		$K_1=Gb_{III}/H$		$K_2=Gw/H$		$K_3=Gh/H$		
1	0.537	N	0.543	N	0.402	N	0.561	M	N-N-N-M
2	0.537	N	0.537	N	0.439	M	0.585	M	N-N-M-M
3	0.557	N	0.563	M	0.430	N	0.608	M	N-M-N-M
4	0.557	N	0.557	M	0.424	N	0.582	N	N-M-N-N
5	0.557	N	0.570	M	0.462	M	0.608	M	N-M-M-M
6	0.537	N	0.537	N	0.439	M	0.585	M	N-N-M-M
7	0.557	N	0.563	M	0.462	M	0.608	M	N-M-M-M
8	0.557	N	0.557	M	0.424	N	0.582	N	N-M-N-N
9	0.537	N	0.537	N	0.439	M	0.585	M	N-N-M-M
10	0.557	N	0.563	M	0.443	M	0.608	M	N-M-M-M
Mean value	0.548	N	0.55259	N	0.43651	N	0.5912	M	N-N-N-M

Table 5

Indexing the morphological characteristics of a torso of experimental female figures (size 88; growth 158, 164; fullness 1–a, 2–a)

Torso section	Descriptive morphological features		Coefficient	Ratios of size features				Figure type
	Facing front	Profile		158		164		
				88–92	88–96	88–92	88–96	
Chest	Broad	Round	$K_b$	3.7	3.7	3.5	3.5	B
Contour of the back	Convexity of shoulder blades relative to the waist	Insignificant	$K_{tl}$	–	0.21	–	0.21	N
		Medium		0.22	–	–	–	M
		Significant		–	–	0.23	–	B
	Convexity of buttocks relative to the waist	Insignificant	$K_{tII}$	0.15	–	0.15	–	N
		Medium		–	0.16	–	–	M
		Significant		–	–	–	0.17	B
Contour of the front	Convexity of breasts	Semispherical	$K_{bw}$	1.4	1.4	–	1.4	M
		Oval		–	–	1.5	–	B
	Convexity of belly	Flat	$K_{blf}$	0.026	–	–	–	N
		Normal		–	0.029	–	–	M
		Round		–	–	0.029	0.031	B
Contour of side lines	Concavity by waistline	Relative to breast diameter	$K_{wb}$	0.8	–	–	–	N
				–	0.9	–	–	M
				–	–	0.91	0.953	B
		Relative to hips diameter	$K_{wh}$	0.76	0.77	–	–	N
				–	–	0.8	0.812	M

Table 6

The ratio of morphological characteristics of dart intake points

Waist dart intake	Name of a dart by location	Formula	Figure size			
			158		164	
			88–92	88–96	88–92	88–96
Back	Dart on a back area	$\delta_{bb1}=0.06 C_w$	2.0	2.1	1.9	2.0
	Dart on a buttocks area	$\delta_{bb2}=0.084 C_h$	3.9	4.0	3.9	4.0
Mean value			2.95	3.05	2.9	3.0
Front	Dart on a front area	$\delta_{ff1}=0.5 (C_{bIII}-C_{bIV})$	4.1	4.0	4.2	4.1
	Dart on an abdomen area	$\delta_{ff2}=(C_h-C_{h,1})$	0.8	1.2	0.5	0.9
Mean value			2.45	2.6	2.35	2.5
Side	Upper dart	$\delta_{ts1}=(d_{bIII}-d_w)/2$	2.6	1.2	1.3	0.6
	Lower dart	$\delta_{ts2}=(d_h-d_w)/2$	4.4	4.5	4.7	4.8
Mean value			3.5	2.85	3.0	2.7
Total dart intake on the waistline, cm			8.9	8.5	8.25	8.2

Note:  $C$  – half-girth;  $d$  – transverse diameter

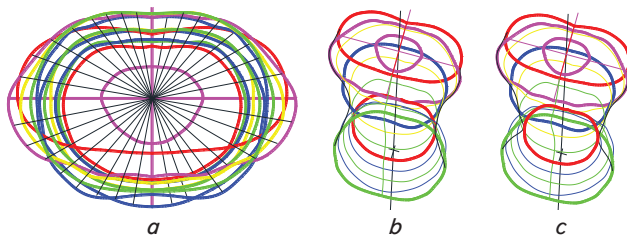


Fig. 4. Zones generation by horizontal cross-sections of the mannequin surface:  $a$  – horizontal cross-sections of the surface of a typical mannequin torso, size 158-88-96;  $b$  – outline of a typical mannequin without tightening;  $c$  – outline of the tightened typical mannequin

5. 2. Development of the algorithm of assessment of corset comfort depending on the magnitude of a modeling effect

The procedure of developing a database of negative allowances for the construction of a 3D model of a tightened mannequin was taken into consideration in the construction of the outline of a tightened mannequin [11].

At the maximum modeling effect, the value of transverse diameters of a figure decreases on average on breasts girth line III by 0.35 cm, on breast girth line IV – by 1.75 cm, on the waistline – by 4.35 cm, on the hips line – by 1.1 cm. The values of the front-back diameters decrease on breast girth line III by 1.75 cm and increase on the breast girth line by 0.65 cm, waist – by 0.15 cm, hips – by 1.6 cm.

According to the results of the studies of three stages of tightening (maximum, medium, minimum), we determined the rational negative allowances in silhouette designs of a corset (Table 7), which were implemented in the silhouette transformation of the optimal design of a female corset (Fig. 5).

Table 7

Rational negative structural ease allowances for a corset

Name of a silhouette	Silhouette designation	Allowance on breast line ( $Gb_{III}$ )	Allowance on breast line ( $Gb_{IV}$ )	Allowance on waistline ( $Gw$ )
		$ACGb_{III}$ , cm	$ACGb_{IV}$ , cm	$ACGw$ , cm
Tight-fitting	$Si_{01}$	-3.0	-3.0	-6.0
Close fitting	$Si_{02}$	-2.5	-1.4	-4.0
Semi-close fitting	$Si_1$	-2.0	-1.3	-2.0

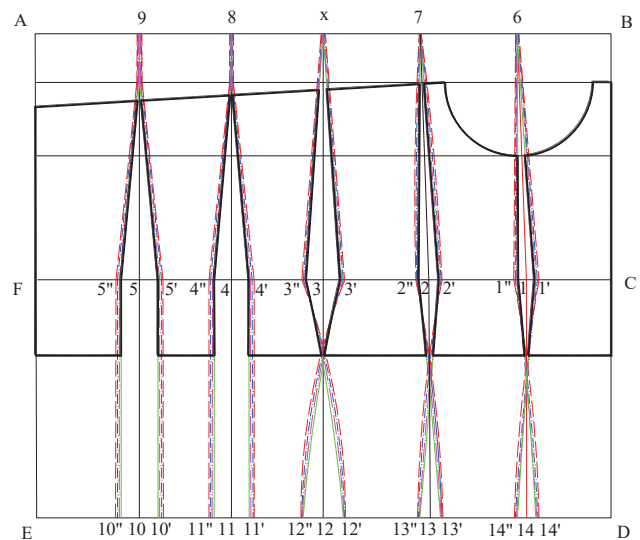


Fig. 5. Silhouette transformation of the optimal design of a belt-corset  $Si_{opt} \rightarrow Si_{01} \rightarrow Si_{02} \rightarrow Si_1$ :  
 — Optimal design  $Si_{opt}$ ; - - - Silhouette design of a corset  $Si_{01}$ ; - - - Silhouette design of a corset  $Si_{02}$ ; - - - Silhouette design of a corset  $Si_1$

The optimal design of a corset takes into consideration the conditions of a stable balance of fabric in longitudinal seams.

Potential energy deformation of material stretching in seams  $P_s$  is described (1):

$$P_s = \frac{T_y \cdot E_y \cdot S_y \cdot l_{k,j} \cdot \delta_{i,j}^2}{8}, \tag{1}$$

where  $T_y$  is the fabric density on a weft, n/10cm (according to technical conditions of the sweep, the warp thread passes perpendicularly to the waistline) ( $T_y=180$  n/10 cm);  $E_y$  is the module of fabric elasticity, N·cm<sup>2</sup> ( $E_y=3.363$  N·cm<sup>2</sup>);  $S_y$  is the area of the transverse cross-section of the weft threads, cm<sup>2</sup> ( $S_y=3.46 \cdot 10^{-4}$  cm<sup>2</sup>);  $l_{k,j}$  is the length of the contour of, cm ( $i=1.6; j=1.6$ ),  $i$  is the right contour;  $j$  is the left contour;  $\delta_{i,j}$  is the magnitude of stretching of the right and left contour on the part join area, cm.

Potential energy of folding deformation  $P_f$  in corset parts is described by (2):

$$P_f = \frac{0.7 \cdot T_y \cdot E_y \cdot \pi^3 \cdot d_0^4}{64 \cdot a_i} \cdot I_{k,j} \left( 1 - \frac{2}{\pi} \right), \quad (2)$$

where  $\pi - 3,14$ ;  $d_0 - 0,021$  cm;  $a_i$  is the mean value of the area width, cm.

The graphic interpretation of the results of the calculation of potential energies of fabric stretching and folding on the areas of joining the longitudinal segmentation is shown in Fig. 6.

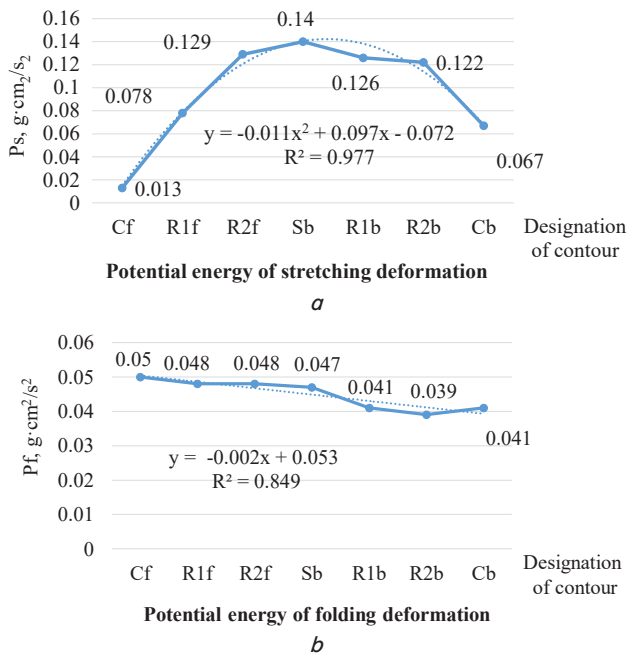


Fig. 6. Change of potential energy of stretching and folding deformation on the contours of corset parts joining: *a* – stretching deformation, *b* – folding deformation

According to the results of research into breaking characteristics of fabrics shown in Table 3, the basic fabric for ensuring the physiological-hygienic characteristics of a corset was selected (Table 8).

According to the complex indicator of deformation ability in providing comfort, there is fabric No. 5 (satin 5/3, PA – 50 %, PE – 30 %, IEA – 20 %). The totality of fabrics in divided into three groups by the indicator of deformation ability: with small  $\leq 35$  %, medium 35–70 %, high  $\geq 70$  % deformation ability.

A combination of deformation ability of fabric in uniting the torso zones using the transformation techniques was proved by research [25].

The selected prototype of the ellipsoid (Fig. 3, c) provides a description of the ability of breast areas (zone 1) to be deformed under the influence of external forces by calculating the approximated breast volume (3):

$$V_b = \frac{2}{3} \pi \cdot a \cdot b \cdot c = \frac{2}{3} \pi \cdot \frac{d_t}{2} \cdot \frac{d_v}{2} \cdot c, \quad (3)$$

where  $d_t$  is the transverse diameter of breasts, ( $d_t = 15.0$  cm);  $d_v$  is the vertical diameter of breasts, ( $d_v = 11.6$  cm);  $c$  is the breast depth.

The breast depth is determined from (4):

$$c = \frac{D_n}{2\pi}, \quad (4)$$

where  $D_n$  is the vertical breast arc, ( $D_n = 23.6$  cm).

The depth of cup C, which is 3.75 cm was calculated for size 75B. The calculated breast volume is 341.5 cm<sup>3</sup>. The weight of the breast is 307.4 g. Conditional force of sagging is 0.0003 kg·m/s<sup>2</sup>.

Since the cup size increases by 2.0 cm, the weight of breast from 75A to 75D makes a variation series: 300.5; 307.4; 314.2; 321.0 g, that is, increases by 6.8 g. This influences the selection of reinforcing elements.

### 5. 3. Recommendations for the use of compromise options of the adaptive transformation of polyvariance of the corset design

A priori ranking of results of the estimation of human self-comfort in the experimental samples of corsets is taken into consideration in recommendations for the use of design solutions to achieve the desired modeling effect (Table 9).

Table 8

Results of studying the deformation characteristics of basic fabric for a corset

Number of material sample	Complete deformation, $\epsilon$ , %		Residual deformation, $\epsilon_3$ , %		Rigidity, N·cm <sup>2</sup>		Relative indicators of studied materials in the percentage of the basic ST2						Area of triangle, cm <sup>2</sup>		Generalized indicator of deformation, %	
	W <sub>r</sub>	W <sub>f</sub>	W <sub>r</sub>	W <sub>f</sub>	W <sub>r</sub>	W <sub>f</sub>	$\epsilon$ , %		$\epsilon_3$ , %		$T$ , %		W <sub>r</sub>	W <sub>f</sub>	W <sub>r</sub>	W <sub>f</sub>
							W <sub>r</sub>	W <sub>f</sub>	W <sub>r</sub>	W <sub>f</sub>	W <sub>r</sub>	W <sub>f</sub>				
CL	3.0	7.5	1.05	2.77	3.63	3.63	18.0	17.8	11.29	9.23	61.7	62.47	58.36	53.74	44.5	41.5
SD	2.65	9.0	0.65	4.8	9.071	5.70	15.9	21.4	6.99	16.0	154.2	98.0	44.98	36.75	34.3	28.4
SC	5.5	11.65	1.0	5.0	3.95	3.96	33.03	27.6	10.8	16.7	67.2	68.2	14.24	15.73	10.85	12.2
ST1	4.85	36.5	2.5	27.15	8.43	4.66	29.1	86.6	26.9	90.5	143.4	79.4	37.2	96.88	28.3	74.8
ST2	16.65	42.15	9.3	30.0	5.88	5.81	100	100	100	100	100	100	131.3	129.5	100	100
BR	11.65	21.65	5.0	9.85	5.56	5.81	69.9	51.4	53.8	32.8	94.6	100	70.5	42.25	53.7	32.6

Note: O – warp; Y – weft

Table 9

Features of the use of design solutions for the achievement of the desired modeling effect

Adjustment magnitude, cm	Desired modeling effect on the waistline	
	Figure tightening on the waistline	
	Basic fabric	Frame elements
2–3	Dense material with medium/high deformation ability	Regilin/plastic underwire at longitudinal seams
3–5	Closely-woven fabric with low deformation ability	Plastic underwire in longitudinal seams
5–8	Closely-woven fabric with low deformation ability, sling on the waistline	Plastic/ metal underwire in longitudinal seams
More than 8	Closely-woven fabric with low deformation ability, sling on the waistline, reinforcing details (interlay materials)	Plastic/metal underwire in longitudinal seams
Decrease in belly bulging		
1–2	Closely-woven fabric with medium/high deformation ability	Rigilin/plastic underwire in longitudinal seams
2–3	Closely-woven fabric with low deformation ability, sling on the waistline	Plastic/metal underwire in longitudinal seams
3–4	Closely-woven fabric with low deformation ability, sling on the waistline, reinforcing details (interlay materials)	Plastic/metal underwire in longitudinal seams, brisk in the central part of detail/underwire in the middle of the detail

Compromise values of modeling effects, which should be taken into consideration in the construction of the ergonomic corset design, are shown in Table 10.

The means of deformation interaction of the design corset zones using the transformation techniques by the stretching-compression principle for ensuring its polyvariability is shown in Fig. 7. Practical implementation of the polyvariability of corset design sizes is based on the method

for grouping the details of bra and belt-corset parts, which are implemented in typical schemes of details' gradation (Fig. 8) and schemes of adaptive dimensional transformation (Fig. 9).

In contrast to the traditional use of coefficients of gradation of the size features [26], the adapted magnitudes of increments ensure fixation of eponymous cuts in the details of technological modules at the tightening level.

Table 10

Variable conditions for determining the rational parameters of correction of female-typical figures

Boundaries of ratio, cm				Modeling effect	I fullness	II fullness
I fullness		II fullness				
$2.1 < Gb_{III} < -6.7; \Delta = -3.0$				Min	$Gb_{III} \in 84.0 \div 96$	$Gb_{III} \in 84.0 \div 96$
$0.4 < Gb_{III} < -6.8; \Delta = -2.4$				Med		
$-1.1 < Gb_{III} < -6.5; \Delta = -1.8$				Max		
$-2.1 < Gb_{IV} < -1.5$	$\Delta = 0.2$	$-2.4 < Gb_{IV} < -1.5$	$\Delta = 0.3$	Min	$P \in 158.164;$ $Gb_{III} \in 84.0 \div 96;$ $Gb_{IV} \in 72.6 \div 82.8$	$P \in 158.164;$ $Gb_{III} \in 84.0 \div 96;$ $Gb_{IV} \in 73.4 \div 83.6$
$-1.9 < Gb_{IV} < -1.3$	$\Delta = 0.2$	$-1.9 < Gb_{IV} < -1.3$	$\Delta = 0.2$	Med		
$-3.0 < Gb_{IV} < -1.8$	$\Delta = 0.4$	$-2.9 < Gb_{IV} < -1.7$	$\Delta = 0.4$	Max		
$-2.8 < Gw < -1.9$	$\Delta = 0.3$	$-2.7 < Gw < -1.8$	$\Delta = 0.3$	Min	$P \in 158.164;$ $Gb_{III} \in 84.0 \div 96;$ $Gb_{IV} \in 62.6 \div 75.2$	$P \in 158.164;$ $Gb_{III} \in 84.0 \div 96;$ $Gb_{IV} \in 64.6 \div 77.2$
$-6.5 < Gw < -1.4$	$\Delta = 1.7$	$-5.7 < Gw < -0.6$	$\Delta = 1.7$	Med		
$-4.7 < Gw < -5.3$	$\Delta = -0.2$	$-4.8 < Gw < -5.4$	$\Delta = -0.2$	Max		

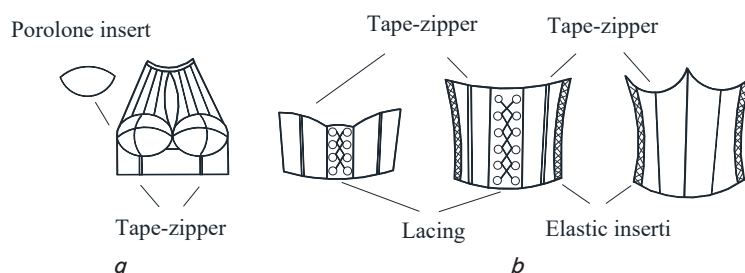


Fig. 7. Means of ensuring polyvariability of corset sizes by the stretching-compression principle: a – bra; b – belt-corset



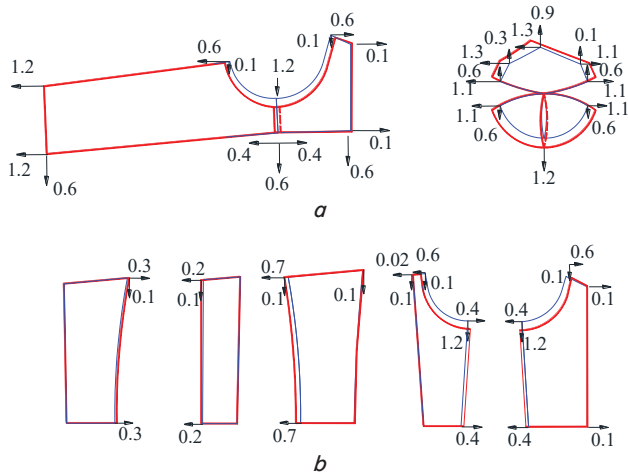


Fig. 8. Schemes of gradation of details: a – of a bra; b – of a belt-corset

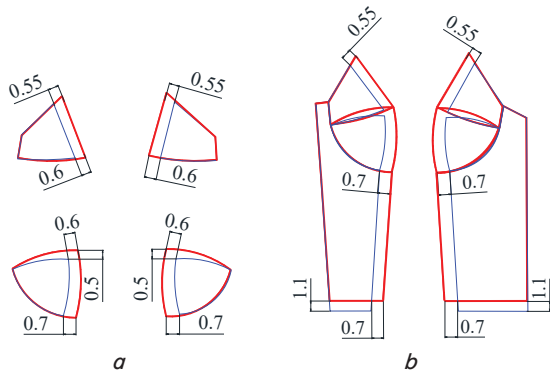


Fig. 9. Scheme of adaptive dimensional transformation: a – of a bra cup; b – of a front of a belt-corset

**6. Discussion of the results of studying the impact of the elements of parametric transformation of segmentation contours on the corset comfort**

The feeling of corset comfort is subordinated to the aesthetic function in modeling the erotic areas of a body (Fig. 2). The difficulty of design is related to the fact that in order to form the female torso and breasts, corsets are designed either without allowances or with negative allowances to the figure dimensions.

The graphic interpretation of the eponymous «reference» points of erotic zones indicates the difficulty of interpreting the zones of modeling effect due to the complexity of the volume-spatial body shape. In this sense, indexing the body proportions by figure types is of special interest [19]. The matrix of indexing proportions for figure types (Table 5) indicates the polyvariability of descriptive morphological features of contours. Variability of figure types in body areas proves the ergonomic appropriateness of using detachable technological corset modules: zone 1 – a bra, zone 2 – a belt-corset.

A comparison of the magnitudes of the potential energy of stretching deformation in the basic fabric for a corset indicates the silhouette subordination of negative allowances. This is in line with the practical data of papers [11, 12].

The largest proportion of potential stretching energy belongs to the side contour of the typical design, which is due to the contour concave and the larger dart intake. The potential energy of stretching deformation on parts join

contours is described by a parabolic function (Fig. 6, a). In details of the front, potential folding energy is caused by the shifting of abdominal muscle tissues upwards, and of the back – downwards from the waist, which explains the linear dependence (Fig. 6, b).

The results of research into biologically active areas of the human body [20, 21] indicate the influence of the width of anthropometric levels of an item on operational comfort. The resulting outlines of the tightened mannequin (Fig. 4) prove the influence of the size features on the different magnitude of waist darts in the spatial shape of the upper and lower areas (Table 6). However, unlike the results of the studies on the impact of pressure on a change of contours of side cuts in torso modeling [24], the obtained data on the zoning of modeling effects make it possible to propose the adaptive design of corset zones. The principle of coordinating the action of increments of size features was used in the change of the size of the technological module. According to the compression-stretching principle, the structure of the polyvariant design of a corset (Fig. 7) is influenced by simulation of the transformation of the mesh frame zones of the typical mannequin – into the typological types of shape sizes within the tightened corset. Regulation of the identity of zone contours in the transformation of technological modules ensures the mechanism of increments by the grouping principle (Fig. 9). However, the experimental magnitudes of transitions impose certain restrictions on the use of combined sizes in corset purchasing, which can be offset by the compression properties of knitted inserts [25].

The potentially interesting direction is further studying the corsets in terms of dynamics of modeling effects based on the geometric properties of models of the structure of the auxetic materials, examined in [27]. The geometric model of materials combined with the technology of generating silhouette parameters makes it possible to substantiate the silhouette comfort of separate technological modules for the individualization of the compositional dominant.

**7. Conclusions**

1. The conducted research proved the impact of morphological types of female torso structure on the individualization of functional properties of a corset. Due to this, it can be argued that the historical aspect of corset development in the XX, XXI centuries reproduces the anthropometric correction of a torso shape in typical segmentation of the design. The dimensional variability of figure types is manifested in indexing the proportionality of body contours. The generalized figure type by average values of proportionality coefficients ( $M=0.548, K_1=0.553, K_2=0.437, K_3=0.591$ ) corresponds to a narrow build type B-B-B-S.

2. The peculiarities of determining the deformation effect of a corset imply determining potential energy of stretching and folding deformation of fabric in joining seams, which makes it possible to assess self-comfort depending on the comfort of the modeling effect. The maximum of the parabolic function of the potential energy of stretching deformation is due to the concave of the side contour, which is explained by a larger dart intake  $P_{smax}=0.14 \text{ g}\cdot\text{cm}^2/\text{s}^2$ . The linear nature of potential energy of folding deformation is explained by the peculiarities of shifting muscle tissues relative to the waistline: those of abdomen – upwards  $P_{jbl}=0.05\text{--}0.041 \text{ g}\cdot\text{cm}^2/\text{s}^2$ , those of the back – downwards  $P_{jbl}=0.41\text{--}0.039 \text{ g}\cdot\text{cm}^2/\text{s}^2$ .

3. The ergonomic feasibility of the zonal technological modules was proved by compromise variants of adaptive size transformation of silhouette segmentation of parts, which should be based on the auxetic effect of insert ma-

terials. The magnitudes of increments for the dimensional transformation of the bra cup width in the upper part are 1.1 cm, in the lower part – 1.4 cm; in the front of a belt-corset – 1.4 cm.

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*The rapid development of digital printing and the popularity of corrugated packaging production encourages manufacturers to improve product quality. Therefore, research into the quality of digital prints, using modern procedures for determining the qualimetric indicators, is important for both consumers and manufacturers. We have studied the prints made by the inkjet printing machine Durst Rho 1312. The printing involved the inks CMYK+Light Cyan+Light Magenta (Austria)+Light Cyan+Light Magenta. The prints were obtained directly on five-layer corrugated cardboard using the post-print technology. In addition, the printing was performed on a liner, followed by its pinning to fluting (the preprint technology).*

*The paper describes a procedure for determining the qualimetric prints' indicators, in particular, optical density, the increase in the tonality of the raster image, color reproduction, resolution, print stability on prints, and in the printing process, and lightfastness. The imprints' quality was evaluated in accordance with the requirements set by the standard ISO/TS15311-2:2018. The quality of digital and offset prints has been compared. It has been established that the digital post-print technology on the five-layer corrugated cardboard BE and the pre-print technology on the cardboard GD180 ensure the same print quality parameters. This includes such a quality indicator as the reproduction of raster image tones, optical density, color difference, printing stability. The print resolution of the imprints has slight deviations.*

*It was found that the color transfer of offset prints is higher (by 10 %) than that of the digital prints based on the pre-print technology. Offset printing also provides higher resolution (by 93 lines/cm) than digital printing. However, in terms of print stability and color difference, the inkjet prints are inferior to the offset technology. Digital prints have good lightfastness (10–20 times better than offset samples)*

**Keywords:** digital and offset printing, five-layer corrugated board, pre-print, post-print, prints' quality

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# DEVISING A PROCEDURE FOR EXAMINING THE QUALITY OF PRINTS OF DIGITAL AND OFFSET PRINTING ON CORRUGATED CARDBOARD

**S. Khadzhynova**

Doctor of Technical Sciences, Associate  
Professor, Deputy Director\*

E-mail: [svitlana.khadzhynova@p.lodz.pl](mailto:svitlana.khadzhynova@p.lodz.pl)

**S. Havenko**

Doctor of Technical Sciences, Professor\*

E-mail: [Svitlana.havenko@p.lodz.pl](mailto:Svitlana.havenko@p.lodz.pl)

\*Center of Papermaking and Printing

Lodz University of Technology

Wólczańska str., 223,

Lodz, Poland, 90-924

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## 1. Introduction

Requirements for the design of printed packaging are constantly growing. Packaging is becoming more attractive while the requirements for reproducing multi-color images are constantly increasing. The modern market offers a wide range of different packaging materials but priority by both

producers and consumers is given to environmentally friendly materials. These include cardboard and corrugated cardboard. Based on data from the research institute Smithers Pira, the global needs in corrugated cardboard in recent years have exceeded 143 million tons. Experts predict an annual increase in the use of corrugated cardboard for the packaging manufacturing at the level of 3.7 % Packaging made from