1.5. Modern information technologies in designing fashion industry products

Automated design of clothing is one of the most promising directions for the development of modern fashion industry. Today, computer programs automate the whole process of designing clothes from the design of the sketch to the development of product patterns and its simulation on the electronic mannequin. Among the modern programs are two-and three-dimensional design programs. Applications that implement technology design from 2D to 3D design technology allow the visualization of clothing on an electronic mannequin of human shapes. 3D applications in 2D envisage the deployment of a three-dimensional clothing image in ready-made patterns, but this area is not well developed today.

Analysis of previous research. Currently, there are new ways of automated projecting, which allow to increase productivity and quality of developments at different stages of designing new models of clothes: sketch designing of a suit and its transformation into construction of clothes, designing and modeling various assortment of clothes, parametrization the form of clothing, etc. In the direction of three-dimensional visualization and designing clothes of different assortment there was been working software developers for clothing design and foreign researchers such as N. Magnenat-Thalmann, P. Volino, A. Psikuta, J. Wang, V. Yeshchenko, A. Yeshchenko [22], V. Ryabukha, O. Kostukevich, O. Khivrina [23], V. Kuzmichev, G. Surikova [24]. They have actively developed this direction of designing garments and solved the tasks of developing various types of clothing for three-dimensional modeling of clothing.

The work [25] is devoted to the analysis of using 3D scan technologies of the system “human-clothes”, the studying of the relationship between the parameters of areas under clothes and fitting clothes on the human body and the calculation of supplements to different sizes of the body for patterns of clothing.

The results of studying the distribution of the supplements and the thickness of the air gap between the clothes and the body are described in the article of M. Guo and V. Kuzmichev.[26] Also, the researchers have determined the effect of the properties of knitwear on the distribution of the air gap and the area of contact clothing with the surface of the human figure.

The influence of the body shape's features and the position of man are considered on the distribution and the size of the air gaps in clothing.[27]

Chinese scientists [28] have been investigated the magnitude and features of the air gaps' distribution in areas under clothes. It is established that the distribution of projective supplements is influenced by such properties of fabrics as stiffness and drapery.

Modeling the shape of horizontal sections of women's jackets was considered in the work of researchers at the Textile Institute in Hong Kong [29]. It has been established that the shape of the

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[22] CAD Grazia [online]. [Cited 16. 01. 2019] Available online: http://www.saprgrazia.com.

[23] CAD JULIVI [online]. [Cited 16. 01. 2019] Available online: http://julivi.com.

[24] Проектирование изделий легкой промышленности в САПР (САПР одежды) / Г. И. Сурикова, О. В. Сурикова, В. Е. Кузьмичев и др. М.: ИД ФОРУМ: НИЦ ИНФРА-М, 2013. 336 с.

[25] Volino, P., Cordier, F., Magnenat-Thalmann, N. (2005) From early virtual garment simulation to interactive fashion design. *Computer-Aided Design Journal*. Vol. 37, Is.6. P. 593-608.

[26] Guo, M., Kuzmichev, V. E. (2013) Pressure and comfort perception in the system «female bodydress». *AUTEX Research Journal*. vol. 13. № 3. P. 71-78.

[27] Kim, A. H., Damhorst, M. L. (2010) The Relations hip of body related self-discrepancy to body dissatis faction,apparel involvement,concerns with fit and size ofgarments,and purchase in tentionsin on line apparel shopping. *Clothing and Textiles Research Journal*. Vol. 2. Is. 4. P. 239-254.

[28] Xiaohui, L., Wanga, Y., Lua, Y. (2011) Effects of Body Postures on Clothing Air Gap in Protective Clothing. *Journal of Fiber Bioengineering & Informatics*. 4:3. P. 277-283.

[29] Wang, ZH. (2004) Study on the relation between garment style and ease distribution. *Journal of Donghua University*. 6 (21). P. 31-37.

horizontal sections of the garment can be modeled by the distribution of supplements in clothes at different heights.

3D digitizer for obtaining three-dimensional body measurement data was proposed by South Korean researchers, which automatically generates a three-dimensional basic design of a product corresponding to an individual figure and automatically generate the patterns of clothes [30].

Experimental studies of the clothing packages' behavior have been carried out in a three-dimensional environment with the use of 3D scanning technology, which contains information on the patterns of changing the surface plastics of clothes under the influence of design parameters of the product.

In the work of I. Petrosova the concept of exterior clothing design has been developed, which provides the ability to select, combine and integrate by the manufacturer of various CAD modules and traditional methods of designing into a single information digital network through the using of 3D technology.[31] Also, this concept provides step-by-step control over the parameters projected product in the form of a sketch, a virtual model, a pattern of clothing.

Statement of the problem. The complexity and ambiguity of the solution of the tasks in relation to the tectonics of clothing require the development of theoretical foundations and conducting additional experimental research aimed at developing a set of measures that provide informational and methodological support for design of clothing with the using of modern technologies. Actual is the establishment of links between the properties of fabrics and the volume and silhouette of clothing in the system of "mannequin-clothes" and the formation of a database sufficient for the formalization of the volume-spatial form of clothing.

Results. With the development of modern information technologies, the study of the three-dimensional form of a garment is relevant, taking into account the principles of tectonics. Plane design methods are gradually being replaced by three-dimensional design's technologies of clothing in specialized programs, therefore, the study of the volume-spatial form of clothing, the patterns of operational behavior of materials and their visualization in three-dimensional programs acquire special relevance. In such researches it is possible to distinguish the following main directions:

- studying the surface of a human figure (mannequin) and developing their electronic copies;
- study of the volume-spatial shape of the "mannequin-clothes" system;
- visualization of sewing products in modern programs;
- development of a three-dimensional image of the system "mannequin-clothes" with the subsequent deployment of their surfaces on the plane, etc.

The analysis of literary sources has shown that contact and contactless methods are used to study the surfaces of the mannequin-clothes system. The contact method is used mainly in the study of the forms and sizes of solids surfaces by direct mechanical touch of special tools or by copying the body shape using plastic masses (cut planes, geodesic lines, grids, topography of projections of horizontal sections, calculation and measuring, etc.). In the study of easily deformable surfaces, the most expedient is contactless method with the help of special devices emitting light or electromagnetic waves, a laser beam, etc. Known contactless methods are: photogrammetric, stereophotogrammetrical, simultate stereophotogrammetry, light sections, X-ray, etc. Recently, widespread technology of three-dimensional scanning with the help of white light or laser beam, which allow measuring the spatial coordinates of individual points of the

[30] Leong, I. F., Fang, J. J., Tsai, M. J. (2013) A feature based anthropometry for garment industry *International Journal of Clothing Science and Technology* Vol. 25. Is. 1. P. 6-23.

[31] Петросова, И. А. (2014) Разработка методологии проектирования внешней формы одежды на основе трехмерного сканирования: дис. … д-ра техн. наук. М. 522 с.

object, for example, digitize the surface of a human figure, represent it in three-dimensional space on the computer screen, remove from the digital image dimensions, etc. Body scanners are characterized by a short measurement time, high accuracy, but high cost. On average, the complete cycle of measuring one body with a body scanner takes 10 seconds and the accuracy of measurements is up to 0.01 cm. Using body scanning systems are carried out contactless measurements of a large number of people, for example, to form national anthropometric standards of figures, as has already been done in the United States, Great Britain, Mexico and other countries.

Of considerable interest is the experience of foreign countries offering devices for contactless measurement of the figure: Cyberwear (USA), Hamamatsu, Hamano (Japan), Textile / Closing Technology Corporation [TC] 2, Telmat Industrie (France), Vitronic (Germany), TecMath, etc. The data obtained during the scans can be used to obtain an electronic copy of a person's figure or dummy in the form of a sketch, frame with a set of horizontal and vertical sections or a mannequin. Electronic mannequins for clothes and underwear propose CAD Optitex, Israel – module Runway Designer, CAD Gerber Garment Technology, USA – Module V-Stitcher, PAD System, Canada – Module 3D Sample, CAD JULIVI, Ukraine – program JULIVI CLO3D, CAD Lectra, France – module Modaris 3D Fit, the company Toyobo, Japan – program Lookstailor etc.

The emergence of three-dimensional scanners, the ability to clearly depict on the screen the human figure and design object – clothing (model, suit), influenced the development of automation design subsystems for the designer. One of the most famous and promising garment CAD systems is the program Runway Designer of the Israeli company Optitex. In addition, some firms, for example Reflection Fabrix Inc. and DigiScents, who are not the developers of high-quality garment CADs, offer three-dimensional clothing visualization packages for use when shopping for clothes over the Internet or in place of dressing rooms in clothing stores.

Most of modern garment CAD systems contain a module of simulation of the fabric behavior in the product and take into account some of the materials' properties such as the visual properties (color, texture, ornament) and physical-mechanical properties (stretching in warp and in weft directions, bending, surface density, thickness, etc.) Generation of the physical model of future clothing contains several stages: visualization of its appearance from the material of the top, reproduction of the behavior of the materials' package on the characteristics of its layers, determination of properties, for example, by the method Kawabata Evaluation System.

Realistic simulation tools are increasingly used by designers in cinema, television, advertising and computer games when creating and dressing up virtual characters. Now, when designing stylish textiles and apparel, they are trying to use 3D graphics software to help digitize the dynamics and visual image of the fabric in the product. At the same time, most programs in various industries work at the level of physiological and psychological similarities. This is Autodesk 3ds Max, Alias Wavefront Maya, TrueSpace – Surface Modeling, Tinting and Animation, Amapi 3DTM for building 3D models and more.

In some 3D clothing design systems, there is a certain database of materials that can be replenished by the user. Demonstration modules of individual CAD clothes make it possible to set the behavior of tissue on a moving figure, to analyze the proportions and location of structural and decorative elements, but the reliability of visualization needs further improvement.

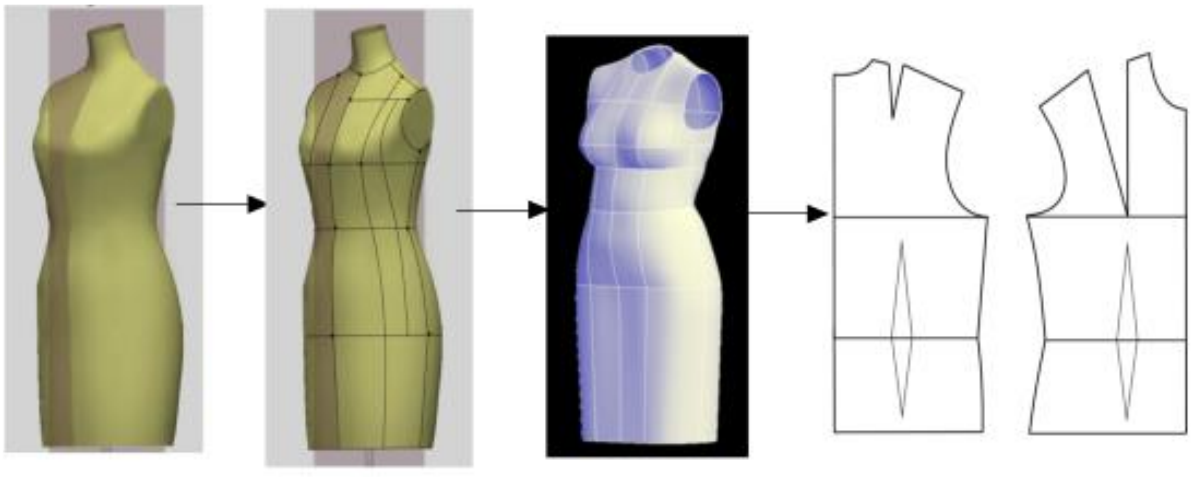
At the present stage of the development of the garment industry a new industrial paradigm of clothing design and production has been formed - the transition from two-dimensional to three-dimensional design of clothing. Virtual design of 3D-based clothing is becoming a major alternative to the traditional approach to designing 2D-grade models and assessing the quality of sewing products at the design stage.

Three-dimensional design of clothing involves creating a three-dimensional image of the clothing model on the monitor screen and getting templates of its parts by deploying the surface

of the garment on the plane for the addition of special software. There is a generation of individual or typical dimensional signs of a three-dimensional virtual mannequin of the human figure, the creation of a three-dimensional virtual model of the product on a virtual dummy, taking into account the plastic properties of the fabric, the scanning of the surface of the garment to the plane, with its division into details of the design. The initial data for three-dimensional design in the "figure-clothing" system are: anthropometric database; mathematical models of mannequin surface dressing by garment details, taking into account the properties of fabrics; simulation methods of outer clothing surfaces for different assortment taking into account the package of materials; geometrical methods of transformation of surfaces of a figure or clothes depending on the sketch of the el-style, features of the structure of the consumer's body, the desired volumetric-spatial form of clothing, etc.; methods of deployment surfaces of clothes which based on the study of the shape of a virtual model of clothing, etc.

At present, there are two approaches to three-dimensional design of clothing. The first approach only involves visualizing the appearance of the product on a three-dimensional mannequin of human figures using patterns of a model that pre-designed in other CAD modules or programs. Such programs allow you to reproduce in a three-dimensional not only the design features of the product, but also the visual characteristics of the fabric (color, pattern, etc.). This approach involves the mandatory presence of a three-dimensional mannequin, which today can be built in special programs, taking into account the size of their features of the human figure and the features of its body structure. The construction of the electronic dummy consists of the following steps: determining the magnitude of the dimensional features by scanning the surface of a human body or a physical mannequin using a 3D scanner, photogrammetry, etc.; parametric construction of a surface of a dummy using a database of dimensional features.

The second approach involves the formation of a three-dimensional image of the model of clothing with the subsequent deployment of its surface and the receipt of details. In this case, the three-dimensional image of the clothing model can be created both with the use of a three-dimensional electronic dummy, and without it. The technology of three-dimensional design of clothing in this case can be realized as follows: on a three-dimensional image of a mannequin of the desired size, varying by projective supplements, the designer creates a model of clothing according to the artistic design (Fig. 1).



a *b* *c* *d*

Fig. 1. Stages of three-dimensional design of clothes:
a – mannequin; b – the surface of clothes, built from the surface of the mannequin;
c – the surface of clothing; d – ready patterns

Projection supplements between the inner surface of the garment and the surface of the mannequin are the main form-forming parameters for the three-dimensional design of clothing. Using the values of supplements at different parts of the "mannequin-clothes" system, the patterns of their change, depending on the type of clothing, silhouette, form of the model, the properties of tissues is generated the representation of clothing in a three-dimensional space (Fig. 2). On the received three-dimensional image of a clothes put lines of a division and its parts are deployed on a plane. This approach to three-dimensional design makes it possible to adjust the "mannequin-clothes" system depending on the parameters of the mannequin (individual or typical figure), which facilitates the development of the desired shape of the garment's surface. Despite the large number of studies, this approach is only partly implemented in industrial production due to the complexity of the surfaces' deployment of the "mannequin-clothes" system.

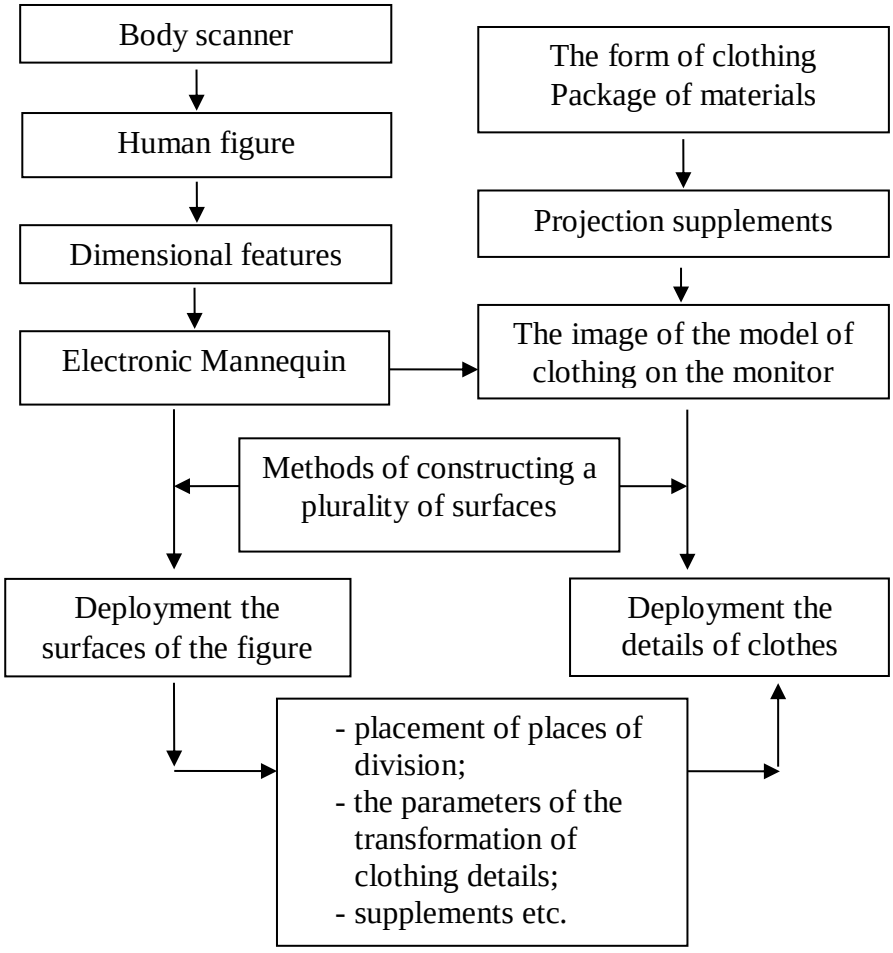


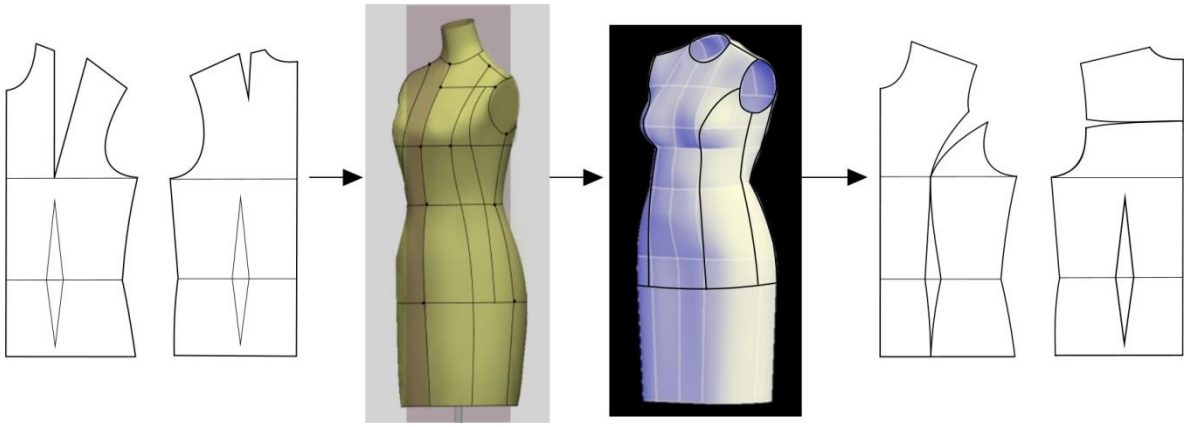
Fig. 2. Sequence of three-dimensional deployment the surfaces of clothes

The three-dimensional modeling of clothing involves the transformation of pre-designed in any way patterns of the basic design of clothing into a three-dimensional image of the model after the task of rules for their virtual "cross-linking" on the electronic dummy (Fig. 3). Next the dividing lines is putted on the three-dimensional image of the model and then the parts of the surface of the virtual model design is deployed to the plane.

In order to obtain a three-dimensional image of a garment, patterns are used to ensure the quality of planting of the product, that is, they are designed taking into account the properties of the fabrics, manufacturing technology and other output parameters and checked in the material. As a result of three-dimensional modeling, the new model will have the same landing quality as

the original base design. In addition, this method allows you to get a variety of clothing patterns for different sizes and growths.

Developers of CAD Lectra in 2005 patented a method for designing garments that comprises the following steps: imaging appearance clothes on electronic human mannequin, modeling clothing details on the electronic dummy, obtaining patterns of clothing details [32]. The approach is promising for the mass production of clothing, because it allows at least partially solve the problem of obtaining details of a three-dimensional virtual product model. For example, Toyobo's program Lokstailor (Japan), offers the ability to modeling garments in three-dimensional space and obtain patterns of clothing, but the resulting patterns do not provide the quality of planting the product on the figure of human [33].



a *b* *c* *d*

Fig. 3. Stages of three-dimensional clothing design: a – flat shapes of the basic design; b – mannequin; c – clothing surface; d – patterns of model design

The most effective variant offers JULIVI CAD in its 3D modeling software [34]. The first version of the "Electronic Mannequin" program of the JULIVI complex implemented the functions of three-dimensional modeling, which involves applying model lines to the product and transferring them to the patterns, changing the silhouette of the model by modifying its cross-section at a certain level, three-dimensional graphics of the patterns, etc. The principal difference of this program from the other is the connection of the product forms and its three-dimensional image on the electronic dummy, in which the mechanism of modification of the worked-out quality base design of clothing is implemented.

For modeling of clothes on a virtual electronic mannequin, we have improved the informational and methodological support of the process of three-dimensional clothing modeling, namely the development of databases for the modification of clothing details, improved methods for transforming the basic constructions of clothing, in accordance with the sketch of the model, the projected form of clothing, etc. To create a program of three-dimensional clothing modeling we have solved the following positions:

- the optimal location of the points and the location of the minimum necessary lines for the design of clothing designs on a three-dimensional mannequin (24 points, of which 6 are anthropometric) are determined;

[32] Патент US2009099683 USA. Device and method for designing a garment. US 8249738 B2 / Lastra J. J., Yepes R.; патентовласник: Lectra SA; заявл.: 19. 12. 2005; опубл.: 16. 04. 2009.
[33] LokStailor. Version 3. [online]. [Cited 16. 01. 2019] Available online: http://loadfree.mobi/movie-download/TnOreF9TxnQ/LokStailor-3.
[34] CAD JULIVI [online]. [Cited 16. 01. 2019] Available online: http://julivi.com.

- between the points on the surface of the electronic mannequin and the points of the surface of the basic design of clothing were established interconnections;

- the database of methods of transformation of details of basic constructions of different types with consideration of properties of materials is developed;

- the sequence was investigated and the optimal parameters of the construction of humeral men's and women's clothing are determined experimentally.

Developed elements of the informational support of the three-dimensional clothing modeling process can be implemented into a three-dimensional clothing modeling program.

Today, manufacturers propose mainly programs for dressing virtual clothing models in order to visualize the finished fabric, which also requires knowledge of the laws of tectonic-plastic behavior of fabrics.

We have tested the results of the study in the JULIVI CLO3D program. The JULIVI CLO3D program provides an opportunity for a high degree of realism to evaluate the external cost of a model of clothing, taking into account the physical and mechanical properties of tissues and the nature of the interaction of tissue with the surface of the mannequin [35]. The "dressing" of templates pre-designed in other JULIVI CAD modules is being implemented on a three-dimensional virtual mannequin – a copy of the figure of a real person. It is also possible to edit the design of the finished product: the choice of color solution, the pattern of fabric, the application and combination of different in texture and texture materials, the selection of structural and decorative elements, decoration and fittings. The program has the ability to put on the dummy several products to assess the harmony of their combination and quality of landing; take into account the thickness of the package of materials when rendering the product, so with all the alternatives to existing programs, CAD JULIVI has, in its technical parameters, has sufficient advantages for designing clothing and conducting research. The sequence of work with a three-dimensional electronic mannequin is as follows: the transfer of patterns from the program Maestro to JULIVI CLO3D; layout the patterns in 2D window; pairs of seams that need to be sewn; Location of the molds around the electronic dummy; simulation of mannequin dressing; problem of material properties; design of the model (Fig. 4).

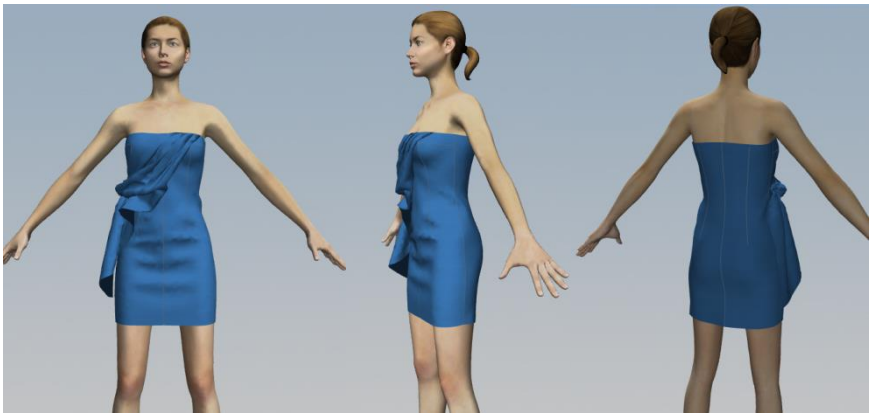


Fig. 4. Visualization of a product on a female figure mannequin in JULIVI C LO3D

The JULIVI CLO3D program contains mannequins for women's, men's and children's figures. Mannequins are formed on the main dimensions, the main of which is the growth and waist circumference. When changing these dimensional signs, the rest of the signs change automatically and proportionally. It is possible to use the finished mannequin of the desired size or set the size manually. The database of the program includes mannequins of typical figures of women and

[35] CAD JULIVI [online]. [Cited 16. 01. 2019] Available online: http://julivi.com.

men, children's figures of different age groups. The mannequin can be adjusted to an individual figure, but only if the figure of the customer has a slight deviation from the dimensional features of a typical figure.

In the program it is possible to evaluate the quality of landing a virtual clothing on a virtual figure, for example: to assess the balance, the location of the side seams, shoulder seams, constructive and decorative elements, etc.; the presence and absence of defects and the nature of tissue's folds at different sites; fitting status of garment; the comfort of the product due to the color chart, which shows the force of pressure on the mannequin at the indicated point; measure the distance between the product and the surface of the mannequin for checking and specifying the magnitude of the supplements for free placement; determine the locations of the contact of the mannequin with the garment (bearing surface), etc. This information is similar to what getting as a result of fitting ready clothing, but the advantages are substantial due to the saving of materials on the production of experimental sample and time at its cutting and manufacturing.

In the process of simulation (dressing the patterns on a virtual mannequin) it is possible to build assemblies, folds, to do something like bend the collar of the garment. The fabric properties are taken into account at visualizing: tensile in warp, weft and diagonal directions, stiffness, draperiness, surface density. Units of measurement of these indicators differ from standardized, only the index of surface tissue density coincides. The program has a database of the characteristics of the main materials (jeans, knitted cloth, jersey, wool, leather, satin, etc.), as well as decorating (fittings, shoulder pads, leather strap, etc.). Degree of realism drapery I material in the program is quite high due to the use of a special structural clothing grid, which consists of equilateral triangles. The size of the triangle side of the grid (from 5 to 10 mm) depends on the degree of realism of the product on the figure: the smaller it is, the more accurate and more detailed the image of clothing looks. The results of the simulation some garments in three-dimensional space with the help of the JULIVI CLO3D program was highly realistic (Fig. 5).

Fig. 5. Models of clothing and their three-dimensional virtual copies in JULIVI CLO3D

Approbation in the production conditions of our proposed recommendations for taking into account the properties of the tissues and the location of the shoulder sewing product, taking into account the distribution of the supplements at the main constructive levels on the electronic mannequin in the JULIVICLO3D program for visualizing of models with the subsequent manufacture of products in the conditions of serial production, showed:

– a high degree of conformity the appearance of finished products to the computer model of the clothing and an adequate reflection of its silhouette and compositional design solution;

– shortening the terms of products' design for a typical and individual figure of consumers as a resulting of excluding examples;

– improving the quality of the drawings of details of garment designs due to the possibility of making adjustments to the drawing based on the results of the virtual sample;

– shortening the time for the development of new clothing patterns due to the possibility of executing simulations in three-dimensional space (changing the length of the product, the sleeves, the configuration of the collar, lapels, boards, etc.).

Conclusions. The analysis the programs of 2D in 3D technology showed a sufficient level of their development and the realism of the models received. The comparative analysis of programs that provide the possibility of visualization of clothes on the electronic mannequin of human figures taking into account the features of human body structure, sex, size and growth are considered and performed. The advantages of the programs considered are the ability to put on a model design on a virtual mannequin, which saves time on the production of a prototype. The disadvantages are that the presented modules require improvement because they do not provide ideal visualization. Among the programs of 3D in 2D technology have analyzed the capabilities of the programs for three-dimensional modeling of clothing LookStailor (Japan) and Tukatech (USA). They allow automatic generation of 2D finished patterns from the 3D representation of sewing items. Such programs are easy to use, they are in demand from ordinary clothing consumers, and not by the specialists of clothing industry, because their main disadvantage is the inadequate quality of the resulting patterns. After analyzing the possibilities of the considered programs, we were concluded that the most successful programs are the hybrid-type one that implement 2D in 3D technology with the further simulation of clothing in three-dimensional space.