DESIGNING OF THE SHOE UPPER USING MODERN INFORMATION AND COMPUTER TECHNOLOGIES

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DESIGNING OF THE SHOE UPPER USING FOOT NUMERICAL CHARACTERISTICS AND MODERN COMPUTER TECHNOLOGIES

ABSTRACT. The article presents the process of designing the details of shoe upper for schoolchildren using the numerical characteristics of the feet and modern computer technology. A software module for processing the obtained data in the MathCad Education program has been developed, which allows to create parametric models of the foot and longitudinal-vertical section of the internal shape with a deviation of not more than 5%. It is established that developing parametric aspects of shoe upper design is advantageous in the age range from 11 to 13 years. Patterns between different parameters of schoolchildren's feet are also determined. On the basis of the developed parametric models and the proposed principles of modular transformation the construction of low shoes (half-boots) is designed and made.

KEY WORDS: foot, design, shoe design, computer technology

PROIECTAREA FEȚELOR DE ÎNCĂLȚĂMINTE UTILIZÂND DATELE ANTROPOMETRICE ALE PICIOARELOR ȘI TEHNOLOGII COMPUTERIZATE MODERNE

REZUMAT. Articolul prezintă procesul de proiectare a detaliilor feței de încălțăminte pentru școlari folosind datele antropometrice ale picioarelor și tehnologia computerizată modernă. S-a dezvoltat un modul software pentru procesarea datelor obținute cu ajutorul programului MathCad Education, care permite crearea unor modele parametrice ale piciorului și secțiunii longitudinal-verticale a formei interne cu o abatere de cel mult 5%. S-a stabilit că dezvoltarea aspectelor parametrice ale designului fețelor de încălțăminte este avantajoasă pentru copii cu vârsta cuprinsă între 11 și 13 ani. S-au determinat și tiparele diferiților parametri ai picioarelor școlarilor. Pe baza modelelor parametrice dezvoltate și a principiilor de transformare modulară propuse s-a proiectat și realizat construcția încălțămintei joase (ghete scurte).

CUVINTE CHEIE: picior, design, design de încălțăminte, tehnologie computerizată

LA CONCEPTION DE LA TIGE DE LA CHAUSSURE À L'AIDE DE DONNÉES ANTHROPOMÉTRIQUES DES PIEDS ET DE TECHNOLOGIES INFORMATIQUES MODERNES

RÉSUMÉ. L'article présente le processus de conception des détails d'une tige de la chaussure pour écoliers en utilisant les données anthropométriques des pieds et la technologie informatique moderne. Un module logiciel de traitement des données obtenues dans le logiciel MathCad Education a été développé, ce qui permet de créer des modèles paramétriques du pied et de la section longitudinale-verticale de la forme interne avec un écart ne dépassant pas 5%. Il est établi que le développement des aspects paramétriques de la conception de la tige de la chaussure est avantageux dans la tranche d'âge de 11 à 13 ans. Les modèles des différents paramètres des pieds des élèves ont également été déterminés. Sur la base des modèles paramétriques développés et des principes de transformation modulaire proposés, la construction de chaussures basses (bottes courtes) a été conçue et réalisée.

MOTS CLÉS : pied, conception, conception de chaussures, technologie informatique

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INTRODUCTION

The efficiency of shoe companies, their adaptation to today's market requirements and consumer demand depends on the assortment policy, the possibility of mobility of production and competitiveness of products. The shoes must be of high quality, meet the anatomical and morphological requirements and fashion trends. In addition, the production of footwear should ensure the cost-effectiveness and profitability of its design and manufacture; the range should be as standardized, unified and consistent with the existing production base.

One of the ways to solve these problems is the design and manufacture of footwear in mass production on the basis of highly efficient technologies. It is advisable to use a comprehensive system of computer-aided design of footwear [1], which allows to take into account the diverse requirements for product quality, shaping their internal form [2, 3] and combine individual characteristics of consumer feet with industrial methods of their design and production.

In the range of footwear, insufficient attention is paid to the production of items for schoolchildren. The issues of expanding the range of footwear for schoolchildren [4] and ensuring a high level of quality and design criteria are especially relevant.

Today, students choose active hobbies, which significantly affects consumer demand for shoes. In addition, in recent decades, due to the impact of the acceleration process, there has also been a change in the parameters of length, width and foot circumference of schoolchildren. Therefore, the creation of comprehensive automated systems for designing shoes for schoolchildren should be carried out considering the modern anthropometric data, the requirements of regulatory documents, the level of psychophysiological development of children, improved methods of shoe design.

The application of the achievements of modern technologies at different stages of design and technological preparation for schoolchildren footwear production allows not only to reduce the production time of new models and the cost of development, but also to improve the quality of footwear.

EXPERIMENTAL

Materials and Methods

The research methodology is to determine the anthropometric and morphological [5, 6] characteristics of schoolchildren's feet, to develop methods of processing the obtained data as parametric models, to develop theoretical preconditions for the development of shoe models for schoolchildren. In particular, this concerns the development of a method of contour profiling using spline curves [7-12], which provides analytical modules for designing the upper part of shoes for students while considering the anatomical and morphological features of the feet.

RESULTS AND DISCUSSIONS

Experimental studies of the process of automated design of shoe uppers for schoolchildren consist of several stages and each of them takes into account the anthropometry and morphology of the feet. Also, studies involve the use of spline curves with curvilinear guides and modular transformation.

The first stage was to determine the distribution of foot lengths according to the age of students. The dependency graph of foot length and girls' age is presented in Fig. 1.

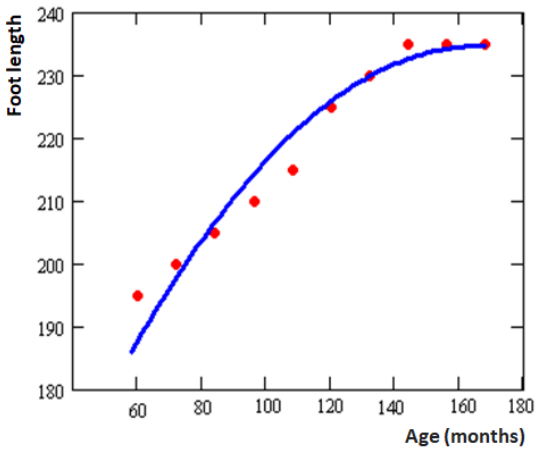


Figure 1. Dependence of foot length on age for the girls group

It is established [13] that these dependences are best approximated by a function of the form:

$$L(v) = 2 \cdot L_m \cdot \left(\frac{v}{v_{max}} - \frac{v^2}{2 \cdot v_{max}^2} \right) + L_0 \quad (1)$$

where v – age of schoolchildren in months;

L_m – limit value of foot length, mm;

v_{max} – maximum value of months;

L_0 – initial value of foot length (length of foot at birth), mm.

On the basis of the given dependences, coefficients of ratios with an error no more than 5% are defined. The obtained research results and dependences allow establishing the dynamics of growth of schoolchildren's feet, to determine the age limits for which it is most expedient to develop parametric aspects of shoe design.

Then anthropometric measurements of schoolchildren were carried out, correlations in dimensional parameters of feet were determined with the subsequent use of the received data for designing of longitudinal-vertical section of internal form and details of top of footwear for the stipulated group of consumers.

Figure 2 shows the empirical and theoretical distribution of length, width and girth of the foot for girls.

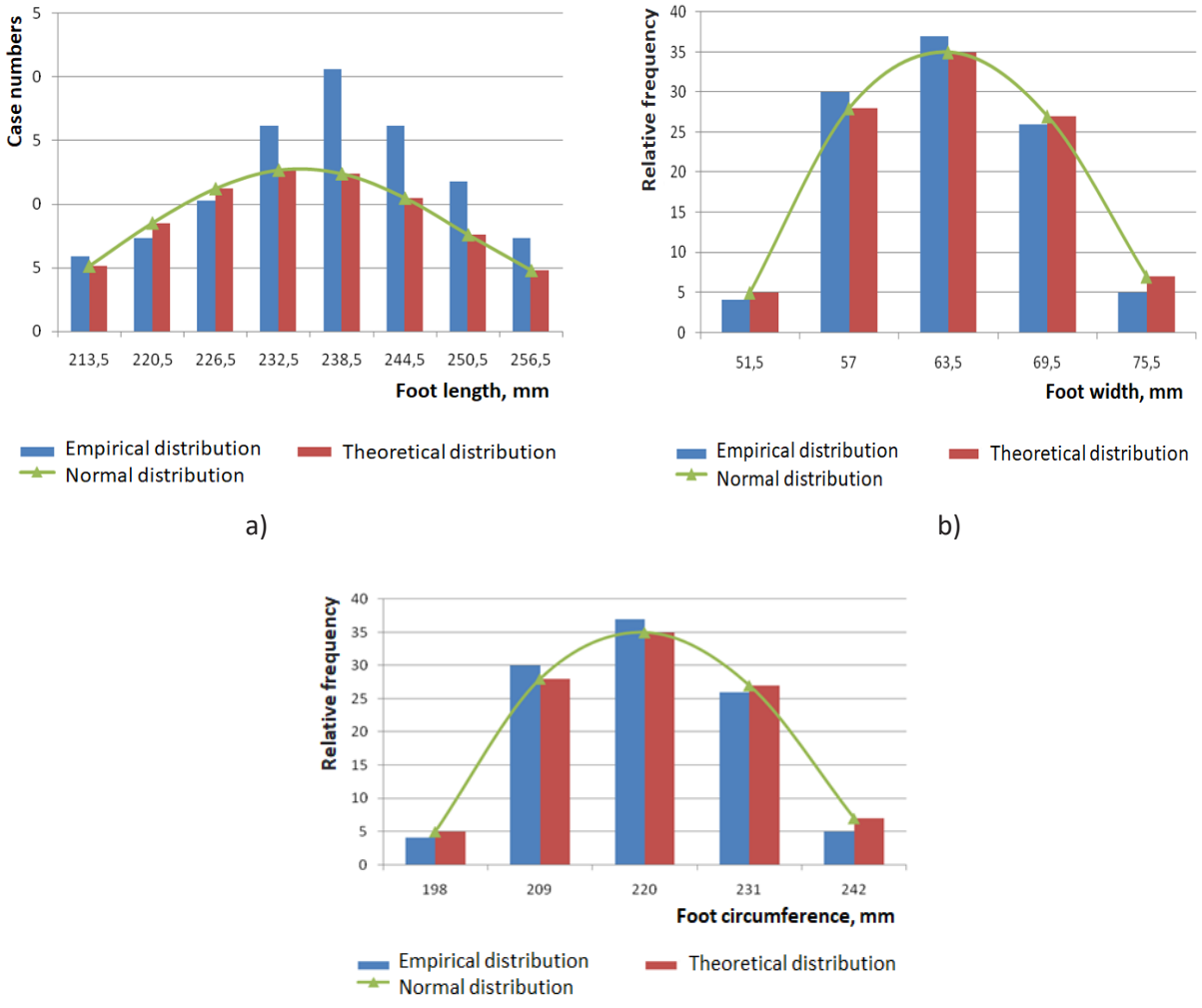


Figure 2. Empirical and theoretical distribution of parameters for girls aged 11-13 years: a) length; b) widths; c) foot circumference

In addition, it was found that the average transverse dimensions of the feet of boys and girls (circumference – C_t та width – W_t) aged 11-13 years are associated with their length L_f orthogonal regression dependence $y=tg\alpha \cdot x+b$ [6], which in our case has the form: $O_n = tg\alpha \cdot Lf + b_1$.

In Fig. 3, as an example, shows the dependence of the foot length with the foot circumference for girls. The values of the correlation coefficients ranged from 0.51 to 0.75. Similar dependences were obtained for the boys' feet.

The study of the third and fourth patterns showed that the same size of the feet of students have a proportional relationship: long - with the foot length, transverse - foot circumference. Thus, analytical dependences were obtained for the design of the longitudinal-vertical section of the internal shape.

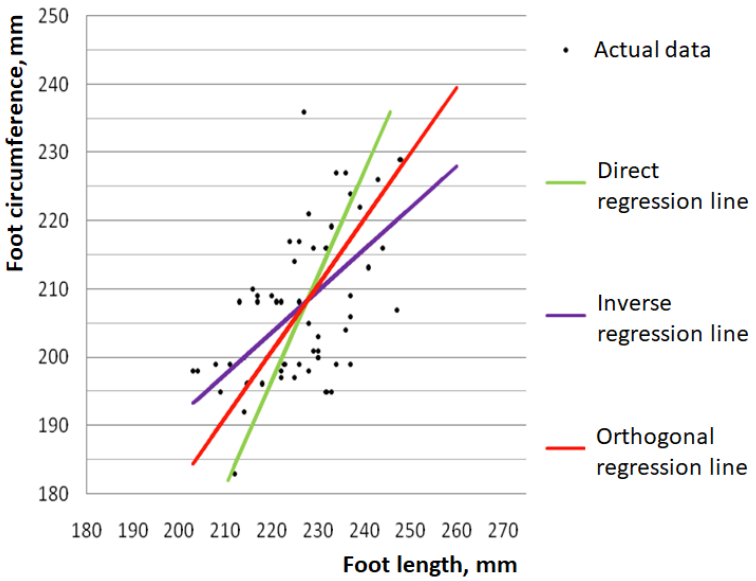


Figure 3. Graph of foot length (mm) with foot circumference (mm) for girls

The revealed distinctive morphological features of feet of schoolboys are showed in Table 1. These features were considered in designing of longitudinal-vertical section of an internal form.

Table 1: Morphological features of schoolchildren's feet

	Morphological features of schoolchildren's feet	Measured girls' feet (11-13 years), %	Measured boys' feet (11-13 years), %
1.	Hypertrophy of the heads of the fifth metatarsal bone	34.5	38.2
2.	Fifth toe muscle hypertrophy	27.6	16.7
3.	Heel outside deviation	39.2	44.3
4.	Hypertrophy of the heads of the first metatarsal bone	53.6	44.5
5.	Combination of hypertrophy of the first and fifth metatarsal bones	35	30
6.	Flat feet of various degrees	12.8	30.6
7.	Claw-shaped toes	25.7	22

The next stage of the study was to develop a method of profiling the outlines of parts, using spline curves, which will reduce the order of the curve of high complexity, including - with the curvature of different signs, which is quite important for designing students' shoes.

Using the developed method, outlines for girls aged 11-13 were obtained and the coordinates of control points were determined. In Fig. 4 is shown a comparison of obtaining the foot outline for 11–13-year-old girls using spline curves with curved guides and spline curves with straight guides. Due to the use of spline curves with curved guides, the curve passes more accurately through all the characteristic anatomical points, especially in the heel.

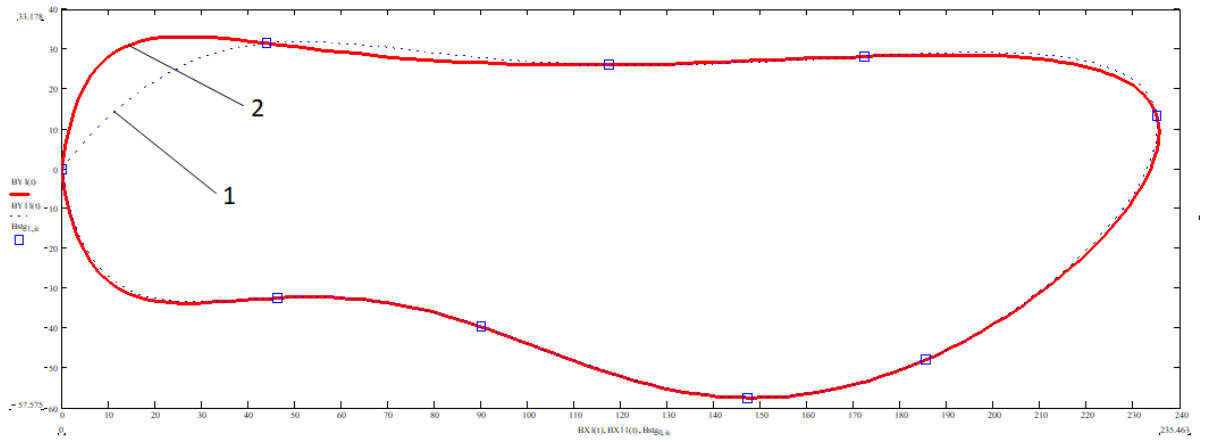


Figure 4. Comparison of footprint outline identification of girls aged 11-13 years with the use of: 1 - curvilinear guides, 2 - rectilinear guides

On the basis of the developed method the algorithm of automatic calculation of coordinates of feet outline curve with various lengths for 11–13-year-old girls is formed (Fig. 5).

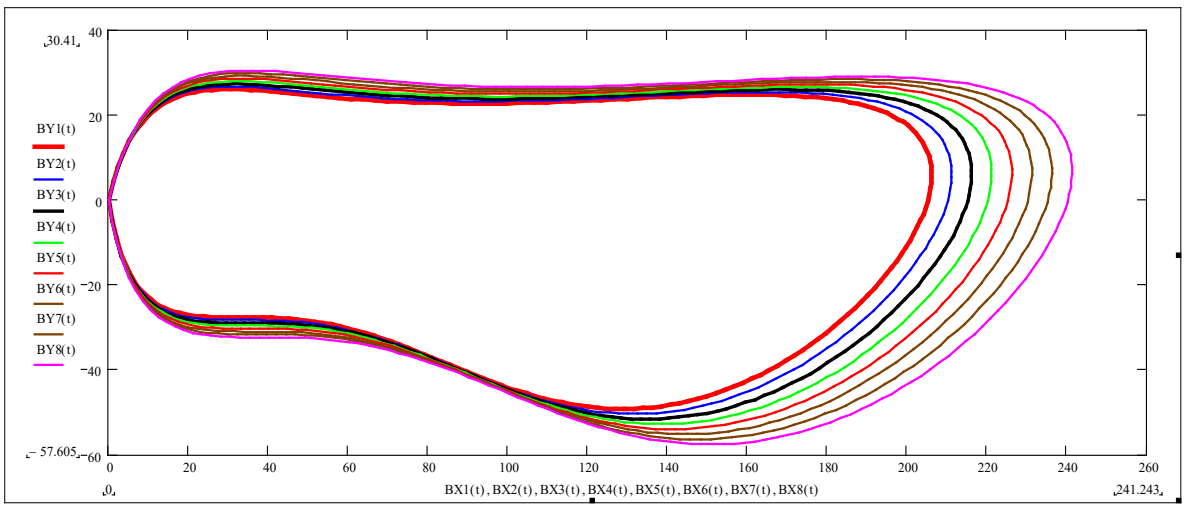
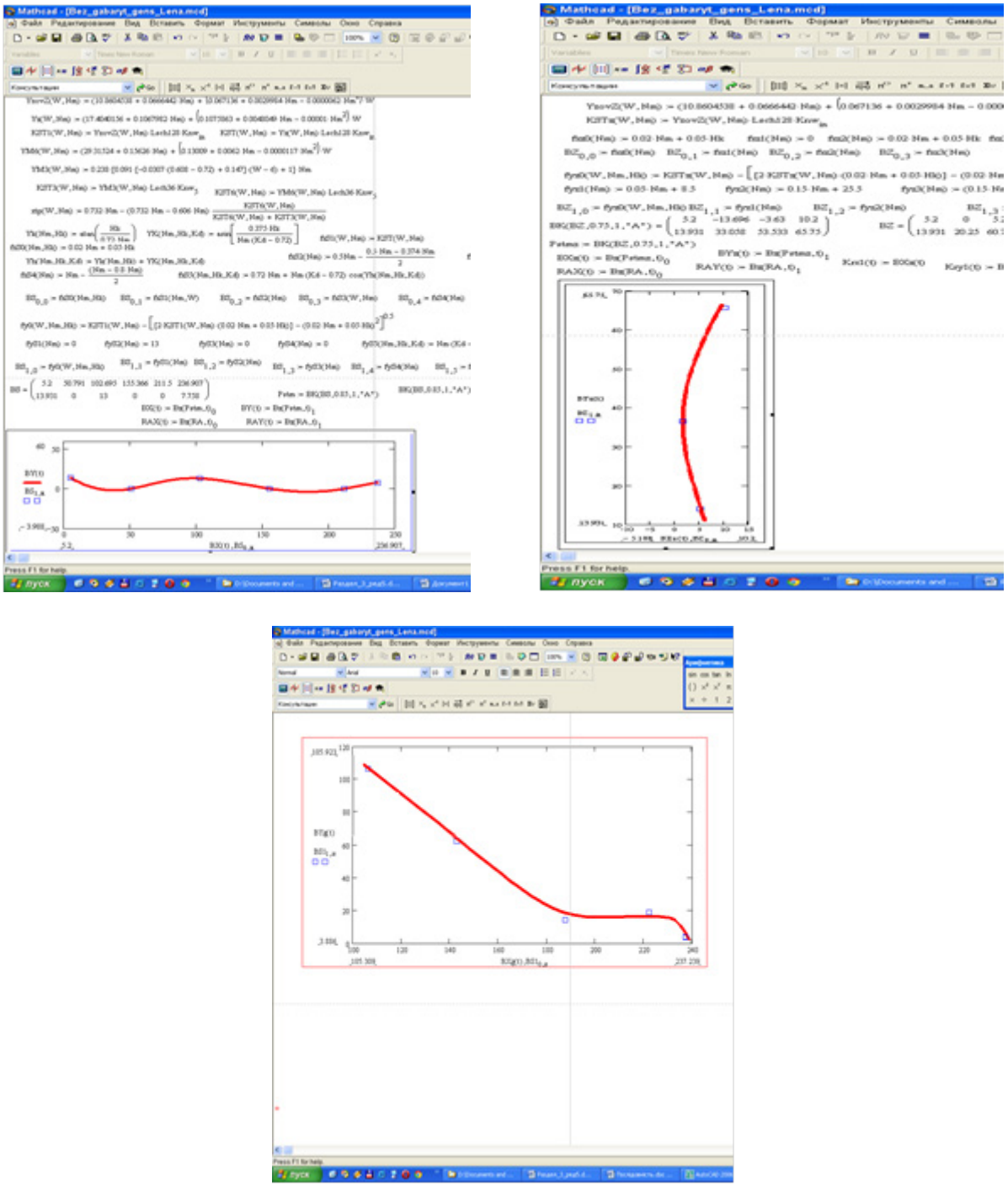


Figure 5. Comparison of outline curves for foot length from 205 to 255 mm for 11–13-year-old girls

Analytical bases of calculation of spline points coordinates for curves with circular curvilinear guides for the basic types combinations of sites are developed (the beginning - curvilinear convex, final - rectilinear; the concave circular guide - rectilinear guide, the convex curvilinear guide - concave, etc.). Blocks for calculation of spline points coordinates for curves with circular curvilinear are also developed. Software modules are compiled in the MathCAD computer system (Fig. 6).



c)

Figure 6. Software module for process of parametric designing the shoe upper details: a) the outline of the trace; b) heel contour; c) the outline of the apex

The software module for process of parametric designing the shoe upper details gives possibility for quickly implement a new range of shoes, while ensuring high accuracy and quality of design.

The term “modular transformation” is proposed to use for developing schoolchildren’s shoe designs. This method means converting one form of construction into another or changing a part within this form using known dedicated modules.

The main design features of modular transformation:

– taking into account the anatomical features of the feet;

– adherence to the basics of shoe design;

– preservation of product functionality;

– manufacturability of the structure;

– providing ergonomic requirements for shoes for schoolchildren;

– aesthetics.

On the basis of the developed parametric models and the proposed principles of modular transformation the low shoes were designed and made (Fig. 7).

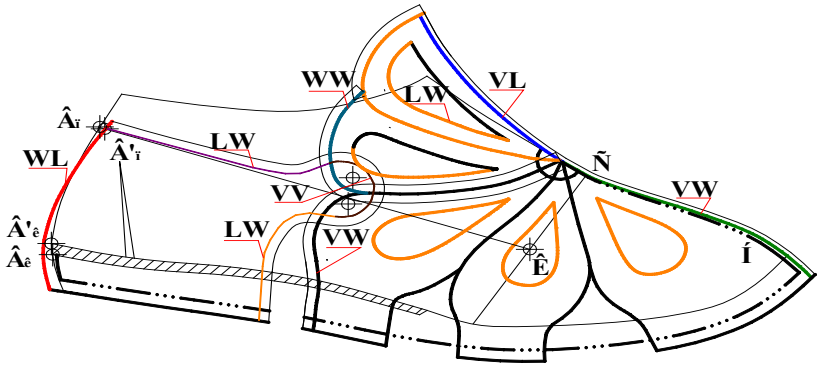


Figure 7. Design of the low shoes using spline curves with curved guides

In Fig. 7, the following designations of combinations of spline curves depending on the generally accepted principles of footwear designing are accepted:

WL initial guide curved convex, final - rectilinear (marked in red);

VL initial guide is curved concave, the final one is rectilinear (marked in dark blue);

WV initial guide curved convex, final - curved concave (marked in green);

VW initial guide rectilinear, final - curvilinear convex (marked in black);

LV initial rectilinear guide, final - curved concave (marked in purple);

LW initial rectilinear guide, final - curved convex (marked in orange);

WW initial guide curvilinear convex, final - curvilinear convex (marked in blue);

VV initial guide curved concave, final - curved concave (marked in brown).

So, as can be seen from Fig. 7, the practical application of the developed software module allows obtaining fundamentally new approaches to the design of uppers shoe for students.

For adequate transition from the calculations and the resulting outlines of the foot of the longitudinal-vertical section of the internal form [14], which are obtained in the computer system MathCAD (PKG-7540-FN Mathacad Education - University Edition) to direct design in AutoCAD used the principles of cloud technology (Fig. 8).

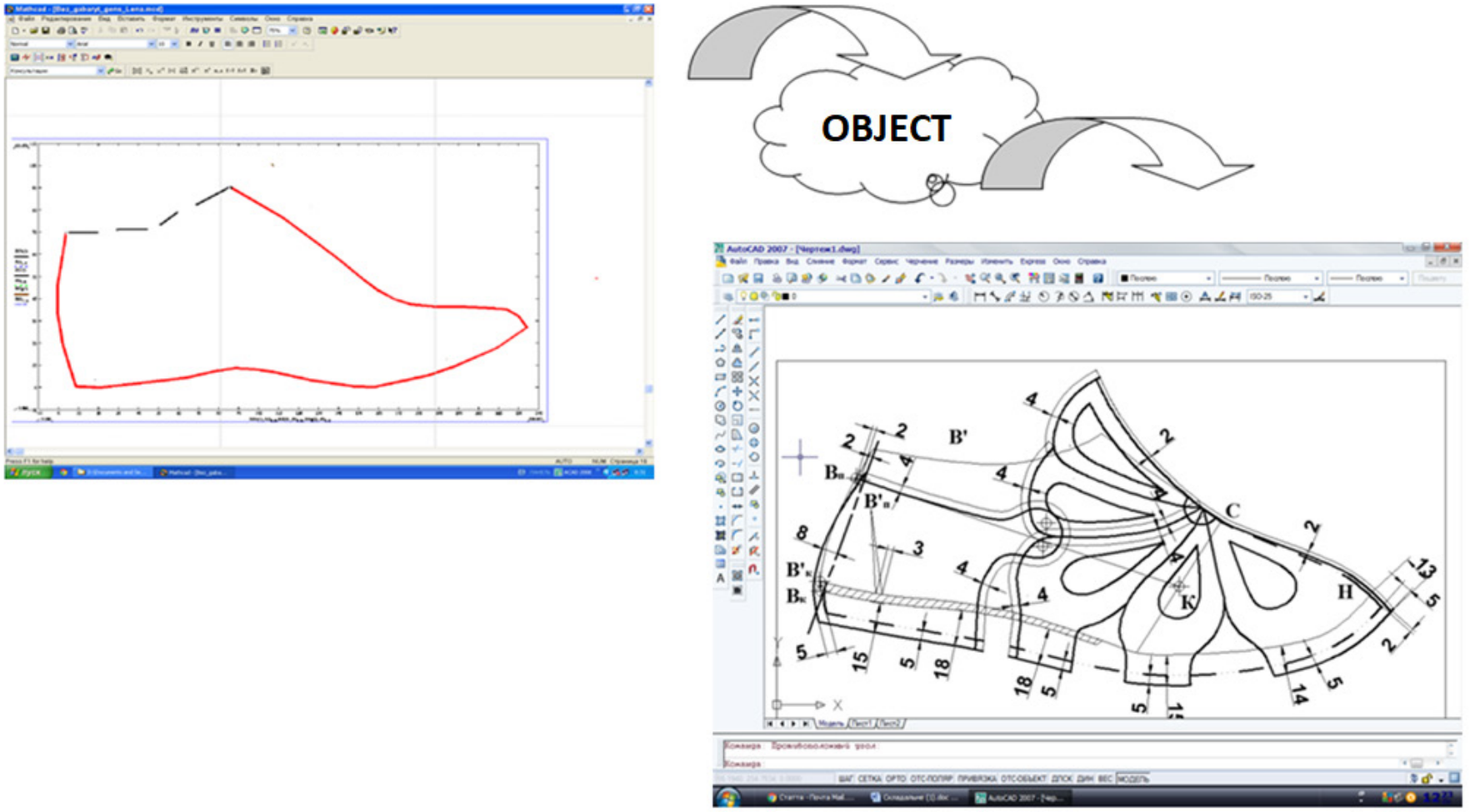


Figure 8. Element of the transition from Mathacad Education to AutoCAD

On the basis of the conducted research, the experimental batch of low shoes for girls (Fig. 9) was made, which was then transferred for carrying out experimental wearing.

Figure 9. Experimental sample of low shoes

According to the experimental wearing results, the experimental batch of low shoes for girls received a positive conclusion, and was launched into shoe production PE "KM-PODILLIA".

CONCLUSIONS

1. The age limits for which it is advisable to develop parametric aspects of shoe upper design are set in 11-13 years.

2. Regularities between different parameters of students' feet are determined:

- frequency distribution of longitudinal, height and transverse sizes of feet (latitudinal and circumferential) with the maximum probability is expressed by the law of normal distribution;
- average circumferential and latitudinal sizes of feet of Ukrainian schoolchildren are connected with their length by orthogonal regression dependence. The absolute values of the error of the regression equations for different parameters range from 0.7 to 7.7 mm, which is very important for shoe design;
- all the same sizes of feet have a close proportional relationship: long - with foot length, transverse - with foot width. This allowed taking into account the real anatomical foot characteristics in the shoe upper design.

3. The software module of received data processing in the MathCad Education was developed, which allows creating parametric models of foot and longitudinal-vertical section of an internal form, with a deviation no more than 5%.

4. The basic principles of modular transformation of footwear for schoolchildren are offered. This approach results in different complexity of product design elements that are interconnected. Application of modular transformation at footwear designing for schoolchildren will allow to receive various transformations of a design on degree of closedness, possibility of the maximum operation of a product and economy on material resources.

5. On the basis of the developed parametric models and the offered principles of modular transformation the low shoes are designed and made. The made experimental batch of low shoes for girls received the positive conclusion on experimental wearing results and was launched into footwear production PE "KM-PODILLIA".

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