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DEVELOPMENT OF INFORMATIONAL-TECHNOLOGICAL SUPPORT FOR DESIGNING CUTTING DIAGRAMS OF HABERDASHERY PARTS

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The object of research is the technological process of cutting rectangular materials into haberdashery parts.

The mathematical statement of the problem to find cutting diagrams of rectangular materials for haberdashery parts is given. The structural components of this problem and its mathematical model were described.

A method for implementing the task set is proposed, which includes the following stages:

– generation of layouts;

– generation of a set of permissible sections of one part, from a combination of two parts, and from a combination of three product parts;

– generation of cutting diagrams of rectangular materials for haberdashery parts from a combination of designed sections.

Implementation algorithms have been proposed for each of the stages of the task. The proposed algorithms were used in the development of information technology support for finding cutting diagrams of rectangular materials for haberdashery parts.

The information and technological support that was offered makes it possible to create graphic visualizations of rational cutting schemes and save them in a file. This feature allows automated cutting systems to use information about such schemes.

The developed information technology support was tested on the parts of haberdashery and showed its effectiveness. This information and technological support can be successfully used at haberdashery enterprises in preparatory and cutting production to increase the utilization of material during cutting by 1.5–2.5 %.

Thus, the proposed information and technological support makes it possible to improve the technological process of designing rational schemes of cutting for haberdashery articles

Keywords: rational cutting, cutting schemes, haberdashery

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1. Introduction

Cutting raw materials into smaller parts is a fundamental stage of many production processes, which has a significant economic and environmental impact. Appropriate solutions to these problems are extremely important for various sectors of the economy, including the textile, footwear, haberdashery, automotive, and shipbuilding industries.

The rapid development of computer equipment created favorable conditions for the introduction of computer technologies in the production of light industry products.

The introduction of computer technologies in the production of light industry articles has the greatest effect in the preparation of design documentation and in preparatory and cutting production.

The implementation of computer technologies in preparatory and cutting production will make it possible to increase labor productivity, the quality of parts of light industry products due to the introduction of automated cutting complexes.

The use of high-quality software for the automated design of rational material cutting schemes for parts of light industry products will increase the percentage of effective use of material during cutting and reduce the amount of waste that will need to be disposed of.

Among the branches of light industry, the leather and haberdashery industries are in the worst state, as far as the introduction of computer technologies in the preparatory and cutting production is concerned. Attempts were made to adapt existing software in the shoe industry of light industry for use in preparatory and cutting production in the leather goods industry. This software did not always take into account the peculiarities of the leather goods industry and did not produce satisfactory results. Therefore, it is a relevant task to devise a method of generating rational schemes for cutting rectangular materials into parts of haberdashery articles, which would take into account the specifics of preparatory and cutting production in the leather haberdashery industry of light industry.

2. Literature review and problem statement

Problems of two-dimensional (2D) irregular dense placement of flat geometric objects in a closed area on a plane are widespread in such industries as mechanical engineering, aviation, shipbuilding, automobile manufacturing, clothing, footwear, haberdashery, and furniture manufacturing.

The problem of two-dimensional packing is a typical task of combinatorial optimization, which involves the compact placement of parts of different shapes on a material with defined dimensions in order to minimize the occupied space or maximize the use of the material. The problem of 2D packing is currently recognized as an NP problem, which is mainly solved using heuristic algorithms [1, 2]. But the software implemented on these algorithms does not always give a satisfactory result in an acceptable time. In addition, these algorithms are mostly used for irregular placement.

Works [3, 4] investigated the problems of irregular 2D packing. But they only presented mathematical models, instead of exhaustively considering the problems of two-dimensional irregular packing.

In [5], an interactive «point-to-point» collision algorithm was proposed for determining the intersection and distance along the direction of collision in case of irregular placement. This made it possible to speed up the process of interactive design and adjustment of cutting schemes.

In [6], a mixed integer programming model with quadratic constraints was proposed for the problem of irregular packing of strips by flat geometric objects, taking into account the possibility of rotating these objects around a fixed control point inside them. But a significant drawback is that only irregular packing of flat strips by geometric objects was considered.

In work [7], they found the relationship between a point and a line and used the D-function to calculate the distance between a line and a point to measure the overlap in irregular placement.

In works [8, 9], the basic problem of irregular placement was stated, which covers a wide range of packing and cutting problems. An exact model of the nonlinear programming (NLP) problem is proposed, using ready-to-use phi-functions, and an effective algorithm for finding local optimal solutions of the problem over an acceptable time.

In [10], a dense placement strategy based on curve coding and feature matching was proposed. This is a new placement strategy that is based on matching curve similarity features. The above placement algorithms give very good results for specific problems, but their reliability and applicability need further verification.

An effective two-dimensional algorithm for the irregular dense placement of flat geometric objects can effectively improve material utilization and reduce processing costs. Reducing material consumption will also have a beneficial effect on the environment [11]. Therefore, the study of the problem of dense placement of flat geometric objects has great technological and social significance.

Since the task of finding optimal schemes for cutting rolled materials into parts of haberdashery belongs to NP-problems that cannot be solved in polynomial time [12], it is necessary to develop a simplified model of the problem, which would ensure the design of rational schemes of cutting.

The considered approaches do not offer regular placement of parts in the cutting pattern, but in the preparatory and cutting production of leather goods, the cutting pattern consists of blocks with regular placement of parts.

Therefore, in order to solve this problem, there is a need to develop specialized information and technological support that would take into account the specifics of preparatory and cutting production in the leather goods industry.

3. The aim and objectives of the study

The purpose of this study is the development of information technology support for generating rational schemes for cutting rectangular materials into haberdashery parts.

To achieve the goal, the following tasks were solved:

– generation of rational schemes for cutting rectangular materials into parts of haberdashery;

– descriptive implementation of the structural components of the task of generating rational schemes for cutting rectangular materials into leather parts.

4. The study materials and methods

The object of research is the technological process of cutting rectangular materials into haberdashery parts.

The subject of the study is the automated design of rational schemes for cutting rectangular materials into haberdashery parts.

The research methods are based on the basic provisions of the haberdashery production technology, mathematical modeling, the theory of lattice laying, the methods of computer graphics, computational mathematics, and analytical geometry.

Since the task of finding optimal schemes for cutting materials of a rectangular form of a haberdashery detail in the general setting refers to NP-problems, the current paper considers a simplified model of this problem.

For the purpose set in the work, the following simplifications are adopted:

– the scheme of cutting the materials of a rectangular form into parts of haberdashery consists of sections;

– the section consists of layouts;

– a set of admissible cutting schemes is generated from a set of generated sections;

– from the set of generated admissible cutting schemes, there is a rational cutting scheme with the highest percentage of utilization.

The Delphi (USA) programming environment and the ObjectPascal (USA) programming language were used for software implementation of the task of finding optimal schemes for cutting materials of a rectangular form into haberdashery parts.

5. Results of research into the automatic generation of rational schemes for cutting rolled materials into parts of leather articles

5. 1. Generation of rational schemes for cutting rectangular materials into parts of haberdashery

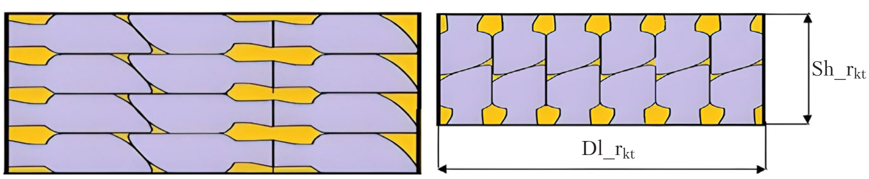
The external contours of haberdashery parts cannot always be described analytically. Therefore, for their unambiguous representation in the cutting diagram, these contours will be approximated. We shall take the piecewise-linear method as the approximation method where there are no restrictions on the configuration of the external contour of the part and in which it is always possible to approximate this contour with a given accuracy. With the piecewise linear approximation method, the outer contour of the part is represented by a polygon for an unambiguous representation of which it is enough to know the coordinates of the vertices and the sequence of passing them. Then the external contour of the part S^k can be uniquely represented as $S^k\{X_i^k, Y_i^k\}$, $i=1,2,\ldots,N_k$, where $X_1^k = X_{Nk}^k$ and $Y_1^k = Y_{Nk}^k$.

Technological statement of the problem. On the material of a rectangular shape with a given length Dl_M and width Sh_M, it is required to tightly place R sets of parts S^k, $k=1, 2 \ldots q$ in such a way that the length of the material DlR_S occupied by the cutting pattern is minimal. At the same time, it is necessary to take into account that one set contains $\tilde{N}_k$ parts S^k. In the cutting diagram, parts can be placed with a rotation of 0 and 180 degrees relative to their basic position.

Mathematical statement of the problem. Among the set of admissible cutting schemes Sm_i, $i=1, 2 \ldots r$ for R sets of parts S^k, $k=1, 2 \ldots q$ in a rectangular area with a given length Dl_M and width Sh_M, it is required to determine the one for which the length of the material DlR_Sx_i, occupied by this cutting scheme, would be minimal, that is, for which $DlR\_S = \min\limits_{i=1,2,\ldots,t}(DlR\_Sx_i)$. It is necessary to take into account that parts in the cut-out diagrams can be placed with a rotation of 0 and 180 degrees relative to their basic position.

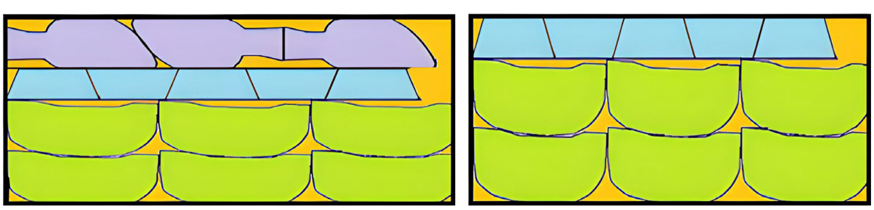
As components of the cutting scheme, we shall take the layouts and sections defined in [13] for sheet materials. We adapt them to rectangular materials. Examples of layouts and sections for rectangular materials are shown in Fig. 1, 2.

We shall take the layout as the basic unit in the cutting diagram. Sections will consist of acceptable layouts, and acceptable cut diagrams will consist of acceptable sections.



a *b*

Fig. 1. Examples of layouts: *a* — layout with a rotation of parts by 180° in a row; *b* — layout without turning parts in a row



a *b*

Fig. 2. Examples of sections: *a* — section that is a combination of two layouts; *b* — section, which is a combination of three layouts

Subtask «Set». From the set of admissible sections $\hat{S}$, it is required to choose such a subset of sections $\breve{S}$, the combination of which will form a cutting scheme, in which the complete output of parts will be taken into account and the utilization of material will be maximal.

5. 2. Description and implementation of structural components of the task of generating rational schemes for cutting rectangular materials into parts of leather haberdashery

In the problem of automated design of schemes for cutting rolled materials into parts of leather goods, taking into account the complete output, the following structural components can be distinguished:

Task «Layout». Since the layout for the part S^k, where $k=1, 2, \ldots, q$, is built according to a rectangular double lattice [14] W^k: $n\bar{a}_1^k + m\bar{a}_2^k + p\bar{g}^k$, where $n=0, 1, 2, \ldots, n_{kt}$, $p=0, 1$, $m=0, 1, 2, \ldots, m_{kt}$, the analytical representation of the acceptable arrangement R'_{kt} takes the form $n_{kt} \cdot m_{kt} = Nr_{kt} \le R \cdot N^k$, where Nr_{kt} is the number of parts S^k in layout R'_{kt}, n_{kt} is the number of parts S^k in a row and m_{kt} is the number of rows in layout R'_{kt}, $t=1, 2, \ldots, t_k$.

Mathematical notation of the set of admissible solutions to the problem.

The set of admissible solutions to the «Layout» problem is the layouts W^k: $n\bar{a}_1^k + m\bar{a}_2^k + p\bar{g}^k$, where $n=0, 1, 2, \ldots n_{kt}$, $p=0, 1$, $m=0, 1, 2, \ldots m_{kt}$, which satisfy the following conditions:

– the number of parts in the layout does not exceed the need for them, i.e., $Nr_{kt} \le R \cdot N^k$;

– the width of the layout is less than the width of the material, i.e., $Sh\_r_{kt} \le Sh\_M$;

– the length of the layout is shorter than the length of the material, i.e., $Dl\_r_{kt} \le Dl\_M$;

– the density of the layout is higher than the permissible density, i.e., $P_{kt} \ge P$.

If $\bar{a}_1^k \parallel OX$ and $\bar{a}_2^k \parallel OY$, then:

$$Dl\_r_{kt} = (n_{kt} - 1) \cdot |\bar{a}_1^k| + Dl\_d_k + g_x^k;$$

$$Sh\_r_{kt} = (m_{kt} - 1) \cdot |\bar{a}_2^k| / 2 + Sh\_d_k. \quad (1)$$

If $\bar{a}_2^k \parallel OX$ and $\bar{a}_1^k \parallel OY$, then:

$$Dl\_r_{kt} = (m_{kt} - 1) \cdot |\bar{a}_2^k| / 2 + Dl\_d_k;$$

$$Sh\_r_{kt} = (n_{kt} - 1) \cdot |\bar{a}_1^k| + Sh\_d_k + g_y^k. \quad (2)$$

Then:

$$P_{kt} = f(\bar{a}_1^k, \bar{a}_2^k, \bar{g}^k) = = n_k m_{kt} + |S^k| / (Dl\_r_{kt} \cdot Sh\_r_{kt}).$$

Objective function. The objective function for the *«Layout»* problem takes the following analytical form:

$$P_{kt} = (R_{st}, R_{gt}, R_{jt}) = = n_k \cdot m_{kt} \cdot |S^k| / (Dl\_r_{kt} \cdot Sh\_r_{kt}), \quad (3)$$

where $|S^k|$ – area of part S^k.

Task «Section». The analytical representation of the admissible section takes the following form:

$$n_{st} \cdot m_{st} = \tilde{N}r_{st} \le R \cdot N^s,$$
$$n_{gt} \cdot m_{gt} = \tilde{N}r_{gt} \le R \cdot N^g, \quad (4)$$
$$n_{jt} \cdot m_{jt} = \tilde{N}r_{jt} \le R \cdot N^j,$$

where n_{st}, m_{st}, n_{gt}, m_{gt}, n_{jt}, m_{jt} – respectively, the number of rows and columns with the part S^s, S^g, S^j in section $\hat{S}_r$, $s,g,j \in [1 \ldots q]$ and $s \ne g$, $j \ne g$, $s \ne j$.

Mathematical notation of the set of admissible solutions to the problem. The set of admissible solutions to the «Section» problem is the sections for which the density of the section is higher than the admissible density, that is, $P\_s_r \geq P$.

Since the width of the section Sh_s_r is always equal to the width of the material, i.e., $Sh\_s_r = Sh$, the length of the section $Dl\_s_r = \max\limits_{k=s,g,j}(Dl\_r_k)$, where $s, g, j \in [1...q]$ and $s \neq g$, $j \neq g$, $s \neq j$ are the indices of parts S^k, $k = 1, 2, ... q$, from which the section $\widehat{S}_r$, is projected, then the analytical form of the set of admissible sections takes the form:

$$\left(\begin{matrix} n_{st} \cdot m_{st} \cdot \left|S^s\right| + n_{gt} \cdot m_{gt} \cdot \left|S^g\right| + \\ + n_{jt} \cdot m_{jt} \cdot \left|S^j\right| \end{matrix} \right) \Bigg/ \left(\max_{k=s,g,j}(Dl\_r_k) \cdot Sh \right) \geq P. \quad (5)$$

Objective function. The objective function for the «*Section*» problem takes the following analytical form:

$$P\_s_r = f\left(R'_{st}, R'_{gt}, R'_{jt}\right) = \\ = \left(\begin{matrix} n_{st} \cdot m_{st} \left|S^s\right| + n_{gt} \cdot m_{gt} \left|S^g\right| + \\ + n_{jt} \cdot m_{jt} \left|S^j\right| \end{matrix} \right) \Bigg/ \left(\left(\underset{k=s,g,j}{Dl\_r_k}\right) \cdot Sh \right). \quad (6)$$

That is, the set of admissible sections will include sections whose density is higher than the admissible density, i.e., $SP\_s_r \geq P$.

Algorithms for generating an admissible set of sections. Let's consider algorithms for generating sections from one type of parts, from two types of parts, and from three types of parts. To this end, it is necessary to determine the number of each part along the length and width of the section, or in other words: the number of parts in a row and the number of rows with a given part.

Generation of a section of one part S^k. From the set of admissible layouts $\tilde{R}_{kt}$, $k = 1, 2, ..., q$, $t = 1, 2, ..., t_k$ we select those layouts (Fig. 3) for which the following condition is fulfilled:

$$\frac{i_0 \cdot j_0 \cdot \left|S^k\right|}{Dl\_r \cdot Sh} \geq P. \quad (7)$$

This is the criterion for selecting a set of valid sections consisting of identical parts.

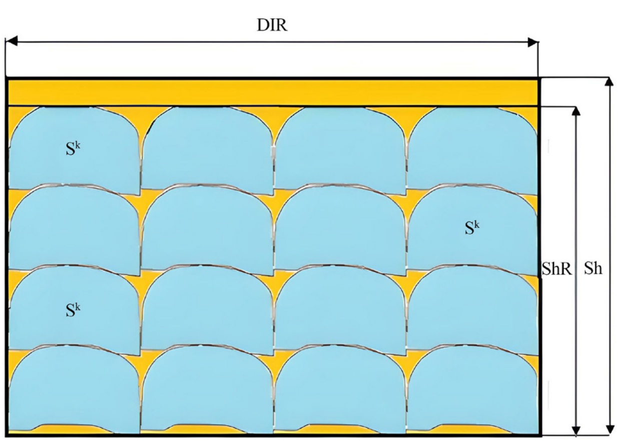


Fig. 3. Section containing one type of part S^k

Generation of sections from a combination of parts S^k and S^l ($k = 1, 2 ... q-1$; $l = k+1, ... q$).

All combined sections, i.e., sections containing two or more types of parts, will be generated from combinations of layouts for different types of parts. Then the generation of sections from the combination of parts S^k and S^l will be performed from the combination of layouts $\widehat{R}_{kr}$ and $\widehat{R}_{lp}$ (Fig. 4).

When generating sections from a combination of parts S^k and S^l, it is necessary to take into account the following limitations of information:

– the total width of the layouts $\widehat{R}_{kr}$ and $\widehat{R}_{lp}$, from which the section is generated, must be less than the width of the material *MS* and greater than the difference between the width of the material and half of the minimum width of the parts S^k and S^l, i.e., $Sh - \min(ShD\_r_{kt}, ShD\_r_{kt})/2 \leq ShS \leq Sh$;

– the absolute value of the difference in the lengths of the layouts $\widehat{R}_{kr}$ and $\widehat{R}_{lp}$, from which the section is generated, must be less than half of the minimum length of the parts S^k and S^l, i.e., $|Dl\_r_{kt} - Dl\_r_{kt}| \leq \min(DlD\_r_{kt} - DlD\_r_{kt})/2$;

– the density of the placement of parts in the section must be higher than the predetermined density *P*, i.e.:

$$\frac{Nr_{kt} \cdot Mr_{kt} \cdot \left|S^k\right| + Nr_{lp} \cdot Mr_{lp} \cdot \left|S^l\right|}{Sh \cdot Dl\_s} \geq P, \quad (8)$$

where $Dl\_s = \max(Dl\_r_{kt}, Dl\_r_{lp})$.

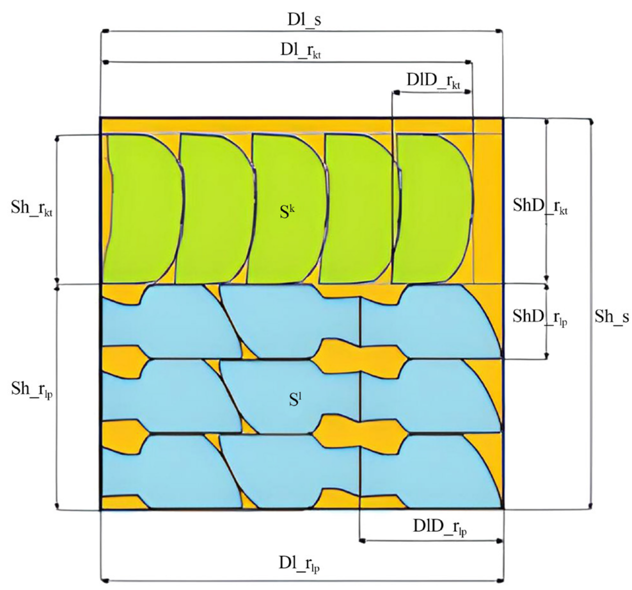


Fig. 4. Example of a constructed section from a combination of parts S^k and S^l

Generation of sections from a combination of parts S^k, S^l and S^r ($k = 1, 2, ..., q-2$, $l = k+1, ... q-1+1, ..., q$).

Generation of sections from a combination of parts S^k, S^l, and S^r will be performed from a combination of layouts $\widehat{R}_{kr}$, $\widehat{R}_{lp}$ and $\widehat{R}_{rj}$ (Fig. 5).

When generating sections from a combination of parts S^k, S^l and S^r (Fig. 5), the following restrictions must be taken into account:

– the total width of the layouts $\widehat{R}_{kr}$, $\tilde{R}_{lp}$ and $\widehat{R}_{rj}$, from which the section is generated, must be less than the width of the material *Sh* and greater than the difference between the width of the material and half of the minimum width of the parts S^k, S^l and S^r, i.e.:

$$Sh - \min\left(ShD\_r_{kt}, ShD\_r_{lp}, ShD\_r_{rj}\right)/2 \leq ShS \leq Sh;$$

– the absolute value of the difference in the lengths of any two layouts from the combination of layouts $\widehat{R}_{kr}$, $\widetilde{R}_{lp}$ and $\widehat{R}_{rj}$ from which the section is generated must be less than half the minimum length of the parts from which these layouts are generated, i.e.:

$$\begin{cases} |Dl\_r_{kt}-Dl\_r_{lp}| \le \min\left(Dl\_r_{kt},Dl\_r_{lp}\right)/2; \\ |Dl\_r_{kt}-Dl\_r_{rj}| \le \min\left(Dl\_r_{kt},Dl\_r_{rj}\right)/2; \\ |Dl\_r_{rj}-Dl\_r_{lp}| \le \min\left(Dl\_r_{rj},Dl\_r_{lp}\right)/2; \end{cases} \quad (9)$$

– the density of placement of parts in the section P_s must be higher than the predetermined density P, i.e.:

$$\frac{R_{kt}\cdot N\cdot R_{kt}\cdot M\cdot\left|S^k\right|+R_{lp}\cdot N\cdot R_{lp}\cdot M\cdot\left|S^l\right|+R_{rj}\cdot N\cdot R_{rj}\cdot M\cdot\left|S^r\right|}{Sh\cdot Dl\_s}\ge P, \quad (10)$$

where $Dl\_s=\max(Dl\_r_{kt}, Dl\_r_{lp}, Dl\_r_{rj})$.

Each generated section $\widehat{S}_i$ will contain the following information:

– a sign of the composition of the section $P\widehat{S}_i$ ($P\widehat{S}_i=1$, if the section consists of one type of parts; $P\widehat{S}_i=2$, if the section consists of two types of parts; $P\widehat{S}_i=3$, if the section consists of three types of parts);– the length of the section Dl_s_i;

– B_{ij} –the number of j-th parts in the section $\widehat{S}_i$;

– three pairs of numbers: Nd_1, Ns_1, Nd_2, Ns_2, Nd_3, Ns_3, where Nd_1 (Nd_2, Nd_3) is the serial number of the part from which the first (second, third) layout of the section is built; Ns_1 (Ns_2, Ns_3) – serial number of the layout with part Nd_1 (Nd_2, Nd_3), used when constructing the section $\widehat{S}_i$;

– the density of placement of parts P_s_i in the section:

$$Q_1=\left(Sh-\min\begin{pmatrix} ShD\_r_{kt}, \\ ShD\_r_{ip}, \\ ShD\_r_{lp} \end{pmatrix}/2\le ShS\le Sh\right); \quad (11)$$

$$Q_2=\begin{pmatrix} \left|Dl\_r_{kt}-Dl\_r_{lp}\right|\le\min\left(DlD\_r_{kt},DlD\_r_{lp}\right)/2 \\ \left|Dl\_r_{kt}-Dl\_r_{rj}\right|\le\min\left(DlD\_r_{kt},DlD\_r_{rj}\right)/2 \\ \left|Dl\_r_{rj}-Dl\_r_{lp}\right|\le\min\left(DlD\_r_{rj},DlD\_r_{lp}\right)/2 \end{pmatrix}; \quad (12)$$

$$Q_3=\frac{R_{kt}\cdot N\cdot R_{kt}\cdot M\cdot\left|S^k\right|+R_{lp}\cdot N\cdot R_{lp}\cdot M\cdot\left|S^l\right|+R_{rj}\cdot N\cdot R_{rj}\cdot M\cdot\left|S^r\right|}{Sh\cdot Dl\_s}\ge P. \quad (13)$$

These parameters of the section $\widehat{S}_i$, $i=1, 2 \ldots i_s$ allow you to unambiguously determine the layouts that make up the section and calculate the coordinates of the poles of the parts in the section, which makes it possible to unambiguously reproduce the generated section.

To select such a combination of sections that ensures a complete output of parts at the maximum density of placement of parts in the cutting scheme, we adapt the algorithm presented in [15].

The density of placement of parts in the cutting diagram will be determined as follows:

$$P\_sx=\frac{\sum_{i=1}^{i_s} Dl\_s_i\cdot Ks_i\cdot P\_s_i}{\sum_{i=1}^{i_s} Dl\_s_i\cdot Ks_i}. \quad (14)$$

The algorithms described above ensure the generation of a set of admissible schemes for cutting rolled materials into parts of leather goods and selecting from them the scheme with the densest placement of parts, which ensures a complete output of parts.

The proposed mathematical models of the task of automated design of schemes for cutting rolled materials into parts of leather goods were implemented in an information product in the Delphi programming environment. The developed information product is easy to use and does not require a lot of time to master it.

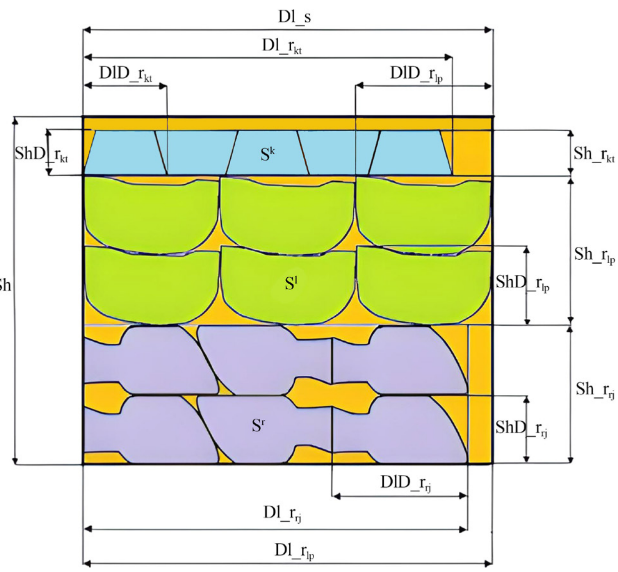


Fig. 5. Example of a constructed section from a combination of parts S^k, S^l and S^r

Fig. 6 shows drawings of the designed cutting scheme using the developed software product.

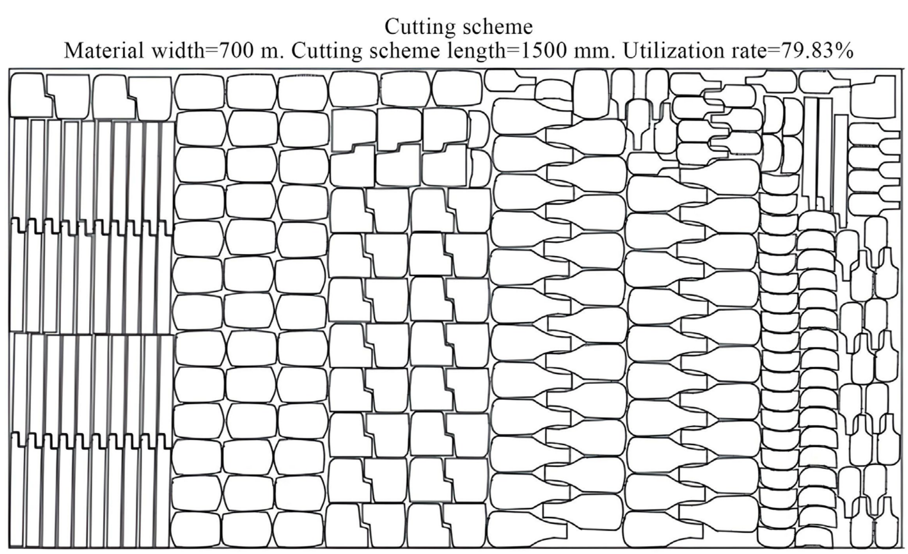


Fig. 6. Projected cutting scheme

Information about designed cutting schemes can be saved in a file and used by cutting equipment for automatic cutting of material into parts of haberdashery according to the projected cutting scheme.

6. Discussion of results of automatic generation of rational schemes for cutting rolled materials into parts of haberdashery

To solve the problem set, it was divided into three consecutive tasks, namely: generation of a set of admissible layouts, generation of a set of admissible sections, generation of a set of admissible cutting diagrams, and search of the most effective one from this set.

The use of a rectangular double grid when generating layouts has made it possible to significantly speed up this process.

When generating, three main types of sections are considered:

– sections that contain rational schemes for each of the product parts;

– sections that contain rational schemes from the combination of two parts of the product;

– sections that contain rational schemes from a combination of three parts of the product.

Algorithms have been proposed for generating a set of admissible sections according to the criteria represented by expressions (7) to (13) and Fig. 3–5.

The selection of three main types of sections, which make up the cutting diagram, made it possible to significantly speed up the process of generating a set of permissible cutting diagrams.

From a set of admissible sections, a set of admissible cutting schemes is generated, and a search for the most effective one from this set of cutting schemes is ensured.

Effective implementation algorithms were proposed for each of the stages of the task. The proposed algorithms were used in the development of software for finding cutting diagrams of rectangular materials for haberdashery parts.

From a practical point of view, information software was developed, which was tested on the parts of haberdashery and showed its effectiveness and ensures the generation of an effective cutting scheme in a few minutes.

This information provision is much more effective than the one proposed in [16], which is based on a modification of the genetic algorithm and does not always provide a satisfactory result in a limited time. Its use will increase the utilization of material during cutting by 1.5–2.5 % and will allow the introduction of automated cutting systems into cutting production.

For the application of information support, in addition to meeting the technological requirements for cut-out diagrams, there is one limitation: the parts of a product must be polygons or be approximated by polygons with the required accuracy. Polygons are defined by the coordinates of their vertices.

The disadvantages of this study are:

– the lack of possibility of automatic or interactive input of information about external contours of parts in the form of coordinates of approximating polygons;

– the lack of possibility of interactive adjustment of projected cutting schemes.

In the future, solving these issues will help develop software that will be more universal and high-quality.

7. Conclusions

1. A method to automatically generate rational schemes for cutting rectangular materials into haberdashery parts, taking into account the complete output of parts, is proposed. In the developed method of automatic generation of rational cutting schemes, an original method for implementing the given task is proposed, by distinguishing three consecutive subtasks:

– generation of a set of admissible layouts;

– generation of a set of admissible sections;

– generating a set of admissible cutting schemes and searching for the most effective one from this set.

2. The main structural components of the task of automatic generation of rational schemes for cutting materials of a rectangular shape into haberdashery parts, taking into account the complete output, are highlighted. The developed algorithms for generating a set of admissible layouts and sections made it possible to create effective information support. The implementation of this information support in the preparatory and cutting production of leather haberdashery will increase the efficiency of the utilization of materials during cutting and implement automated cutting systems in cutting production. The developed information support was tested on parts of haberdashery products and showed its effectiveness by increasing the use of material during cutting by 1.5–2.5 %.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

All data are available in the main text of the manuscript.

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