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Economic and mathematical model for calculation of preliminary production costs of multidimensional products for objects of protection having complex geometric shape

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Annotation. The research presents a description of the operational and economic indicators of the protective multidimensional product. The structure of the protective product and the classification system of its model range depending on the type of protection object are described. The estimation of development dynamics of the protective products market is carried out. The process of formation of the industrial enterprise pricing policy on the basis of ABC method and the method of cutting by "Mueller and son" is presented, the mechanism of preliminary calculation of material consumption for the production of protective products on individual order is visualized

1. Introduction

In 2015, the industrial company "NPO "Permneftegaz" expanded its range of products, organizing the manufacture of protective products. The protective product limits the impact of negative and harmful factors on the equipment (hereinafter the object of protection) of the client or its maintenance personnel, creating a closed shell around the object of protection after installation.

Properties of the protective shell are defined by the customer requirements when ordering. The list of specified properties can be formed from the following list: conditions of constant or time-limited maintenance of the specified thermal regime for the object of protection, moisture resistance, vibration protection, noise insulation, dust protection, chemical insulation, visual isolation or hiding, indication of the occurrence of specified events, convenience and speed of installation and dismantling, constructive compliance with the specified form.

Implementation of safety products at the client's company allows to improve economic performance, developing the following tasks:

1. increase in working life of expensive equipment operated in a negative environment;
2. reduction of heat and energy losses of the production line;
3. exception, reducing the impact of harmful factors of the production environment on the staff, decreasing the cost of personal protective equipment (PPE) subject to compliance with labor protection standards.

Compliance with the requirements to the protective product set by the client is achieved by combining it with different properties of materials, components, selected design.

2. Multidimensional product

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Protective products manufactured by the industrial enterprise LLC "NPO "Permneftegaz" are a multidimensional products, described with a set of consumer properties $X=(X_1, X_2,\ldots, X_N)$, amenable to the stage of coordination with the client adjustment, in accordance with the established external conditions while maintaining its overall structural scheme.

The proposed range of protective products consists of a standard model range and products manufactured individually in accordance with the project agreed with the client. Shut-off and adjustment valves were chosen as the basis for the standard model range of protective products, as well as other objects of protection, often repeated in the applications of customers. When agreeing on individual performance of a protective product, the client provides a detailed list of information about the object of protection: operating conditions, geometric dimensions, connector lines, viewing windows, doors, pockets, entry points, and the necessary components.

Compliance with the requirements set by the client to the protective product is achieved by the use of appropriate materials of the upper and lower coatings, filler, filler layer thickness, additional components.

3. Preliminary calculation of production costs

The market of manufacturers of protective products is a model of perfect competition. The client distributes an application for calculation with a limited amount of general information about the object of protection to potential performers in order to establish the range of prices offered on the market. Efficiency in the calculation of the application submitted by the client and not an inflated value of the set price among other competitors can be the key to the success of attracting the client. When carrying out such a preliminary calculation of the protective product cost, it is important for an industrial enterprise to immediately establish a price order taking into account the additional costs that may be incurred during the production process.

A general analysis of all the work carried out by the enterprise allowed to establish that about 10% of all processed applications from the client is confirmed by the order, and the rest pass either to competitors or were submitted by the client for an analytical assessment of the possible cost. Therefore, in order to ensure the stable development of the enterprise direction, it is necessary to increase the volume of processed applications and reduce the price offered to the client while maintaining the overall profitability of production. Reducing the cost of production while maintaining its quality indicators should be ensured by reducing the time of submission processing.

Objects of protection can be divided into several types: elements of the pipeline, shut-off and control valves, test equipment and objects of complex geometric shape. In this paper, we consider the mechanism of preliminary calculation of material consumption for objects of protection with complex geometric shapes.

The protective products produced by an industrial enterprise are manufactured using technical textile materials and fillers. Due to the fact that this area is rather new in comparison with the market of the clothing industry, it is characterized by the absence of uniform standards. At present, the level of development of the clothing industry has reached a stage where for each well-known cutting of a model of clothing or a textile product, depending on their size, the consumption of material for single or mass production is determined.

In the case when the cut is different from the generally accepted standards, the developers calculate its patterns and layout on the material. Carrying out such calculations using specialized software packages is a time-consuming process even for a highly qualified employee. Such an approach for the preliminary calculation of the consumption of material to perform non-standard protective products is not acceptable, and requires a different method of calculation.

The ABC method and the method of designing the cutting by “Muller and Son” were taken as the basis for the authors’ method of calculation. The ABC method is a functional cost calculation, where the calculated product is represented as a system of interrelated functions. The design technique by “Muller and Son” is based on the representation of a three-dimensional body into planar segments that can be measured in length and width.

To simplify the calculation system, we assume that a protection product can be represented as consisting of one or several shapes of a rectangular parallelepiped shape (RPS) for any object of protection of a complex geometric shape. RPS can be described by a combination of its overall dimensions (x, y, z) and the presence of each of its faces (A, B, C).

The amount of material needed to perform such a RPS product can be estimated by presenting it in the form of an unfolded surface consisting of all its faces. Figure 1 shows an example of an isometric product RPS (type a) with its unfolded surface (type b).

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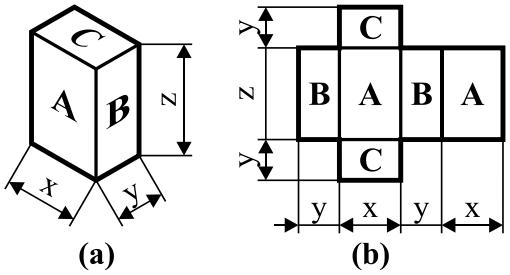


Figure 1. The product RPS and its surface

As can be seen in figure 1 (type b), each of the faces (A, B, C) has its own pair and has two dimensions from its constituent RPS.

The protective product is a combination of layers, consists of top, bottom coatings and filler. This means that such a protective product can be represented as three separate RPS products made of materials corresponding to each layer.

3.1. Estimation of the value occupied by the protective product surface on the material.

When determining the preliminary calculation of the material consumption for the product manufacture, it is necessary to take into account the quantity of the trimmed material obtained. Trimmed material is unused or rarely used in the future work of the enterprise, remains of this material require disposal or prolonged storage in the warehouse for further use.

The materials used by the enterprise are not subject to recovery on its territory, and their cost is significantly lost upon delivery to the processing points. Therefore, the cost of materials should be distributed in proportion to the total volume of their consumption for each protective product.

Each layer of a protective product can be represented as one or several details that can be described as rectangular ones with two overall dimensions - Xw and Lw, where the dimensions are across and along the roll, respectively. The designation of the dimensions of the part varies depending on the location of the part on the roll. Figure 2 shows graphical examples of placing a part with a size Xw smaller than the useful roll width (figure 2a) and exceeding it (figure 2b).

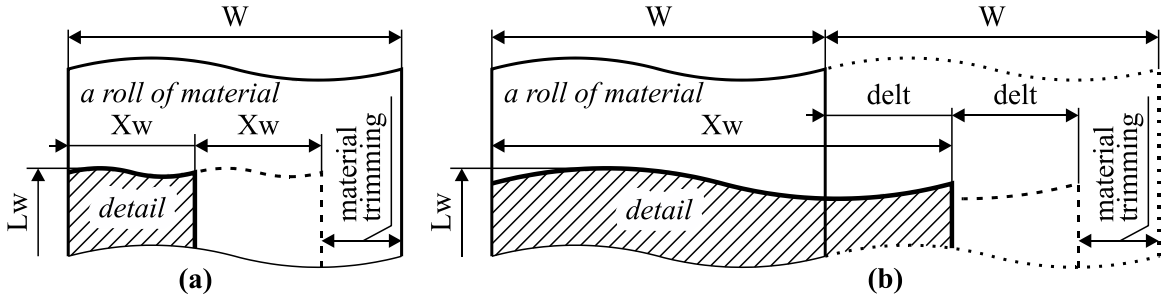


Figure 2. Graphic examples of placing the detail on a roll of material

3.1.1. KDR algorithm for calculating the filling of a roll detail. The input data for the algorithm are Xw (overall dimensions of the part along the roll), W (useful width of the roll), Rz (permission to cut the part along the length of the roll). Based on the accepted condition that each RPS can be represented in the form of one or more rectangular details, described by horizontal and vertical dimensions. Then for each part or combination of details you can set two coefficients (k) for filling the roll with them, the smallest of them will correspond to the optimal material consumption. Different

values of the coefficient (k) are explained by the size of the material cut-off, depending on the multiplicity of dimensions of parts (Xw) to the useful width of the roll (W).

The following figure 3 shows such an algorithm, divided into the following blocks:

Steps 1 and 2. Data entering and analyzing it for completeness of information;

Step 3. Calculation and derivation of the coefficient for the detail, not exceeding the value of W;

Step 4. Check for permission to cut the detail;

Steps 5, 6, and 7. Setting the bandwidth (delt) of the part to be cut from the detail along the length of the roll, calculating the coefficient and deriving it.

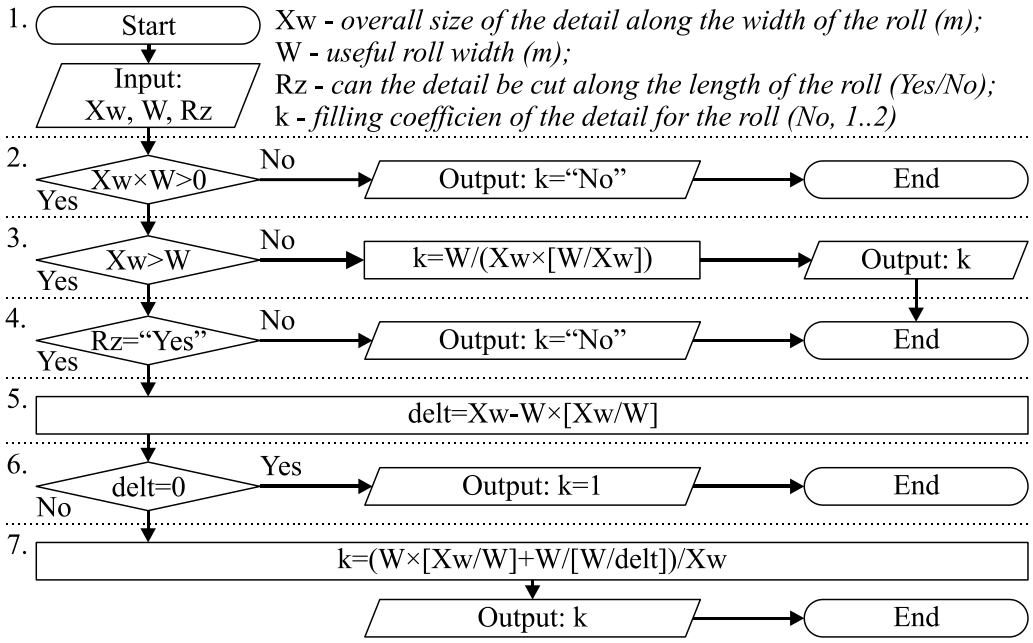


Figure 3. Algorithm KDR for calculating the filling coefficient of the detail on the roll

3.1.2. SRPSR algorithm for calculating the space occupied by the RPS on a roll. The input data for the algorithm are X, Y, Z (overall dimensions of RPS), nA, nB, nC (the required number of corresponding faces in the figure), W (useful roll width), Rz (permission to cut the edges along the length of the roll).

The calculation algorithm is based on the following statement: "On a roll of material, the layout of each face is considered separately, or its layout with the other in combination is one to two." Examples of the layout of faces A and B in various combinations are presented in figure 4. In types 4a and 4f, a combination of faces A and B is depicted in a one-to-one ratio. Views 4b, 4c, 4d, 4e, 4g, 4h, 4i, and 4j reflect different combinations of faces A and B in a ratio of one to two. Types 4b and 4g are not acceptable, since pieces of material equal to faces A and B, respectively, are lost on them in trimming.

From figure 4 it can be seen when calculating the space occupied by the RPS on a material roll, filling factors for a roll detail (k) are required for the following values: x, y, z, 2x, 2y, 2z, (x+y), (x+z) and (y+z), as well as the maximum values of the following pairs: (x, 2y), (x, 2z), (y, 2x), (y, 2z), (z, 2x), (z, 2y). These values will allow to determine the occupied area on a roll for various combinations of pairs of faces from A, B, C in ratios of one to one or one to two.

The input data for the algorithm are Xw (overall dimensions of the part along the roll), W (useful width of the roll), Rz (permission to cut the part along the length of the roll).

The SRPSR algorithm for calculating the space occupied by the RPS on a roll is shown in figure 5. This algorithm consists of the following steps:

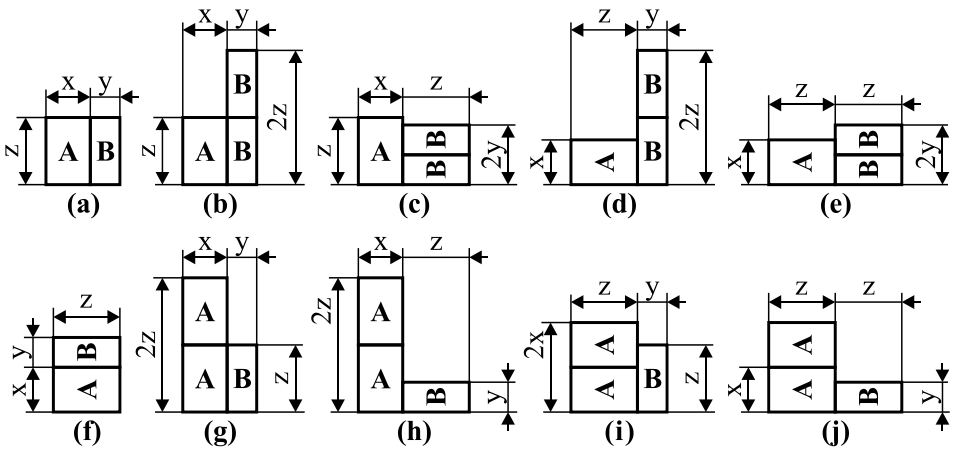


Figure 4. Variations of the layout of faces A and B

Stages 1 and 2. Data entering and analyzing it for completeness of information;

Stages 3 and 4. Calculation of intermediate data for determining the areas occupied on a roll of various combinations of faces;

Stages 5 and 6. Calculation of the spaces A, B and C occupied on a roll and their combinations AB, AC, CB, AB2, AC2, BA2, BC2, CA2, CB2. The space is defined by multiplication of its two dimensions to the minimum of the roll filling factor corresponding to these overall dimensions;

Stage 7. Calculation of ten different variations of the space occupied by the RPS based on the values established at stages 5 and 6.

Step 8. Determination of the minimum of ten variations which is equal to the least space occupied by the RPS and the removal of the spaces of the faces not included in the calculation according to the values of nA, nB and nC from it.

This calculation algorithm has the following limitation - only one or a pair of one type of faces is allowed to be removed from the calculation.

4. Conclusion

Usage of the algorithm presented in this work makes it possible to estimate quickly the required material consumption for each layer of a protective product without the involvement of a highly qualified specialist, to perform the optimal selection of the shape, size and materials of a protective product according to the preferences of the client.

Any additional viewing windows, doors and sleeves that are necessary for making a product can be calculated separately using the KDR roll filling algorithm and adding it to the total volume of materials.

The techniques used in modern programs for designing and calculating textiles are relatively complex and mostly applicable to confirmed orders. The proposed method of calculating textiles is much easier to implement. The efficiency of calculation provided by it allows one to select the properties of a protective product in the maximum accordance with the requirements of the consumer in the shortest possible time, namely, in the interactive mode with direct communication with the consumer.

The enterprise, which focuses on the responsiveness to consumer expectations and the completeness of compliance with them, implements a strategy of non-price competition. The portfolio of satisfied customersformed on this basis, allows the enterprise to provide the necessary balance between profit and workload. With such approach it receives the rights of an expert monopolist in a dedicated segment of the market, which guarantees a stable position and development.

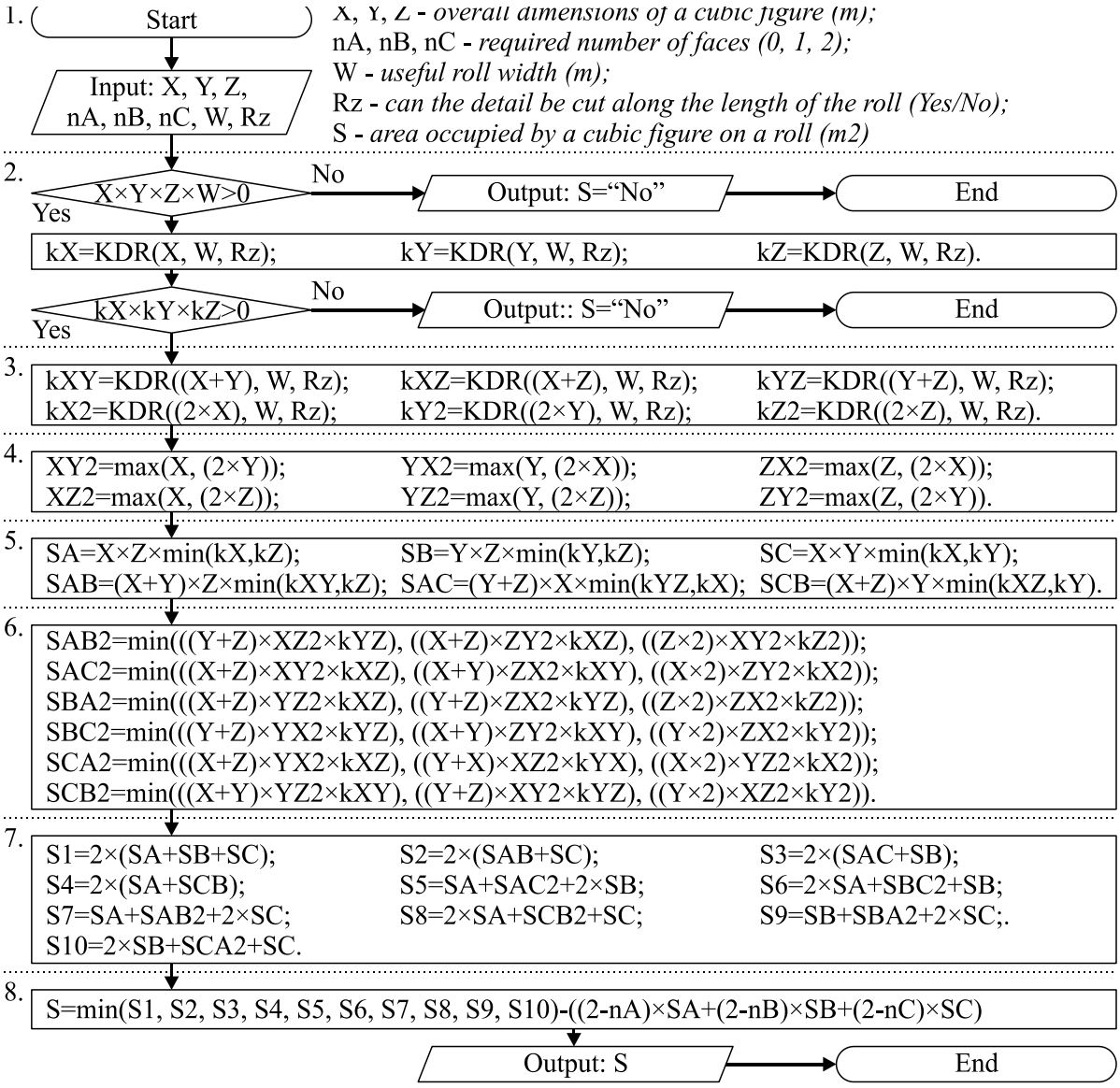


Figure 5. Algorithm SRPSR for calculating the area occupied by the RPS on a roll

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