TECHNICAL SCIENCES

UDC 685.31.02

OPTIMIZING THE MOVEMENT OF THE CUTTING TOOL IN AUTOMATIC CUTTING WITH WATER JET OR LASER BEAM

Chuprynka Viktor Ivanovich
Doctor of Technical Sciences, Professor
Chuprynka Natalia Viktorovna
Candidate of Technical Sciences, Associate Professor
Naumenko Bohdan Vitaliyovych
Vasylenko Oleksiy Leonidovych
graduate students
Kyiv National University of Technology and Design, Kyiv, Ukraine
Syrotynskyi Oleksandr Artemovych
Candidate of Technical Sciences, Associate Professor
National University of Water and Environmental Engineering
Rivne, Ukraine

Introduction. The purpose of automated cutting of materials is to reduce material costs, shorten cutting times and increase the quality of products.

Aim. Development of algorithms and a software product for optimizing the movement of a cutting tool during automatic cutting using a water jet or a laser beam.

Materials and methods. The object of research is the technological process of cutting rectangular materials into haberdashery details. The subject of the study is the automated design of rational schemes for cutting rectangular materials into haberdashery details.

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

Materials and methods. Let us have a cutting diagram of parts, according to which it is necessary to cut with a robotic complex using a laser beam (water jet). The cutting diagram is represented by the coordinates of the vertices of the contours of the polygons, into which the details of the cutting diagram are approximated; coordinates of the point of the initial position of the pen.

Technological formulation of the problem. Cut the rolled material with a laser beam (water jet) according to the original cutting pattern so that the idle speed of the equipment is minimal.

Mathematical formulation of the problem. Find such a sequence of vertices that the circuit of the contours of all parts, starting from the starting point and returning to it, is the shortest.

Since the contour of the details is represented by polygons, we will refer to polygons later (meaning the contours of the details as well).

Let's call the contour of a walk (CW) of a finite set of polygons a closed broken line that contains all (without repetitions) links of the polygons and whose links do not intersect.

Since the traversal loop is closed, the traversal direction and its starting point are chosen arbitrarily.

Since it is necessary to find the minimum path, when moving from polygon to polygon, the shortest distance must be observed - the segment whose ends are the closest points of the contour of the two polygons.

The minimum traversal contour (MTC) of a finite set of polygons will be called the traversal contour of minimum length.

When cutting, the contour of each details must be completely bypassed with a pen. Since the problem of minimization arises, repeated traversals of contours or their details are excluded.

Therefore, we will not take into account the total length of the contours of the details when searching for the MTC, since it has become It is only necessary to minimize the length of the idle stroke of the pen:

$$L = \sum_{i=1}^{n} l_i + idling \to \min;$$

$$l = \sum_{i=1}^{n} l_i = const; \ (1)$$

$$L = const + idling \to \min \Rightarrow idling \to \min,$$

where n is the number of p details in the cutting diagram; i - details number; L is the total length of the pen path when cutting this cutting pattern; li — contour perimeter of the i-th detail; l is the total length of the perimeters of the contours of the details in the cutting diagram; idling is the length of the path with idling.

Since the total length of the perimeters of the part contours l is constant, only the total length of the idling sections is important. Let's present the cutting scheme in the form of a connected graph. Each vertex will correspond to a detail of the cutting scheme, and to the edges - sections of the idle speed.

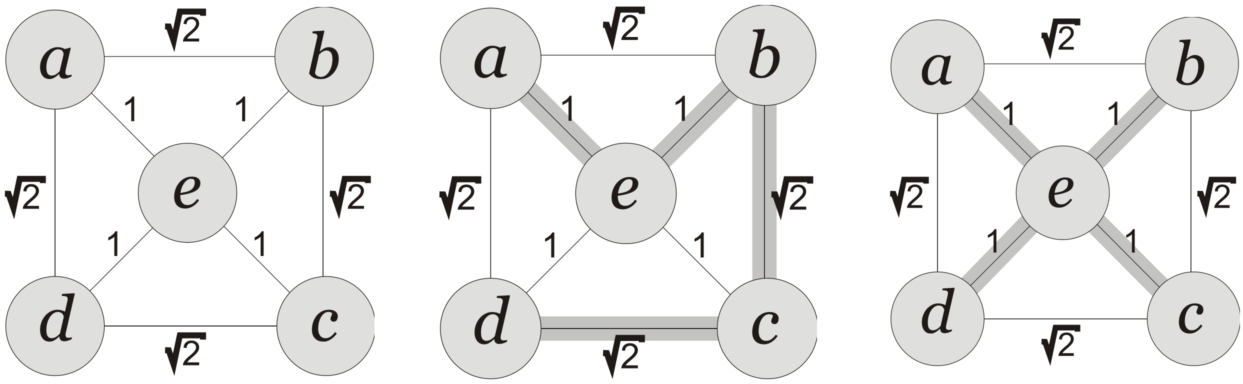
The weight of the edges will be determined as the distance between the nearest vertices of the detail polygons.

It is necessary to define such a subgraph, which would be the basis (skeleton) of the MTC. Since all polygons need to be traversed, the subgraph of the base must include all vertices [1].

It can be a spanning tree or a chain containing all vertices. Let's find a chain containing all vertices and a covering tree of minimum weight for the graph in Fig. 1.a.

The weight of the edges is defined as the geometric distance between the corresponding end vertices of the edges (a triangle inequality occurs). We will consider vertex a as the beginning of the chain and the root of the tree. In fig. 1.b and fig. 1.c the results of this search are displayed.

The length of the chain is much greater than the length of the spanning tree, and when constructing a traversal circuit, its length will double: the traversal length of a→e→b→c→d→c→b→e→a is 9.66 for the chain and the traversal length of a→e→ b→e→c→e→d→e→a is 8 for spanning tree.



a) *b)* *c)*

Fig. 1. Comparison of MTC skeletons by length:

a — count; b is the minimum chain (length = $2 + 2\sqrt{2} \approx 4.83$); c — minimum covering tree (length = 4.0);

Constructed subgraphs do not contain cycles. The use of cycles is impractical for the following reasons:

• the inner or outer contour of the vertices-polygons, which form a cycle, can be bypassed only by repeated partial bypass of their contours, while the edges (idle stroke) must still be bypassed twice;

• the formation of a cycle requires the presence of an extra edge, which increases the idle speed in the CW, which must be minimized. In general, idling can be avoided only if there is no inter-pattern bridge (the weight of the ribs is zero);

Obviously, it is possible to go around the contours of all vertices exactly once with a repeated transition from vertex to vertex. Therefore, the bypass contour is equal to the length of the contours of the parts plus twice the total weight of the idling tree. This will be the smallest bypass circuit.

Stages of construction of the minimum contour of the polygons.

1. Find a vertex-polygon that is located closer than other polygons to the starting point (the point where the pen is located before the start of cutting). (This vertex will be the root of the covering tree.)

2. Construct the adjacency matrix of weighted edges (symmetric). The weight of an edge (i, j) is defined as the geometric distance between the vertices of polygons i and j. In parallel, fill in the matrix of numbers of end edge points with data.

3. Construct a minimal spanning tree with a root at vertex a from item 1. 4.

Build a tree traversal contour, represented by a list of polygon vertices, using the Labyrinth algorithm. To date, the most effective algorithm for finding a minimal covering tree is considered to be the Prim's algorithm, implemented with the help of a Fibonacci heap [1]. At the output of Prim's algorithm, we get a list of edges of the minimal spanning tree. The next step is to turn the unoriented edges of the covering tree (Fig. 3) into oriented links of the bypass circuit (Fig. 4) by applying the "Labyrinth" algorithm.

Results and discussion. The proposed mathematical model and algorithms for optimizing the movement of the cutting tool were implemented in a software product for calculating the minimum contour of bypassing parts in the cutting diagram for the Windows operating system in the Delpi programming environment. The developed software product has a friendly interface and does not require special knowledge of computer science when working with it.

The minimum covering tree for the cutting scheme in fig. 2 is presented in fig. 3. The calculated trajectory of the cutting tool for the cutting diagram in fig. 2 is presented in fig. 4. The proposed software will allow the introduction of automatic cutting complexes with a cutting tool in the form of a water jet or a laser beam into the cutting production. This will improve labor productivity when cutting materials into parts and the quality of the parts that are cut.

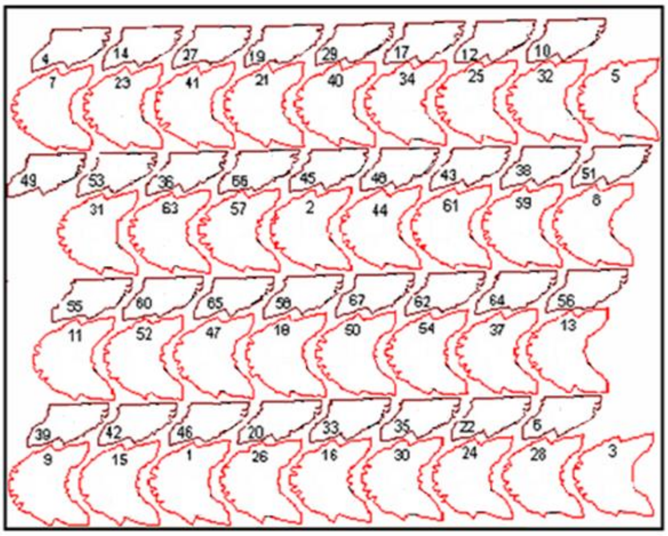


Fig. 2. Cutting scheme, for which the minimum contour of bypassing details is defined

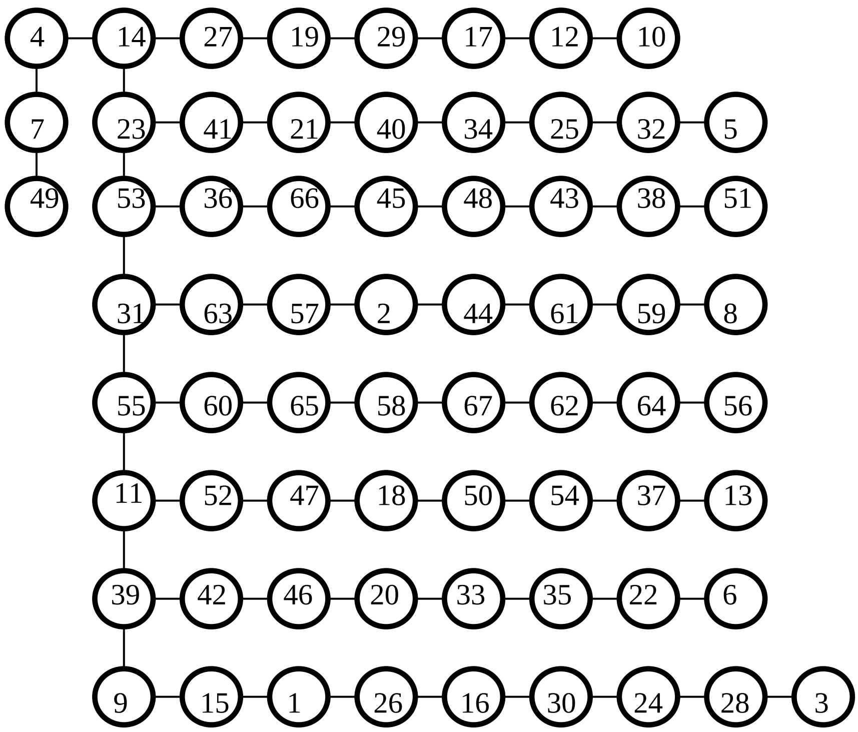


Fig. 3. The minimum covering tree for the cutting diagram in fig. 3.

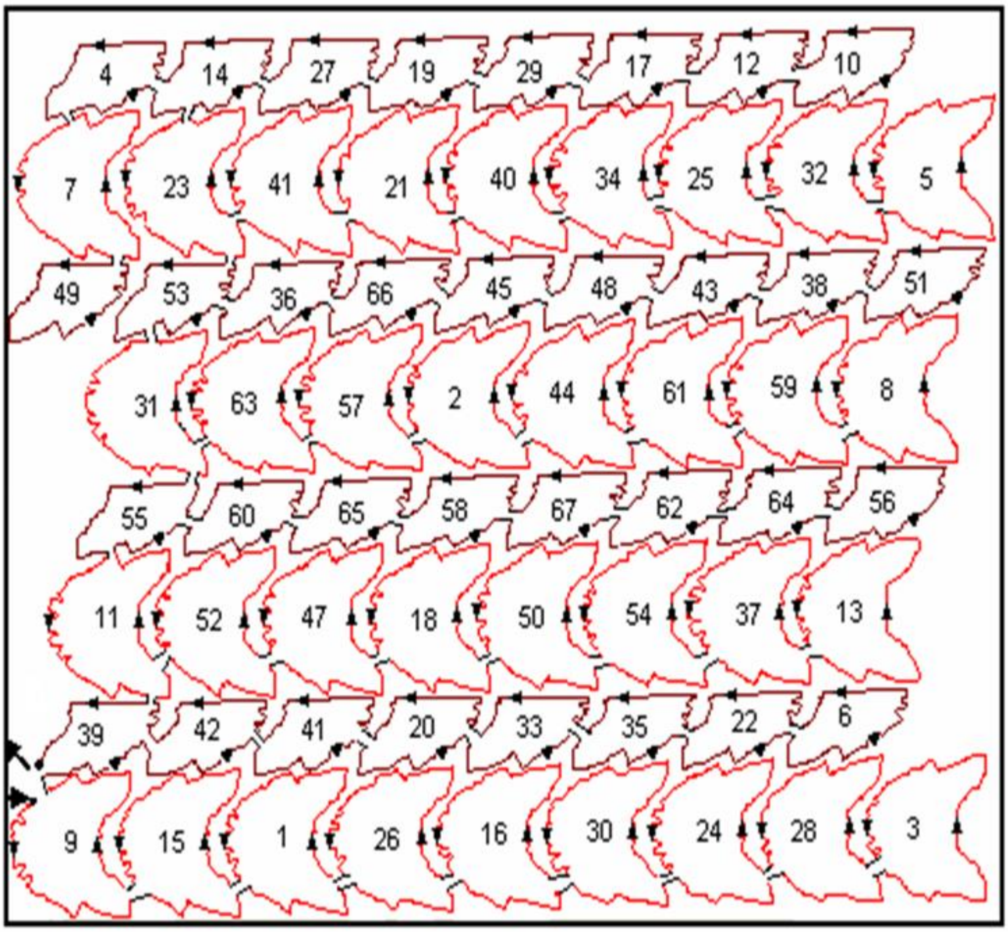


Fig. 4. The minimum contour of bypassing parts in the cutting diagram in fig. 3

Conclusions. The developed mathematical model of the task of optimizing the movement of the cutting tool (laser beam, water jet) was implemented into a software product for an effective robotic cutting complex. The proposed mathematical models and the developed software product can be successfully used in mechanical engineering and other industries.

REFERENCES

1. Kas′yanov V. N. Hrafy v prohrammyrovanyy: obrabotka, vyzualyzatsyya y prymenenye / V. N. Kas′yanov, V. A. Evstyhneev. – S. Pb.: BKHV-Peterburh. – 2003. – 1104 p.