

# Algorithm for automatic calculation of static forces to structural equilibrium

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**ABSTRACT:** This article is devoted to one of the tasks that allow you to automatically perform calculations of the static problems of equilibrium of engineering structures. For this, the authors propose one of the options for the automation algorithm. This version simulates the construction of the tension structure and a simple way to automatically calculate the algorithm

**KEYWORDS:** algorithm, construction, statics, computer programs, force and direction, controlling key, block schema

## I. INTRODUCTION

It is known that the static equilibrium of a structure is one of the main conditions for its stable operation. The designs are heterogeneous, and the external factors acting on it are quite diverse. As a simple task, which is an example, it is given in (Fig. 1a). Calculation of the equilibrium conditions of such structures requires rather complicated computational work. Similar computing work has been carried out for a long time.

## II. OBJECT OF RESEARCH

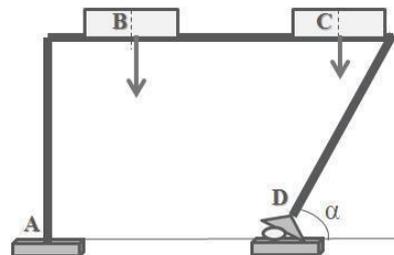
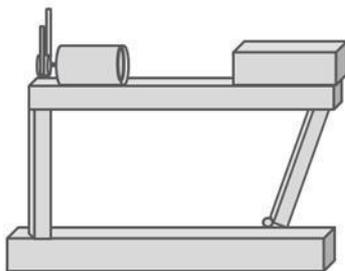


Fig. 1 a. Static equilibrium design Fig. 1 b. Engineering image of external forces vectors

The application of analytical geometry, to simulate the forces of the existing structure and automate the process to quickly and correctly complete the task.

An engineering structure consists of a combination of various figures and can be mathematized using analytical geometry. (Fig. 1b). During the design period of structures (bridges, tunnels, buildings, etc.), a calculation is made for the static equilibrium of structures.

The forces acting on the structure are determined by the point of application and direction. It is known that these forces were balanced, it is necessary that the sum of the projections of these forces on the coordinate axes and the torque relative to the point be equal to zero. The direction of forces can be divided into:

- directed to the point of application “to the point”;
- directed against the point of application “from point”.

The coordinate axis is selected to the horizon parallel and perpendicular. The origin of the coordinate axes so that the entire structure is only on the first octant which can always be achieved. Then the projection of forces on the coordinate axes is easily programmed. In addition, the expression for calculating the torque is found by the well-known formula of mechanics:

$$\vec{M} = \sum_{i=1}^n \pm \vec{P}_i \cdot h_i \quad (1)$$

where  $\vec{P}_i$  are external forces;

$h_i$  is the shoulder of these forces;

$\pm$  sign depending on the direction of torque.

The distance between two points (or in our definitions) the shoulder is determined by the well-known formula:

$$h_i = \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2} \quad (2)$$

The projection of forces to the coordinate axes is determined by the formula:

$$\begin{aligned} \vec{X} &= \sum_{i=1}^n \vec{P}_i \cdot \cos(\widehat{x_i, \vec{P}_i}) \\ \vec{Y} &= \sum_{i=1}^n \vec{P}_i \cdot \sin(\widehat{x_i, \vec{P}_i}) \quad (3) \end{aligned}$$

If you save this information on external computer devices, they are the coordinates of the points:  $A_i(x_i, y_i)$ . One of the basic concepts of statics: for the equilibrium of a solid under the action of a plane system of forces, it is necessary and sufficient that two sums of projections of forces on the coordinate axis and the sum of the algebraic moments of all forces relative to any point on the plane are equal to zero.

Based on this statement and the conditions for finding the structures of the first octant, the calculation of algebraic moments is taken “+” if the force acting on the structure is directed from the point and “-” otherwise.

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### III. METHODOLOGY

The basis of this method is based on analytical geometry. Therefore, when animating, showing the coordinates of the application point is considered necessary. For this purpose, we introduce a scroll bar along the axes OX and OY.

The difficulty in compiling the algorithm lies mainly in displaying the acting forces in the form of a vector, which should show the direction. The length of the vector of the acting forces of the structures, when shown in the form of animation, does not play a role, since only its numerical value is taken into

account. This facilitates the construction of the force vector. The application point is  $A_i(x_i, y_i)$ . The length of the segment representing the force is assumed to be constant equal to 100 pixels. The angle between the axis OX is entered manually. Then to display the segment we get two points

$$A_i(x_i, y_i) \text{ и } B(\bar{x}_i, \bar{y}_i)$$

where  $\bar{x}_i = x_i + 100 \cdot \cos\alpha$ ,  $\bar{y}_i = x_i + 100 \cdot \sin\alpha$ .  $\alpha$  -  $\sin\alpha$ .  $\alpha$  is the angle between the force and the OX axis.

The line connecting these points is an external force.

It should be noted that to draw arrows the direction of forces requires special calculation formulas. Due to the bulkiness, these expressions are not given here.

The main torque according to the formula (1), taking into account the above statements. Leverage torque according to the formula (2). Finding the equivalent projection forces to the coordinate axes is calculated by the formula (3).

To show the direction “from point” or “to point” we use separate control icons. It is necessary to distinguish external forces from the reaction of forces on supports. This can be implemented by entering control icons.

To draw up the equation of balance of forces acting on the structure, we need to have the following:

$$\begin{cases} \vec{X} = \sum_i^n \pi p_x(\vec{P}_i) = 0 \\ \vec{Y} = \sum_i^n \pi p_y(\vec{P}_i) = 0 \\ \vec{M} = \sum_i^n M_0(\vec{P}_i) = 0 \end{cases} \quad (4)$$

where  $M_0$  is the calculation of the torque of the forces relative to the origin.

Based on the above, we construct a block diagram of the algorithm for finding the condition of equilibrium of structures from acting forces

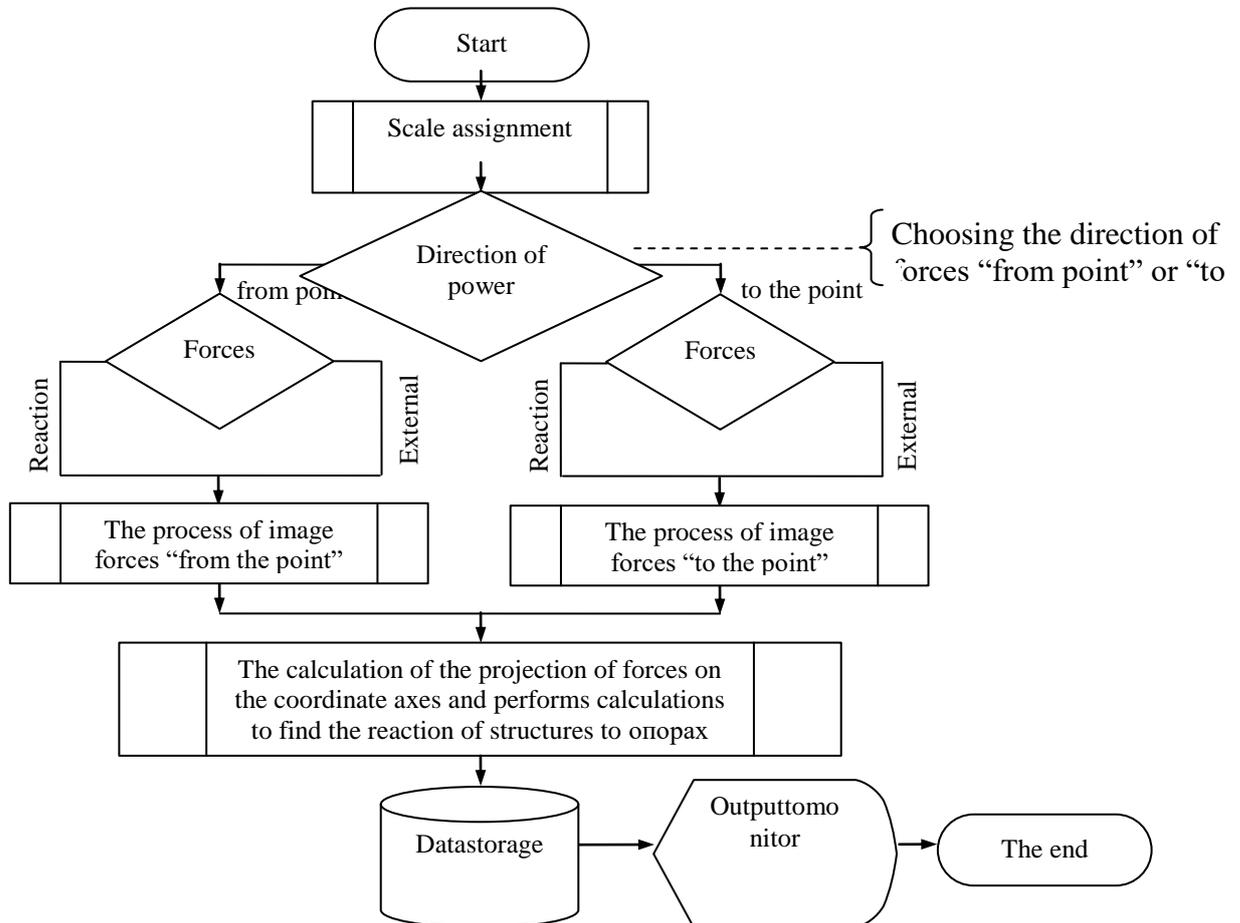


Fig. 1 v. The block diagram of the algorithm is finding the condition of equilibrium of structures from acting external forces.

**IV. EXPERIMENTAL DATA**

Based on the foregoing model, a program in DELPI 7 was compiled. The result of the programs is given in Fig. 1 g. It can be seen from the figure that the display of the acting external forces is possible both on the drawing and on the structure itself.

It should be noted that the figure shows the ability of the module. The figure shows that:

- the point of application of forces is determined by the scroll bar;
- the control button you can select the mode of forces (external or reaction forces support);
- in the area of the result, he will trace the correctness of the initial data and get a calculation of the forces projected on the coordinate axes;
- in the result areas, the letter F is external, R is the reaction force on the supports.

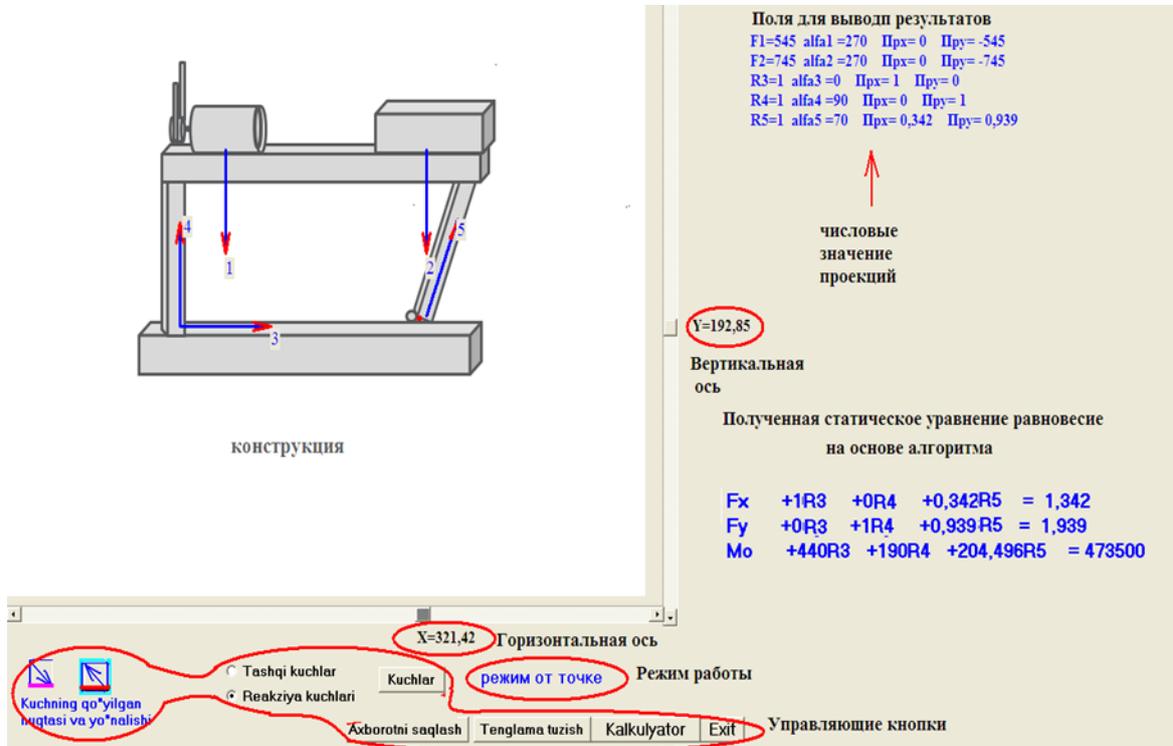


Fig. 1 g. The result of the programs

From the obtained results, taking into account (4), we obtain a system of algebraic equations in a written matrix form :

$$A \cdot X = B$$

Here, the A-matrix, whose elements are the reaction coefficients of forces on the supports.

$$A = \begin{pmatrix} \overline{pp}_x R_1 & \overline{pp}_x R_2 & \overline{pp}_x R_3 \\ \overline{pp}_y R_1 & \overline{pp}_y R_2 & \overline{pp}_y R_3 \\ M_0(\overline{P}_1) & M_0(\overline{P}_2) & M_0(\overline{P}_3) \end{pmatrix}$$

B-represents external forces acting on the structure.

$$B = \begin{pmatrix} \sum_i^n \overline{pp}_x(\overline{F}_i) \\ \sum_i^n \overline{pp}_y(\overline{F}_i) \\ \sum_i^n M_0(\overline{F}_i) + \sum_{j=1}^k M_j \end{pmatrix}$$

where  $M_j, j = \overline{1, k}$ , the torques applied to the structure.

k- is the number of torques applied to the structure.

From the vector equation (4), the reaction force of the structural supports is determined by the formula :

$$X = A^{-1}B$$

which is easily programmed for computers to obtain the numerical value of the forces on the supports.

## V. CONCLUSION

When the design is completely in the first octant, we get the opportunity to describe an algorithm for solving the problem of determining the reaction forces on the supports. In addition, the number of



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external forces is unlimited and it makes it possible to design machine parts taking into account all possible acting forces, quite accurately.

Displaying the design on the monitor makes it easier for the designer to select the acting forces more accurately than abstractly.

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