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OPTIMIZATION OF GEOMETRICAL PARAMETERS OF A METAL FARM

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Annotatsion: This scientific work is devoted to the creation of methods, working out geometrical and machine algorithm in search of optimal geometrical parameters of single-layers rod constructions (rod girders, hanging systems, vaults and space rod constructions with cut-off supporting contour) according to criterion of minimization of material capacity of rod frame. Algorithms of optimization of a geometrical form of rod systems have been built on the bass of the static geometrical method of forming diskrete nets. A new modification has been suggested of the net method of searching for the extremum of purpose function on the basis of Its hyperbolical approximation.

Keywords: rods, material consumption, cross-sectional area, area, geometric scheme of the farm, goal of minimization, mass, load, solution model, complex shell, emerging difficulties.

Flat rod systems include trusses. The simplest structure is a truss consisting of rods that are hinged together. One of the criteria for finding the optimal parameters of a truss is its material consumption.The cross-sectional area of each rod must ensure its stable resistance to longitudinal forces caused by the farm's own weight and payload,i.e. the rod is a function of the longitudinal force in the rod. The longitudinal forces in the rods, in turn, depend on the shape of the truss and its own weight.Among the many possible geometric schemes of a farm, it is possible to choose one that has a minimum self-weight and meets the conditions and requirements imposed on it. This optimization process of the farm's shape can be achieved by varying its various geometric parameters. In addition to the shape parameters, there may be parameters of the topological organization of the geometric scheme (the number of nodes, rods, or cells). To find the optimal result, it is necessary to compose and minimize the objective function, which is the dependence of the self-weight or volume of the farm material on the variable parameters.

When writing the objective function, the idea developed in the section on a single triangle is used. This idea is as follows. The force in each rod is defined as a function of the cross-sectional area in two ways: firstly, from the equilibrium condition of the system under its own weight and external load, and secondly, from the conditions of strength (for the stretched rods) or stability (for the compressed rods). Equating two values of the same force, which meet different criteria, we obtain the cross-sectional area of the rod as a function of the geometric parameters of the farm. The objective function is the sum of the volumes of all rods (the volume of each rod is determined as the product of the rod length and its cross-sectional area):

$$V = 2\sqrt{\frac{l^2}{(n+l)^2} + h^2} * \sum_{i+1}^{\frac{n+1}{2}} a^2_{i.i+1} + \frac{2l}{n+1}\ a^2_{\frac{n+1}{2}\frac{n+5}{2}} + 2\sum_{i+1}^{\frac{n+1}{2}} a^2_{i.i+2}\ . \quad \textbf{(1)}$$

The difference between the process of compiling a target function for optimizing the geometric parameters of a farm with n cells and the analogous process for a single triangle is in determining the forces in the rods. Each geometric scheme of a farm requires an original analytical algorithm for determining the forces in the rods.Therefore, we will consider the process of creating a target function using a specific example.

Figure 1 shows a geometric diagram of a farm with n cells in the form of isosceles triangles. Let's introduce a system of node numbering for the farm, which allows us to formally distinguish between the lower and upper belt rods and the braces. We will number the nodes of the lower belt with odd numbers and the nodes of the upper belt with even numbers, as shown in Figure 1. Then, any parameter of the lower belt rod will be denoted by the corresponding letter with two odd indices, for example, the force in the lower belt rod $R_{zi,2i+2}$(l=1, 2, 3, ..., (n+2)) the parameter of the upper belt rod is a letter with two even indices, for example, $R_{i,i+1}$(l=1, 2, 3,.., (n+1)) .

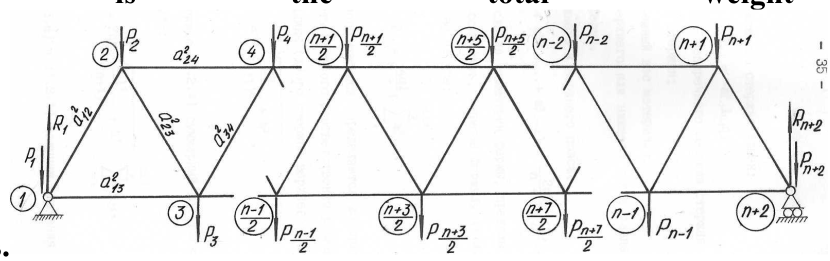
As variable (design) parameters, we set the height of the farm h and the number of farm cells n. We consider the following parameters to be constant: the span of the farm 1, the equality of the lengths of the upper and lower belt rods, the equality of the lengths of the braces, and the external load Q on the truss, which is evenly distributed between the nodes.

The reactions in the supports of a symmetrical truss are equal to half the sum of the self-weight of all the rods and the payload with the opposite sign (Fig. 1):

$$R_1 = P_{n+2} = \frac{-P' - P'' - Q}{2} \qquad \textbf{(2)}$$

where P' is the total weight of the upper and lower belt rods;

P" is the total weight of the



struts.

Fig. 1.

The self-weight of each rod is:

$$P_{i,j} = -a^2_{i,j} l_{i,j} q . \qquad \textbf{(3)}$$

where $a^2_{i,j}$ - the cross-sectional area of the rod;

***$l_{1,j}$* - rod length;**

q- the bulk weight of the material.

The length of the upper or lower belt rod is equal to: $\frac{2l}{n+1}$

where 1 - farm span.

Weight of the lower and upper belt rods:

$$P' = \frac{2l}{n+1} q(a_{13}^2 + a_{24}^2 + \ldots + a_{n,n+2}^2) = \frac{2l}{n+1} q \sum_{i=1}^{n} a_{i,i+2}^2 . \qquad (4)$$

Given the symmetry conditions of the farm, the limits of change in quantity 1 can be reduced by writing formula (4) for half of the farm and multiplying it by two:

$$P' = \frac{4ql}{n+1} \sum_{i=1}^{\frac{n+1}{2}} a_{i,i+2}^2 , \quad (5)$$

The length of each brace is determined from a right triangle, whose legs are equal to the height h of the truss and half the length of one rod in the upper or lower belt, respectively:

$$l_{pas} = \sqrt{\frac{l^2}{(n+1)^2} + h^2} , \quad (6)$$

then, by analogy with (5), the total weight of the diagonal braces can be determined by the formula:

$$P'' = 2q\sqrt{\frac{l^2}{(n+1)^2} + h^2} \sum_{i=1}^{\frac{n+1}{2}} a_{i,i+1}^2 , \quad (7)$$

Substituting (7) into (2), we obtain the values of the reactions in the farm supports:

$$R_1 = R_{n+2} \frac{2ql}{n+1} \sum_{i=1}^{\frac{n+1}{2}} a_{i,i+2}^2 - q\sqrt{\frac{l^2}{(n+1)^2} + h^2} * \sum_{i=1}^{\frac{n+1}{2}} a_{i,i+1}^2 - \frac{Q}{2}. \qquad (8)$$

The load on an arbitrary node Mi is determined as half the sum of the self-weight of the rods adjacent to the node plus the useful load divided by the number of nodes in the farm:

$$P_1 = \frac{P_{i-1,i} + P_{i,i+1} + P_{i-2,i} + P_{i,i+2}}{2} + \frac{Q}{n+2}. \qquad (9)$$

By substituting (3) and (6) into (9), we obtain the load on an arbitrary node, expressed in terms of the cross-sectional areas of the rods adjacent to the node:

$$\begin{aligned} R_1 = \frac{-q}{2}(a_{i-1,i}^2 + a_{i,i+1}^2)\sqrt{\frac{l^2}{(n+1)^2} + h^2} - \\ -\frac{ql}{n+1}(a_{i-2,i}^2 + a_{i,i+2}^2) + \frac{Q}{n+2}. \end{aligned} \qquad (10)$$

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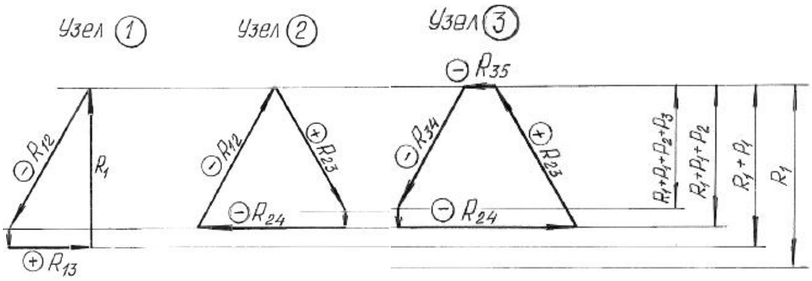
Given the load (1) on each node of the truss, the reaction force (2) in the support can be determined using another formula:

$$R_1=R_{n+2}=-P_1-P_2-P_3-\frac{P_{n+1}}{2}-\frac{\frac{P_{n+1}}{2}}{2}. \qquad (11)$$

The forces in the truss braces are determined by the node cutting method. Considering the force polygons (Fig. 2) By sequentially cutting out the nodes of the truss, we can see that each successive force Ri,i+1 in the brace is proportional to the sum of the vertical components of the reaction in the first support and the loads on the nodes. starting from the first and ending with the cut-out one. Compressed skewers have an odd index i, and stretched skewers have an even index. Therefore, the sign of the force in the skewer is defined as (-1)i:



Rice.2.

$$R_{i,i+1}=\frac{(-1)^i \left(R_1+\sum_{i=1}^{i} P_j\right)\sqrt{\frac{l^2}{(n+1)^2}+h^2}.}{h}. \quad (12)$$

Substituting (11) and (10) into (11), we obtain the value of the force in an arbitrarily selected brace, expressed in terms of the geometric parameters of the farm

$$R_{i,i+1}=\frac{(-1)^i}{h}\sqrt{\frac{l^2}{(n+1)^2}+h^2}\ \frac{-q}{2}\sqrt{\frac{l^2}{(n+1)^2}h^2\ a^2_{i,i+1}+2\sum_{j=i+1}^{\frac{n+1}{2}} a^2_{i,i+1}}\ + \qquad (13)$$

$$+\frac{ql}{(n+1)}\ a^2_{i-1.i+1}+a^2_{i-.i+2}+\frac{a^2_{n+1}}{2}\frac{n+5}{2}+2\sum_{j=i+1}^{\frac{n+1}{2}} a^2_{i,j+2}\ +\frac{Q(n+2_i+2)}{2(n+2)}\ .$$

In the same sequence, a formula is derived for determining the forces in the upper and lower belts:

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$$R_{i,i+2} = \frac{(-1)^{i+1}}{h(n+1)} \frac{q}{2}\sqrt{\frac{1^2}{(n+1)^2}+h^2} \;\; {}_{j=1}^{i} (2j-1)a_{j,i+1}^{2} + 21 {}_{j=i+1}^{\frac{n+1}{2}} a_{i,j+1}^{2} \;\; +$$

$$+\frac{q1}{(n+1)} \;\; 2 {}_{j=1}^{i} ja_{j,i+2}^{2} + 21 {}_{j=i+1}^{\frac{n+1}{2}} a_{i,j+2}^{2} a_{i,j+2}^{2} - 1a^{2}_{\frac{a^2_{n+1}}{2}\frac{n+5}{2}} \;\; + \tag{14}$$

$$+\frac{Q(n+2_i+2)}{2(n+2)} \; .$$

By equating the values of the forces in the bonds calculated according to formulas (3), (4), and (13), (14), we obtain a system of n+1 nonlinear (quadratic) equations. The solution of this system is the value of the area $a_{1,1+1}^2$ and $a_{1,1+2}^2$ cross-sections of all the rods of the half of the symmetric truss, which must be substituted into the objective function (1). Solving large systems of nonlinear equations is an independent research topic that is not included in this thesis. Therefore, let us consider a simpler case, when all the rods are divided into four groups. Within each group, the rods are assumed to be identical, and a2 is calculated for the most stressed rod.The first group includes the compressed rods of the upper belt, and the most stressed rod in this group is either the central rod or the rod adjacent to the central node, depending on the number of farm cells. The second group includes the stretched rods of the lower belt. The most stressed rod of this group is also either the central rod or the rod adjacent to the central node. The third group includes compressed struts, of which the most stressed element is the cross-section element. The fourth group includes stretched struts. The most stressed strut in this group is the cross-section rod $a_{2,3}^2$.

Since the position of the most stressed upper and lower belt rods depends on the number of truss cells, it is necessary to consider two truss options.

The first version of the farm has an even number of upper-belt rods and an odd number of lower-belt rods:

n = 4 m+ 1, (15)

where n is the number of farm cells;

2m is the number of upper belt rods.

The most stressed rod of the upper belt has a cross-section $a^2_{\frac{n-1}{2},\frac{n+3}{2}}$ and $a^2_{2m+1,2m+3.}$ The most stressed rod of the lower belt is the central rod with a cross-section $a^2_{\frac{n-1}{2},\frac{n+3}{2}}$ $a^2_{2m-1,2m+1.}$.

The second version of the farm has an odd number of upper-belt rods and an even number of lower-belt rods

:n= 4m- 1. (16)

The most stressed rod of the upper belt is the central one, which has a cross-section $a^2_{\frac{n+1}{2},\frac{n+5}{2}}$ and $a^2_{2m,2m+2.}$. In the lower belt, the most stressed rod is adjacent to the central node and has a cross-section $a^2_{\frac{n-1}{2},\frac{n+3}{2}}$ and $a^2_{2m-1,2m+1.}$.

This simplification allows the system of n+1 nonlinear equations (in the general case) to be reduced to four equations, two of which are quadratic and two are linear. Solving such a system is not difficult.

Conclusions. The proposed method of calculating the free parameters of a farm under different combinations of four conditions of equality of the lengths of rods of different groups allows to vary the number of design parameters of the target function at optimization of the geometric shape of the farm. The target function is based on the cross-sectional areas of the rods, which depend on the geometric parameters of the farm and the strength or stability of the rods.

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