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Optimization of the Geometric Parameters of the Metal Truss

Abduraimov Muratkul
Associate Professor of the Department of Engineering Graphics and Computer Design, Samarkand State Architecture and Construction University

Abstract: This article is devoted to the optimization of the geometric parameters of the metal truss, and the following are studied in the article. Trusses belong to flat rod systems. The simplest structure is a truss consisting of rods spherically connected to each other. One of the criteria for finding the optimal parameters of a farm is its material consumption.
Keywords: metal truss, rod, geometric scheme, objective functions, triangle.

I. INTRODUCTION

The cross-sectional area of each rod must ensure its stable resistance to longitudinal forces arising from the truss own weight and payload, i.e. the sectional area of the rod is a function of the longitudinal force in the rod. 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 the farm, you can choose one that has a minimum dead weight and ensures the fulfillment of the conditions and requirements for it. This process of optimizing the shape of the truss can be achieved by varying its various geometric parameters. Among them, 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 own weight or volume of the truss material on variable parameters.

II. MAIN PART

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

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

The difference between the process of compiling the objective function for optimizing the geometric parameters of a truss of n cells from a similar process for a single triangle is in determining the forces in the rods. Each geometric diagram of a truss requires the compilation of an original analytical algorithm for determining the forces in the rods. Therefore, we will consider the process of compiling the objective function using the example of a specific geometric scheme of a farm.

Figure 1 shows a geometric diagram of a farm of n cells in the form of isosceles triangles. Let us introduce a numbering system for truss nodes, which makes it possible to formally distinguish between the bars of the lower and upper chords and braces. We number the nodes of the lower belt with odd numbers, and the upper - with even numbers, as shown in Fig. 1. Then any parameter of the rod of the lower belt will be denoted by the corresponding letter with two odd indices, for example, the force in the rod of the lower belt Rzi,2i+2(l=1, 2, 3, ..., (n+2)) bar parameter of the upper chord - a letter with two even indices, for example, Ri,i+1(l=1, 2, 3,.., (n+1)) .

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

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

$$R_1 = P_{n+2} = \frac{-P' - P'' - Q}{2} \tag{2}$$

where P' is the total weight of the rods of the upper and lower chords; R'' - the total weight of the braces.

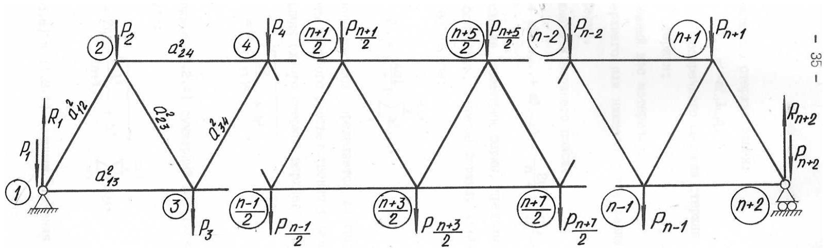


Fig. 1. The self-weight of each rod is equal to: (3) where is the cross-sectional area of the rod; l1,j - rod length; q is the volumetric weight of the material. The length of the rod of the upper or lower chord is: where 1 is the truss span. The weight of the rods of the lower and upper chords:

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

Taking into account the symmetry conditions of the truss, the limits of change in the value of 1 can be reduced by writing formula (4) for half of the truss and multiplying it by two:

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

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

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

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

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

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

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

The load on an arbitrary node Mi is defined as half the sum of the own weight of the rods adjacent to the node plus the payload divided by the number of truss nodes:

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

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:

$$R_1 = \frac{-q}{2}(a^2_{i-1,i}+a^2_{i,i+1})\sqrt{\frac{l^2}{(n+1)^2}+h^2} - \\ -\frac{ql}{n+1}(a^2_{i-2,i}+a^2_{i,i+2})+\frac{Q}{n+2}. \tag{10}$$

Having a load (1) on each truss node, the reaction value (2) in the support can also be determined by another formula:

$$\text{R1=Rn+2= –P1 – P2 – P3 –}\ \frac{P_{n+1}}{2} - \frac{\frac{P_{n+1}}{2}}{2} \tag{11}$$

The forces in the braces of the truss are determined by the method of cutting nodes. Considering the force polygons (Fig. 2) of sequentially cut truss nodes, one can notice that each successively determined 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 one being cut out. Compressed braces have an odd index i, while stretched braces have an even index. Therefore, the sign of the force in the brace is defined as (-1)i:

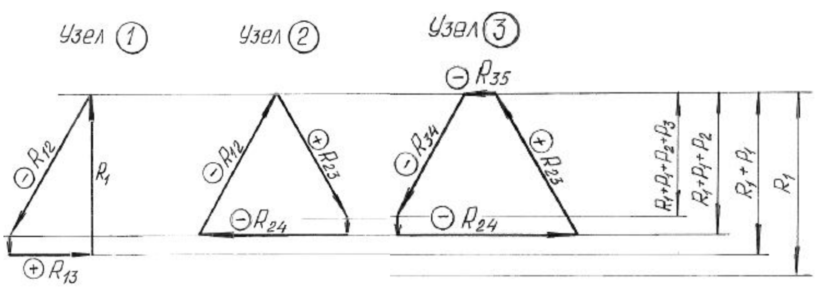


Fig. 2.

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

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

$$R_{i,i+1} = \frac{(-1)^i}{h}\sqrt{\frac{l^2}{(n+1)^2}+h^2}\left(\frac{-q}{2}\sqrt{\frac{l^2}{(n+1)^2}h^2}\left(a^2_{i,i+1}+2\sum_{j=i+1}^{\frac{n+1}{2}}a^2_{i,i+1}\right)+\right. \\ \left.+\frac{ql}{(n+1)}\left(a^2_{i-1.i+1}+a^2_{i-.i+2}+\frac{a^2_{n+1}}{2}\frac{n+5}{2}+2\sum_{j=i+1}^{\frac{n+1}{2}}a^2_{i,j+2}\right)+\frac{Q(n+2_i+2)}{2(n+2)}\right). \tag{13}$$

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

$$R_{i,i+2} = \frac{(-1)^{i+1}}{h(n+1)}\left(\frac{q}{2}\sqrt{\frac{1^2}{(n+1)^2}+h^2}\left(\sum_{j=1}^{i}(2j-1)a^2_{j,i+1} + 21\sum_{j=i+1}^{\frac{n+1}{2}} a^2_{i,j+1}\right)+\right.$$

$$+\frac{q1}{(n+1)}\left(2\sum_{j=1}^{i} ja^2_{j,i+2} + 21\sum_{j=i+1}^{\frac{n+1}{2}} a^2_{i,j+2}a^2_{i,j+2} - 1a^2_{a^2_{\frac{n+1}{2}}\frac{n+5}{2}}\right)+$$

$$\left.+\frac{Q(n+2_i+2)}{2(n+2)}\right). \qquad (1.3.13)$$

(14)

Pairwise equating the same-name values of forces in bonds, calculated respectively by formulas (3), (4) and (13), (14), we obtain a system of n + 1 nonlinear (quadratic) equations. The solution of this system is the values of the areas $a^2_{1,1+1}$ and $a^2_{1,1+2}$ cross sections of all the rods of the half of the symmetrical truss, which must be substituted into the objective function (1). The solution of large systems of nonlinear equations is an independent object of research, which is not included in this dissertation. Therefore, we consider a simpler case, when all the rods are divided into four groups. Within each group, the rods are assumed to be the same, and the cross-sectional area a2 is calculated for the stressed rod itself. The first group includes compressed rods of the upper chord, the most stressed rod of this group is, depending on the number of truss cells, either the central rod or the rod adjacent to the central node. The second group includes stretched rods of the lower chord. The most stressed member of this group is either the central member or the member adjacent to the central node. The third group includes compressed braces, of which the most stressed element is with a cross sectionем $a^2_{1,2}$. The fourth group includes stretched braces. The most stressed brace of this group is a rod with a cross section $a^2_{2,3}$.

Since the position of the most stressed rods of the upper and lower chords depends on the number n of truss cells, it is necessary to consider two variants of the truss. The first version of the farm assumes an even number of rods of the upper belt and an odd number of lower ones:

n = 4 m+ 1, (15)

- where n is the number of farm cells;
- 2m is the number of rods of the upper belt.

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

The second version of the truss involves an odd number of rods of the upper belt and an even number of rods of the lower one:

n= 4m- 1. (16)

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

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

III. COMCLUSION

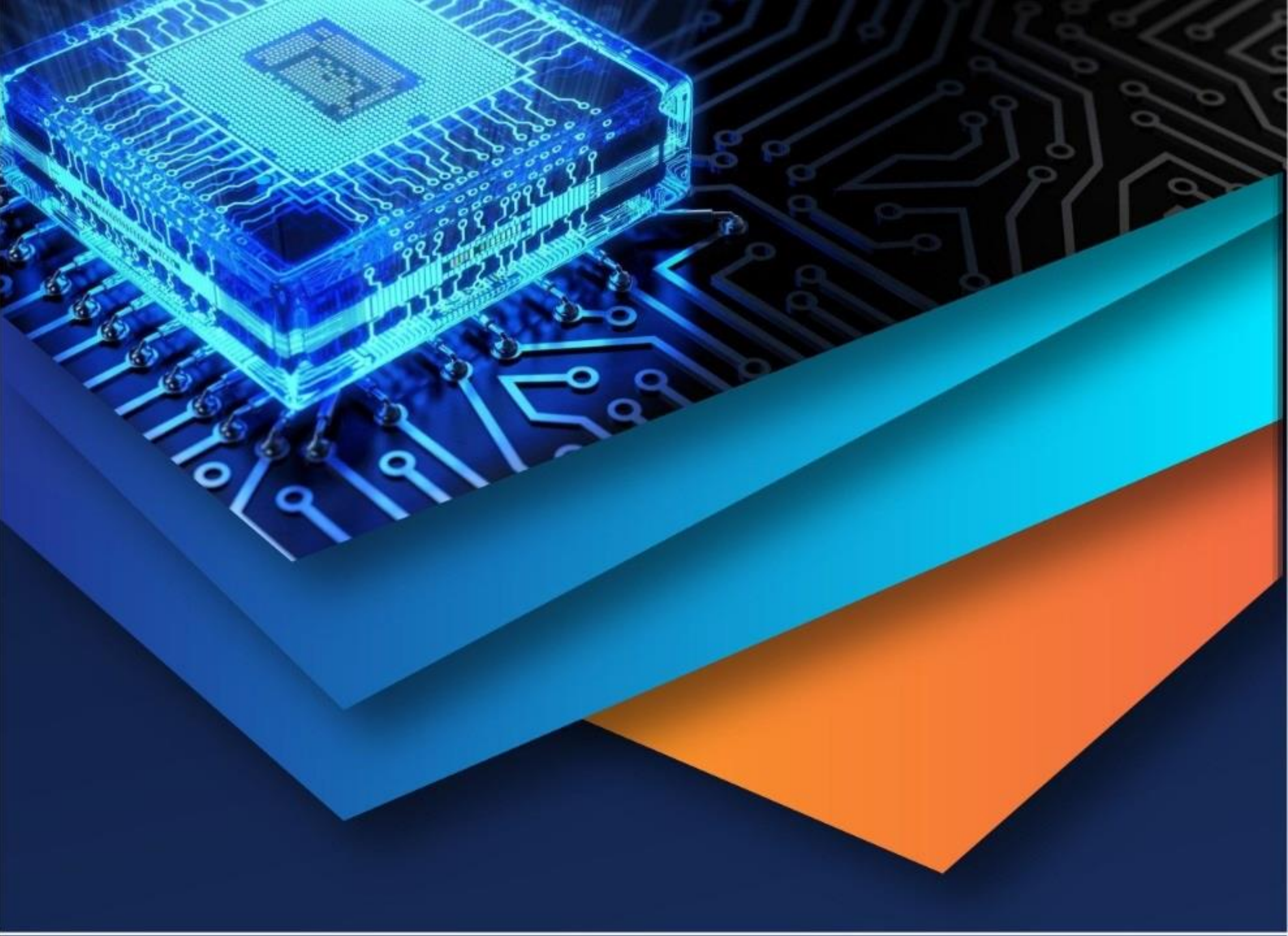
The proposed method for calculating the free parameters of the truss with various combinations of four conditions for the equality of the lengths of rods of different groups allows you to vary the number of design parameters of the objective function when optimizing the geometric shape of the truss. The objective function is based on the cross-sectional areas of the rods, on the one hand, depending on the geometric parameters of the truss, and on the other hand, on the conditions of strength or stability of the rods.

REFERENCES

[1] Aleksandrov A.B.Yu., Potopov V.D. Basic theories of elasticity and plasticity. M: Higher School, 1990, -p.245.

[2] Abduraimov M.M. Static-geometric approach in the formation of structural systems with complex outlines. Abstracts of the conference "Modeling of processes and technological equipment in agriculture'. Melitopol, 1994, p.72.

[3] Abduraimov M.M. Deyaki podvishchennya firmness and hardness of space systems on the basis of bionic principles in -In the book: Applying geometry and engineering graphics. - Kiev: KDTUBA, 1994, VIP. 56, p. I2I-I22.



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