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L. Soldatenko, HhD. tech. Sciences, associate Professor, E-mail: leonid541247@gmail.com

ORCID 0000-0003-4423-088X Researcher ID: U-7423-2017

A. Shipko, Post-graduate student, E-mail: shipko.arkadiy@gmail.com

ORCID 0000-0002-5665-1748 Researcher ID: M-1249-2016

I. Shipko, HhD. tech. Sciences, associate Professor, E-mail: shipkoigor@gmail.com

ORCID 0000-0003-4148-397X, Researcher ID: U-3829-2017

Odessa National Academy of Food Technologies, 112, Kanatna Str., Odessa, 65039, Ukraine, +380487124113

ESTIMATED DETERMINATION OF PARAMETERS OF MOUNTING MASTS

Abstrakt

When carrying out installation work at the enterprises of the branch, the use of universal lifting equipment is sometimes impossible or impractical. In such cases, resort to the use of mounting masts - relatively simple in design and quite efficient lifting equipment [1], the construction of which is largely based on the practical experience of foremen of assembly organizations or foremen-riggers. Existing methods of calculation of mounting masts, developed many decades ago on the basis of sufficiently primitive considerations, without taking into account additional loads, give approximate results and should be revised and improved. An attempt at such work is reflected in this article. Since the main structural elements of the mounting mast are its riser and cables, the definition of the parameters of the mast is to calculate the strength of the riser and cables of the accepted dimensions under the loads provided by the initial data of a specific technical task. Evaluation of the strength of the riser should be performed both in the plane of torque and from the plane of torque. To find the value of the maximum stress in the mast riser and the maximum stress in the i -th cable, it is necessary to calculate the stress-strain state of the riser and cables using a mixed method, according to which some unknowns are displacement and part - effort. The mathematical model of the problem is described by four algebraic equations. The equation of continuity of riser deformations is based on the use of Tymoshenko's functions, which take into account the influence of longitudinal forces on the deflection of the mast riser in the plane of action of wind load and weight of cargo. Loads from the weight and tension of the cables are taken into account their possible ice and the force of pre-tension. The wind load of the riser and cables is determined using data on the standard speed pressure, N/m^2 , which for Ukraine is 0.38 kPa. Calculations of riser and cable parameters also take into account the temperature difference, which in the climatic conditions of Ukraine does not exceed the interval $\pm 40^\circ C$. Mast structures are recommended to rely on the combination of both permanent and temporary loads according to the data given in the article. All this together gives reason to hope that the considered method of calculation of parameters of assembly masts will be useful to experts of the assembly organizations and students studying questions of technics and technology of rigging works.

Keywords: mounting mast; mast riser; stretching (guy); evaluation of the strength of the riser; calculation of the stress-strain state of the mast riser; Tymoshenko's functions; voltage of the guys

Introduction

During installation work, the use of cranes is sometimes impossible or impractical. In such cases, resort to the use of mounting masts - relatively simple in design and quite effective lifting equipment [1].

Since the main structural elements of the mounting mast are its riser and cables, the determination of the parameters of the mast is to calculate the strength of the riser and cables of the accepted dimensions under the loads provided by the initial data of a specific technical task.

The design and material of the riser of the mounting mast depend on its load-height characteristics. For example, wooden risers are used for masts with a capacity of up to 6 tons and a height of 12 meters (material - semi-dry pine 2nd grade, or spruce 1st or 2nd grade). The risers are made of one wood, two or three, connected by through bolts and external clamps.

The risers from 10 to 30 meters' high are made, for the most part, of solid steel pipes with an outer diameter of 159 to 529 mm without reinforcement or with reinforcement with angular equilateral steel. Tubular risers are assembled from separate unified sections, which have connecting flanges for bolted connection.

Mast risers 30 ... 50 meters high, with a capacity of up to 100 tons, have a lattice welded structure.

The riser 1 (Fig. 1) is installed on the base 2, which is made of steel sheet 16...20 mm thick with the edges bent upwards. This facilitates, if necessary, the movement of the mast within the assembly site without its dismantling. If the mast is to be used with a vertical position of the riser, it is attached to the base rigidly, for example, by welding. But sometimes it is possible to deviate the riser from the vertical by $10 \dots 15^\circ$. In these cases, use a hinged connection of the riser with the base (one plane or even a universal hinge). The base is securely fastened to the anchors 10 to avoid unacceptable movement of the riser during operation.

Braces, or cables 3, are designed to maintain the mast riser in the working position. The number of cables depends on the operating conditions of the mast, but cannot be less than three. In most cases, the number of cables is four. The cables are pre-tensioned 1 ... 3 kN using hand winches or lanyards 12. The angle of the cables relative to the horizon is taken from 30 to 45 degrees. The design of the mounting unit 4 cables to the riser depends on the design of the riser, in particular, the material from which it is made, as well as the intended features of further use of the mast (in particular, with the possibility of rotating the riser relative to the longitudinal axis).

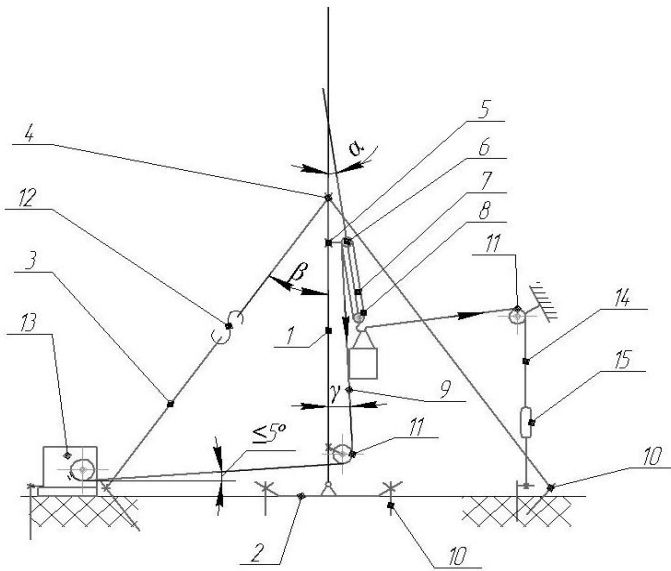


Fig. 1. Scheme of installation and application of the mounting mast: 1-riser; 2 - base; 3- brace (cable); 4 - point of attachment of cables to the riser; 5 - point of attachment to the riser of the upper fixed block of the cargo hoist; 6 - upper fixed block; 7 - cargo hoist; 8 - movable unit with a hook; 9 - cargo rope; 10 - anchor; 11 - outlet unit; 12 - lanyard; 13 - cargo winch; 14 - delay; 15 - lever winch.

Of course, the cables are made of steel wire rope - a cable-single spiral coil, or a cable 6x19 in accordance with GOST 3070-88. The lower end of each brace is fixed to the anchor of the corresponding structure.

Slightly below the node 4 (at a distance of about 300 mm) is the point 5 of attachment to the mast riser of the upper (fixed) unit 6 of the cargo hoist 7. To do this, use special brackets that prevent direct contact between the unit and the riser. The design of the mounting point 5 depends on the design and material of the riser. The cargo hoist 7, which, in addition to the unit 6, includes a movable unit 8 with a hook and a cargo rope 9, reduces the traction force on the cargo winch inversely proportional to the multiplicity of the hoist, which is usually taken in the range 1...10.

The outlet unit 11 changes the direction of the descending branch 10 of the cargo rope, which enters the rope receiving drum of the cargo winch 13 at an angle of inclination to the horizon not exceeding 5°.

The cargo winch is located outside the rigging area and is appropriately secured against shifting or overturning by the forces arising during lifting.

The extension 14, connected to a hand winch or hoist, deflects the load from the riser to avoid damage to the load and deformation of the mast.

Determination of riser parameters

This work can be design or verification. The method of checking the strength of the riser of the accepted dimensions under the load conditions provided by the initial data of the corresponding technical task is considered below.

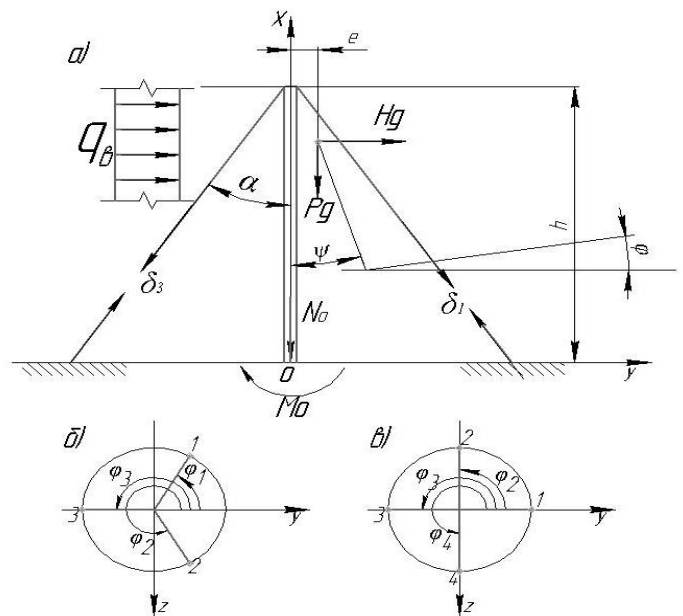


Fig. 2. Estimated scheme of the mounting mast: a - front view; b - top view with the number of cables $n_B = 3$; in - top view with the number of cables $n_B = 4$

Evaluation of the strength of the mast riser is performed both in the XOY plane of the moment of action and from the plane of action of the moment (Fig. 2).

1. In the plane of action of the moment

the strength condition is as follows

$$\sigma_{max} \leq R_y \cdot \gamma_c \tag{1.1}$$

where σ_{max} - the highest stress in the dangerous cross section of the riser, Pa; R_y - calculated resistance of the riser material, Pa (Table 1); γ_c is the coefficient of working conditions, which is taken for steel masts 0.95, and for wooden-1.

Table 1 - Mechanical properties of materials used for the manufacture of structural elements of mounting masts

Mechanical properties of materials	Structural elements of the mast	
	Risers	Guys
design resistance, MPa		
steel grades	215	
B st 3; B st 3 ps		
- steel 20	225	
- wood (pine, spruce)	10	
Modulus of elasticity (Young's modulus), MPa	$2,06 \cdot 10^5$	$1,27 \cdot 10^5$
Density, kg / m ³		
- steel 20	770	770
- wood (pine, spruce)	600	

The greatest stress in the dangerous section of the mast riser

$$\sigma_{max} = \frac{M_{max}}{I_x} \gamma_{max} + \frac{N_0}{F_c}, \text{ Па} \tag{1.2}$$



where M_{max} - largest bending moment in the riser (Fig. 3), Nm; I_z - moment of inertia of the cross section of the riser relative to the axis Z, m⁴ (when using risers of equal cross section $I_z = I_y$; otherwise take into account I_{min}); U_{max} - the distance from the Z axis to the farthest cross-sectional point of the riser, m; N_o - force acting along the axis of the riser, H; F_c - cross-sectional area of the riser, m².

The largest bending moment in the mast riser

$$M_{max} = \max(|M_o|, |M_{ekc}|, |M_g|), \quad (1.3)$$

where M_o - bending moment at the point of attachment of the riser is determined by the expression (1.31) below; M_g - bending moment from the weight of the load and the hoist; M_{ekc} - extreme bending moment (see Fig.3).

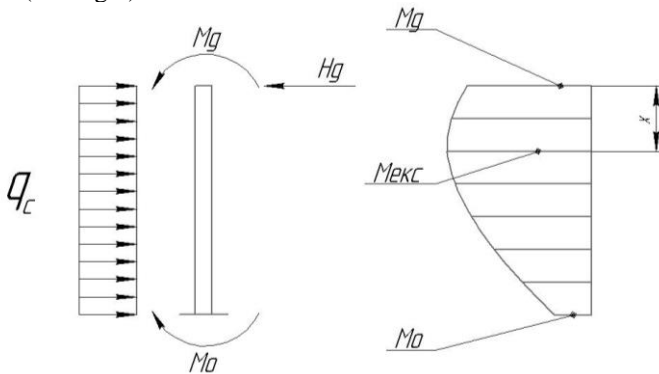


Fig. 3. Calculation scheme for determining the bending moment in the mast riser

Obviously, $|M_g| = P_g \cdot e, \text{ HM}, \quad (1.4)$

where P_g - weight of the cargo and the hoist, H; e - is the eccentricity of the mounting of the cargo hoist, ie, the distance from the axis of the mast riser to the point of attachment of the upper block of the hoist, m.

The force of gravity of the cargo and the hoist is equal to

$$P_g = 9,81(m_B + m_{full}), \text{ H}$$

where m_B - load capacity of the mast, kg; m_{full} - mass of pulley, kg.

The extreme bending moment of the expression (1.3.) is defined as follows

$$M_{ekc} = M_g - H_g \cdot X - q_c \frac{X_o}{2}, \text{ HM} \quad (1.5)$$

where $X = \left| \frac{H_g}{q_c} \right|, \text{ m}$. It should be taken into account that M_g is found by the already known expression (1.4), and q_c - by expression (1.19) and H_g - by expression (1.21), given below.

2. The condition of the strength of the mast riser from the plane of action of the moment is also expressed by relation (1.1). With

$$\sigma_{max} = \frac{N_o}{\varphi_y \cdot F_c} \quad (1.6)$$

where φ_y - coefficient of longitudinal bending of the riser, which for steel and wooden structures is determined by the formulas given in [4; 5], some of which are shown in table. 2.

$$\rho = \frac{R_y}{E_c}; \quad \bar{\lambda} = \lambda \sqrt{\rho}; \quad \lambda = \sqrt{\frac{F_c}{I_y}} h,$$

where E_c - Young's modulus of the riser material, Pa; I_y - moment of inertia of the cross section of the riser relative to the axis Y, m⁴; h length of the riser, m.

3. The condition of the strength of the guys

$$\max \sigma_i \leq R_B \cdot \gamma_c^B, \quad (1.7)$$

where $\max \sigma_i$ - maximum stress in the i -th cable, Pa; R_b -calculated resistance of the guy, Pa; γ_c^B - coefficient of working conditions, which is taken equal to 0.95.

The calculated resistance of a cable made of steel wire rope is determined by the formula

$$R_B = \frac{N_p}{n F_r}, \text{ Pa} \quad (1.8)$$

where N_p - calculated breaking force of the rope of the accepted diameter, H;

n dimensionless coefficient of the safety margin of the rope (for cables it is recommended to take $n = 3 \dots 3,5$); F_r - cross-sectional area of the rope, m² (cross-sectional area of all wires that create the rope).

4. To determine the magnitude of the maximum stress in the mast riser

- σ_{max} - in terms of (1,2; 1,6) and the maximum voltage in the i-th guy

- $\max \sigma_i$ - according to expression (1.7) it is necessary to calculate the stress-strain state of the mast and cable with the use of a mixed method, according to which it is assumed that part of the unknown is the movement, and part - the force. Unknown are: Δ - displacement of the mast riser at the point of at-

ment, and part - the force. Unknown are: Δ - displacement of the mast riser at the point of at-

Table 2 - Formulas for determining the coefficient of longitudinal bending φ_y

Riser material	Formula	Condition
Steel	$1 - (0,073 - 5,53\rho)\bar{\lambda} \cdot \sqrt{\bar{\lambda}}$	$\bar{\lambda} < 2,5$
	$1,47 - 13\rho - (0,371 - 27,3\rho) \cdot \bar{\lambda} + (0,0275 - 5,53\rho) \cdot \bar{\lambda}^2$	$2,5 \leq \bar{\lambda} \leq 4,5$
	$332 / \bar{\lambda}^2 (51 - \bar{\lambda})$	$\bar{\lambda} > 4,5$
Wood	$1 - 0,8(\lambda / 100)$	$\lambda \leq 70$
	$3000 / \lambda^2$	$\lambda > 70$

Note: In table. 2 the following designations are accepted



tachment of the cables, m; σ_3 and σ_1 - stresses in windward and leeward cables, Pa; M_0 - bending moment at the place of mounting the riser (Fig. 2 and 3), Nm.

The mathematical model of the problem is represented by the following four algebraic equations [2; 3]:

4.1. Equation of continuity of riser deformations

$$\frac{hF_1(u)}{3E_c I_x} M_0 + \frac{hF_2(u)}{6E_c I_x} M_g + \frac{\Delta}{h} + \frac{q_c h^2 F_3(u)}{24E_c I_x} = 0 \quad (1.9)$$

where $F_1(u), F_2(u)$ and $F_3(u)$ - are Tymoshenko's functions that take into account the influence of longitudinal forces on the deflection of the mast riser in the XOYplane of action of wind load and weight of cargo; q_c is the calculated load per unit length of the mast riser from the action of wind (wind load), N / m.

Tymoshenko's functions are as follows

$$F_1(u) = \frac{3}{u} \left(\frac{1}{\sin 2u} - \frac{1}{2u} \right), \quad (1.10)$$

$$F_2(u) = \frac{3(\tan u - u)}{u^3}, \quad (1.11)$$

$$F_3(u) = \frac{3}{2u} \left(\frac{1}{\tan 2u} - \frac{1}{2u} \right), \quad (1.12)$$

$$u = \frac{h}{2} \sqrt{\frac{N_0}{E_c \cdot I_x}}, \text{ rad} \quad (1.13)$$

$$N_0 = P_g + Q_c + N_B, H \quad (1.14)$$

Q_c - the force of gravity of the mast riser, N

Obviously that

$$Q_c = 9,81 h m_c, H \quad (1.15)$$

where m_c - mass of one meter of pipe or other profile from which the mast riser is made, kg / m; N_B - load from its own weight and tension of the cables, N.

In turn, the load from the force of gravity and tension of the cables is

$$N_B = n_B (g_B h / \cos \alpha + F_B y_0 \cos \alpha, H \quad (1.16)$$

where n_B - number of cables; g_B - weight of one meter of a guy with an ice crust, N / m;

σ_0 - stress of the cables from their previous tension, N / m² (it is recommended to take $\sigma_0 \approx 0.5R_B$; R_B - the calculated resistance of the cable material, N / m², calculated by (1.8); α - the angle of the cables relative to the vertical, deg.

Obviously, the weight of one meter of a guy with an ice crust is equal to

$$g_B = 9,81 m_B + g_{kp}, \frac{H}{m} \quad (1.17)$$

where m_B - mass of one meter of the cable, kg / m; g_{kp} - load from the force of gravity of the ice crust per unit length of the cable, N / m

It's easy to see that

$$g_{kp} = K_H \cdot \gamma_{kp} \cdot \Delta_{kp} \cdot \pi \cdot (d_B + \Delta_{kp}), \frac{H}{m} \quad (1.18)$$

where K_H - coefficient of reliability on the load ($K_H = 1.3$); γ_{kp} - density of ice crust, N / m³ (take

$\gamma_{kp} = 9 \frac{kN}{m^3}$); d_B - diameter of the guy, m; Δ_{kp} - the thickness of the ice crust, m (taken depending on the height of the mast h according to table. 4.

Table 3 - Mechanical properties of materials

Mechanical properties of materials	Structural elements of the mast	
	Risers	Guys
design resistance, MPa		
steel grades B st 3; B st 3 ps	215	
- steel 20	225	
- wood (pine, spruce)	10	

Table 4 - The thickness of the ice crust depending on the height of the mast

Height of a mounting mast, h, m	Ice crust thickness, Δ_{kr} , mm
up to 10	10
from 10 to 20	12
from 20 to 50	20

The wind load on the mast riser is calculated by [3; 4]

$$q_c = K_H \cdot \beta \cdot C_x \cdot d \cdot q_0, \frac{H}{m} \quad (1.19)$$

where K_H - coefficient of reliability on the load (take $K_H = 1.4$);

β - coefficient of increase of normative speed pressure ($\beta = 1,35$);

C_x - aerodynamic coefficient, which is taken equal to 0.7 - for the mast riser and 1.2 - for the cables; d is the diameter of the element (riser or cable), m; q_0 - normative speed pressure, N / m² (for Ukraine $q_0 = 0,38$ kPa).

4.2. Equilibrium equation of the upper node of the mast at the place of attachment of the cables

looks as follows

$$\frac{1}{h} M_0 - \frac{1}{h} M_g + \frac{N_0}{h} \Delta + \frac{q_c h}{2} + \frac{q_B n_B h (1 + \cos^2 \alpha)}{4 \cos \alpha} + H_g + F_B \sin \alpha (n_1 \sigma_1 \cos \varphi_1 + \sigma_3 \cos \varphi_3) = 0 \quad (1.20)$$

where q_B - calculated load per unit length of the cables from the action of wind, N/m; H_g horizontal force at the point of attachment of the upper block of the cargo hoist from the force of gravity of the cargo and hoist, N; φ_i - the angle between the horizontal projection of the i -th guy and the axis Y, deg; n_1 - dimensionless parameter, which is taken from table. 5.

Table 5 - The value of the dimensionless parameter n_1 as a function of the number of cables nb and the value of the angle φ_i

Number of guys, n_a		3	4
Angle size, degrees	φ_1	60	0
	φ_3	180	180
Dimensionless parameter	n_1	2	1

Horizontal force at the point of attachment of the upper block of the cargo hoist



$$H_g = \frac{\cos \varphi \sin \psi}{\cos(\varphi - \psi)} P_g, H \quad (1.21)$$

where φ - angle of inclination of the load relative to the horizon, deg; ψ angle of deviation of the cargo rope from the vertical, deg (Fig. 2).

4.3. The equation of equilibrium of the guy 1 has the form

$$-\frac{B_2(\alpha)}{n_1} \Delta = \sigma_1 - \frac{A \cdot B_1(\alpha)}{\sigma_1^2} - B. \quad (1.22)$$

4.4. The equation of equilibrium of the guy 2 is as follows

$$B_2(\alpha) \Delta = \sigma_3 - \frac{A \cdot B_2(\alpha)}{\sigma_3^2} - B \quad (1.23)$$

It should be noted that equations (1.22) and (1.23) are nonlinear, which is due to the geometric nonlinearity of the deformation of the cables.

The parameters included in equations (1.9), (1.20), (1.22) and (1.23), not described above, have the following values

$$B = \sigma_0 - \frac{A \cdot B_0(\alpha)}{\sigma_0^2} - a_t \cdot E_B \cdot \Delta t \quad (1.24)$$

where a_t coefficient of linear expansion, $^{\circ}\text{C}^{-1}$ (for steel $a_t = 1,05 \cdot 10^{-5} \text{ }^{\circ}\text{C}^{-1}$); Δt - temperature difference, $^{\circ}\text{C}$ (in climatic conditions of Ukraine practically does not go beyond the interval $\pm 40 \text{ }^{\circ}\text{C}$); E_B - Young's modulus of the cable material, Pa (Table 1);

$$B_0(\alpha) = \tan^2 \alpha \quad (1.25)$$

$$B_1(\alpha) = (K - \tan \alpha)^2 \quad (\text{at } n_B=4) \quad (1.26)$$

$$B_1(\alpha) = K^2(1 + 0,75 \tan^2 \alpha) - K \tan \alpha + \tan^2 \alpha \quad (\text{at } n_B=4) \quad (1.27)$$

Where $K = \frac{q_B}{g_B}$; q_B - the estimated wind load per unit length of the cable, N / m, calculated by expression (1.19); g_B - according to (1.17).;

In addition

$$B_2(\alpha) = E_B \frac{\tan \alpha}{h} (1 + \tan \alpha)^2 \quad (1.28)$$

$$B_3(\alpha) = (K + \tan \alpha)^2, \quad (1.29)$$

$$A = \gamma_B \cdot h^2 \cdot \frac{E_B}{\gamma_4}, \quad (1.30)$$

where γ_B - density of the cable material, N / m³ (Table 1).

5. Algorithm for solving the system of equations (1.9), (1.20), (1.22) and (1.23).

Write a system of equations in the form of table 6.

Non-zero coefficients of the system of equations are equal to

$$a_{11} = F_1(u) \frac{h}{3} E_c I_z; \quad a_{12} = a_{21} = \frac{1}{h};$$

Table 6 - System of equations

$a_{11}M_0$	$+a_{12}\Delta$			$= P_1$
$a_{21}M_0$	$+a_{22}\Delta$	$+a_{23}\sigma_1$	$+a_{24}\sigma_2$	$= P_2$
	$+a_{32}\Delta$	$+a_{33}\sigma_1$		$= P_3$
	$+a_{42}\Delta$		$+a_{44}\sigma_2$	$= P_4$

$$a_{22} = \frac{N_0}{h}; \quad a_{23} = F_B n_1 \sin \alpha \cos \varphi_1;$$

$$a_{24} = F_B \sin \alpha \cos \varphi_3; \quad a_{32} = B_2 \frac{(a)}{n_1};$$

$$a_{42} = -B_2(a); \quad a_{33} = a_{44} = 1.$$

The elements of the right part (cargo members) have the form

$$P_1 = F_2(U) M_g \frac{h}{6} E_c I_z - F_3(U) q_c \frac{h^3}{24} E_c I_z;$$

$$P_2 = -q_c \frac{h}{2} - q_B n_B h (1 + \cos^2 \alpha) \frac{1}{4 \cos \alpha} - \frac{M_g}{h} - H_g;$$

$$P_3 = B + A \cdot B_1 \frac{(a)}{\sigma_{1, i-1}^2};$$

$$P_4 = B + A \cdot B_3 \frac{(a)}{\sigma_{3, i-1}^2},$$

where $\sigma_{1, i-1}$ and $\sigma_{3, i-1}$ - the value of the stress in the leeward and windward cables in the previous approximation. In the first approximation ($i = 1$) should be taken $\sigma_{1, 0} = \frac{\sigma_0}{m}$; $\sigma_{3, 0} = \sigma_0 m$, where $m = 1,5$.

The solution of the system of equations can be written in the form

$$M_0 = (\bar{a}_{22} P_1 - a_{12} \bar{P}_2) / \bar{D}; \quad (1.31)$$

$$\Delta = (-a_{21} P_1 + a_{11} \bar{P}_2) / \bar{D}; \quad (1.32)$$

$$\sigma_1 = P_3 - a_{32} \Delta; \quad (1.33)$$

$$\sigma_3 = P_4 - a_{42} \Delta, \quad (1.34)$$

where

$$\bar{D} = a_{11} \bar{a}_{22} - a_{12} a_{21}; \quad \bar{a}_{22} = a_{22} - a_{23} a_{32} - a_{24} a_{42};$$

$$\bar{P}_2 = P_2 - P_3 a_{23} - P_4 a_{24}.$$

The values of σ_1 and σ_3 are compared with those obtained in the previous approximation. If the difference is more than 5%, accept

$$\sigma_1,^3 + 1 = 0,5 (\sigma_1,^3 - 1 + \sigma_1,^3), \quad \sigma_3,^3 + 1 = 0,5 (\sigma_3,^3 - 1 + \sigma_3,^3)$$

and the calculation is repeated. If the discrepancy is less than 5%, the iterations are stopped.

Mast structures are recommended to rely on a combination of loads [3], listed in the following table.7.



Table 7 - The combination of loads when calculating the mast

Load combinations	Loading					
	permanent		temporary			
	own weight	pre-tensioning of cables	cargo weight	wind	ice crust	temperature difference
1	1	1	1	0,5	-	-
2	1	1	-	1	-	-
3	1	1	1	0,25	1	1

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Л.С. Солдатенко, канд. техн. наук, доцент, E-mail: leonid541247@gmail.com

А.І. Шипко, аспірант, E-mail: shipko.arkadiy@gmail.com

І.М. Шипко, канд. техн. наук, доцент, E-mail: shipkoigor@gmail.com

Одеський національний технологічний університет, 112, Канатна, Одеса, Україна, 65039

РОЗРАХУНКОВЕ ВИЗНАЧЕННЯ ПАРАМЕТРІВ МОНТАЖНИХ ЩОГЛ

Анотація

Під час проведення монтажних робіт на підприємствах галузі, застосування універсальної вантажопідійомної техніки інколи є неможливим або недоцільним. В таких випадках вдаються до використання монтажних щогл - відносно простих за конструкцією і досить ефективних вантажопідійомних засобів, спорудження яких, здебільшого, базується на практичному досвіді виконробів монтажних організацій або бригадирів-такелажників. Існуючі методики розрахунків монтажних щогл, розроблені багато десятиріч тому на підставі достатньо примітивних міркувань, без урахування додаткових навантажень, дають орієнтовні результати і мають бути переглянуті і поліпшені. Спроба такої роботи відображена у цій статті. Оскільки основні конструктивні елементи монтажної щогли - це її стаяк і ванти, то визначення параметрів щогли полягає у розрахунку міцності стаяка і вант прийнятих розмірів в умовах навантажень, передбачених початковими даними конкретного технічного завдання. Оцінку міцності стаяка слід виконувати як у площині дії моменту прикладених сил, так і з площини дії моменту. Для знаходження величини найбільшого напруження у стаяку щогли і максимального напруження в і-й ванті, необхідно виконати розрахунок напружено-деформованого стану стаяка і вант з застосуванням змішаного методу, згідно з яким вважають, що частина невідомих - це переміщення, а частина - зусилля. Математичну модель задачі описують чотири алгебраїчними рівняннями. Рівняння нерозривності деформацій стаяка базується на використанні функції Тимошенка, що враховують вплив поздовжніх сил на прогин стаяка щогли в площині дії вітрового навантаження і ваги вантажу. Навантаження від ваги і натягу вант знаходять з урахуванням можливої їх ожеледі і сили попереднього натягу. Вітрове навантаження стаяка і вант визначають з використанням даних про нормативний швидкісний напір, що для України складає 0,38 кПа. Розрахунки параметрів стаяка і вант враховують також температурний перепад, який в кліматичних умовах України не виходить за межі інтервалу $\pm 40^{\circ}\text{C}$. Щоглови споруди рекомендують розраховувати на сполучення як постійних, так і тимчасових навантажень згідно з даними, наведеним у статті. Усе це разом дає підстави сподіватись, що розглянута методика розрахунку параметрів монтажних щогл стане у пригоді фахівцям монтажних організацій і студентам, які вивчають питання техніки і технології такелажних робіт.

Ключові слова: монтажна щогла; стаяк щогли; розтяжка (ванта); оцінювання міцності стаяка; розрахунок напружено-деформованого стану стаяка щогли; функції Тимошенка; напруження вант.

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