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THE PLANE STATICS OF THE HUMAN RESCUE TRIPOD

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***Abstract**: One of the most important parameters which influences the human rescue tripod are the forces which act upon it. To determine this parameter from the design stage is an important aspect to any designer. This paper comes with a mathematical model, on which this force can be easily determined.*

Key word: *influence, human rescue tripod, important, mathematical model;*

1. INTRODUCTION

The human rescue tripod is a type of equipment used for rescuing humans and animals from different types of dangerous environments like: sewers, pits, wells, shafts, gorges etc.

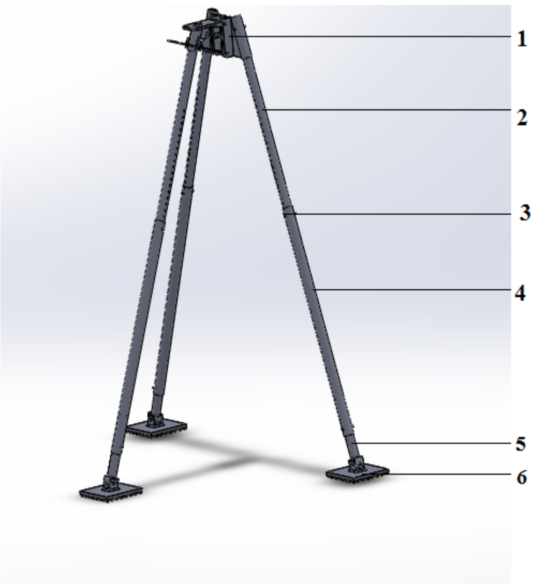

Fig.1. Human rescue tripod

From the constitutive point of view the human rescue tripod (Fig.1.) is composed of: (1) a fixing body (used for sustaining the legs); (2) fixing leg (helps to fix the fixing body to the fixing leg 2); (3) bolt (used to connect and fix the component parts); (4) enlargement leg (allows the enlargement of the tripod); (5) fixing leg 3 (has the purpose of sustaining the tripod on the plate, 6); (6) fixing plate on soil level (has the purpose of fixing the tripod on the soil).

For a proper functioning, the tripod is fixed on the soil with the help of the fixing plates, and with the help of some cables it is anchored to have a better equilibrium (we use around 3 fixing cables). After being fixed the tripod has a clip mounted which is connected to a pulley, on the pulley's disk on of the cables is passed (on one end of the cable the victim is tied, on the other it is tied on a winch), from the winch a lever is acting which allows the victim to be pulled up. The tripod can be electrically acting (with the help of a electric winch, figure 2) or manually (with the help of a manual winch, figure 3 or without a winch, figure 4).

Two of the tripods legs are fixed, they can only be prolonged on the height, the third leg is mobile and can trace a horizontal movement, function of necessity, like the other two legs this one also can be prolonged.

Fig.2. Electric action

Fig.3. Manual action

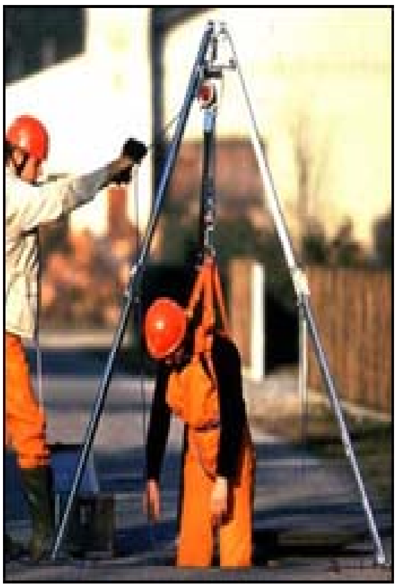

Fig.4. Manual action

2. MATHEMATICAL MODEL

On the tripod an ensemble of forces acts, forming a system of forces, for the system of forces to be in equilibrium this must be equal to zero. To determine easily the forces acting on the tripod we will compute at first the forces which act on the fix legs, and after that the forces which act on the working position of the tripod.

2.1 The forces which act on the fixed legs

In Figure 6 the mechanic model and the forces which act upon the two fixed legs of the tripod are represented. Starting from this point a mathematical model was proposed for this paper.

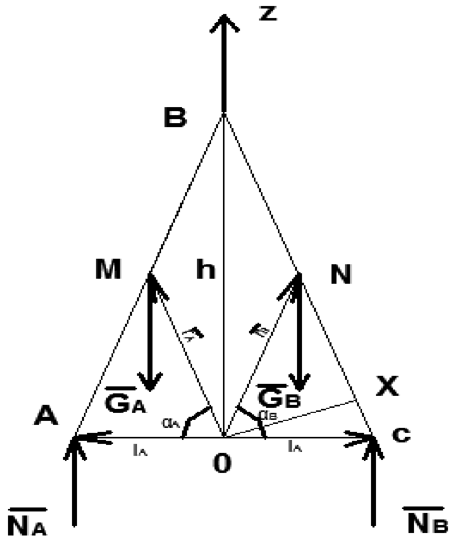

Fig.5. Forces applied to the fixed legs of the tripod

In figure 6 it can be seen that four forces act on the two legs, forming a system of forces. The two legs have a height of 2m and form a triangle with two equal sides having the sides AB=BC, AB and BC being the tripod legs, the angle between them measures 40º, from the tip of the triangle we consider the height h (BO) on the AC side, from here we deduce that AO=OB, AO=l_A and OB=l_b. From O we trace a median to AB and BC, in the points M and N, and point N, on BC we trace a height to compute the length of the medians.

AB=BC=2; AM=MB=BN=NC=AB/2=1; the angle ABC=40 °; the angle ABO= the angle OBC=20 °; h=BO; From the computations results that the medians NO=MB; NO=$\overline{r_b}$; MO=$\overline{r_a}$; $\overline{r_a} = \overline{r_b}$=0.82m;

If the medians are equal it results that the forces G_A and G_B are equal, to determine their values we will need the gravitational acceleration (g=9,8065 $\frac{m}{s^2}$) and the material density of aluminum, ($\delta = 2,7\frac{kg}{m^3}$);

$$G_A = l_A \cdot g \cdot \delta \tag{1}$$

where: G_A =18.36 N

From Figure 6 we can mention:

- the moment equation

$$N_A \cdot l_A - G_A \cdot r_A \cdot \cos\alpha_A - N_B \cdot l_B + G_B \cdot r_B \cos\alpha_B = 0 \tag{2}$$

- the equation of vertical projections

$$N_A - G_A - G_B + N_B = 0 \tag{3}$$

We input the two equations in a system:

$$\begin{cases} N_A \cdot l_A - G_A \cdot r_A \cdot \cos\alpha_A - N_B \cdot l_B + G_B \cdot r_B \cos\alpha_B = 0 \\ N_A - G_A - G_B + N_B = 0 \end{cases} \tag{4}$$

It results:

$$\begin{cases} N_A = N_B \\ N_A = G_A \end{cases} \tag{5}$$

After the computations it results:

$$G_A = G_B;\ N_A = N_B;\ G_A = N_A, \tag{6}$$

$G_A = 18.36$ N

$$\overline{r_1} = \frac{\sum_{i=1}^{4} G_i \overline{r_i}}{\sum_{i=1}^{4} G_i} \tag{7}$$

It results:

$$\overline{r_1} = \frac{G_A r_A + G_B r_B + N_A l_A + N_B l_B}{G_A + G_B + N_A + N_B} \tag{8}$$

$\overline{r_1} = 1.1$ N

Where point $\overline{r_1}$ obtained from figure 6 is called **the center of the parallel forces** and represents the intersection point of all central axes of the system of parallel forces which are obtained from the initial system by rotating the axes in parallel planes with the same angle, in the same direction, leaving the absolute values of the forces unchanged.

$$G_1 = N_A + N_B - G_A - G_B \tag{9}$$

It results: $G_1 = 0$, where G_1 is the center of mass.

2.2 The forces acting on the working position of the tripod:

To simplify the computations, we consider a favorable position of the tripod, that being when the legs 1 and 2 form with the third leg an angle of 90º. In figure 7 it can be observed that on the tripod are acting seven forces, forming a system of parallel forces. The third leg has a length of 3.5m maximum, it's length can vary when the case is needed.

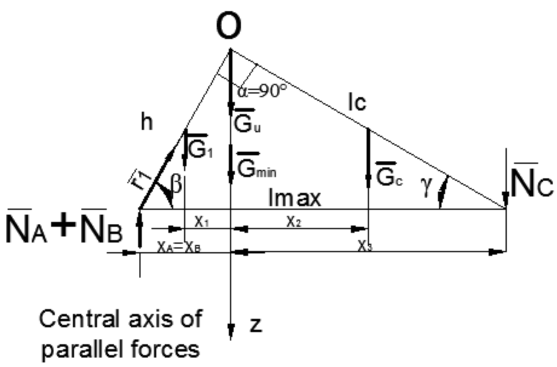

Fig.6. The Forces acting on the working position of the tripod

We mark the height of the arms with 1 and 2 (h=2),with lc the third arm, (lc=3.5), and maxim length between h and lc with lmax which will have to calculate.

$l_{max}=\sqrt{h^2+lc^2}$ (10)

l_{max}=4m

After obtaining the lmax`s length we can calculate the following lengths: height i, x_3, x_2, x_1.

i=sin30º·lc (11)

i=1.75m

$x_3=\sqrt{lc^2-i^2}$; or x_3=lc·cosγ (12)

x_3=3 m,

$x_3$represent the length between forces G_u and N_C;

$x_2=\frac{lc}{2}\cdot$ cosγ (13)

x_2=1.51m,

represent the length between forces G_u şi G_C;

cosγ=$\frac{l_c}{l_{max}}$; (14)

cosγ=0,866, results the angle, γ=30º

cosβ=$\frac{h}{l_{max}}$; (15)

cosβ=0,5, results the angle, β=60º

x_1=(h-r_1) cosβ; (16)

x_1=0.65m,

represent the length between forces G_u şi G_1;

For determining the useful weight G_u (the stage that must be reach), we need the weight that is applying tripod (this will be equal with 1000kg) and gravitational acceleration (g=9,8065 $\frac{m}{s^2}$; g approximate at 10 to have a better stability of the tripod).

Gu= m·g (17)

G_u=10000N

For determining G_1 we calculated earlier G_A and G_B, G_B=G_A=18,36N;

$G_1=G_A+G_B$ (18)

G_1=36.72N

$G_C=G_A$; (19)

$r_u=\sqrt{l_c^2-x_3^2}$; (20)

r_u=1.8;

r_u- represents the center of parallel forces;

$r_c=\sqrt{\frac{l_c^2}{4}-(x_3-x_2)^2}$; (21)

r_c=0.92;

r_c – is the position vector of a point, which belongs to the symmetry central axis called the weight center of the point material system. This point remains static when the system forces are rotated around the application points with the same angle and the same way.

$x_A=x_B=l_{max}-x_3$; (22)

x_A=1m;

x_A-represents the length between forces G_u and G_A or G_B;

$G_1x_1-N_Ax_A-N_Bx_B-G_cx_2+N_cx_3=0$ (23)

From the formula results that: N_c =13.52N;

$l_{1c}=\sqrt{l_c^2-h^2}$; (24)

$l_{1c}=2.44$m;

$$\bar{r_2}= \frac{r_1 \cdot G_1 + r_C \cdot G_C - l_{40} \cdot N_C - r_a \cdot N_A - r_b \cdot N_B}{G_1 + G_C - N_C - N_A - N_B} \tag{25}$$

$\bar{r_2}$=-4.24;

$$\bar{r_3}= \frac{\sum_{i=1}^{4} r_i \cdot G_i}{\sum_{i=1}^{4} G_i} ; \tag{26}$$

$$\bar{r_3} = = \frac{r_1 \cdot G_1 + r_u \cdot G_u + r_C \cdot G_C - l_{max} \cdot N_C - r_a \cdot N_A - r_b \cdot N_B}{G_1 + G_u + G_C - N_C - N_A - N_B} \tag{27}$$

$\bar{r_3}$=1.8,

where $\bar{r_3}$- the center of mases ;

$G_{min}=G_1 + G_u + G_c - N_C$ (28)

G_{min}=10042N

G_{min}- the minimum useful weight;

If the equation is not equal with 0, means that the force surplus applies to useful weight:

$F_e=m_u \cdot a$; $a=\frac{F_e}{m_u}$ (29)

$G_1 + G_u + G_c - N_C=0$

– the projection equation on Oz,

If the moments are different from 0 value, this one rotates around Ox

$M=I_x \cdot \varphi$ (30)

I_x-axial mechanical inertia moment of entire system (will not taking in discussion)

3. CONCLUSIONS

If the minimum useful weight(G_{min}=10042N) is greater than applicable useful weight(G_u=10000N) results that system is functional in any conditions.

The mathematical model developed in this paper represents a very useful instrument in determining the forces that act on the tripod and influences the functional mode of the device. The determinations of the forces depends of a lot of factors wich influences directly the functionality equipment.

Because of the mathematical model we can say that force's vector is directioned in the tripod's interior between the three legs, even when the mobile leg is extending.

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Statica plană a trepiedului de salvare umana

Rezumat: Unul dintre cei mai importanţi parametri care influenţează funcţionarea trepiedului pentru salvari persoane este reprezentat de forța care acționează asupra sa. Determinarea acestui parametru din faza de proiectare este un obiectiv important pentru orice designer. Această lucrare a venit cu un model matematic, pe baza căreia valoarea forței poate fi determinată cu uşurinţă.

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