

## **CALCULATION OF FALLING ACCELERATION AND SPEED IN CASE OF DAMAGE OF TRANSPORTATION VESSEL OF THE MUD EVACUATION INSTALLATION AT AUXILIARY SHAFT NO. 12 IN LUPENI MINING PLANT**

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**Abstract:** Due to the great variety of geological and hydro-geological conditions and to exploitation methods, the water inrushes in mines vary in a wide range. The main source of underground water is atmospheric precipitations, as well as water from rivers and lakes that go through the permeable rocks underground. A part of the underground water can come from deliberate introduction of water in case of hydraulic dumps or for other necessities (drinking water for the staff, dust suppression etc.).

In a mine there can be main and auxiliary pumping stations that direct water towards the principal collecting and decanting basins. The main (central water evacuation stations are usually found in the immediate vicinity of the main extraction shaft, which can also be used for water evacuation. The mud evacuation installation is situated at level 400 in an annex of the main pumping station at shaft No. 12 and it is intended to remove mud from the water collecting basins.

The paper presents the calculus of the acceleration and mechanical strain in the traction and balancing cable of the installation, necessary to determine the strains.

**Keywords:** calculus, acceleration, speed

### **1. TECHNICAL CHARACTERISTICS OF MUD EVACUATION INSTALLATION**

Depth from which mud is evacuated (traction space covered vertically by the evacuation vessel)  $H_t = 14$  m;

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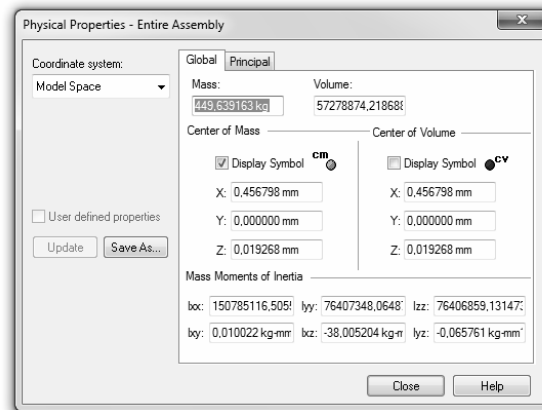
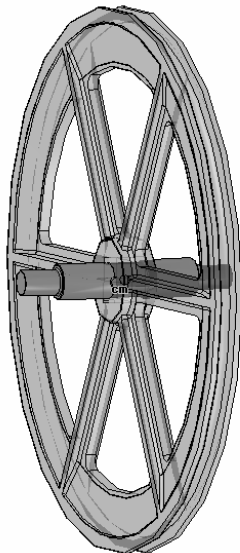
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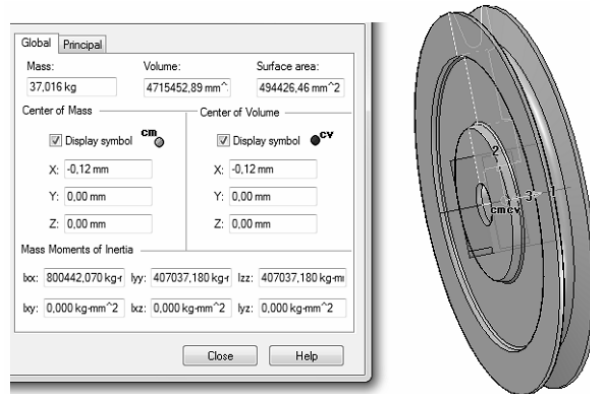
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- Maximum traction speed of the trolley,  $v = 0,8$  m/s;  
 Average traction speed of the trolley,  $v_m = (0,8 \dots 0,9) \cdot v$ ,  $v_m = (0,64..0,72)$  m/s;  
 Maximum traction speed of the evacuation vessel,  $v_{max,t}: 0,4$  m/s;  
 Starting traction acceleration of the trolley,  $a_p = 0,2 \dots 0,5$  m/s<sup>2</sup> [3];  
 Maximum traction speed of the trolley when the trolley motor works as generator,  $v_0 \approx 1,05 \cdot v$ ,  $v_0 \approx 0,84$  m/s [3];  
 Reduction gear and trolley motor drum efficiency,  $\eta = 0,7 \dots 0,8$  [3];  
 Own mass of evacuation vessel, together with the fixing device (without the mass of the mobile winch of the traction cable, to reduce traction force),  $m_{ve} = 1000$  kg;  
 Traction cable diameter:  $\varnothing 18$  mm;  
 Specific mass of traction cable,  $q_{ce} = 1,135$  kg/ml;  
 Maximum suspended length of the traction cable,  $H_c = 23,6$  m;  
 Minimum suspended length,  $H_m = 9,6$  m;  
 Number of wagons,  $n_v = 1$ ;  
 Own mass of a wagon,  $m_v = 650$  kg;  
 Useful load of a wagon,  $m_u = 1200$  kg (useful volume, density of primary mud, with values between 1008-1200 kg/m<sup>3</sup> for mud humidity in the range of 98-95%);  
 Diameter of the counterweight suspension cable:  $\varnothing 22$  mm;  
 Specific mass of the cable of which the counterweight is suspended,  $q_{cc} = 1,66$  kg/ml;  
 Counterweight mass,  $m_{cg} = 600$  kg;  
 The mass of the fixed deviation and guiding pulley (fixed winch, Fig. 1) of the traction cable,  $m_{mct} = 450$  kg;

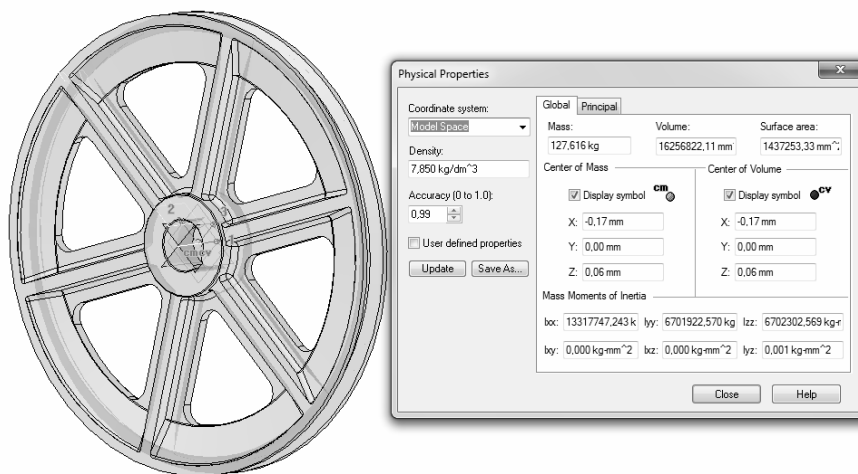


**Fig. 1.** Mechanical characteristics of the fixed deviation and guiding pulley (fixed winch) of the traction cable

The mass of the mobile winch of the traction cable (Fig. 2), to reduce the traction force,  $m_{set} = 38$  kg;



**Fig. 2.** Mechanical characteristics of the mobile pulley of the traction cable, to reduce traction force



**Fig. 3.** Mechanical characteristics of the fixed deviation and guiding pulley (fixed winch) of the cable that connects counterweight and the evacuation vessel

The mass of the fixed deviation and guiding pulley (fixed winch, Fig. 3) of the cable that connects the counterweight and the evacuation vessel,  $m_{mcg} = 128$  kg;

The mass of the deviation rum of the traction cable chord (Fig. 4),  $m_{tct} = 121,5$  kg;

The inertia moment of the fixed deviation and guiding pulley (fixed winch, Fig. 1) of the traction cable,  $J_{mct} = 151$  kg·m<sup>2</sup>;

The moment of inertia of the mobile winch of the traction cable (Fig. 2), for

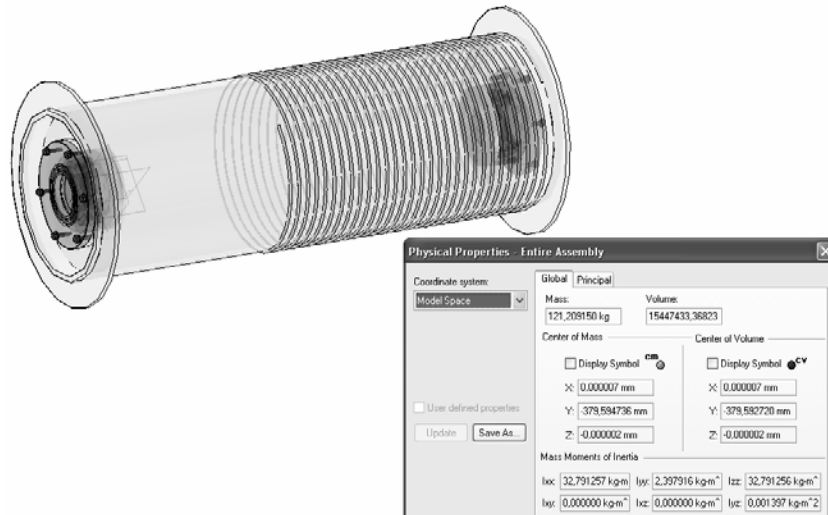
traction force reduction (to the rotation axis),  $J_{set} = 0,9 \text{ kgm}^2$ ;

The moment of inertia of the fixed deviation and guiding pulley (fixed winch, Fig. 3) of the cable connecting the counterweight and the evacuation vessel (Fig. 4),  $J_{mcc} = 13,5 \text{ kg}\cdot\text{m}^2$ ;

The moment of inertia of the deviation drum of the traction cable chord,  $J_{tcc} = 2,4 \text{ kgm}^2$ ;

For the fixed deviation and guiding pulley (fixed winch, Fig. 1) of the traction cable (Fig. 2) to reduce the traction force and for the fixed deviation and guiding pulley (fixed winch, Fig. 3) of the cable that connects the counterweight and the evacuation vessel, the XX axis is along the axis of the shaft, axis XY is upwards and axis ZZ on the direction of the wedge.

For the traction cable chord deviation drum (Fig. 4) axis YY is along the drum axis, axis ZZ is upwards perpendicular in vertical plane to axis YY and axis XX is perpendicular in a horizontal plane to axis YY, [6], [7], [8].



**Fig. 4.** Mechanical characteristics of traction cable chord deviation drum

Maximum static load:

$$Q_1 = [m_{ve} + n_v \cdot (m_v + m_u) - m_{cg}] \cdot g = 22072,5 \text{ N} \approx 2208 \text{ daN} \quad (1)$$

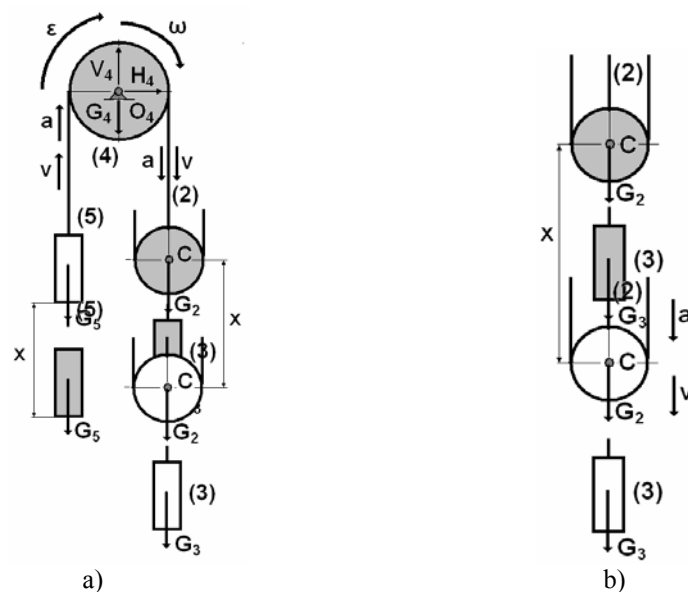
Minimum static load:

$$Q_2 = (m_{ve} + m_v - m_{cg}) \cdot g \approx 10300,5 \text{ N} \approx 1031 \text{ daN} \quad (2)$$

Maximum unbalanced static load:

$$Q_3 = \frac{Q_1 - Q_2}{2} = 588,5 \text{ daN} \quad (3)$$

## 2. CALCULATION OF THE FALLING ACCELERATION AND SPEED OF THE EVACUATION VESSEL IN CASE OF CABLE RUPTURE WHEN PARACHUTES DO NOT FUNCTION TO APPLY THE BRAKE TO THE EVACUATION VESSEL



**Fig. 5.** Diagram for the calculation of falling acceleration and speed of the evacuation vessel;  
a) – in case of rupture of traction cable, when parachutes do not function to apply the brake;  
b) – in case of rupture of the traction cable and counterweight when parachutes do not function to apply the brake.

It is considered that the system starts from rest from the superior level (level 400), reaching the inferior one (level 390) by free fall, the parachutes do not operate to apply the brakes to the evacuation vessel, in case of rupture of the traction vessel (Fig. 5.a) and in case of rupture of the cable connecting the vessel and the counterweight (Fig. 7.b, the most unfavorable situation) [1], [2], [3], [4], [5], [8].

### 2.1. Calculation of the falling speed and acceleration of the evacuation vessel in case of traction cable rupture, when parachutes do not operate to apply the brake to the vessel

The system is given a certain movement with arbitrary cinematic parameters  $x$ ,  $a$  and  $v$  (Fig. 5.a) and the cinematic and dynamic study of the system is performed according to the indications of the table from below (Table No. 1).

To determine the cinematic parameters, kinetic energy theorems are applied

for a system of material bodies.

Cinematic and dynamic parameters are shown in Table 1.

The mechanical work column and the kinetic energy column in the table are summed up, and are entered in the expression of the kinetic energy theorem in finite form ( $E_1 - E_0 = L_{0-1}$ ).

Table 1. Cinematic and dynamic parameters of the system

No. body	Movement	Speed	Acceleration	Moving	External forces	Mechanical work	Kinetic energy	
							Initial position (0)	Final position (1)
2+3	translation	$v_2 = v_3 = v$	$a_3 = a$	$x$	$G_2 + G_3$	$(G_2 + G_3) \cdot x$	0	$m_3 \cdot v^2 / 2$
4	rotation	$\omega_4 =$	$\varepsilon_4 = a/r_4$	0	0	0	0	$J_4 \cdot \omega_4^2 / 2$
5	translation	$v_5 = v$	$a_5 = a$	$x$	$G_5$	$G_5 \cdot x$	0	$m_5 \cdot v^2 / 2$

$$\frac{1}{2} \cdot m_5 \cdot v^2 + \frac{1}{2} \cdot J_4 \cdot \omega_4^2 + \frac{1}{2} (m_2 + m_3) \cdot v^2 = m_5 \cdot g \cdot x + (m_2 + m_3) \cdot g \cdot x, \quad (4)$$

Substituting the known values,

$$\begin{aligned} \frac{1}{2} \cdot 600 \cdot v^2 + \frac{1}{2} \cdot 13,5 \cdot \frac{v^2}{(0,445)^2} + \frac{1}{2} (38 + 1000 + 650 + 1200) \cdot v^2 = \\ = 600 \cdot 9,81 \cdot x + (38 + 1000 + 650 + 1200) \cdot 9,81 \cdot x \end{aligned} \quad (5)$$

is obtained.

Making the calculations, the formula:

$$1778 \cdot v^2 = 34217,28 \cdot x, \quad (6)$$

is deduced.

By derivation of formula (6) in relation to time

$$1778 \cdot 2 \cdot v \cdot v' = 34217,28 \cdot x', \quad (7)$$

is obtained.

Hence acceleration:

$$a = \frac{34217,28}{3556} = 9,62 \text{ m/s}^2 \quad (8)$$

results.

Maximum speed reached by the evacuation vessel in fall is:

$$v = \sqrt{2 \cdot a \cdot h} = \sqrt{2 \cdot 9,62 \cdot 14} \cong 16,41 \text{ m/s} \quad (9)$$

## 2.2. Calculation of the falling acceleration of the evacuation vessel, when the traction and balancing cables are ruptured, and the parachutes do not apply the brakes to the vessel

For this case, the cinematic and dynamic parameters of the system are shown in Table 2.

Table 2. Cinematic and dynamic parameters of the system

No. body	Movement	Speed	Acceleration	Moving	External forces	Mechanical work	Kinetic energy	
							Initial position (0)	Final position (1)
2+3	translation	$v_2 = v_3 = v$	$a_3 = a$	$x$	$G_2 + G_3$	$(G_2 + G_3) \cdot x$	0	$m_3 \cdot v^2 / 2$

The columns for mechanical work and kinetic energy in the table are summed up and are entered in the expression of the theorem of kinetic energy in finite form ( $E_1 - E_0 = L_{0-1}$ ).

$$\frac{1}{2}(m_2 + m_3) \cdot v^2 = (m_2 + m_3) \cdot g \cdot x, \quad (10)$$

Substituting the known values,

$$\frac{1}{2}(38 + 1000 + 650 + 1200) \cdot v^2 = (38 + 1000 + 650 + 1200) \cdot 9,81 \cdot x, \quad (11)$$

is obtained.

Making the calculations, the formula:

$$1444 \cdot v^2 = 28331,28 \cdot x, \quad (12)$$

is deduced.

Derivation of the formula (2.12) in relation to time, gives:

$$1444 \cdot 2 \cdot v \cdot v' = 281331,28 \cdot x', \quad (13)$$

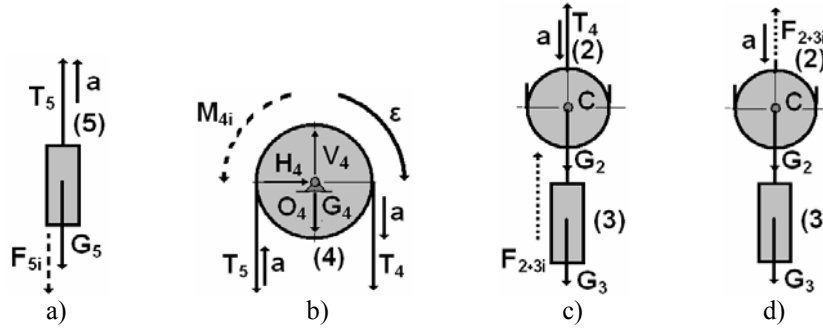
Hence the acceleration result:

$$a = \frac{28331,28}{2888} = 9,81, \text{ m/s}^2 \quad (14)$$

The maximum speed reached by the evacuation vessel in fall is:

$$v = \sqrt{2 \cdot a \cdot h} = \sqrt{2 \cdot 9,81 \cdot 14} \cong 16,6 \text{ m/s} \quad (15)$$

*With kinostatic method.* Each body is separated one from the other (Fig. 2.6), the given forces, the connecting forces, the elements of the inertia torsor (forces and moments) are figured, and then the fictive dynamic balance formulae are written and solved (calculation stages of kinostatic method).



**Fig. 6.** Diagram of separation of the system bodies for the calculation of the acceleration with kinostatic method:

- a) - counterweight (5); b) – deviation pulley (4); c) – mobile winch (2) plus the evacuation vessel (3) at the rupture of the traction cable; d) – mobile winch (2) plus the evacuation vessel (3) at the rupture of the traction cable and the balancing cable

*At the rupture of the traction cable:*

For body 5 (Fig. 6.a)

$$\left(\sum Y = 0\right): T_5 - G_5 - F_{5i} = 0, \quad (16)$$

For body 4 (Fig. 6.b)

$$\begin{aligned} \left(\sum X = 0\right): H_4 &= 0 & (a) \\ \left(\sum Y = 0\right): -T_5 - T_4 + V_4 - G_4 &= 0 & (b), \\ \left(\sum M_{O_4} = 0\right): T_5 \cdot r_4 - T_4 \cdot r_4 + M_{i4} &= 0 & (c) \end{aligned} \quad (17)$$

For bodies 2 and 3 (Fig. 6.c)

$$\left(\sum Y = 0\right): -T_4 + G_2 + G_3 - F_{2+3i} = 0, \quad (18)$$

From (16) it results:

$$T_5 = G_5 + F_{5i} = 600 \cdot (9,81 + a) = 5886 + 600a, \text{ [N]} \quad (19)$$



From (17.c) it result:

$$T_4 = \frac{T_5 \cdot r_5 + M_{i4}}{r_5} = T_5 + \frac{M_{i4}}{r_4} = 5886 + 600a + 13,5 \frac{a}{0,445^2} = 5886 + 668,2a, \text{ [N]} \quad (20)$$

From (18) it results:

$$-(5886 + 668,2a) + (38 + 1000 + 650 + 1200) \cdot (9,81 - a) = 0 \text{ N} \quad (21)$$

$$-(5886 + 668,2a) + 2888 \cdot (9,81 - a) = 0 \text{ N} \quad (22)$$

$$22445,28 - 3556,2 \cdot a = 0 \text{ N} \quad (23)$$

Resulting

$$a = \frac{22445,28}{3556,2} = 6,311 \text{ m/s}^2 \quad (24)$$

Maximum speed reached by the evacuation vessel in fall, considering the forces and moments is:

$$v = \sqrt{2 \cdot a \cdot h} = \sqrt{2 \cdot 6,311 \cdot 14} \cong 13,3 \text{ m/s} \quad (25)$$

*At the rupture of the traction and balancing cable* (the most unfavorable case for this situation)

For bodies 2 and 3 (Fig. 6.d)

$$\left(\sum Y = 0\right): G_2 + G_3 - F_{2+3i} = 0 \text{ N} \quad (26)$$

From (26) shows that  $a = g$ , where:

$$v = \sqrt{2 \cdot a \cdot h} = \sqrt{2 \cdot 9,81 \cdot 14} \cong 16,6 \text{ m/s} \quad (27)$$

### 3. CONCLUSION

Plant sludge disposal is a device designed solely for transporting material.

Sludge disposal facility lies on the horizon 400 in an annex to the main pump station shaft 12 Horizon 400 and is intended for disposal of sludge from water collection basins.

With this installation works are carried out cleaning of cesspools mine water, the main station for waste water from the well 12 Horizon 400. Area where the facility is located consists of a gallery 50 meters below the river transverse and vertical mining work 30 m ventilation of these spaces is performed under general depression of the

mine.

In this paper were calculated maximum values of acceleration, velocity and mechanical stresses for the cases considered failures: to break the tow cable and tow rope breaking and balancing the (worst case for this situation).

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