# STORAGE OF THE GOODS UNDER THE OPERATION OF THE MINING DUMPER TRUCK

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**ABSTRACT.** Storage of the goods means the non-scattering of the transported bulk load outside the body of the mining dump truck during its operation. When overcoming unevenness and various obstacles along technological roads, inertia forces arise, which can cause some different size particles of load to bounce off and out of the body. This reduces productivity and creates conditions for production accidents. In this work, a dynamic model of a mining dumper truck is investigated, taking into account the arising vibrations due to road roughness. The formula for determining the maximum safe operating speed, adapted to the road conditions, has been analytically derived. A numerical experiment was also conducted.

**Keywords:** mining dump truck, storage of the goods

**СЪХРАНЯЕМОСТ НА ТОВАРА ПРИ ЕКСПЛОАТАЦИЯТА НА РУДНИЧЕН САМОСВАЛ**

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**РЕЗЮМЕ.** Под съхраняемост се разбира неразпиляването на транспортирания насипен товар извън каросерията на рудничния самосвал в процеса на неговата експлоатация. При преодоляването на неравности и различни препятствия по технологичните пътища възникват инерционни сили, които могат да предизвикат отскачане и излизане извън каросерията на частици от товара с различна големина. Това намалява производителността и създава условия за трудови злополуки и производствени аварии. В настоящия труд се изследва динамичен модел на рудничен самосвал с отчитане на възникващите трептения вследствие от пътните неравности. Аналитично е изведена формула за определяне на максималната безопасна експлоатационна скорост, съобразена с пътните условия. Проведен е и числен експеримент.

**Ключови думи:** рудничен самосвал, съхраняемост на товара.

## Introduction

An important requirement when transporting ore is to preserve the integrity of the cargo. The technological roads on which the mining dump truck travels are full of large single and also periodically recurring unevenness. In order to achieve high productivity, it is often allowed to overload the mining dump truck and move at high speed. Intense vibrations and large inertial forces occur, which also affect the transported load. Overcoming unevenness at high operating speeds causes pieces of ore to bounce and scatter outside the body. This endangers other vehicles and people nearby and degrades the quality of the technological road. Especially important is the role of the driver in choosing a safe operating speed, tailored to the characteristics of the road. The purpose of this work is to determine the maximum safe operating speed allowing storage of the transported bulk cargo.

## Dynamic model

Due to the large size of the mining dump truck, it can be assumed that the oscillations of the front and rear suspension are independent. Much of the load (about 70%) rests on the rear axle and there is a risk of falling pieces of the body. The dynamic model for studying the oscillations of the rear suspension is presented in fig. 1. The following denotations are made:

M – mass of the mine dump truck together with the load carried by the rear suspension;

$m$ - mass of one piece of the transported load, endangered by falling;

$y$ - vertical movement of the vibrating mass;

$c$ - reduced coefficient of elasticity of the rear suspension.

The cross-section of a horizontal path is considered as a sine wave with amplitude $a$ and period $l$, which represent respectively the height and length of the predominant irregularities in a given road section. If the dump truck is moving at a constant speed on a straight horizontal section, the distance traveled by it will be $s = v.t$. The kinematic disturbance on the wheels is represented by the periodic function $q = a.\sin\frac{2\pi vt}{l}$ (Pulev 2012).

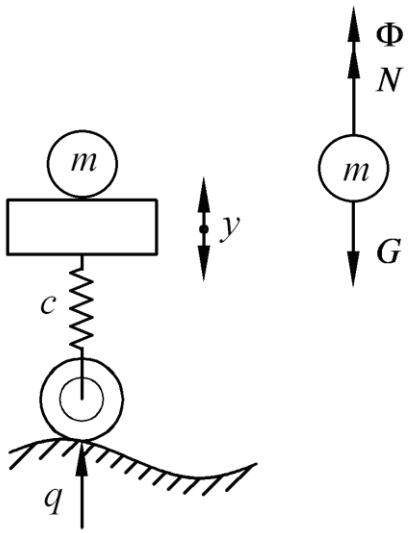


**Fig. 1. Dynamic model**

The differential equation describing the vertical vibrations of the dump truck is

$$m\ddot{y} + c(y - q) = 0 .$$

After transformation it acquires the form

$$\ddot{y} + k^2 y = k^2 a.\sin\frac{2\pi v t}{l}, \qquad (1)$$

where $k = \sqrt{\frac{c}{M}}$ is the circular frequency of the free vibrations. This is an inhomogeneous second-order differential equation with constant coefficients. Due to the rapid attenuation of the free ones, the purely forced oscillations of the minimg dumper truck are of interest. That is why we are looking for a private solution in the form:

$$y = C.\sin\frac{2\pi v t}{l}. \qquad (2)$$

After substituting (2) in (1) for the integration constant is obtained

$$C = \frac{k^2 a}{k^2 - \left(\frac{2\pi v}{l}\right)^2}.$$

Therefore, the law of motion is

$$y = \frac{k^2 a}{k^2 - \left(\frac{2\pi v}{l}\right)^2}\sin\frac{2\pi v t}{l}$$

and the acceleration of the oscillating mass has the form

$$\ddot{y} = -\frac{\left(\frac{2\pi v}{l}\right)^2 k^2 a}{k^2 - \left(\frac{2\pi v}{l}\right)^2}\sin\frac{2\pi v t}{l}.$$

Figure 1 presents the acting forces on a piece with a mass $m$ of the transported load. These are the normal reaction $N$ of the support, the inertial force $\Phi$ and gravity $G = mg$. The inertial force is variable

$$\Phi = m\ddot{y} = -\frac{m\left(\frac{2\pi v}{l}\right)^2 k^2 a}{k^2 - \left(\frac{2\pi v}{l}\right)^2}\sin\frac{2\pi v t}{l}$$

and has an amplitude

$$\Phi_{\max} = \frac{m\left(\frac{2\pi v}{l}\right)^2 k^2 a}{k^2 - \left(\frac{2\pi v}{l}\right)^2}; \qquad (3)$$

The friction forces between the particles of the transported bulk load are not taken into account because the pieces threatened by scattering have little contact with the others. In order for the particle in question to be in equilibrium, the following equation must be satisfied

$$N = G - \Phi .$$

In this work, it is considered that in order not to bounce out of the body, the particle in question should not lose contact with the support. This means

$$N \geq 0$$

or

$$\Phi_{\max} \leq G . \qquad (4)$$

Taking into account (3), inequality (4) acquires the following form

$$\frac{\left(\frac{2\pi v}{l}\right)^2 k^2 a}{k^2 - \left(\frac{2\pi v}{l}\right)^2} \leq g . \qquad (5)$$

The frequency of free vibrations is many times higher than the frequency of the disturbance, which means that the denominator of (5) can only accept positive values. This fact is also confirmed by the applied numerical experiment and is of

great importance in the analytical solution of the inequality (5). In view of the purpose of the study, it is important to decide (5) the operating speed of the mining dumper truck. Thus the following condition for storage of the transported cargo is obtained:

$$v \le v_{\max} = \frac{l}{2\pi}\sqrt{\frac{g.c}{a.c + M.g}} \,. \qquad (6)$$

This means that the operating speed must not exceed the maximum value $v_{\max}$ , which depends to the greatest extent on the length and height of the irregularities and on the mass of the dump truck together with the load carried.

## Numerical experiment and discussion

The object of the experiment is a mine dump truck BELAZ-7555B with a mass without load 40250 kg, maximum load capacity 55000 kg and a total mass of 95250 kg, 67% of which rests on the rear axle. The values of the parameters are:

$M$ = 63818 kg,
$c$ = 2.7.106 N / m,
$a$ = 0.05 m and
$l$ = 10 m.

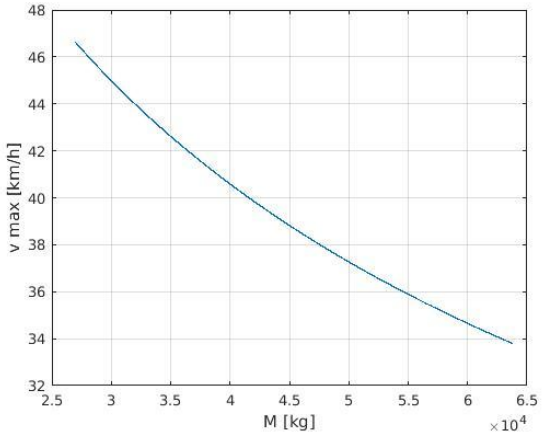


**Fig. 2. Influence the mass on the speed**

For the frequency of free vibrations we get

$k$ = 6,5 $s^{-1}$ ,

and the maximum operating speed according to (6) is

$v_{\max}$ = 9,4 $m/s$ = 33,8 $km/h$ .

The frequency of the disturbance is $\frac{2\pi v}{l}$ = 5,9 $s^{-1}$ , which confirms the assumption of a positive denominator in inequality (5).

Formula (6) makes it possible to assess the influence of individual factors on the operating speed of the mining dump truck. Figures 2 and 3 show that the operating speed is low with large bumps and heavy load. Figure 2 shows that the larger the lengths of the irregularities, the higher the velocity.

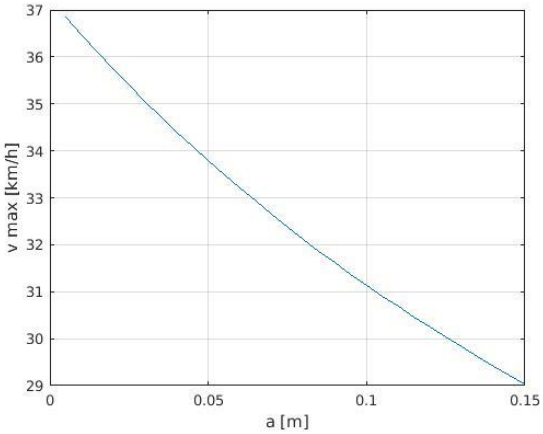


**Fig. 3. Influence of irregularities height on the speed**

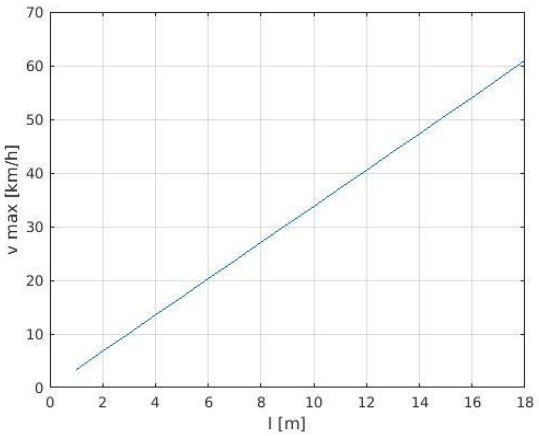


**Fig. 4. Influence of irregularities length on the speed**

Properly selected operating speed, ensuring that the load is not scattered outside the body, is an extremely important condition for high productivity and prevention of accidents at work. The obtained formula (6) makes it possible to calculate the maximum permissible safe speed, ensuring the storage of the transported bulk cargo, taking into account the heights and lengths of the irregularities characteristic for a given section of the road. The role of the driver of the mine dump truck is also very important in providing an appropriate speed, in accordance with the specific dimensions of the road irregularities and the weight of the transported cargo.

## References

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