pISSN:2349-5707 Volume:12,Issue 11,November-2025 eISSN:2349-5715

DEVELOPMENT OF TECHNICAL SOLUTIONS FOR INCREASING THE SERVICE LIFE OF THE BODY OF QUARRY HIGHWAYS

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Annotation: In this article, the theory of dump truck body loads, the calculation of forces influencing the operational indicators of dump truck bodies using physical geometric modeling, increasing the efficiency of dump truck body operation based on the improvement of dump truck bodies, the development of a rubber body covering for dump trucks, methods of its use, and economic indicators are presented.
Keywords: Quarry dump truck, body design, ANSYS stress analysis, unloading angle, protective linings, rubber coating, stress concentration, impact loads, BelAZ dump truck body, maintenance strategies.

Introduction

At mining enterprises, automobile transport should be recognized as a transport vehicle that stands out in terms of high productivity during operation. Truck dump trucks are achieving great success due to their widespread use along with other vehicles for transporting minerals over long and short distances. Due to road unevenness of ore transported in dump trucks, load displacements occur in the body, which is one of the main causes of cracks, abrasion, and malfunctions of other elements in the body, frame, and longitudinal members due to changes in the forces acting on the dump truck. Therefore, if the study of indicators related to the body, frame, and chassis of a dump truck is one of the main tasks, then the solution of such basic tasks as ensuring their constant control and proper operation is of particular importance [1-6].

Currently, scientific research is being conducted worldwide to improve the technical and economic indicators of road transport, ensure safe and high-quality transportation during mining operations, ensure their efficient operation, develop methods for suppressing the impact of loads on the supports of dump trucks at loading and unloading points, and prevent deterioration of the dump truck body. In this regard, special attention is paid to conducting scientific research aimed at increasing and improving the reliability, durability, and efficiency of quarry road transport, reducing malfunctions of working elements, timely maintenance and repair work, and reducing costs [6-11].

As one of the effective ways to solve such problems as preventing the destruction of quarry dump truck bodies, it is possible to calculate the stress state of the system based on modeling using finite element analysis methods and software. The finite element method is one of the most widespread methods of numerical calculation, the essence of which lies in the analysis of engineering problems, representing the considered constant medium as a series of discrete sections, in which the main parameters of the material and the force field are distributed almost uniformly [12-16].

Von Mises stress is an important concept in mechanical engineering, measuring the stress state of a material under a complex load. In materials science and engineering, stress is defined as the force acting on a unit area of a material. When an external force is applied to a material, if the stress exceeds its strength, it can lead to deformation or destruction. Stress can be divided into three types: compression, tension, and shear.

MATERIALS AND METHODS

When materials are subjected to a complex load, the stress state cannot be determined by a single stress component. Instead, it is determined by the combination of three principal stresses acting on the material in three different directions. Von Mises voltage is a scalar quantity that represents the equivalent voltage resulting from the combination of principal stresses [6-16].

Von Mises stress is a useful measure for predicting when a material will leak or deform. In the design and analysis of mechanical components and structures, they are widely used to ensure their ability to withstand expected loads without failures.
Von Mises stress is calculated as the square root of the sum of the squares of the differences of the three principal stresses. Mathematically, it looks like this:
Based on physical laws:
Von Mises voltage model (energy-based stress)

$$\sigma_V=\sqrt{\frac{1}{2}[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2]} \qquad (1)$$

$\sigma_1,\sigma_2,\sigma_3$ − where: basic normal stresses
Strain is the ratio of the force applied to a body's cross-section to its cross-sectional area.

$$\sigma=\frac{F}{A} \qquad (2)$$

$\sigma - F - A$ − where: stress (MPa); force (N); surface area (mm^2 or m^2)
Von Mises stress is a fundamental concept in materials science and engineering, allowing for the assessment of the equivalent stress state of a material subjected to a complex load. Using von Mises stress, engineers can accurately predict the behavior of material and design components that can withstand expected loads.
Currently, there are many programs based on various mathematical methods and allowing the analysis of physical processes under certain conditions. At the same time, there are not many programs that provide interdisciplinary calculations - simultaneous calculation and analysis of equations from different fields of physics. ANSYS is now a unique system that combines most branches of physics into a single interface. In addition, the modern ANSYS Workbench platform is compatible with many SAPR packages and allows modeling physical processes using three-dimensional models built into design programs, eliminating the need to transfer the model from one program to another [5-15].
The finite element method, implemented in the ANSYS software, was used for long-term calculation of the stress-strain state and justification for the design reliability of equipment and pipelines used in nuclear energy. Due to the need for equipment development and improvement, the scope of application of this software is constantly increasing. At the same time, despite the need to correctly assess the reliability of newly created equipment and the remaining service life of operating equipment, such software is practically not used in the mining industry. This is primarily due to the lack of methodological developments in this area, regulating the limits and methods of application of this software [7-16].
Thus, modeling using the finite element method is the collection and solution of a system of a large number of partial differential equations. In this case, there is no need to make important assumptions that could significantly distort the nature of the system voltage [1-5]. The finite element method allows not only to significantly reduce the volume of work, but also to evaluate various design options for units.
In the SOLIDWORKS program, the dump truck body was modeled, and its compliance with the body parameters was determined, which is G=7.5 t. Since the body volume is designed for 55 tons, we set a load of 55 tons to calculate the stress-strain state of our model. After this, the stress-strain state of the dump truck body was determined (Fig. 1).

pISSN:2349-5707 Volume:12,Issue 11,November-2025 eISSN:2349-5715

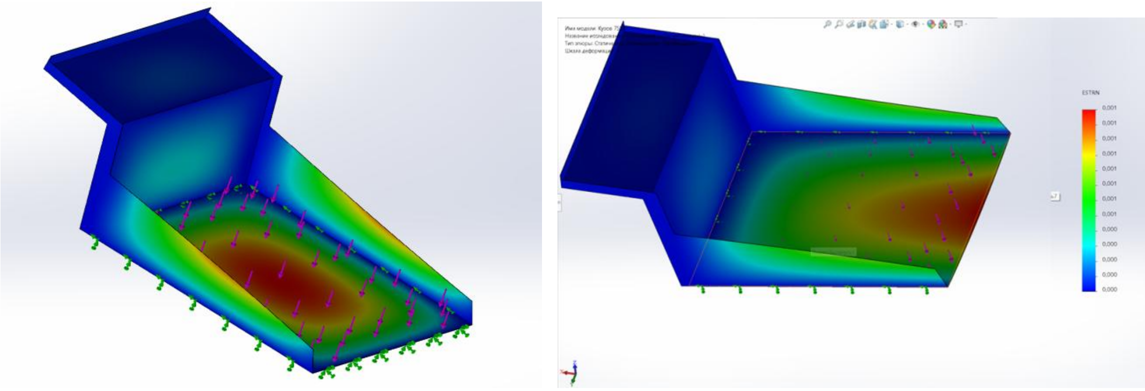

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Figure 1. Stress of the dump truck body in the horizontal position with a load of 55 tons.

Fig. 1 shows that in the horizontal position of the dump truck body, when a load of 55 tons is installed, the main stresses fall on the middle part of the body. If this result is for the horizontal position, then when lifting the body from 0^0 to 46^0 for the purpose of unloading the load on the body, the displacement of the stress state of this body was determined. Based on Figure 10a.b, it can be concluded that during each unloading process of the dump truck, a 0.001 mm deterioration of the lower part of the body is observed.

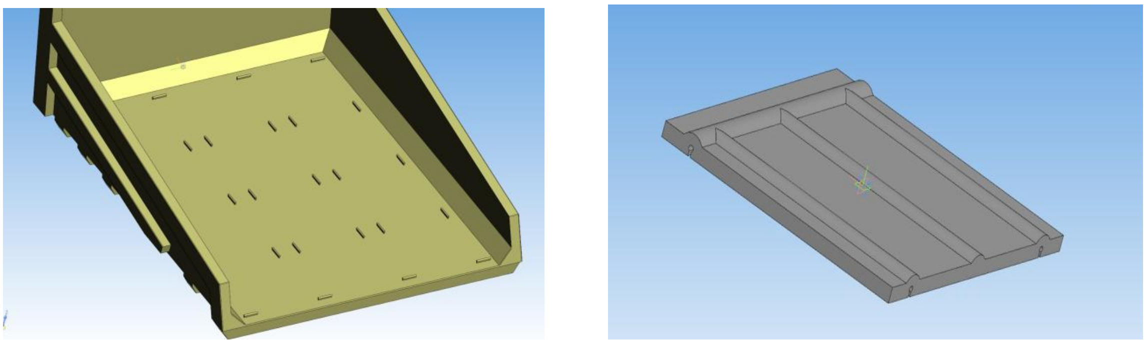

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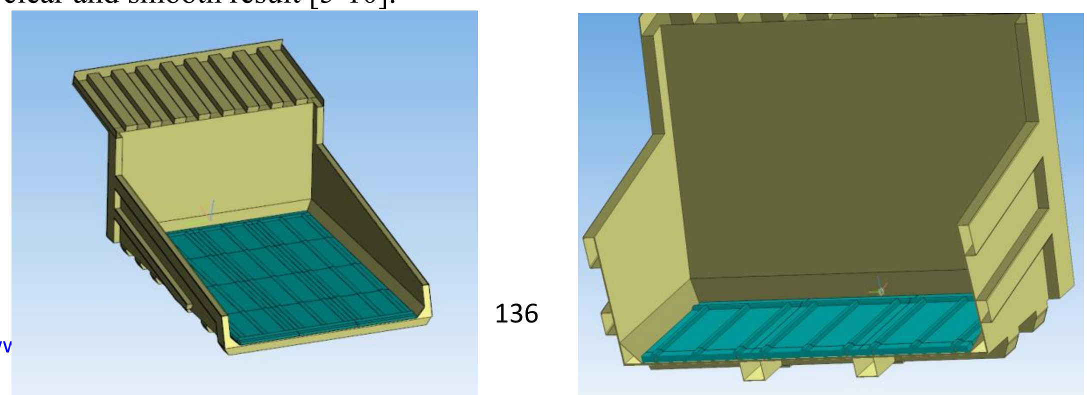
Figure 2. Elements that securely hold the rubber in the lower part of the body (a) and rubber lining (b).

Figure 2 shows the method of installing the rubber coating, which was divided into small squares (1250x1250 mm). The advantage of this method is the replacement of covers in areas with a high tendency to deterioration of the bottom of the body [1-5].

The dimensions of the rubber lining shown in Fig. 2 are as follows: the thickness of the rubber is h=50 mm, the length is l=1250 mm, and the width is b=1250 mm. From each side of the rubber covering, a distance of 5 cm is left, and on both sides, a special shape is placed where the body connecting element will be located. This connecting element is a connecting element that gives the shape of a common chaspak with a width of 1 cm, a height of 1.5 cm, having the shape of a rectangle and an adjacent circle with a diameter of 1.5 cm.

The drawing of the dump truck body, adopted from the SOLIDWORKS program, is shown in Fig. 3a, which we divide into grids in the ANSYS program based on finite elements in order to obtain a clear and smooth result [5-10].



pISSN:2349-5707 Volume:12,Issue 11,November-2025 eISSN:2349-5715

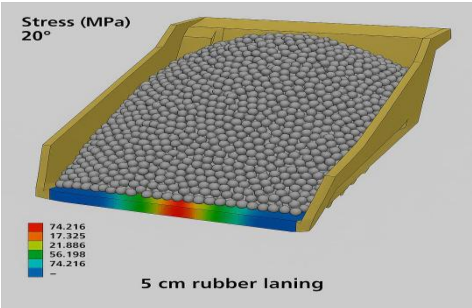
a b

Figure 3. Position of the body with rubber lining installed (a - full view, b - view of the section along the width of the body)

A virtual experiment was conducted with the filling of the dump truck body with rock and the lifting angle of the body from the horizontal position to the unloading of the cargo from the body.

RESULTS

Research results were obtained when lifting the dump truck body from a horizontal position, i.e., from 0^0 to 46^0 (Fig. 4). When loading the dump truck body with a load of 55 tons, starting from the middle part of the body towards the rear unloading section, a tensile stress arose in the rubber covering. This stress was maximal at 74.2 MPa (Fig. 4a).



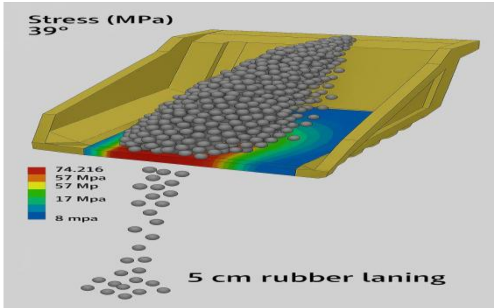


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Fig. 4. Stress state of the dump truck body (a-rise of the body to 20^0, b-rise of the body to 39^0)

Figure 4b depicts the same body raised to 39^0 to unload the load, showing that most of the load has already been unloaded from the body. The results obtained by lifting the dump truck body from 20 degrees to 45-46 degrees and unloading the cargo were as follows:

- to 20^0 , the load was released by 15-20%, the stress zone of the rubber coating shifted to the rear of the body by 10-15%, and the maximum stress remained unchanged at 74.2 MPa.
- to 30^0 , the load was released by 35-40%, the stress zone of the rubber coating shifted to the rear of the body by 30-40%, and the maximum stress changed by 87 MPa.
- to $39\text{-}40^0$, the load was released by 75-80%, the stress zone of the rubber coating shifted to the rear of the body by 40-50%, and the maximum stress returned to 74.2 MPa.
- to $45\text{-}46^0$, the load was released 100%, the tension zone of the rubber coating shifted to the rear of the body by 95-100%, and the maximum stress decreased by 17.3 MPa.

The physical stress distribution of the Belaz body in the coated state is shown in 3D based on the von Mises stress model. The stress at the highest point is located near the center at 0.053 MPa and occurs in the receding part of the body.

CONSIDERATION

The stress distribution is similar to the 2D Gaussian normal distribution, where stress reaches its maximum value near the center and gradually decreases.

In this case, its mathematical expression (surface force function) is:

$$\sigma(x,y)=\sigma_{max}*e^{-\left(\frac{(x-x_1)^2}{2\sigma_x^2}+\frac{(y-y_1)^2}{2\sigma_y^2}\right)} \qquad (3)$$

$\sigma(x,y)$—where: surface tension of the body, MPa;

$\sigma_{max}=0{,}053\ MPa$—Maximum stress value.

$x,y\in[0,1]$—Relative coordinates along the body length and width.

$x_0\approx 0{,}45$; $y_0\approx 0{,}25$—Coordinates of the stress center.

pISSN:2349-5707 Volume:12,Issue 11,November-2025 eISSN:2349-5715

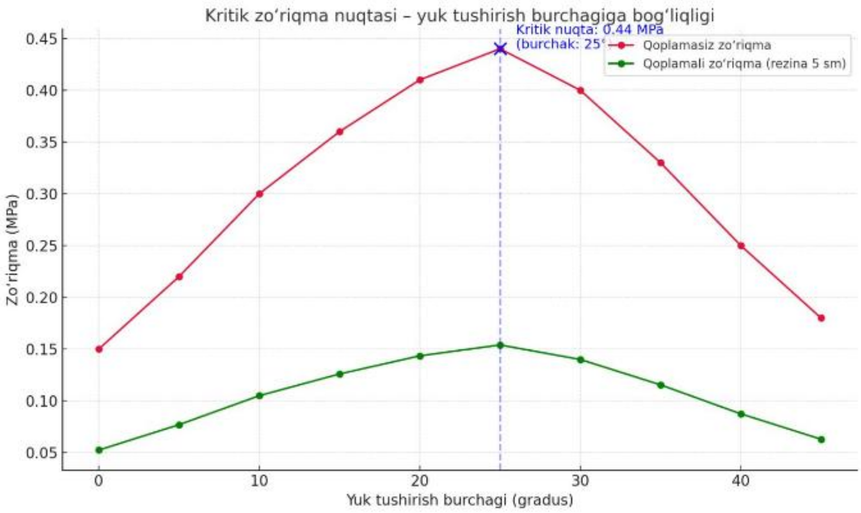


Figure 5. Graph of the dependence of the force and the angle of unloading during unloading from the dump truck body.

Studies have shown that during unloading with a body without a covering, the maximum stress value is 0.44 MPa and is considered the most critical zone in the range of 20-30°, and after the installation of a rubber covering, this critical zone remains precisely in the range of 20-30°, but the maximum stress value is 0.15 MPa. In this research work, the stress during unloading from the body was reduced by 66%.

DISCUSSION

With the help of this software, a virtual experimental test was conducted, and it can be concluded that during the process from the horizontal position of the load to its unloading, the stress zone formed in the middle part of the body, with the dumping of the load, creates friction between the rubber body covering, and on the basis of this friction, the rubber covering undergoes wear.

Now if the 55-ton load fully affects this body

$$F=55000x9{,}81=539{,}550N$$

$$\sigma=\frac{F}{A}=\frac{539{,}550}{18{,}91}=28{,}52kPa=0{,}0285\ Mpa$$

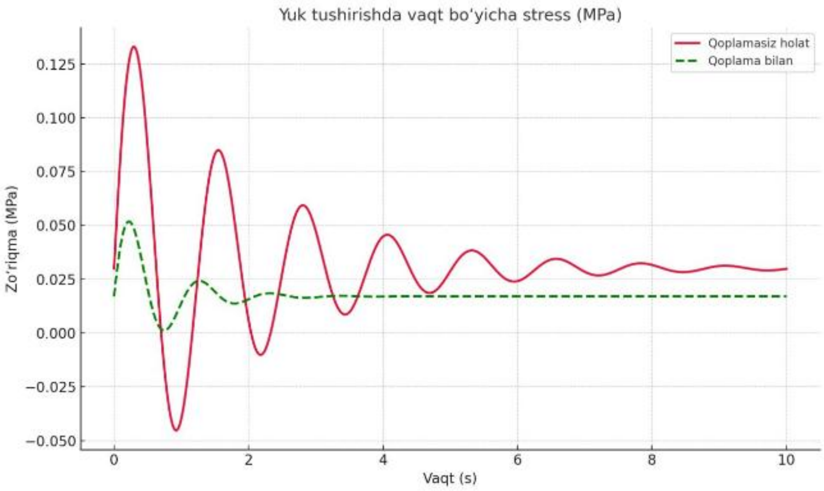


Figure 6. Graph of the dependence of the stress on time in the case of a dump truck body without a rubber coating and with a coating during unloading.

The graph of the voltage dependence on time when unloading from the dump truck body in the case of a body without a rubber coating and with a coating is shown in Figure 4.14, which shows that the body without a coating extends to a maximum of 0.13 MPa and extinguishes within 7-8 seconds. After the rubber coating is installed, it reaches a maximum of 0.05 MPa, and internal damping occurs within 2 seconds. This leads to a decrease in the initial internal load by 0.08

MPa (61.5%), and a decrease in the time unit by 5 s (71.4%).
Effect of unloading angle:
When the angle of incidence changes, the components of the force also change. This is estimated by the following formula.

$F_n = F \cdot \cos\theta; \quad F_t = F \cdot \sin\theta$ (4)

$\theta - F_n - F_t -$where: angle of incidence (degree); normal force (vertical pressure); tangential force
The stress at each angle is expressed as follows:

$\sigma(\theta) = \frac{F_n(\theta)}{A} + \Delta\sigma_t(\theta)$ (5)

Considering the role of the coating:
Because the rubber coating absorbs energy, the forces are not fully transferred to the rigid structure (the metal part of the body). Therefore:
Uncovered:

$\sigma_{metal}(\theta) = \frac{F\cos(\theta)}{A}$ (6)

Coated state

$\sigma_{rezina}(\theta) = \alpha \cdot \frac{F\cos(\theta)}{A}$ (7)

$0 < \alpha < 1$

$\alpha -$where: depreciation coefficient (usually taken in the range of 0.3-0.5).
Based on the obtained results, we can see that the stress occurs at 25^0 as a critical angle, the result is 0.44 MPa in the case without coating and 0.15 MPa in the case with coating.
Hooke's Law (in the region of elasticity):

$\sigma = E \cdot \varepsilon$ (8)

$E - \varepsilon -$where:young modulus; relative desertification.
$M = F \cdot d$ Transformation of forces into moments: the distribution of stress between elements is influenced by the modulus of the material and the angle.
The force graph is a curve near the sinusoid and paraboloid:
This corresponds to the general type formula below:

$\sigma(\theta) \approx \alpha \cdot \sin(b \cdot \theta + c)$ (9)

or

$\sigma(\theta) \approx -\alpha \cdot (\theta - \theta_0)^2 + \sigma_{max}$ (10)

The decay process is represented by a modified exponential or linear decay model.
a) for rubber residue (rapid wear):
When the rate of decay is constant:

$h_r(t) = h_{r0} - v_r \cdot t$ (11)

$h_r(t) -$where: is the thickness of the rubber at the moment of time (mm);
$h_{r0} = 50 -$initial thickness
$v_r = 0{,}03 \frac{mm}{sikl} - decay\ rate$
$t - time\ (days)$
Archard's law - for abrasive wear

$V = \frac{K \cdot F \cdot s}{H}$ (12)

$V - K - F - s -$where:absorbed volume;age coefficient;surface force;sliding distance;H-hardness of the material
Distribution of forces along the lengtheron (for the new and old frame) according to the Euler-Bernoulli theory of linear bending

$M(x) = EI \frac{d^2 y(x)}{dx^2}$ (13)

$M(x) - E - I - y(x) - x -$ where: bending moment; modulus of elasticity; moment of inertia; bending line; coordinate along the length of the longitudinal member

RESULT

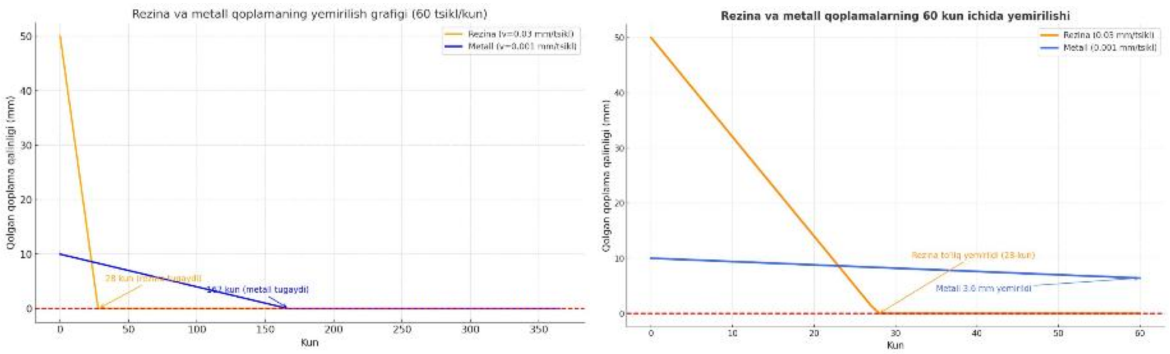
The dynamics of wear of rubber and metal coatings is shown in Fig. 5, and this graph requires

pISSN:2349-5707 Volume:12,Issue 11,November-2025 eISSN:2349-5715

the following justification. The graph shows the trend of wear of 5 cm of rubber and 10 mm of metal coatings over 60 days.

$$y(t)=y_0-v\cdot t \qquad (14)$$

$y(t)\, y_0\, v v=0{,}03\, v=0{,}01$ where:- coating thickness depending on time,- initial thickness, - wear rate. mm for rubber, mm for metal.



a **b**

Figure 7. Graph of the dependence of the wear duration of the metal and rubber covering of the lower part of the body (a-167 days, b-60 days).

Based on the obtained results, a graph of the dependence of the wear of the metal of the lower part of the body and the rubber coating on the duration of wear was developed, and from this graph it can be seen that the 10 mm metal of the body completely wears out in 167 days, and the rubber lining of the coating wears out and replaces it in 28 days (Fig. 7a). In production, it is observed that in 60 days the body without coating is ready for repair. Based on this conclusion, the wear of the body without coating in 60 days is 3.6 mm or 36%.

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