AUTOMATIC SYSTEM FOR MODELING VIBRO-IMPACT UNLOADING BULK CARGO ON VEHICLES

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ABSTRACT

This article is devoted to the development of an automated system for the theoretical study of vibro-impact unloading of bulk cargo on vehicles – dumper trucks. The high efficiency of the technological process of unloading bulk cargo by means of the application of vibro-impact loads is determined.A high degree of intensification of the process of unloading of bulk cargo is achieved by using original vibrating and vibro-impact unloaders with a hydroimpulse drive. The system approach to the unloading technological process (unloading device, process, body, bulk cargo) is considered and an automated system of mathematical modeling of the stress-strain state of the body of a dump truck with vibro-impact unloading is developed.The finite element method in the FEM-program was used to determine the main parameters of the stress-strain state of the body of a dump truck under vibro-impact unloading. The results of automated modeling allowed us to evaluate the effectiveness of the impact of shock loads on the body of a dump truck when unloading bulk cargo, as well as the efficiency of the developed designs of vibration-resistant unloading devices with a hydroimpulse drive.

Keywords: automation, modeling, finite element method, stress, deformation, shock, unloading.

INTRODUCTION

The modern growth of transportation bulk cargo by road requires increasing the level of mechanization and automation of loading and unloading operations. Loading and unloading works on vehicles (cars and tractors) are classified as the most labor intensive and heavy.In the total volume of goods transported on vehicles, bulk cargo is about 80%. When unloading bulk cargo, depending on their humidity, temperature, granulometric composition, some of the cargo remains on the body. Depending on the type of cargo and its composition, the remains in the body range from 3% to 20% of the transportation volume.

Applications to objects of transportation of useful vibrations or shock impulses allow to considerably intensify the course of the unloading process. This makes it possible to accelerate the unloading, reduce costs and reduce over-standard idle times of vehicles under unloading operations [1]. To implement the most effective regimes of pulsed action on unloading materials and media, the use of a vibro-impact discharge device (VIDD) with a hydroimpulse drive (HID) is promising [2].The parameters of the GIP VIDD [1] meet the requirements for both unloading of various types of goods (harmonic vibrations and shock impulses) and for technical and structural parameters of hydraulic attachments. The study of the VIDD impact process with the dump body allows to determine the ways of increasing the efficiency of unloading cargo of bodies of vehicles and is an actual scientific and practical task.

Currently, there is a wide application of mathematical modeling in various technological processes [3]. It allows to deeply study the influence of constructive and regime factors on the main characteristics of the device, to outline concrete ways to improve them, while substantially reducing the amount of experimental research.

In work [4] for simulation of abrasive wear of the body during unloading of bulk cargoes, the methods of finite and discrete elements were used. In conjunction with the contact model and the Archard model, this provides new opportunities for understanding the wear process and using more physically correct models to study the process of unloading granulometric (bulk) cargoes. But this simulation technique does not take into account possible vibration and vibration loads, which can be applied to the load bearing body (body of a dump truck) to intensify the unloading process.

The article [5] developed a fuzzy model for predicting the efficiency of the unloading process of wheeled cars under the action of vibrations caused by longitudinal impact forces. To determine the complete fuzzy rules for this system, together with the definition of the terms for fuzzy sets, a common coevolutionary algorithm was used. And the resulting fuzzy model was evaluated for its suitability as a predictive model. At the same time, this approach to modeling the efficiency of unloading does not take into account the stress-strain state of the body caused by local shock loads.

In the paper [6], the longitudinal impact of the coupling device was simulated in combination with the rocking movements of the car body and coal carts. Attempts were made to simulate the interaction data using the model of train-wagon interaction and using one component of the longitudinal force. But this technique does not allow to determine the impact of impacts and vibrations on the object, which is directly in contact with the body.

The solution of these questions is impossible without the use of hydrodynamic equations, to study the work of HID VIDD [7], as well as the equations of the theory of elasticity for the study of the stress-strain state of the body of a dump truck [8]. Carrying out of such researches is based on modern methods of mathematical modeling with carrying out of calculations on the computer with application of modern, advanced algorithms. This makes it possible to prevent an unjustifiably large number of complex and expensive experimental studies, significantly reduce the time and cost of design work, and carry out qualitative and quantitative assessments of physical phenomena with sufficient accuracy for engineering practice [2, 3].

The purpose of the work is to increase the efficiency of unloading operations on vehicles, by developing an automated system for modeling shale-weight unloading of bulk cargo.

To achieve this goal, the following tasks were accomplished:

– Develop an automated system for modeling the unloading of bulk cargo under the action of a vibro-impact load with the help of HID VIDD;
– To develop a mathematical model for the investigation of the stress-strain state of the body of a dump truck under the action of vibro-impact loads HID VIDD;
– On the basis of the developed mathematical model, determine the effective parameters of the HID VIDD operation for vibro-impact unloading of bulk cargoes of vehicles.

DEVELOPMENT OF AN AUTOMATIC SYSTEM FOR MODELING VIBRO-IMPACT UNLOADING BULK CARGO ON VEHICLES

Under the action of a vibro-impact load on the dispersed material, a number of physical transformations take place in the latter [1, 8], the nature of which depends on the intensity and type of the vibro-impact load. Vibro-impact loads, depending on the physical-mechanical properties of the discharge material, cause the contact zones of particles in the dispersed medium to break down in this system. Due to the destruction of internal power connections and the emergence of wave processes, the dispersed medium passes into a fluidization state, which provides it with additional mobility and speeds up the unloading process.

The technology of vibro-impact unloading of bulk cargo on vehicles is realized with the help of hydraulic attachments - VIDD [1]. VIDD generates impact pulses at a certain frequency, which are transmitted directly to the bottom of the load-bearing body (BB) - the body of the vehicle, and accordingly to the bulk cargo.

This VIDD meets the requirements both for the parameters of unloading of various types of bulk cargo, and for the technical and structural parameters of hydraulic attachments. The key feature of HID VIDD is: constructive simplicity; regulation of the amplitude of vibrations by changing the pressure, which is carried out by simple mechanisms (adjusting screw), ease of implementation of the vibro-impact regime.

In the technological complex for vibro-impact unloading we can distinguish three main interrelated systems [2]: the unloading object (system I), the work process (system II) and the unloading machine (system III), which are combined into a common system of the technological complex (Fig.1) .

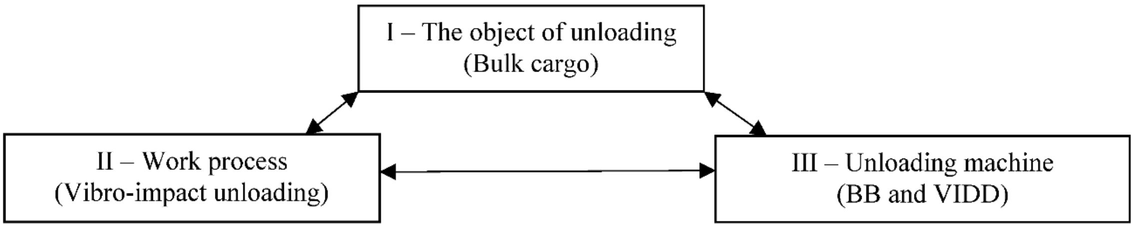


Fig. 1. Scheme of the technological complex of vibro-impact unloading of bulk cargoes

Based on the system approach to research of unloading workflows (Fig. 1), an automated system for simulating vibro-impact unloading (ASSVIU) of bulk cargo was developed (Fig. 2). In this computer-aided designe (CAD) system, based on the HID VIDD design documentation, a solid model HID and BB software is formed. Also at this stage, the preparation of information (graphical, tabular, etc.) for the formation of reporting documentation on the results of the study. At the second stage, the CAD model of HID VIDD is exported to the computational fluid dynamics (CFD) system FlowVision 3.10.01 [9]. Based on this CAD-model, workflows are calculated in HID VIDD by FlowVision databases.

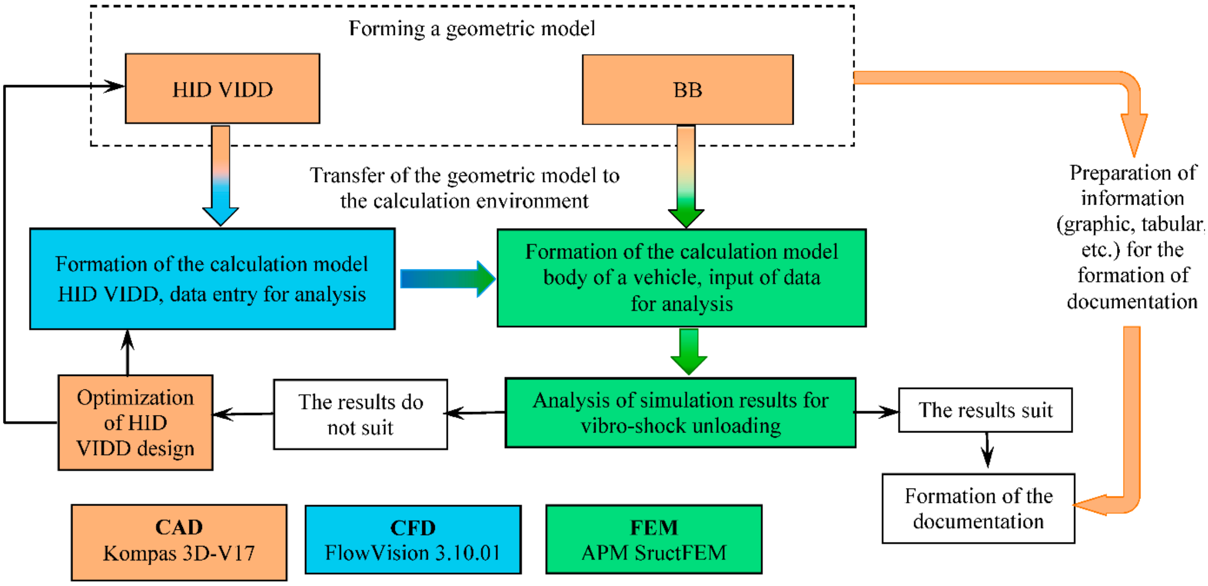


Fig. 2. Automated system for simulation of vibro-impact unloading of bulk cargoes of vehicles

In parallel, the CAD model of BB is exported to the finite element method (FEM) system (Fig. 3). In this FEM-system in the preprocessor, based on the results of calculation of the HID VIDD in the CFD-system, the calculation model of the software is calculated, which is calculated by the APMStructFEM databases [10]. The calculation results are formed in the preprocessor, with step-by-step recording of the calculation results. The calculation results are recorded in a file and can be displayed.

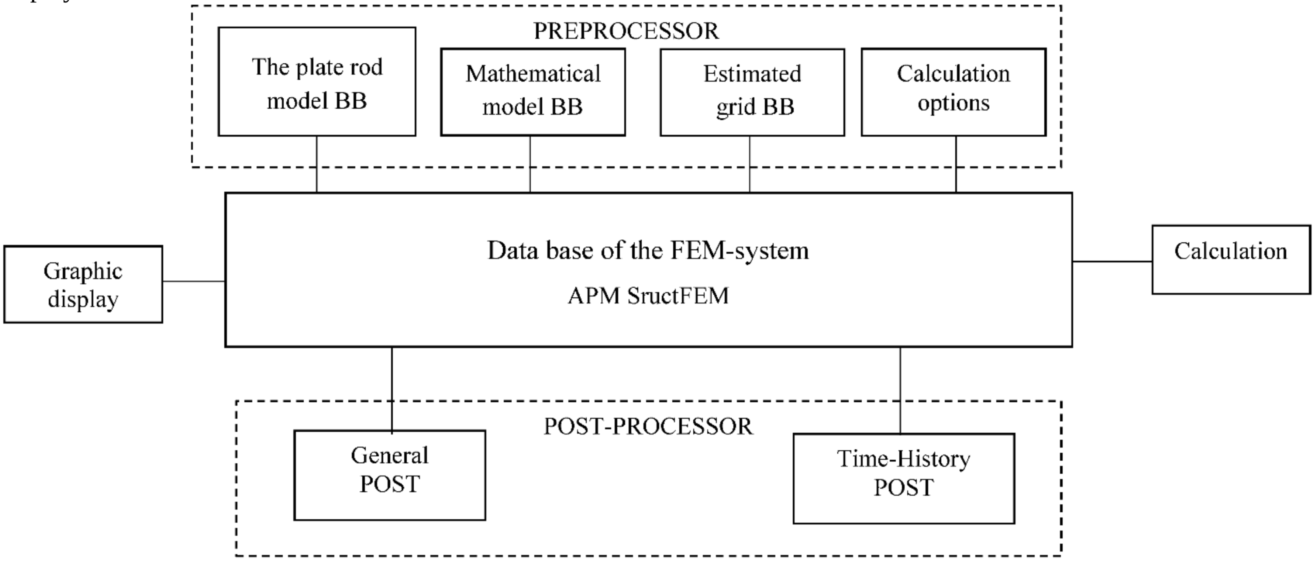
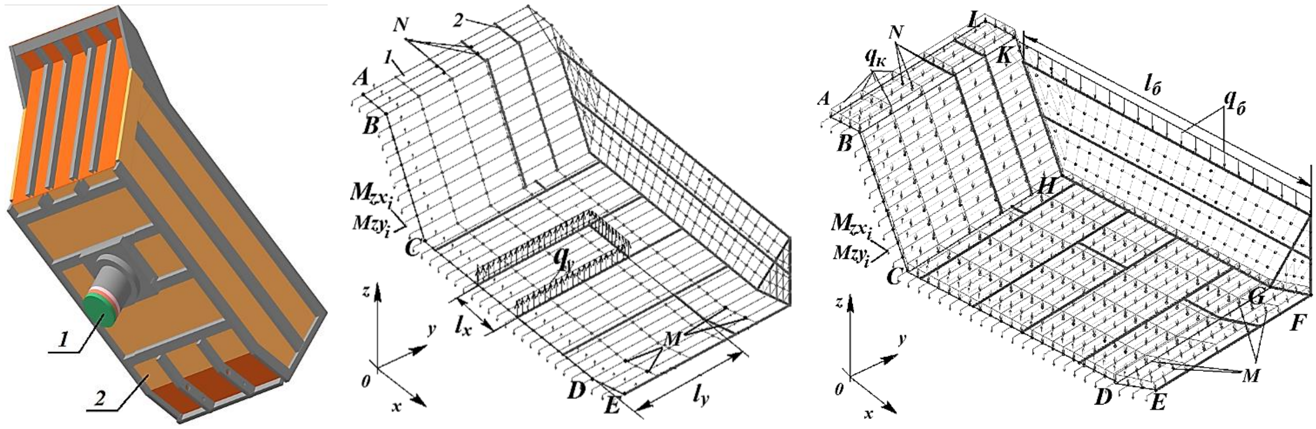


Fig. 3. Automatic system for calculating hydrodynamic processes in the HIDVIDD

If the results of the calculation are satisfied, then the final formation of the documentation of the design results takes place. If the design results are not satisfactory, then the basic geometric model of HIDVIDD and BB software is optimized in the CAD system, and then the simulation procedure is repeated.

DEVELOPMENT OF A MATHEMATICAL MODEL OF A VIBRO-IMPACT UNLOADING OF A VEHICLE

The technological complex (Fig. 4, a) for vibro-impact unloading consists of VIDD 1 (fixed at the center of the bottom of the body) and BB 2. For the theoretical study of vibro-impact unloading of a vehicle (Fig. 4, a), the side walls of the body will be considered as plates 1, which are connected by a rod frame 2 (Fig.4, b, c) and fixed by hinges at points *N* and *M*
(Fig. 4, b, c). The calculation of such a scheme requires the application of the theory of shells and the theory of core systems in a complex [11-14]. When calculating the stress-strain state, when the structure and loads are symmetrical with respect to the vertical longitudinal plane passing through the points *ABCDDE* (plane of symmetry of the body), it is sufficient to consider only half of the system (Fig. 2, b, c). On the side of the rejected part, connections are introduced corresponding to the bending moments Mzx_i, Mzy_i. Consider the three-dimensional scheme of the load of the body of a dump truck (Fig. 4, a).



a) b) c)

Fig. 4. Structural and calculation scheme of the body load:

a – general view of the technological complex of vibro-impact unloading; b – the structural and design scheme of the body load from HIDVIDD to the bottom of the body of the dump truck; c – the structural and design scheme of the body load from the gravity of the body

Symmetric loads on the body relative to the average vertical plane:

– The impact force acting on the bottom of the body from VIDD:

$$q_y = F_y / 2(2l_y + l_x), \quad F_y = ma,$$

where l_y, l_x – the length of the stiffeners to which the impact force from VIDD; m – weight VIDD; a – acceleration of VIDD at the time of contact with the bottom of the body (the results of modeling HID VIDD in the CFD-system FlowVision 3.10.01).

– The force of gravity from the body part, distributed over the bottom of the body *ABCDEFGHKL*:

$$q_k = M_k \,/\, S_{ABCDEFGHKL},$$

where $M_к$ – the mass of the body *ABCDEFGHKL*; $S_{ABCDEFGHKL}$ – area of the underbody *ABCDEFGHKL*;

– The force of gravity from the sides of the body, distributed over the floor area of the body *ABCDEFGHKL*:

$$q_б = M_б \,/\, l_б,$$

where $M_б$, $l_б$ – weight and length of the sides of the body of a dump truck.

To calculate the stress-strain state of the body of a dump truck, we will use the force method [11-13], in a matrix form, using a computer [10]. To do this, we form the matrix $\boldsymbol{B_1}$ of the ordinates of the unit diagrams. This stage consists of the choice of the basic system and the unknown X_i, the calculation of the ordinates of the internal forces (M_z, M_y, M_x, Q_y, Q_z, N) from $X_i=1$ and the recording of these ordinates in a certain order in the form of a matrix $\boldsymbol{B_1}$. Plates 1 and rods 2 of the body (Figure 2) are divided into small sections t, within which the diagrams from all $X_i=1$ are rectilinear (Fig. 5). The ordinates of the diagrams are calculated at the ends *A* and *B* of the sections t. The average value of the section t is denoted by the letter *C* (Fig. 6).

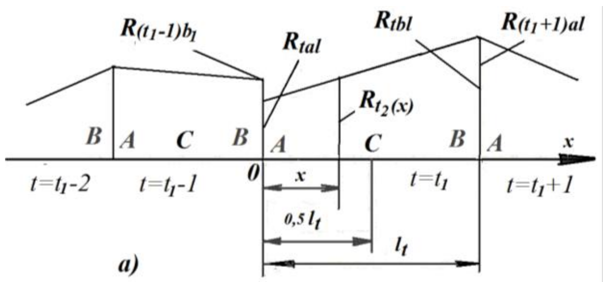


Fig. 5. Structural-design scheme for designating small sections of plates and rods, as well as diagrams of internal forces

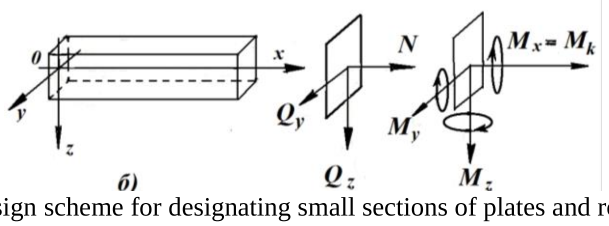


Fig. 6. The structural and design scheme for designating small sections of plates and rods, and the directions of the internal forces acting on them

We form the universal matrix $\boldsymbol{B_1}$, for which a general form is adopted, including the ordinates of the unit diagrams of all kinds of internal forces M_z, M_y, M_x, Q_y, Q_z, N (Fig. 6).

$$\boldsymbol{B_1} = \begin{Vmatrix} \boldsymbol{L}_{Mz} \\ \boldsymbol{L}_{My} \\ \boldsymbol{L}_{Mx} \\ \boldsymbol{L}_{Qz} \\ \boldsymbol{L}_{Qy} \\ \boldsymbol{L}_{N} \end{Vmatrix} = \begin{array}{c c} \overbrace{\begin{array}{ccccc} X1 & X2 & X3 & & Xn \end{array}} & t \\ \begin{Vmatrix} c_{11} & c_{12} & \dots & c_{1i} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2i} & \cdots & c_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ c_{t1} & c_{t2} & \cdots & c_{ti} & \cdots & c_{tn} \\ \vdots & \vdots & & \vdots & & \vdots \\ c_{h1} & c_{h2} & \cdots & c_{hi} & \cdots & c_{hn} \end{Vmatrix} & \begin{matrix} 1 \\ 2 \\ \vdots \\ t \\ \vdots \\ h \end{matrix} \end{array},$$

where $\boldsymbol{L_{Mz}}, \boldsymbol{L_{My}}, \boldsymbol{L_{Mx}}, \boldsymbol{L_{Qz}}, \boldsymbol{L_{Qy}}, \boldsymbol{L_N}$ –matrix-blocks containing ordinates of the diagrams of only one kind of force in accordance with the index; $\boldsymbol{c_{ti}}$ –matrix-blocks (columns) containing two elements (the ordinates at the ends *A* and *B* of the plot *t* of the diagram from $X_i=1$(Fig.5)).

If in the section *t* there is a diagram of the bending moments M_z, then:

$$\boldsymbol{c_{ti}} = \begin{Vmatrix} M_{zt\,ai} \\ M_{zt\,bi} \end{Vmatrix} = \begin{Vmatrix} R_{t\,ai} \\ R_{t\,bi} \end{Vmatrix},$$

where $M_{zt\,ai}, M_{zt\,bi}$ –the bending moments $M_z=R$, respectively, at the ends *A* and *B* of the section *t* from $X_i=1$;*R* is a letter that replaces the notation of internal force in accordance with the number*t* $(M_z, M_y, \dots N)$.

The next stage is the construction of the compliance matrix, which should contain the geometric characteristics of the sections of the rods of the design scheme and the moduli of elasticity. Such a matrix must have a structure corresponding to the selected matrix $\boldsymbol{B_1}$ and the formula defining the matrix $\boldsymbol{D}$, the coefficients for unknowns in the canonical equations.

We use a variant of the formulas for determining the matrix $\boldsymbol{D}$, which allows us to apply the compliance matrix $\boldsymbol{U}$ in the form of a block matrix (column):

$$\boldsymbol{U} = \frac{1}{E_0 J_0} \begin{array}{cc} & t \\ \begin{Vmatrix} u_1 \\ u_2 \\ \vdots \\ u_t \\ \vdots \\ u_h \end{Vmatrix} & \begin{Vmatrix} 1 \\ 2 \\ \vdots \\ t \\ \vdots \\ h \end{Vmatrix} \end{array},$$

where $\boldsymbol{u_t} = a_t = \dfrac{l_t E_0 J_0}{6 E_t J_t}$; a $J_t(x)$ – the geometrical characteristic of the cross-section of the rod in the section *t*, corresponding to the form of the force determined by the number *t*; $E_0 J_0$ is the flexural riHIDity of one of the rod and plate sections; E_t is the modulus of elasticity of the material of the rod and plate in the section *t*.

The next step is to compile the matrix $\boldsymbol{D}$ of the coefficients for the unknown X_i and the canonical equations:

$$\boldsymbol{D} = \begin{Vmatrix} \delta_{11} & \delta_{12} & \dots & \delta_{1n} \\ \delta_{21} & \delta_{22} & \cdots & \delta_{2n} \\ \vdots & \vdots & & \vdots \\ \delta_{n1} & \delta_{n2} & \cdots & \delta_{nn} \end{Vmatrix}.$$

The coefficients δ_{kj} of the matrix $\boldsymbol{D}$ are determined by the formula:

$$\delta_{kj} = \frac{1}{E_0 J_0} \sum_{t=1}^{h} f(\boldsymbol{c}_{tk}, \boldsymbol{c}_{tj}, \boldsymbol{u}_t), \tag{1}$$

depending on the elements of the two matrices $\boldsymbol{B_1}$ and $\boldsymbol{U}$. The function $f(\boldsymbol{c}_{tk}, \boldsymbol{c}_{tj}, \boldsymbol{u}_t)$ expresses the value of the Mohr integral for the section *t*. For sections *t*:

$$f(\boldsymbol{c}_{tk}, \boldsymbol{c}_{tj}, \boldsymbol{u}_t) = \left[2\left(R_{tak} R_{taj} + R_{tbk} R_{tbj}\right) + R_{tak} R_{tbj} + R_{tbk} R_{taj}\right] a_t \tag{2}$$

For two matrices chosen from $\boldsymbol{B_1}$:

$$\mathbf{c_{tk}} = \begin{Vmatrix} R_{tak} \\ R_{tbk} \end{Vmatrix} \text{ i } \boldsymbol{c_{tj}} = \begin{Vmatrix} R_{taj} \\ R_{tbj} \end{Vmatrix},$$

constitute a standard program by the formula (2).

Consider the construction of the ordinate matrix $\overline{\boldsymbol{B}}_{\boldsymbol{p}}$ of the diagrams in the main system from external forces. Suppose that there are *m* groups of external forces, each of which is in proportion to the quantities $P_1, P_2, P_3, \dots, P_m$. Then it is expedient to build the matrix $\overline{\boldsymbol{B}}_{\boldsymbol{p}}$ from the ordinate of the diagrams from the unit forces P_r ($P_1=1, P_2=1, P_3, \ldots, P_m=1$) in the main system. We write the matrix $\overline{\boldsymbol{B}}_{\boldsymbol{p}}$ in the form:

$$\overline{\boldsymbol{B}}_{\boldsymbol{p}} = \begin{array}{c} \overbrace{\begin{array}{cccc} P1 & P2 & \cdots & P3 \end{array}}^{t} \\ \left\| \begin{array}{cccc} c_{1p1} & c_{1p2} & \cdots & c_{1pm} \\ c_{2p1} & c_{2p2} & \cdots & c_{2pm} \\ \vdots & \vdots & \vdots & \\ c_{np1} & c_{np2} & \cdots & c_{npm} \end{array} \right\| \end{array} \begin{array}{c} \\ 1 \\ 2 \\ \vdots \\ h \end{array}, \ \boldsymbol{c}_{\boldsymbol{tpr}} = \left\| \begin{array}{c} R_{tapr} \\ R_{tbpr} \end{array} \right\|,$$

where c_{tpr} – matrix-blocks (columns) R_{tapr} and R_{tbpr} are the ordinates of the diagram R (rectilinear in the section t), respectively, at the ends A and B of the section t in the main system from $P_r=1$.

The column of the number r in the matrix $\overline{\boldsymbol{B}}_{\boldsymbol{p}}$ includes all the coordinates of the diagrams from the group of forces of the number r with $P_r=1$, written in order of t.

The matrix $\overline{\boldsymbol{D}}_{\boldsymbol{p}}$ of the free terms of the canonical equations has the following general form:

$$\overline{\boldsymbol{D}}_{\boldsymbol{p}} = \begin{array}{c} \overbrace{\begin{array}{cccc} P1 & P2 & \cdots & P3 \end{array}}^{t} \\ \left\| \begin{array}{cccc} \Delta_{1p1} & \Delta_{1p2} & \cdots & \Delta_{1pm} \\ \Delta_{2p1} & \Delta_{2p2} & \cdots & \Delta_{2pm} \\ \vdots & \vdots & & \vdots \\ \Delta_{np1} & \Delta_{np2} & \cdots & \Delta_{npm} \end{array} \right\| \end{array} \begin{array}{c} \\ 1 \\ 2 \\ \vdots \\ h \end{array}.$$

Elements Δ_{kpr} ($k=1, 2, \ldots, n$) of the matrix $\overline{\boldsymbol{D}}_{\boldsymbol{p}}$ – the free terms that correspond to the group of forces of the number r for $P_r=1$, can be determined by formulas (1) and (2), if the elements c_{tj} replace c_{tpr} from the matrix $\overline{\boldsymbol{B}}_{\boldsymbol{p}}$.

Combining formulas (1) and (2) and performing the indicated replacement, we obtain:

$$\Delta_{kpr} = \frac{1}{E_0 J_0} \sum_{t=1}^{h} \left[2\left(R_{tak} R_{taj} + R_{tbk} R_{tbj} \right) + R_{tak} R_{tbj} + R_{tbk} R_{taj} \right] a_t .$$

Thus, the calculation of all the elements Δ_{kpr} of the matrix $\overline{\boldsymbol{D}}_{\boldsymbol{p}}$ can be reduced to the use of matrices $\boldsymbol{B_1}$, $\overline{\boldsymbol{B}}_{\boldsymbol{p}}$ and $\boldsymbol{U}$. Here, the index k is the column number from the matrix $\boldsymbol{B_1}$; r is the number of the column from the matrix $\overline{\boldsymbol{B}}_{\boldsymbol{p}}$.

It is practically expedient to use the matrix $\boldsymbol{D}$ and $\overline{\boldsymbol{D}}_{\boldsymbol{p}}$ represent it in the form of one extended matrix [7]:

$$\left\| \boldsymbol{D} \quad \overline{\boldsymbol{D}}_{\boldsymbol{p}} \right\| . \tag{3}$$

In this case, it is convenient to calculate all the elements of the extended matrix (3) on the basis of formula (1), proceeding directly from two matrices: $\boldsymbol{U}$ and the expanded matrix of ordinates of unit diagrams:

$$\left\| \boldsymbol{B_1} \quad \overline{\boldsymbol{B}}_{\boldsymbol{p}} \right\| .$$

In addition to the matrices $\boldsymbol{B_1}$, $\overline{\boldsymbol{B}}_{\boldsymbol{p}}$ i$\boldsymbol{U}$, for calculating the structure under consideration for the action of given groups of external forces, it is necessary to form a matrix $\boldsymbol{P}$ of external loads proportional to the quantities $P_1, P_2, P_3, \ldots, P_m$. In the matrix $\boldsymbol{P}$ each column corresponds to the variant of a combination of simultaneously acting forces:

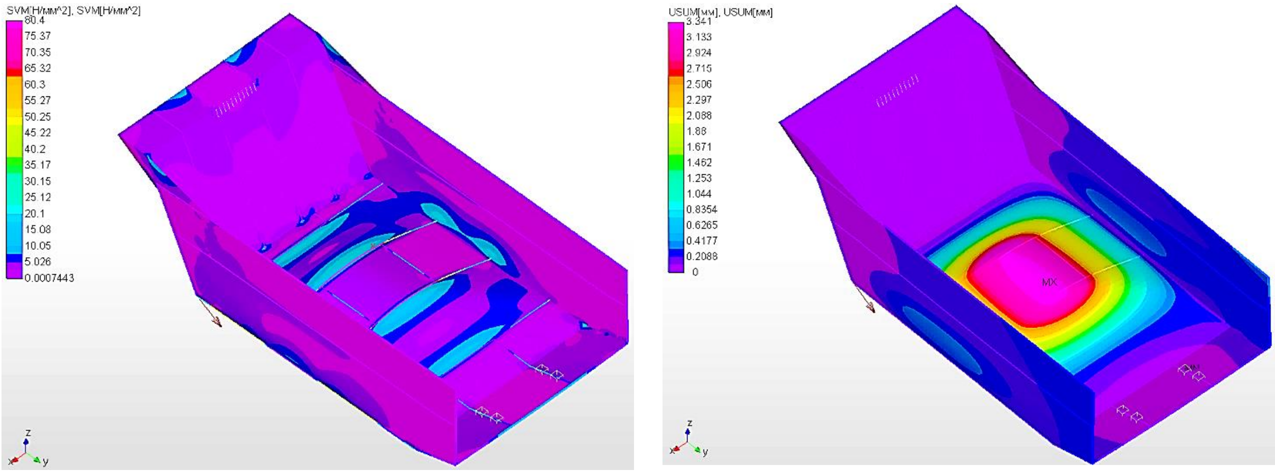
$$\boldsymbol{P} = \left\| \begin{array}{cccc} P_1 & & & \\ & P_2 & & \\ & & \vdots & \\ & & & P_m \end{array} \right\| .$$

The final result of the calculation in the form of a matrix $\boldsymbol{S}$ of internal forces in sections A and B of all sections t of a given statically indeterminate system is determined by the general matrix formula:

$$\boldsymbol{S} = (\overline{\boldsymbol{B}}_{\boldsymbol{p}} - \boldsymbol{B_1} \ \boldsymbol{D}^{-1} \ \overline{\boldsymbol{D}}_{\boldsymbol{p}})\boldsymbol{P} . \tag{4}$$

Calculations based on the formula (4) are performed on a computer by standard programs [15-17]. The matrix $\boldsymbol{S}$ contains as many columns as the matrix $\boldsymbol{P}$. The unknown ordinates of the diagrams of the internal forces $P_1, P_2, P_3, \ldots, P_m$ for each combination of external forces are arranged in a separate column in the order of the numbers t.

Based on the above method of calculating the body of a dumper truck, the FEM program APM StructureFEM [10] modeled and calculated the vibro-impact unloading of bulk cargo. For the real body of the KamAZ-55111 dumper truck [1], pictures of the stress-strain state of the body of a dump truck (Fig. 5) were obtained during impact interaction of the VIDD with the bottom of the BB (Fig. 7).



a) b)

Fig. 7. Scheme of the stress-strain state of the BB vehicle

a – distribution of stresses on the body of a dump truck in the case of vibro-impact unloading of bulk cargo; b – the distribution of deformation on the body of a dump truck in the case of vibro-impact unloading of bulk cargo

Based on the results of numerical simulation of the real body of the KamAZ-55111 dumper truck (Fig. 5), the following conclusions can be drawn:

1) The main stress concentrations in the body arise at the junction of the stiffeners with the body plates (Fig.7, a), and the maximum stresses occur only in the stiffeners and they do not exceed the allowable bending stress (Fig. 7, b)

2) The maximum deflection of the bottom of the body, with a vibro-impact load, (Fig. 7, b) is located in the place of the greatest accumulation of cargo. The deformation of the bottom of the body takes place practically along the whole plane. The maximum amplitude of the underbody oscillation is 3,3 mm, the minimum amplitude of the body underbody oscillation is 0,6 mm. The amplitude of the oscillation corresponds to the effective frequency of the vibro-impact unloading of 17 Hz for the main bulk types of cargo.

3) Analysis of deformations of the side walls (sides) of the body of a dump truck (Fig.7, b), with vibro-impact unloading, showed that the maximum deformation of the side walls of the body is 0,2 mm. The interaction of the side walls (sides) of the body with the load, which remained on the side walls of the body, facilitates efficient unloading.

CONCLUSIONS

- An automated system for modeling the unloading of bulk cargo under the action of a vibro-impact load with the help of VIDD was developed;
- A mathematical model has been developed to study the stress-strain state of the body of a dump truck under the action of vibro-impact loads of VIDD;
- On the basis of the developed mathematical model, the efficiency of the VIDD operation for vibro-impact unloading of bulk cargoes of vehicles has been determined.

The obtained results of numerical simulation of the stress-strain state of the body, with vibro-impact unloading, showed the advantages of the chosen approach to the creation of automated design systems. This also made it possible to prove the efficiency of VIDD use on the basis of HID, for vibration shocks of vehicles.

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