Estimation of the vibration loading vehicle with pneumohydraulic suspensions

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Abstract. The spatial model of an all-terrain vehicle with pneumohydraulic suspensions, which allowed executing the estimation of a vibration loading construction taking into account large motions of solid bodies, exact kinematic of suspension elements and features of their mounting on a vehicle, is built. Comparison of charts of power spectral density of vertical accelerations shows quality accordance of calculation and experimental spectra for the examined modes of motion. The built dynamic model fully satisfies the requirements of adequacy to the real object and can be used for further calculations.

1. Introduction
The increase of efficiency of decision of the tasks related to the necessity of perfection of the vibroprotective systems of modern vehicles is indissolubly related to the necessity of search of new technical decisions, allowing us to use the different variants of management of resilient and damping descriptions of the suspension directly in the process of the motion of the vehicle. In this regard, there are significant prospects for the creation of mathematical models of vehicles with adaptive suspensions, giving a possibility of debugging the construction of the suspension at the stage of imitation computer modeling.

A distinctive feature of this work is the formulation of the problem in the extended interpretation, which implies rejection of the hypothesis of the small motions of bodies, traditionally used for similar calculations, and allows us to carry out the complete calculation chart of the vehicle of geometrical non-linearity of the motion of elements of the construction on the base of differential equations of large motions of bodies [1-6]. Under large motions here, we imply the term meaning exact description in equations of dynamics of the angular orientation of bodies, without the use of assumption about the smallness of the rotation angles.

This approach allows the creation of dynamic model of the vehicle more exactly taking into account such properties, as a spatial character of the motion, the structure of the dynamic model, different non-linearity of descriptions of resilient and damping elements, multidimensional determined and casual indignations, as well as providing a possibility to include the models of specific interactions, for example, woobling of wheel with elastic tyre.

2. The dynamic model of the all-terrain vehicle with pneumohydraulic suspensions
This article describes the multimass dynamic model of all-terrain vehicle with pneumohydraulic
suspensions, taking into account the specific of kinematics of elements of independent suspensions and corresponding resilient and damping connections.

The dynamic model of the examined vehicle contains a frame, a cab, a van, a power aggregate, elements of independent pneumohydraulic suspensions, elements of the steering system, wheels connected to each other by connecting elements. The longitudinally located engine with a gear-box is set on a frame on two front and two back rubber mountings having identical resilient and damping descriptions. For a calculation scheme, shown in Figure 1, all bodies are accepted as absolutely solid. The operation of the transmission is not taken into account; therefore, a transfer box and cardan shafts are absent from a model.

![Figure 1. The calculation scheme of the all-terrain vehicle with pneumohydraulic suspensions.](image)

The functions of the resilient and damping devices of suspension combine in themselves a pneumohydraulic element (Figure 2). Its underbody is a joint fastened to the axis of the lower arm suspension, and an overhead – to the bracket of the vehicle frame.

The advantages of pneumohydraulic elements include: non-linearity descriptions; compactness, conditioned by high pressure of gas and combining of the resilient element and the shock absorber in one knot; a possibility of adjusting the height of the basket above by the linen of the road. A defect is the high cost related to the necessity of producing details with high accuracy.

Control suspension arms of each wheel are presented by two arms swinging in a transversal plane. Every upper arm has a V-configuration, thus the heads of its fastening are located at the tops of a corresponding triangle. In contrast to the upper lever, the lower one of suspension of the ∀-configuration is provided with an axis for joint connecting to its lower head of pneumohydraulic element fastening.

Providing counteraction to the transversal rolls of the vehicle is achieved by plugging of front and back stabilizers of transversal stability in the model. Each of them appears to be consisting of two halves connected by an element with given torsional stiffness. The end part of each of these halves is connected to the lower arm of the suspension by means of an earring joint, and the middle part is fastened through rubber pillows to the bracket of the vehicle frame.

Researches of vehicle dynamics were conducted by means of the modeling system ‘FRUND’ [1, 2].
3. Results and Discussion

To verify the adequacy of the dynamic model, we compared the calculation results with experimental data, obtained during the road tests.

External road forcing was determined by two discrete, stationary and random processes of the change of ordinates’ microprofile of the road surface, given separately on right and left wheels.

A rectilinear motion of the vehicle has been simulated on the random microprofile of the road surface with constant vehicle velocity. The standard types of the microprofile are used in the calculations: even a cobble (velocity 25…30 km/h) and dynamometric road (velocity 50…60 km/h).

For the estimation of vibration loading of the vehicle construction, the signals from sensors of vertical accelerations were written down in the following points:

- on the cab floor, under the driver seat (Figure 3, Figure 5);
- on the left frame girder, above the back left wheel (Figure 4, Figure 6).

Realizations of accelerations were processed by means of the programmatic system ‘FRUND’ [1, 2].

The calculation charts of power spectral density of vertical accelerations in indicated points were compared with those obtained experimentally during road tests.

The spectrum analysis of vertical accelerations in the indicated points of the vehicle construction shows, that the shape of the spectrum, even for the same transport vehicle and for the same loading, can be different depending on a level and spectrum indignations operating from the side of the road, and also from the position of the measuring point.

Since in experimental tests, it is difficult to provide a strict constancy of the vehicle velocity, it is required to adjust the calculation and experimental spectrums of vertical accelerations to the minimums conditioned by the effect of the wheel base.

As shown in Figure 3, during the motion of the vehicle along even cobble with a speed of 27, 30 km/h on the spectrums of vertical accelerations of the point located on the cab floor, under the driver seat, we clearly see three minimums from the first three harmonics of excitation of vertical vibrations corresponding to wave lengths $L; (1/2)L; (1/3)L$, where $L$ is the wheel base of the vehicle. Such phenomenon is named after the effect of the wheel base [7]. The best coincidence with the experimental data is provided by the spectrums obtained during motion along even cobble at a speed of 27 km/h.
Figure 3. Adjustment of spectrums of vertical accelerations on the cab floor, under the driver seat, on the minimums conditioned by the effect of the wheel base (during the motion of the vehicle along even cobble): 1 – experiment, velocity is 25…30 km/h; 2 – calculation, velocity is 30 km/h; 3 – calculation, velocity is 27 km/h.

Figure 4. Charts of power spectral density of vertical accelerations on the left frame girder, above the back left wheel (during the motion of the vehicle along even cobble): 1 – experiment, velocity is 25…30 km/h; 2 – calculation, velocity is 27 km/h.

During the motion of the vehicle along a dynamometric road with speeds of 50, 60 km/h on the spectrums of vertical accelerations of the point located on the cab floor, under the driver seat, we can clearly see only one minimum on the frequency of the first harmonic of the effect of the wheel base (Figure 5), corresponding to wave length \( L \).

Thus, the best coincidence with experimental data is provided by the spectrums obtained during the motion of the vehicle along an even cobble at a speed of 27 km/h (Figure 3) and on a dynamometric road at a speed of 60 km/h (Figure 5).

Comparison of charts of power spectral density of vertical accelerations shows the quality accordance of calculation and experimental spectrums for the examined modes of motion.
Figure 5. Adjustment of spectrums of vertical accelerations on the cab floor, under the driver seat, on the minimum conditioned by the effect of the wheel base (during the motion of the vehicle along a dynamometric road): 1 – experiment, velocity is 50…60 km/h; 2 – calculation, velocity is 50 km/h; 3 – calculation, velocity is 60 km/h.

Figure 6. Charts of power spectral density of vertical accelerations on the left frame girder, above the back left wheel (during the motion of the vehicle along a dynamometric road): 1 – experiment, velocity is 50…60 km/h; 2 – calculation, velocity is 60 km/h

4. Conclusion
The spatial model of an all-terrain vehicle with pneumohydraulic suspensions, which allowed executing the estimation of a vibration loading construction taking into account large motions of solid bodies, exact kinematic of suspension elements and features of their mounting on a vehicle, is built.

Since in experimental tests, it is difficult to provide a strict constancy of the vehicle velocity, the adjustment of the calculation and experimental spectrums of vertical accelerations is required on the minimums conditioned by the effect of wheel base.

Comparison of charts of power spectral density of vertical accelerations shows quality accordance of calculation and experimental spectrums for the examined modes of motion. The built dynamic model fully satisfies the requirements of adequacy to the real object and can be used for further calculations.
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