Measure for extinguishing vertical vibrations on the seat of a wheel tractor when moving along a random profile of the path

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Abstract. Various measures of damping vertical vibrations on the seat of a wheeled tractor when driving along a random path profile are analysed. The distribution of vibration frequencies over the structural elements of a wheeled tractor is given. A device has been developed and manufactured to ensure the verticality of the operator's seat. The seat damper device has been experimentally studied, while the efficiency of using dynamic vertical vibration dampers in the seat cushioning system, which provide vibration damping at transport and technological tractor speeds of 5...35 km/h on unequal roads with natural surface.

1. Introduction

How does the loading of each component of the tractor change when a damper with certain damping parameters is installed at a given transmission point? Distinctive features of the advanced damping and vibration damping systems being developed are: speeds, accuracy, wear resistance, energy efficiency, a wide range of load, temperature and speed operating conditions.

The existing types of shock absorbers are largely unable to provide the required reliability, high efficiency and expected durability, therefore, magnetorheological combined damping and vibration-damping systems can serve as a good alternative to the currently widespread designs. Insufficient development of the prior art and technology, as well as the lack of a theoretical basis, lead to the creation of magnetorheological systems of depreciation of the combined type of control without the possibility of focusing on analogues and prototypes, complicating the process of their design and calculation.

It is obvious that the accuracy of forecasting the parameters of the working processes of any technical systems is determined by the effectiveness of the selected methods for calculating their parameters, the identification of the characteristics of the calculation models and the adopted design decisions.

The ever-increasing requirements for the efficiency of damping systems, for the level and quality of their operating parameters and characteristics, for the safety and environmental friendliness of their working environments, make it necessary to improve existing design and calculation methods, as well as create new ones.
It is important to ensure the versatility of the developed techniques, since the elements of depreciation systems, depending on their designs, require a different approach to modeling the technological effects that arise in the working environment located in their working mechanisms.

2. Methods
The research is based on a systematic analysis of the cause-and-effect relationships of the process of the emergence of dynamic influences on a human operator of a wheeled tractor. The research methodology is complex and includes both theoretical and experimental sections.

3. Results and Discussion
In order to compare the level of vibration on the operator's seat for compliance with its value of the domestic and international standard [1-3] (Table 1), it is necessary to obtain estimates of the root mean square values (RMS) of vertical accelerations in octave frequency ranges (RMS): 0.7–1.4 Hz - geometric mean frequency (MGF) 1 Hz; 1.4-2.8 Hz - CGCH 2 Hz; 2.8-5.6 Hz - 4 Hz MGH; 5.6 - 11.2 Hz - SGH 8 Hz.

Table 1. Recommended [4] and permissible [3] RMS accelerations (m/s2) on the seat

| GHS, Hz | Frequency range, Hz | ST ISO 2631 [4] | GOST 12.2019-86 [3] |
|---------|---------------------|-----------------|---------------------|
|         |                     | X.Y             | Z                   |
| 1       | 0.7-1.4             | 0.39            | 1.1                 |
| 2       | 1.4-2.8             | 0.42            | 0.79                |
| 3       | 2.8-5.6             | 0.8             | 0.57                |
| 4       | 5.6-11.2            | 1.62            | 0.6                 |

Table 2. Parameters of excitations by acceleration from tracks and forest backgrounds

| Path profile | Speed, m / s | ODC. Hz | 0.7-1.4 | 1.4-2.8 | 2.8-5.6 | 5.6-11.2 |
|--------------|--------------|---------|---------|---------|---------|---------|
| Agrophone GOST 12.2.002-91 | 2.5 | Absolute values of RMS m/s² | 0.44 | 1.14 | 3.07 | 7.04 |
| Road GOST 12.2.002-91 | 4.17 | Exceeding the parameters of the agrophone (times) | 1.22 | 1.24 | 1.47 | 1.2 |
| Smooth surface (road) GOST 31323-2006 (ISO 5008.2002) | 3.33 | | 1.41 | 1.62 | 1.55 | 1.18 |
| Apiary carriage | 2.5 | | 0.71 | 0.97 | 1.77 | 9.61 |
| Forest Road | 2.5 | | 0.75 | 0.81 | 1.42 | 4.62 |

Table 3. Tractor chain dynamic system information model

| Designation | Dimension | Variation range |
|-------------|-----------|-----------------|
| m1          | Kg        | 480             |
| m2          | Kg        | 920             |
| m3          | Kg        | 60              |
| c1          | kN / m    | 336             |
| c2          | kN / m    | 50.70.100.130.10000 |
| c3          | kN / m    | 4.3             |
| k1          | kNs / m   | 3.0             |
| k2          | kNs / m   | 4.8, 12, 16, 20 |
| k3          | kNs / m   | 0.5, 0.8, 1.0, 1.5 |
The creation of an effective vibration protection system for a wheeled tractor driver is an urgent task [1–5] aimed at improving the driver's work and ensuring safety. Seat acceleration and noise levels in the driver's cab of a wheeled vehicle are strictly regulated by international standards. Therefore, global manufacturers of wheeled vehicles are constantly improving vibration protection systems and introducing new noise-absorbing materials in the design of driver's cabs. Thus, studies [2] determined the frequency ranges of natural vibrations of various human organs (Fig. 1), and also established the distribution of vibration frequencies over the structural elements of a wheeled tractor (Fig. 2).

F. Daine [2] and M. Michke pay special attention to low-frequency vibrations (1 ... 8 Hz), which have the most harmful effect on the driver and cause him occupational diseases.

The studies have established that the natural frequency of human vibration on the seat of modern wheeled tractors is 1 ... 3 Hz, and the permissible values of the root-mean-square accelerations and amplitudes of vertical movements of the seat should not exceed 8.5 m/s² and 0.02 m, respectively, as provided by GOST 12.1.012-90 and Council Directive No. 78/764.

Figure 1: Distribution of natural vibration frequencies

![Figure 1](image1.png)

Figure 2: Distribution of vibration frequencies among the structural elements of a wheeled tractor

Currently, the problem of vibration protection of the driver is being solved by creating effective suspension systems for the driver's seat and cab. In modern wheeled tractors, the secondary suspension method (suspension of the driver's cab) is widely used to improve vibration protection of the wheeled tractor driver.

Based on the analysis of the results of modeling the oscillations of the masses of a wheeled tractor, a cushioning scheme for the driver's seat is proposed, including an element of damping relaxation. The simulation results showed that this suspension system significantly reduces the root-mean-square
acceleration on the driver's seat when the tractor is operating on field surfaces with low-frequency exposure from 1 to 8 Hz, as well as on paved roads with high-frequency exposure from 10 to 30 Hz.

The analysis of the results of studies of suspensions indicates that single impulse influences require special attention, since they most often lead to a breakdown of the suspension. Therefore, the response of the oscillatory system to single disturbances has been theoretically investigated.

We have developed and produced a device that ensures the verticality of the operator's seat. (Figure 3)

Figure 3. Device providing verticality of the operator: a – damper, b- seat with damper

Figure 4. Height change of the front (z15) and rear (z16) parts of the wheel tractor frame

Figure 5. Height change of the front (z31) and rear (z32) parts of the wheel tractor cab

4. Conclusion

1. Thus, the calculated assessment of the vertical vibration of the tractor when simulating its movement along the reference track profile and the choice of rational parameters of the operator's vibration protection system according to the criterion of the attainability of the standards allowed at the design stage to formulate the basic requirements for the parameters of the suspension system of the main parts of a wheeled tractor.

2. The seat damper has been experimentally studied, with the efficiency of using dynamic vertical vibration dampers in the seat cushioning system, which provide vibration damping at transport and technological tractor speeds of 5 ... 35 km/h on unequal natural roads.

3. The developed mathematical model was solved and numerical data were obtained, which testifies to the efficiency of our developed theory. The numerical data of the stiffness coefficient and the damping coefficient when the road is uneven converges with the experimental data. We have developed a mathematical model to serve the development of a new design of a tractor with a different damper when driving on uneven roads.
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