Improvement of human operator vibroprotection system
in the utility machine

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Abstract. The article is devoted to an urgent problem of improving efficiency of road-building utility machines in terms of improving human operator vibroprotection system by determining acceptable values of the rigidity coefficients and resistance coefficients of operator’s cab suspension system elements and those of operator’s seat. Negative effects of vibration result in labour productivity decrease and occupational diseases. Besides, structure vibrations have a damaging impact on the machine units and mechanisms, which leads to reducing an overall service life of the machine. Results of experimental and theoretical research of operator vibroprotection system in the road-building utility machine are presented. An algorithm for the program to calculate dynamic impacts on the operator in terms of different structural and performance parameters of the machine and considering combination of external perturbation influences was proposed. Keywords – vibration, vibroprotection, utility machine, performance parameters of the machine.

1. Introduction
In spite of current achievements in the field of development of modern antivibration systems in the last decades, which provide vibration decrease up to the safe level, issues concerning comfortable working conditions for operators of road-building machines are still relevant. Current international regulations [1, 2] do not prescribe acceptable values, but offer recommendations to obtain minimum possible values of vibration acceleration at the operator’s workplace while designing antivibration systems. During operation process operators of utility machines are subjected to vibrating impacts from the power plant and chassis elements contacting uneven microrelief as well as impacts from the brush, which is in contact with the surface under treatment.

2. Materials
It is possible to improve operator vibroprotection system by determining efficient parameters of coefficients of rigidity and coefficients of resistance of operator’s cab suspension system elements and those of operator’s seat. To accomplish this task a theoretical research was undertaken aimed at investigating effect of machine structural parameters on the magnitude of dynamic impact at the operator’s workplace. MATLAB software product was used as a research tool which enabled development of DUPM application. Geometric dimensions, mass of units, coefficients of rigidity and resistance of elastoviscous elements of the system were taken as source data for the program. The mathematical model was based on the algorithm of calculating dynamic impact magnitude at the operator’s workplace (Fig. 1) [3].

The algorithm proposed is universal. It enables calculation of parameters of vibroprotection system elements for a number of road-building machines if the input data are known. Except for the research of machine structural parameters effects on the mean-square values of vibration acceleration at the operator’s workplace, this algorithm allows to study the impact of performance parameters, such as operating conditions, machine movement speed, peculiarities of the uneven microrelief, etc.
Figure 1. Algorithm of DUPM application for determining the magnitude of dynamic impacts at the operator’s workplace.

3. Theory
During mathematical modeling of a complex dynamic system «Pertrubation Influence – Municipal Machine – Operator» effect of machine structural parameters, such as coefficients of rigidity and coefficients of resistance of operator’s cab suspension system elements and those of operator’s seat, on the dynamic impact magnitude was investigated [3]. The relations obtained demonstrate vividly the influence of these parameters on the magnitude of the dynamic impacts at the operator’s workplace (Fig. 2–4). They enable calculation of appropriate intervals between operator’s cab suspension system elements and operator’s seat to obtain the minimum possible magnitude of dynamic impacts at the operator’s workplace [6].
Figure 2. Relations between vibration acceleration values at the cab floor and coefficients of rigidity and those of resistance of operator’s cab suspension system elements.

Figure 3. Relations between vibration acceleration values at the operator’s seat and coefficients of rigidity of seat suspension with the following coefficients of resistance: 1) $b = 4 \cdot 10^3$ N·s/m; 2) $b = 8 \cdot 10^3$ N·s/m; 3) $b = 12 \cdot 10^3$ N·s/m; 4) $b = 20 \cdot 10^3$ N·s/m.

On analyzing the results of mathematical modeling it was shown that in terms of vibroprotection the acceptable values for the coefficients of rigidity of operator’s cab suspension system elements should be within $1.2 \cdot 10^6$ – $1.8 \cdot 10^6$ N/m. Values for the coefficients of resistance are to be determined within $2.0 \cdot 10^5$ – $5.0 \cdot 10^5$ N·s/m [4].

Figure 4. Relations between vibration acceleration values at the operator’s seat and coefficients of resistance of seat suspension with the following coefficients of rigidity: 1) $C = 5 \cdot 10^3$ N/m; 2) $C = 20 \cdot 10^3$ N/m; 3) $C = 40 \cdot 10^3$ N/m; 4) $C = 80 \cdot 10^3$ N/m.

Besides, theoretical research made it possible to draw a conclusion that coefficients of rigidity and coefficients of resistance of the seat suspension affect the magnitude of dynamic impacts at the
operator’s seat (Fig. 5). Due to this the values of coefficients of rigidity and coefficients of resistance of the cab suspension system elements were defined [4].

![Figure 5](image)

**Figure 5.** Relations between vibration acceleration values at the operator’s seat and coefficients of rigidity of the cab suspension system elements with the following coefficients of resistance: 1) b = 50·10³ N·s/m; 2) b = 100·10³ N·s/m; 3) b = 250·10³ N·s/m; 4) b = 500·10³ N·s/m.

On analyzing mathematical modeling results with different combinations of external perturbation influences and performance parameters a range of acceptable values of suspension system elements was defined: coefficients of rigidity of the cab suspension system elements should vary within 1.3·10⁶–1.5·10⁶ N/m, coefficients of resistance of the cab suspension system elements should be within 2.5·10⁵–5.0·10⁵ N·s/m [7]. At such values the magnitude of the mean-square vibration acceleration at the operator’s workplace is minimal.

4. Experimental results

Based on the results obtained by theoretical research an engineering solution for the problem of decreasing dynamic impacts was designed – a pneumatic suspension for the operator’s seat with a rubber-cord cover (Fig. 6) [5].

![Figure 6](image)

**Figure 6.** Operator’s cab suspension system elements: a) metal base with a shoulder; b) rubber-cord cover in the seat suspension design; c) general view of the seat.

The mechanism operates as follows: vibrations from a unit to be vibro-isolated are transmitted to the shock absorber with the rubber-cord cover being subjected to vertical dynamic impacts, which reduces dynamic impacts at the operator’s workplace [5]. When the machine moves taking up vibrations is provided by the rubber-cord cover deformation. The suspension rigidity is changed depending on the internal pressure in the rubber-cord cover [5, 6].

Quantitative indicators in assessing performance of the proposed vibroprotection system is the magnitude of vibration at the operator’s workplace before and after the implementation of the proposed vibroprotection system (Fig. 7), particularly, decrease in the magnitude of dynamic impacts. Based on the comparative analysis of vibration magnitude before and after the implementation of the
proposed vibroprotection system a conclusion was made that the decrease in the magnitude of
dynamic impacts was at an average 13-16% depending on the frequency considered.

Figure 7. Magnitude of vibration acceleration values at the seat place in operating conditions with the
speed of 10 km/hr: 1 – for the machine with the original seat suspension; 2 – for the machine with the
modernized seat suspension.

5. Summary and conclusions
Research provided by the use of the mathematical model of a complex dynamic system “Pertrubation
Influence – Municipal Machine – Operator” allowed to reveal the effect of coefficients of rigidity and
resistance on the magnitude of vibration acceleration at the operator’s workplace and to define the
range of acceptable values [5].

The proposed algorithm of calculating the magnitude of vibration acceleration values at the
operator’s workplace made it possible to define the range of acceptable values for the coefficients of
rigidity and resistance of operator’s cab suspension system elements and those of operator’s seat in the
utility machine.

The results obtained in the theoretical study provide an opportunity to design new prospective
vibroprotection systems not just for the utility machine, but also for a number of other road-building
machinery. The algorithm was certified as an electronic resource (RF certificate). The operator’s seat
suspension proposed was patented as a useful model (RF patent).

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