Upgrading seat suspension of tractor Belarus 1221

O I Polivaev\textsuperscript{1}, A V Loschenko\textsuperscript{1}, R G Belyansky\textsuperscript{2} and A N Kuznetsov\textsuperscript{1}

\textsuperscript{1}Department of Agricultural Machines, Tractors and Automobiles, Voronezh State Agricultural University named after Emperor Peter I, Voronezh, Russia
\textsuperscript{2}Department of Russian and Foreign Languages, Voronezh State Agricultural University named after Emperor Peter I, Voronezh, Russia

E-mail: kuz-basss@yandex.ru

Abstract. Ways to reduce vibrations at the tractor operator’s workplace in the unit with a trailer by improving the design of the suspension cushioning system are considered. Analysis of existing types of suspension systems shows that the most effective, in terms of reducing vibration loading, are active and semi-active systems. To reduce the vibration level at the tractor operator’s workplace in an aggregate with a trailer, an active seat suspension design has been developed. It includes a system of sensors and actuators that allow the current stiffness and damping of structural elements to be highly efficient in controlling the tractor operator’s workplace. To assess the effective use of the developed design, and compare it with the efficiency of the serial seat suspension, road tests were carried out. The tractor-transport unit in the tractor Belarus-1221 and the trailer 2PTS-4.5 with the serial and experienced suspension design were chosen as the object of research. During the field tests, the acceleration values were determined for the operator’s seat, the cab floor, the front and rear axles of the tractor. The test results showed that the developed technical solution allows reducing the vibration acceleration levels by 12-18% in comparison with the serial design.

1. Introduction
Nowadays the increase in the use efficiency of agricultural machinery is associated with an increase in tractor power, an increase in their speeds and productivity. However, an increase in the speed and power of the tractor engine inevitably entails an increase in vibration levels at the operator’s workplace. This leads to a decrease in comfort and labor safety, as well as to a decrease in the quality of the tractor-transport unit (TTU) process \cite{1}.

Using elastic tires, cushioning systems, cab, and operator’s suspension the decrease in the level of vibration in the operator’s workplace during the movement of the TTU is exercised. Most modern models of tractor equipment are equipped with only two devices - elastic tires and a sprung seat. This fact imposes high demands on the nature of efficiency and device suspension seat modern automotive tools \cite{2,3}.

Figure 1 shows the stages of the development of TTU seat suspension designs and the reduction of vibration levels in the workplace \cite{4,5}. A number of studies have noted that the best suspension of vehicle seats are the best in terms of improving the smoothness of the course.

In Voronezh State Agricultural University, the design of the active seat suspension is developed, the scheme of which is shown in Figure 2.
Figure 1. The development of designs of seat suspension: 1 – with one elastic element along z; 2 – with an elastic and damping element along the z axis; 3 – with adjustable elastic and damping element along the z axis and high-quality seat; 4 – with elastic and damping elements along 2 axes and automatic stiffness control; 5 – with automatically adjustable elastic and damping elements along 2 axes.

Figure 2. Experienced TTU Operator Seat Suspension Design: 1 – seat frame; 2 – hydraulic cylinder; 3 – piston; 4 – stock; 5 – the base of the cabin; 6 – the lower cavity; 7 – upper cavity; 8 – connecting oil lines; 9 – adjustable throttle; 10 – pneumohydraulic accumulator; 11 – hydraulic cavity; 12 – pneumatic cavity; 13 – pressure solenoid valve; 14 – solenoid valve discharge pressure; 15 – receiver; 16 – electronic control unit; 17 – resistive seat position sensor; 18 – front axle acceleration sensor; 19 – acceleration sensor suspension seat.

The device works as follows. During operation, the TTU suspension is exposed to vibrations transmitted from the pavement through the tires to the base 5 and the seat 1 itself. This changes the position of the seat, which is fixed by the sensor 17. Signals from this sensor, as well as from acceleration sensors of the front axle 18 and seat 19, enter the electronic control unit 16, where, after converting the input signals, a control signal is generated, which is fed to the adjustable throttle 9 and solenoid valves 13 and 14. With vertical seat vibrations, the working fluid in line 8 through an adjustable choke 9 flows between the cavities 6, 7 of the hydraulic cylinder 2 and the hydraulic cavity 11 of the accumulator 10. The flow rate of the working fluid, as well as its amount, is determined by the control unit 16. A fast change in the cross-sectional area of the working channel in the choke allows you to adjust the damping coefficient design effectively, and the discharge or injection of pressure in the pneumatic cavity of a pneumonic hydro accumulator using solenoid valves 13 and 14 allows changing the stiffness of the suspension seat elastic element. This method of stiffness and damping active control effectively
eliminates the possibility of resonance phenomena, and significantly reduces the possibility of suspension breakdown. Seat acceleration sensor 19 serves to monitor residual vibration during operation of the system and adjust its parameters.

Under favorable conditions, the operation of the seat suspension occurs in the middle section of the characteristic.

2. Methods of experimental research.

The tractor and transport unit consisting of a Belarus 1221 tractor and a 2PTS-4.5 trailer with a serial and experienced seat suspension were chosen as the object of research. Comparative tests of TTU were carried out on transport operations on a dirt road and when moving artificial irregularities.

During the field tests, the vibration acceleration levels were determined in the center of the framework, on the front and rear axles of the tractor, as well as on the operator's seat, while simultaneously measuring the tractive effort on the tractor hook [6]. The measuring equipment installed on the tractor is shown in Figure 3.

![Figure 3. Transport unit Belarus 1221 + 2PTS-4.5, equipped with measuring equipment: 1 – landing disc; 2 – ICP acceleration sensor; 3 – strain gauge vibro axle meter of the tractor front axle; 4 – tensometric vibro–accelerometer of the tractor rear axle; 5 – tensometric vibroaccelerometer of the center point of the tractor frame; 6 – strainer; 7 – strain amplifier](image)

Processing of the data was carried out according to standard methods. As a result, logarithmic vibration acceleration levels (L<sub>a</sub>) were obtained, in dB, measured in octave frequency bands [6]:

\[ L_a = 20 \cdot \log \left( \frac{a}{a_0} \right) \]

\( a \) — root mean square value of the vibration acceleration, m/s\(^2\); \( a_0 = 10^6 \) is the reference acceleration value m/s\(^2\).

3. Results and its discussion.

The obtained octave spectra of vibration acceleration at the operator’s workplace during TTU movement at speeds of 30 and 35 km/h are shown in Figure 4.
Comparative tests of vibration loading of the TTA operator:

(a) speed of 30 km/h; (b) speed of 35 km/h.

4. Conclusion

Analyzing the results of research, we can draw the following conclusions:

1. The use of an experienced seat suspension design, in comparison with a serial one, makes it possible to reduce vibration levels at the operator’s workplace much more effectively (by 12–18%) when TTA is moving at a speed of 30 and 35 km/h.

2. The use of the developed design made it possible to bring the vibration levels to safe values determined by sanitary norms SN 2.2.4 / 2.1.8.566-96.

3. The maximum amplitudes of disturbing accelerations are located in octave bands with geometric average frequencies of 2 and 4 Hz, which determines the need to adjust the seat suspension with maximum efficiency in this zone.

4. The use of an experienced seat suspension can significantly increase the comfort of the operator, which in turn leads to an increase in the productivity of the unit.

References

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