

COMPARING OF DRIVER'S SEATS DYNAMIC PROPERTIES

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This article deals with the definition of the optimal driver's seats properties on the examples of two systems with different kind of damping. In the first case use the springing support of driver seat uses a pneumatic spring and a telescopic hydraulic damper. In the second case, the damping effect is achieved by two pneumatic springs whose forces effect in the phase shifted by a throttle valve which is in the connecting piping system. The springing support driver's seat issue is very serious and the effort grows by manufactures to optimize their dynamic properties. The main optimization criterion is vibration insulation efficiency with regard to health research and their associated health standards and regulations.

KEYWORDS

vibration minimization, driver's seat, vibro insulation, stiffness, damping

1 INTRODUCTION

The springing support of driver seat (Fig. 1) consists of a guide mechanism in which is placed a pneumatic spring. A damper is connected parallel to the air spring in a guide mechanism (Fig. 2). Force effects $F_1(z_r)$ and $F_2(\dot{z}_r)$ are phased shifted by $\pi/2$.

In the original author's solution, there are two air springs which by themselves force's effects acts against each together. They are pneumatically connected through the throttle valve, which achieves phase shifting their force effects $F_1(z_r)$ and $F_2(z_r)$, and thereby damping oscillatory motion (Fig. 3).



Figure 1. Vehicle driver's seat

When the vehicle is moving, the seat is kinetically energized by the movement of the floor. The excitation function u is in fact in respect frequency and amplitude very diverse and its character depends on the road surface, vehicle suspension and on the speed.

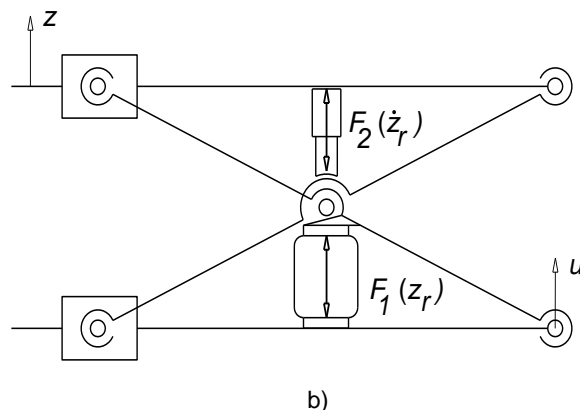


Figure 2. Springing seat support with a hydraulic damper

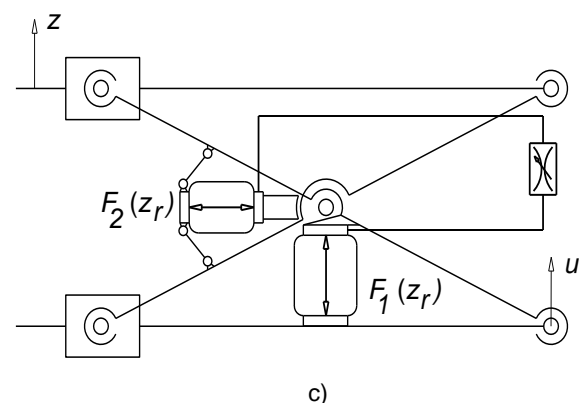


Figure 3. Springing seat support with two air springs

Driver's seats producer assesses the dynamic properties of the springing support and the vibration insulation effect based on their own practices and policies. It is usual measurement and evaluation of the feedback z to the excitation signal u which is measured when the vehicle is driving on the test polygon. General evaluation enabling an objective comparison of driver's seats from different manufacturers in terms of vibration insulation efficiency is practically non-existent.

2 MECHANICAL MODEL

The basis for evaluating the driver's seat suspension system is undoubtedly the creation and compilation of mechanical model and solving equations of motion.

For commonly known system of Fig. 2 the equation of motion can be written for simplifying assumptions of linearization dynamic parameters in the form

$$m\ddot{z} + i_b b(\dot{z} - \dot{u}) + i_k k(z - u) = 0 \quad (1)$$

where m is the reduced mass of moving parts of the seat including the driver, b is the coefficient of vibration damper damping, k is the spring stiffness and a i_b and i_k are the springs and dampers transfers, $u(t)$ is the displacement of the

base under the kinematic excitation, $z(t)$ is the absolute displacement of the object.

Equation (1) is possible to write

$$m(\ddot{z}_r + \ddot{u}) + i_p b \dot{z}_r + i_k k z_r = 0 \quad (2)$$

where $z_r(t)$ is the relative displacement of the object and the base.

For pneumatically – mechanically system according Fig. 3 is possible to write equation of motion in the form

$$m(\ddot{z}_r + \ddot{u}) + b_{constr} \dot{z}_r + i_1 F_1(z_r) + i_2 F_2(z_r) = -mg, \quad (3)$$

where b_{constr} is construction damping coefficient, i_1 and i_2 are transfers of springs in mechanism [Harris 2005].

The air exchange between the springs is described by isentropic air flow through the throttle valve. In the next two equations, the rate of air exchange depends on pressures p_A and p_B ; the pressure p_A signs the higher pressure of p_{p1} , p_{p2} at a given time, p_B is the other one. Which of the two pressures is higher determines the sign of the flow rate. The rate of air mass is then

$$\frac{dm_{a1(a2)}}{dt} = A_v c p_A \sqrt{\frac{2}{\gamma T_A} \frac{\kappa}{\kappa-1} \left[\left(\frac{p_B}{p_A} \right)^{\frac{2}{\kappa}} - \left(\frac{p_B}{p_A} \right)^2 \right]} \quad (4)$$

for subcritical flow conditions, where $p_B/p_A \geq \beta^*$ or

$$\frac{dm_{a1(a2)}}{dt} = A_v c p_A \sqrt{\frac{2}{\gamma T_A} \frac{\kappa}{\kappa-1} \left(\frac{p_B}{p_A} \right)^{\frac{2}{\kappa-1}}} \quad (5)$$

otherwise. Critical pressure ratio β^* is

$$\beta^* = \left(\frac{2}{\kappa+1} \right)^{\frac{\kappa}{\kappa-1}}, \quad (6)$$

where κ is specific heat ratio for the air. In the equations (4) and (5) are c discharge coefficient and A_v cross-section of the throttle valve.

Differential equation (3) supplemented by differential equation for air mass inside the springs describe the presented pneumatic-mechanical system. We have considered closed pneumatic system, so the air masses are bound by condition [Pešík 2011a] and [Pešík 2011b]

$$m_{a1} + m_{a2} = m_a \quad (7)$$

3 EVALUATION OF SPRINGING SUPPORT

Based on solutions of equations of motion in the preceding paragraph a transmission frequency characteristic can be obtained which are usually concerned to displacement amplitude of the oscillatory movement of the seat. According to these data can evaluate the function of the spring base due to changes in the position of the driver to the vehicle controls and set the appropriate size of the damping coefficient.

In case the springing support with hydraulic damper according to Fig. 2 the transmission frequency characteristics are based on as shown on Fig. 4.

Particular damping characteristics correspond to the relative damping coefficient of 0.01 and 0.1 to 0.5 with step 0.1. Generally it is possible to say, the damping has a positive effect when the system is erected near to its natural frequency. Outside of this region is the damping importance with respect to the displacement amplitude small to rather negative.

In case the springing support according to Fig. 3 are the transmissions frequency characteristics based on as is shown on Fig. 5 [Homišín 2009].

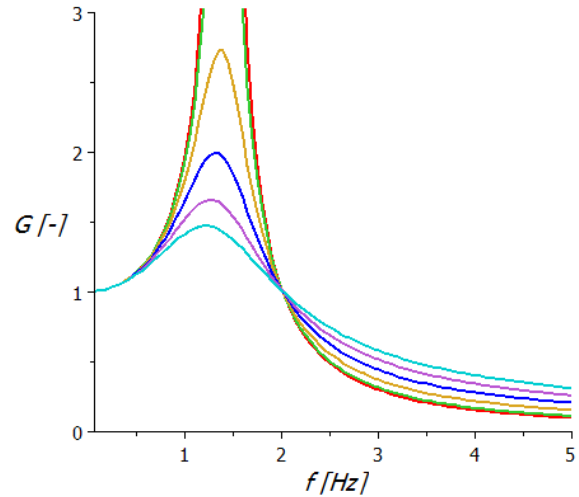


Figure 4. Transmission frequency characteristics of springing support with hydraulic damper

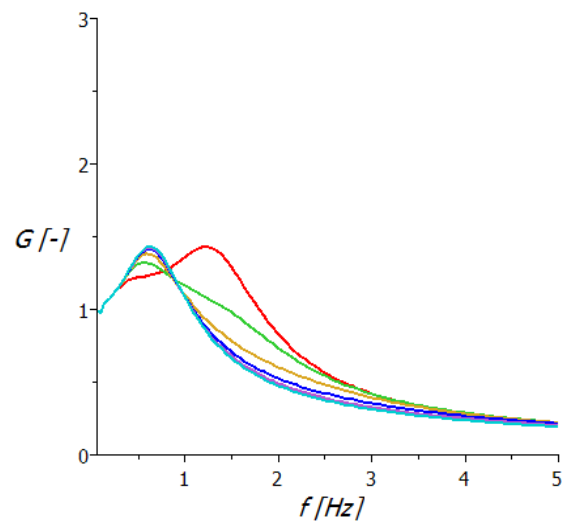


Figure 5. Transmission frequency characteristics of springing support with two air springs

Individual characteristics correspond to different intensities throttling the flow of compressed air between the two air springs of the support. The diameters of the holes are graded from 1 mm to 3.5 mm with step 0.5 mm. The damping character of the oscillation is in this case favourable in the wider frequency range and the gain does not exceed the value 1.5.

Another criterion of driver seat vibration insulation evaluation properties is acceleration value and frequency, which act on the driver and adversely affect the driving comfort.

In Fig. 6 are acceleration transmission frequency characteristics of springing support with linear hydraulic damper. It shows that damping is decreasing displacement amplitude, but significantly increases the acceleration values. This fact requires vibration insulation systems seats which show outside the resonance region negligible damping.

In Fig. 7 are the acceleration amplitude frequency characteristics of springing support with two air springs. This springing system significantly reduces amplitude acceleration values compared to the classic springing support design. Acceleration amplitudes increase almost linearly with excitation frequency.

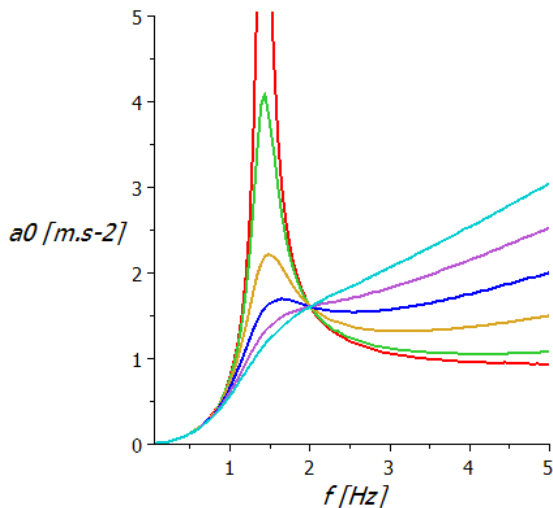


Figure 6. Acceleration amplitude frequency characteristics of springing support with hydraulic damper

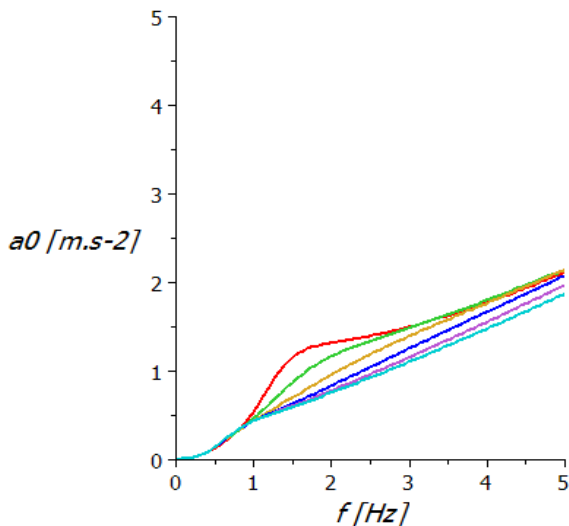


Figure 7. Acceleration amplitude frequency characteristics of springing support with two air springs

Vibration isolation properties of the driver seat can be quantified on the basis of hygiene standards. There is medical research, where the result is the definition of sitting person's comfort under the influence of acceleration of a certain amplitude and frequency. In Fig. 8 are graphs taken from the internationally valid standards ISO 2631, ISO 5982 and VDI 2057.

Using these findings could contribute to an objective evaluation of vibration insulation properties of driver seats and to remove

the element of subjective assessment, which currently dominates among the manufacturers of driver seats.

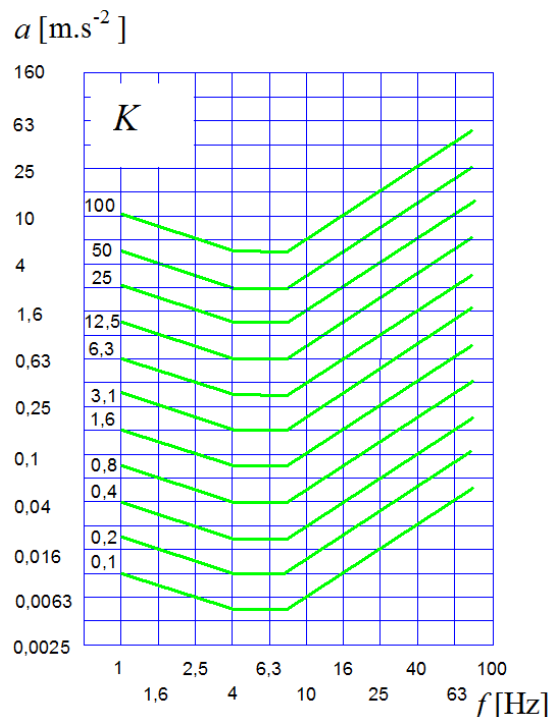


Figure 8. Amplitude and frequency dependence of the coefficient of seated human on acceleration

Using the coefficient K the vibration insulation level of the driver seat properties can be deduced. In fig. 9 dependence the coefficient K is calculated on seat's excitation frequency in the case of the seat with hydraulic telescopic shock damper and Fig. 10 shows this dependence on the seat with two pneumatic springs.

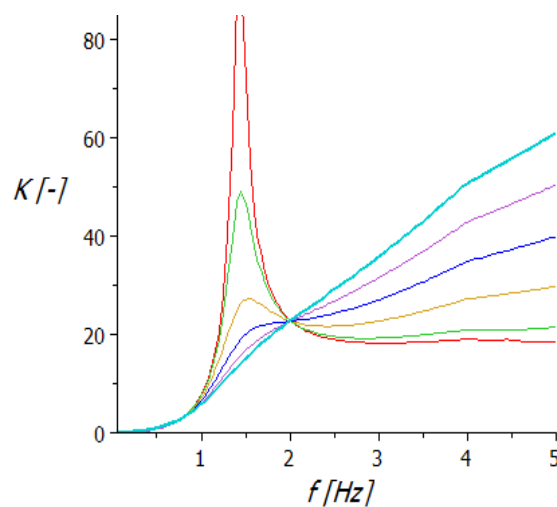


Figure 9. Frequency dependence of the coefficient of seated human loading on the acceleration of seat with hydraulic damper

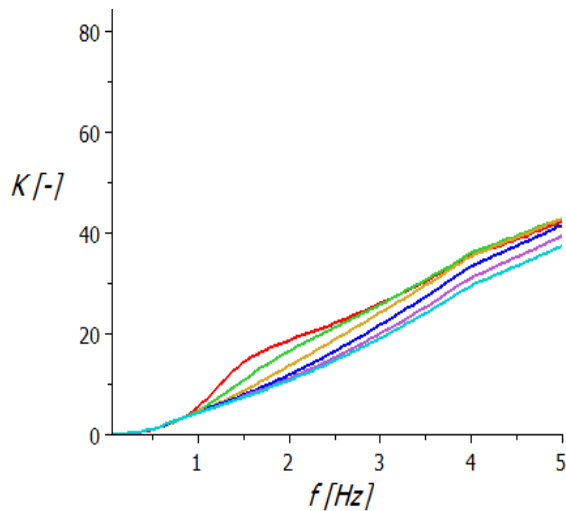


Figure 10. Frequency dependence the coefficient of seated human loading on the acceleration of seat with two air springs

4 CONCLUSION

There are many technical problems that are connected with a necessity of the minimization of the vibrations, especially in the automotive industry. There are many types of equipment which have an excitation through the movement of the foundation. The typical instance of this set is a driver seat. With vibration isolation of these objects, there are further problems that come from variable excitation frequency. It is clear that the condition of the sufficient difference between the force excitation frequency and resonant frequency of the dynamic systems cannot be ensured at all times. In these cases, it is necessary to use special supports with the possibility of the stiffness changing, and to tune the natural frequency of the system appropriately. In the paper are presented two possibilities of the driver's seat design. One of them is the classical solution with a hydraulic damper. The second one is an original solution of authors which has two pneumatic springs in the guide mechanism.

This original solution presents a pneumatic spring system with a differential configuration and the throttling of the air flow between the springs. The springs act one against the other. This system can be used with benefits to the vibration isolation of the objects of the systems with kinematic excitation, e.g. driver seats, ambulance couchettes, etc. Based on the frequency spectrum of excitation, it is possible to choose the optimum cross-section of the throttling element and achieve efficient damping of vibration in a relatively broad range of low excitation frequencies. Similar results can be seen by measurement of the real system.

Evaluation of both seats is made on the basis of simulation of vibration excitation at constant amplitude support displacements at frequencies from 0 to 5 Hz. The obtained

frequency characteristics of kinematic quantities are further processed for the purpose the seated human loading of vertical acceleration coefficient determination.

Calculation results showed that a qualitatively higher level of vibration insulation properties seat has the seat with two air springs.

REFERENCES

Book:

[Harris 2005] Harris, C. M, Shock and Vibration Handbook. Fifth edition. McGraw-Hill., NewYork, 2005, ISBN 0-07-137081-1

Paper in a journal:

[Homisin 2009] Homisin, J., Kassay, P. Comparison of Tuning in Shipping System Using pneumatic Tuners of Torsional Oscillations, In: Machine Modeling and Simulation, Scientific and Technical Society at the University of Zilina. Zilina, 2009, s. 147-154, ISBN 978-80-89276-18-9.

[Pesik 2011a] Pesik, L., Skarolek, A. Tuning of Vibration Isolation Differential Pneumatic System by Means of Trottle Valve. In: Transactions of the Universities of Kosice: Research reports from the Universities of Kosice. Kosice, 2011. ISSN 1335-2334.

[Pesik 2011b] Pesik, L., Skarolek, A., Vancura, M. The Supporting of the Driver's Seat with the Adjustable Load Characteristic. In: Proceeding of the 52. International Conference of Machine Parts and Mechanisms Departments. Ostrava, 2011. ISBN 978-80-248-2450-5. (Podstavec sedadla řidiče se řízenou zatěžovací charakteristikou)

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