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SEAT SUSPENSION SYSTEM OF THE ELECTRIC GOLF CART

Summary. The paper deals with reducing vibrations transmitted from electric golf cart wheels to the seat and the seated person. These vibrations appear while driving a golf cart on uneven terrain of a golf course. This problem can be solved by using the elastic and damping link between the cart frame and seat, which is tightly connected to the electric power battery. A mathematical calculation is used to evaluate the designed solution in which the golf cart is defined as a system of masses connected with elastic and damping links. The result of the designed solution's mathematical description provides a reference step response of the golf cart seat.
Keywords: suspension system; golf cart seat; minimization of vibration

1. INTRODUCTION

Suspension seats are used in a wide range of vehicles, especially for the purpose of protecting people's health when exposed to whole-body vibration during travel, and also increasing comfort. Driving on the uneven terrain of a golf course leads to the high-intensity vibration of wheels, which is transmitted to the frame, the seat and the seated person. As conventional battery-powered electric golf carts do not have suspension seats, the elastic and

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damping link between the chassis and frame is used to reduce transmitted vibrations to the seat and the seated person. Such a link only partially reduces the transmission of vibrations, meaning that driving in a golf cart can still become uncomfortable.

2. EFFECT OF VIBRATION ON COMFORT

Evaluating the effect of vibration on the comfort of the seated person while driving a golf cart was made in accordance with [1]. The result of this evaluation relates to the frequency-weighted root mean squared (RMS) acceleration of the measured acceleration as a function of time during the golf cart drive; see the comparison with this acceleration value in the table in [2]. A comparison of the frequency-weighted RMS acceleration with the table in [1] shows that the effect of vibration on comfort during golf cart driving is in interval between uncomfortable and very uncomfortable [3].

3. REDUCTION OF TRANSMITTED VIBRATION

Minimization of vibration, transmitted from golf cart wheels to the seat and the seated person, is based on the principle described in the patent application.

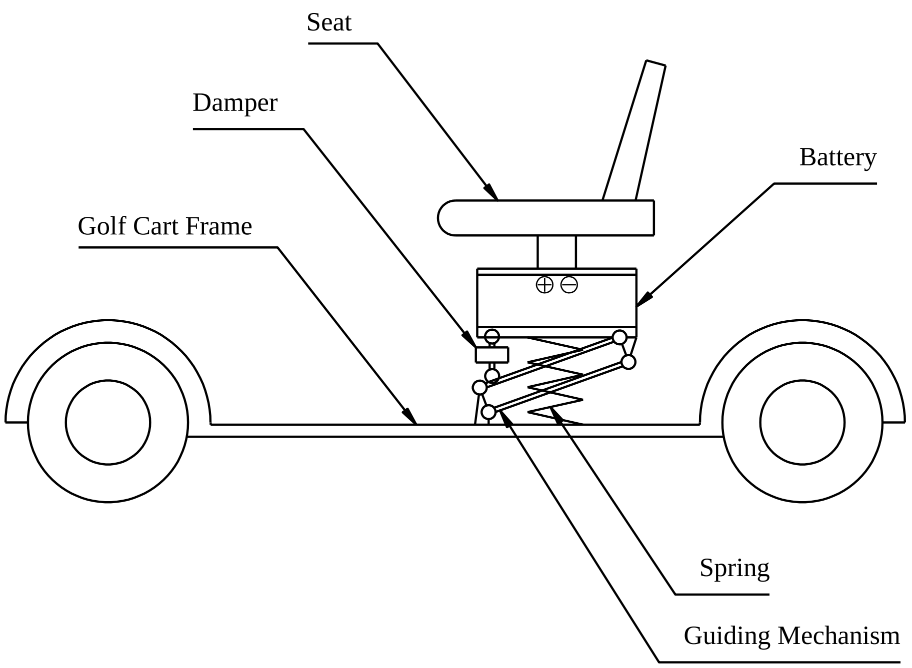

Fig. 2. Principle of vibration isolation of the seat

Transmitted vibrations can be reduced by using the elastic and damping link between the cart frame and seat, which is tightly connected to the electric power battery. As a result of this tightness, the seat increases the inertial effect of mass, which reduces seat vibration. The principle is shown in Fig. 2.

4. TRANSMITTED VIBRATION CALCULATION

The system shown in Fig. 2 can be described in a simplified way by differential equations:

$$m_R.\ddot{x}_R+b_R.(\dot{x}_R-\dot{u})+b_{SB}.(\dot{x}_R-\dot{x}_{SB})+k_R.(x_R-u)+k_{SB}.(x_R-x_{SB})=0 \quad (1)$$

$$m_{SB}.\ddot{x}_{SB}+b_{SB}.(\dot{x}_{SB}-\dot{x}_R)+k_{SB}.(x_{SB}-x_R)=0 \quad (2)$$

where m_R is the mass of the frame, m_{SB} is the mass of the seat, battery and seated persons, b_R is the damping coefficient of the chassis, b_{SB} is the damping coefficient between the seat with the battery and the frame, k_R is the stiffness of the chassis, k_{SB} is the stiffness between the seat with the battery and the frame, u is the deflection of the chassis, x_R is the deflection of the frame, and x_{SB} is the deflection of the seat with the battery.

The system can be presented in a simplified matrix form by the following equation:

$$\vec{q}=(\mathbf{K}+i.\omega.\mathbf{B}-\omega^2.\mathbf{M})^{-1}.\vec{f} \quad (3)$$

where $\vec{q}$ is the vector of deflection, $\mathbf{K}$ is the matrix of stiffness, $\mathbf{B}$ is the matrix of damping, $\mathbf{M}$ is the matrix of mass, $\vec{f}$ is the vector of the force substituting deflection u, ω is the angular frequency and i is the imaginary unit.

In the case of using an elastic and damping link between the golf cart frame with a tightly connected battery and the seat, the differential equations are:

$$m_R.\ddot{x}_R+b_R.(\dot{x}_R-\dot{u})+b_S.(\dot{x}_R-\dot{x}_S)+k_R.(x_R-u)+k_S.(x_R-x_S)=0 \quad (4)$$

$$m_S.\ddot{x}_S+b_S.(\dot{x}_S-\dot{x}_R)+k_S.(x_S-x_R)=0 \quad (5)$$

where m_S is the mass of the seat and seated persons, b_S is the damping coefficient between the seat and the frame, k_S is the stiffness between the seat and the frame, and x_S is the deflection of the seat.

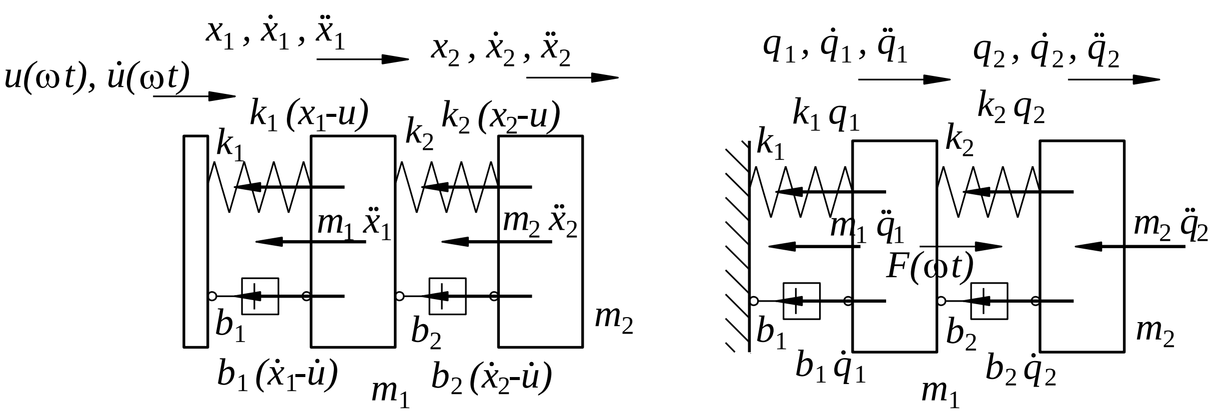

Fig. 3. Description of Eqs. 1-5

The results obtained by Eqs. 1-5 comprise the amplitude-frequency response, as shown in Fig. 4, and the reference step response of systems, as shown in Fig. 5.

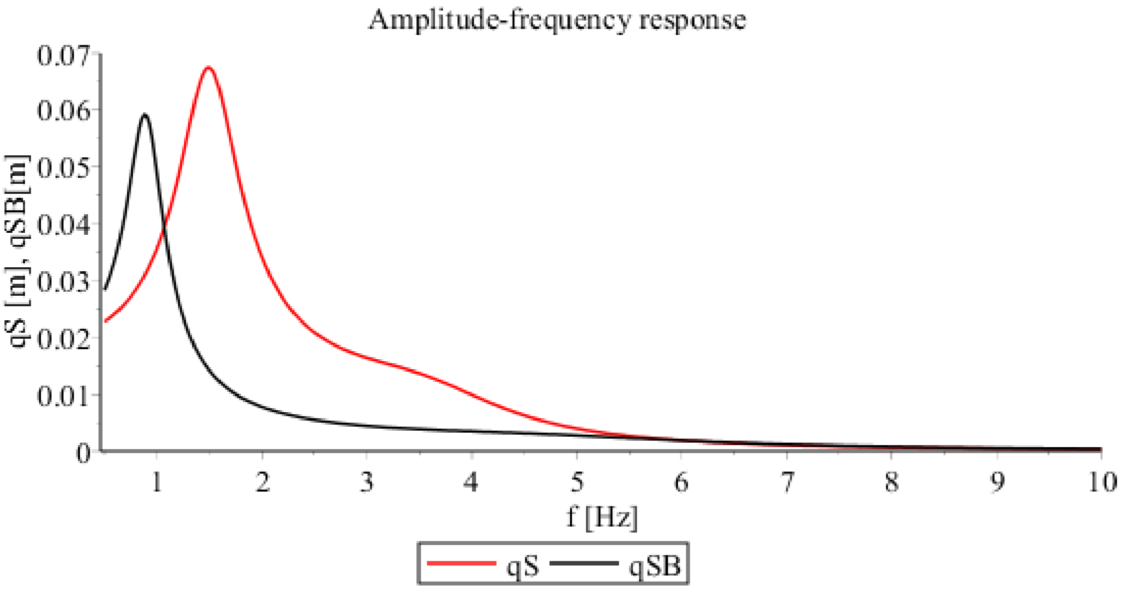

Fig. 4. Amplitude-frequency response

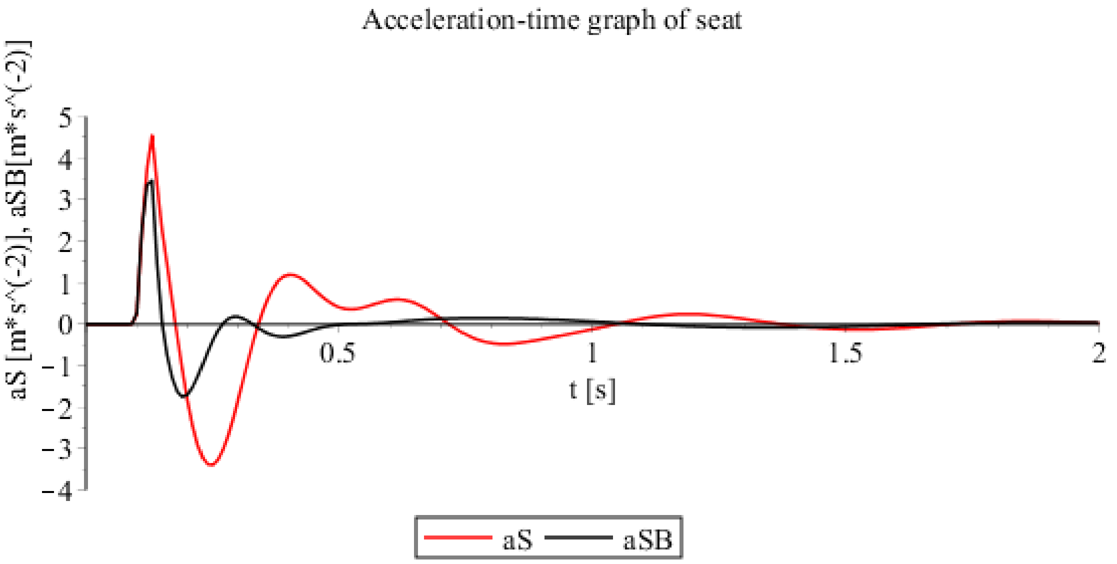

Fig. 5. Step response of systems: acceleration-time graph

Driving a golf cart on uneven terrain of a golf course leads to non-periodic and non-harmonic vibration. In a simplified way, this vibration can be represented by separate step functions. The deflection u in differential Eqs. 1-5 can be substituted by a reference step signal. The amplitude-frequency response, as shown in Fig. 4, is the decisive reference step response of a system when evaluating the effect from increasing seat inertia.

5. TRANSMITTED VIBRATION EVALUATION

The system of an electric golf cart without a suspension seat can be described in a simplified way by the following differential equation:

$$m_R.\ddot{x}_{RS}+b_R.(\dot{x}_{RS}-\dot{u})+k_R.(x_{RS}-u)=0 \quad (6)$$

where x_{RS} is the deflection of the frame with a seat.

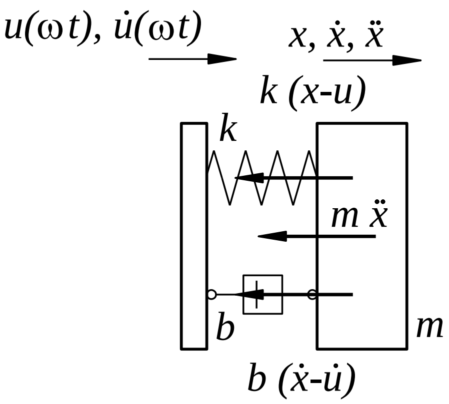

Fig. 6. Description of Eq. 6

The result obtained from differential Eqs. 1-6 is the reference step response of systems. The acceleration-time graph for the suspension seat and the seat tightly connected to the golf cart frame is shown in Fig. 7.

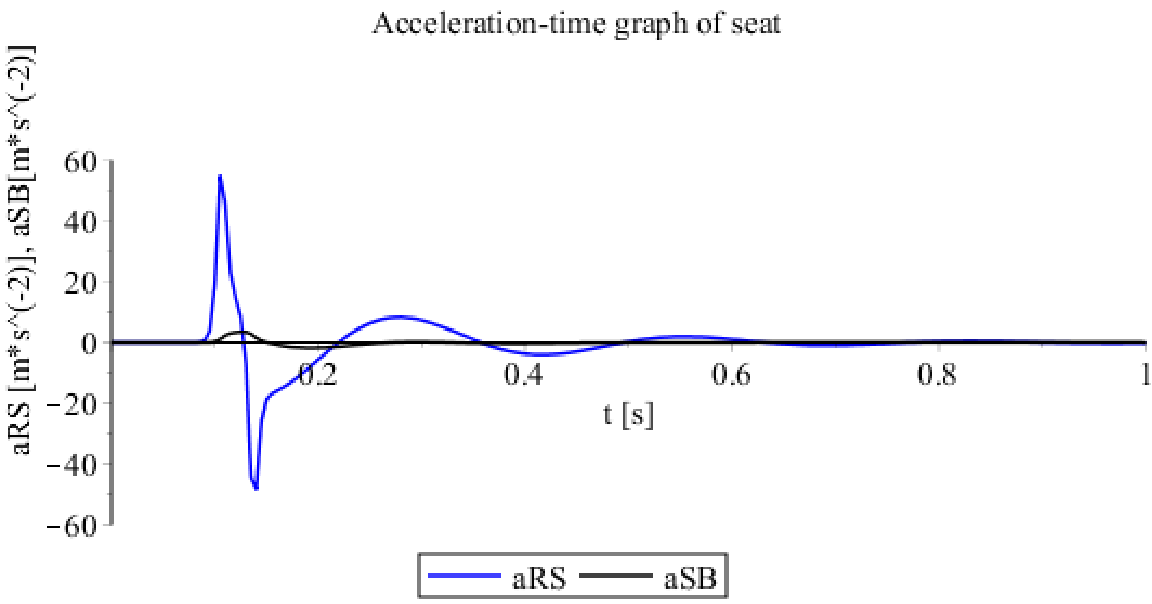

Fig. 7. Step response of systems: acceleration-time graph

6. CONCLUSION

The paper deals with the current issue of the vibration isolation of golf cart seats. The solution uses the inventive concept of increasing the inertia of the tightly connected mass in relation to seat. This significantly reduces the vibration transmitted from the golf cart wheels to the driver and passenger.

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