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Vibroprotective and Energetic Properties of Oscillating System Equivalent to Vehicle Suspension with Pendular Regulator on Shock Absorber

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Abstract

The purpose of the article is to study the vibroprotective and energetic properties of vehicle suspension with pendular regulator on shock absorber in a two-mass oscillating system. A mathematical model of suspension with pendular regulator on shock absorber in a two-mass oscillating system is developed. The analysis of the research results with the vibroprotective properties of the two-mass oscillating system with pendular regulator on shock absorber under harmonic and random road impact is presented. The study revealed that the suspension with pendular regulator on shock absorber in the two-mass oscillating system provides higher vibroprotection of a vehicle body and higher energy-saving properties compared to a classic unregulated suspension. Using pendular regulator on shock absorber in the two-mass oscillating system leads to the increase in the tire deformation in the area of spectrum corresponding to the high-frequency resonance of the system.

Keywords: vehicle suspension; vibroprotective properties; damping control; pendular regulator; two-mass oscillating system.

1. Introduction

The study of inefficient work areas in shock absorber of vehicle suspension, conducted by the authors of the article, has revealed the need to reduce of resistance or full shutdown of shock absorber in these areas [1-7]. Further study of shock absorber resistance regulation in the oscillation cycle [8-22] showed that instantaneous optimal switching off and switching on of shock absorber in vehicle suspension provides reduction of vibration in the region of sprung mass resonance – however, it is accompanied by shocks and noise in suspension. Therefore, the authors

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suggested pendular regulator that provides smooth regulation of damping in the inefficient work areas of shock absorber. It has a simple design and doesn't require the supply of additional energy. Its study was carried out in a single-mass oscillating system [21-23], which showed that it provides higher vibroprotective and energy-saving properties than classic unregulated suspension. Therefore, it is advisable to conduct the study of vibroprotective and energy-saving properties in suspension with pendular regulator on shock absorber in a two-mass oscillating system which is more difficult and more appropriate to vehicle suspension.

2. The mathematical model of vehicle suspension with pendular regulator on shock absorber

In developing the mathematical model, the authors used the scheme of elastic and damping bonds in suspension, shown in Fig. 1.

To simplify the mathematical model, the obvious assumptions were made:

- spring and shock absorber of pendulum have linear characteristics;
- the influence of pendulum oscillations on sprung mass oscillations is neglected;
- the variable damping factor of vehicle shock absorber varies proportionally to the displacement of pendulum mass with respect to sprung mass;
- dry friction in suspension is not taken into account;
- damping of tire is not taken into account.

Taking into account the accepted assumptions for calculating the mass oscillations in a two-mass oscillating system with pendular regulator on shock absorber, the following system of differential equations is obtained:

$$\left.\begin{aligned} &m_1\ddot{z}_1 + uk\left(\dot{z}_1 - \dot{z}_2\right) + c_1\left(z_1 - z_2\right) = 0, \\ &m_2\ddot{z}_2 + c_2\left(z_2 - q\right) - uk\left(\dot{z}_1 - \dot{z}_2\right) - c_1\left(z_1 - z_2\right) = 0, \\ &m_\text{r}\ddot{z}_\text{r} + k_\text{r}\left(\dot{z}_\text{r} - \dot{z}_1\right) + c_\text{r}\left(z_\text{r} - z_1\right) = 0, \end{aligned}\right\} \tag{1}$$

where k – basic damping factor of shock absorber; u – control parameter of pendular regulator: $u = \dfrac{S_{\min}}{S}$.

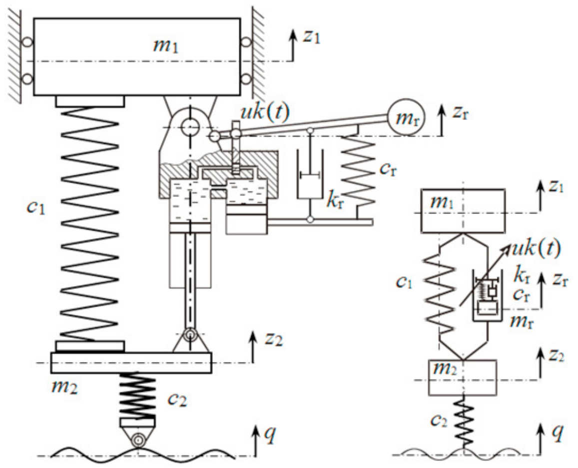

Fig. 1. Scheme of elastic and damping bonds in suspension: m_1 – sprung mass; m_2 – unsprung mass; m_r – pendulum mass in regulator; k – basic damping factor of shock absorber in regulator; uk – variable damping factor of shock absorber; c_1 – stiffness factor of suspension; c_2 – stiffness factor of tire; c_r – stiffness factor of regulator spring; k_r – damping factor of shock absorber in regulator; q – displacement of road profile; z_1 – displacement of sprung mass; z_2 – displacement of unsprung mass; z_r – displacement of pendulum mass.

The total flow area S of two throttle channels in shock absorber varies according to the following law when the pendulum moves: