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ANALYTICAL MODEL OF ENERGY DETERMINATION VERTICAL VIBRATIONS WITH MULTI-NUMBER AND MULTI-LEVEL DAMPING OF MOBILE MACHINES ACCOUNTING FOR ROAD IRREGULARITIES

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Annotation. The results of theoretical studies of multi-numerical and multi-level damping, as well as the influence of the relaxation element on the vibration-protective properties of the suspension of mobile vehicles, are presented. The vertical vibrations of mobile machines with multi-numerical and multi-level damping and on a relaxation damper were mathematically modeled. The damping of the main parts of a wheeled tractor was analytically determined, and the damping of the main parts of a multi-row relaxation wheeled tractor was also analytically determined.

Key words: damping; multi-level damping; relaxation element; vibration-proof property; suspension; mobile car; vertical oscillation; relaxation damper; wheeled tractor.

АНАЛИТИЧЕСКАЯ МОДЕЛЬ ОПРЕДЕЛЕНИЯ ЭНЕРГИИ ВЕРТИКАЛЬНЫХ КОЛЕБАНИЙ С МНОГОЧИСЛЕННЫМ И МНОГОУРОВНЕВЫМ ДЕМПФИРОВАНИЕМ МОБИЛЬНЫХ МАШИН С УЧЕТОМ НЕОДНОРОДНОСТЕЙ ДОРОЖНОГО ДВИЖЕНИЯ

Аннотация. Представлены результаты теоретических исследований многочислового и многоуровневого демпфирования, а также влияния

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релаксационного элемента на виброзащитные свойства подвески мобильных транспортных средств. Математически смоделированы вертикальные колебания мобильных машин с многочисловым и многоуровневым демпфированием и на демпфере релаксации. Аналитически определено демпфирование основных частей колесного трактора, а также аналитически определено демпфирование основных частей многорядного релаксационного колесного трактора.

Ключевые слова: демпфирование; многоуровневое демпфирование; элемент релаксации; виброустойчивое свойство; приостановка; мобильный автомобиль; вертикальное колебание; демпфер релаксации; колесный трактор.

YO‘L HOLDAGI BUZISHLARINI HISOBIGA QO‘YILGAN MOBIL MOSHINALARNING KO‘P SONLI VA KO‘P DARAJALI SO‘G‘ARISHI BILAN VERİKAL VIBRASYONLARNI ENERGIYANI ANALITIK TAHLILIK MODELI.

Annotatsiya:. Ko'p sonli va ko'p darajali amortizatsiyaning nazariy tadqiqotlari natijalari, shuningdek, bo'shashtiruvchi elementning mobil transport vositalarining suspenziyasining tebranish-himoya xususiyatlariga ta'siri keltirilgan. Ko'p sonli va ko'p darajali amortizatsiyaga ega va bo'shashtiruvchi amortizatorda joylashgan mobil mashinalarning vertikal tebranishlari matematik modellashtirilgan. G'ildirakli traktorning asosiy qismlarining dampingi analitik tarzda aniqlandi va ko'p qatorli bo'shashuvchi g'ildirakli traktorning asosiy qismlarining dampingi ham analitik aniqlandi.

Kalit so'zlar: damping; ko'p darajali damping; dam olish elementi; tebranishlarga chidamli xususiyat; to'xtatib turish; mobil avtomobil; vertikal tebranish; dam olish damperi; g'ildirakli traktor.

Introduction. The movement of mobile vehicles occurs under the influence of unevenness on the supporting surface of the road on its wheels, which leads to vibrations of the body, driver and passenger seats and is accompanied by vibration loads on the human body and vehicle mechanisms. Much attention is paid to reducing vibration loads when creating new equipment.

One way to solve this problem is to regulate the vibration damping of the sprung masses of the suspension system of mobile vehicles.

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American scientists D. C. Karnopp and M. J. Crosby in 1973 proposed the principle of damping control, called semi-active suspensions (semi-active regulation) [1].

D. Karnopp also proposed the concept of a smooth change in damping - skyhook [2]. A similar solution was considered in 1965 by R.I. Furunzhiev [3]. During the research and testing process, a number of significant shortcomings of such suspensions were identified. The main one is the instability of the functioning process, caused by a significant increase in the amplitudes of mass oscillations as the frequency of influence approaches the natural frequency of oscillations, which leads to the wheels being lifted off the road and the vehicle losing stability and controllability.

To solve this problem, the Czech scientist M. Valášek proposed a concept called grondhook [4].

In [5], a detailed analysis of the results of the research carried out by its authors on the mentioned principles of regulating vibration damping is presented and their futility is shown, since the oscillatory suspension system turns out to be unstable.

In [6] a structural diagram of a suspension with a relaxation element is given. The relaxation element is a set of elastic and dissipative elements connected to each other in series. It is installed in the suspension system between the sprung and unsprung masses instead of a conventional shock absorber parallel to the main elastic element, i.e. parallel to the spring.

The relaxation element model was proposed by Maxwell in connection with the study of the properties of thick solutions, suspensions and other bodies with the properties of viscoelasticity and creep under elastoplastic deformations [7]. Maxwell's model represents a sequential arrangement of elastic and damping elements. Viscoelasticity models are used, in particular, to describe the physical properties of polymer materials, which are characterized by the phenomenon of creep propagation of deformation.

However, a detailed analysis of the physical properties of the given structural diagram was not carried out in [6]. At the same time, many researchers are showing interest in this scheme [8,9,10]. The solution to this issue will be discussed further.

Studying the physical properties of the vibration damping process in the suspension system of mobile vehicles with a relaxation element and identifying its most rational location in the suspension system.

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Research methods. Maxwell's model allows for the sequential arrangement of elastic and damping elements. In analytical simulations, the theory of vibration for a suspension system is between sprung and unsprung masses instead of conventional damping parallel to the main elastic element.

Research results.

Vertical vibration of mobile machines with multi-number and multi-level damping [11-13].

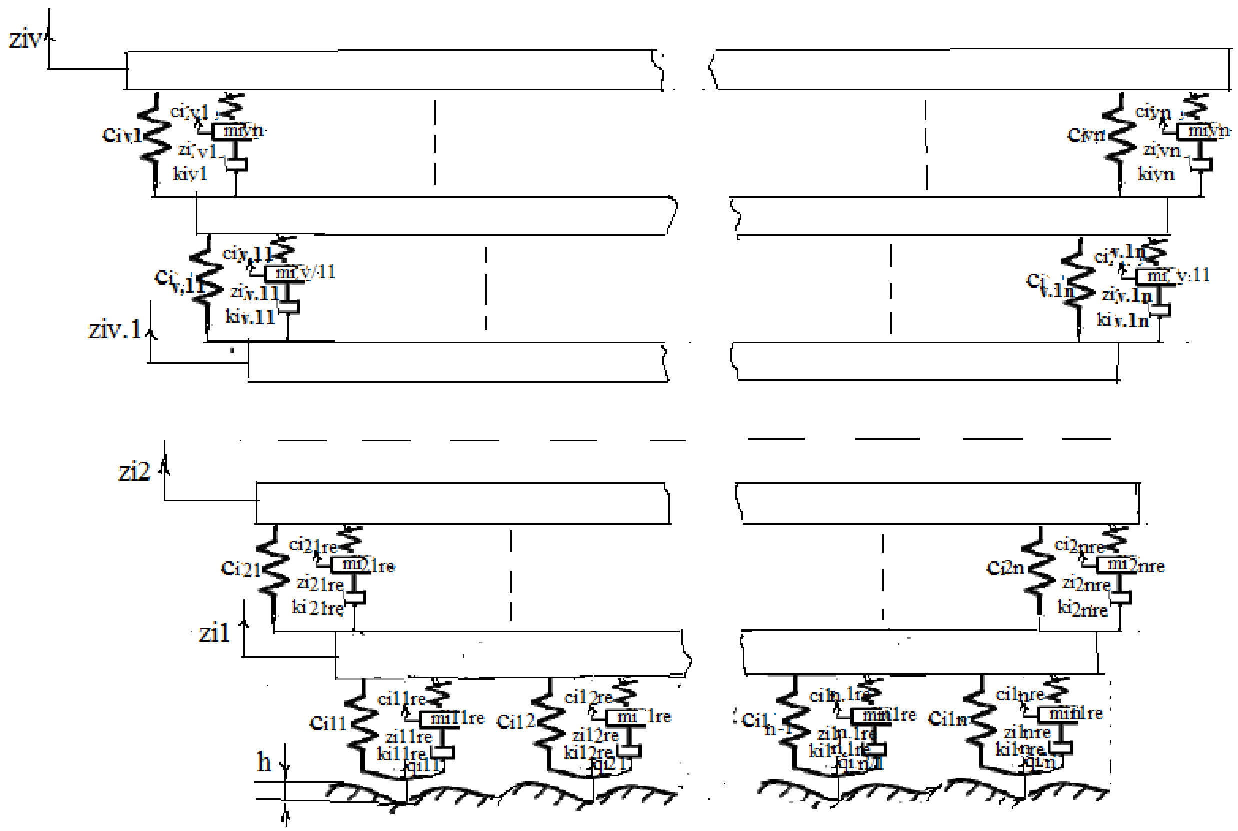

Figure 1 - Equivalent design scheme for multi-numerical and multi-level damping of mobile machines (cars, tractors, self-propelled vehicles, etc.) / or stationary machine

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$$
\begin{aligned}
m_1\ddot{z}_1 + \big(k_{(i1)1} + k_{(i1)2} + \cdots + k_{(i1)1re} + .. + k_{(i1)n\,re} + \ldots + k_{(i1)n}\big)\dot{z}_1 \\
+ + \big(c_{(i1)1} + c_{(i1)2} + \cdots + 2\big(c_{(i1)1re} .. + c_{(i1)\text{т}\,re}\big) \ldots \ldots + c_{(i1)n}\big)z_1 \\
- \big(c_{(i2)1} + c_{(i2)2} + \cdots + 2\big(c_{(i2)1re} .. + c_{(i2)\text{т}\,re}\big) \ldots \ldots + c_{(i2)n\,re}\big)z_2 - \cdots \\
- \big(k_{(ij-s)1} + k_{(ij-s)2} + \cdots \\
+ k_{(ij-s)1re} + .. + k_{(ij-s)n\,re} \ldots + k_{(ij-s)n\,re}\big)\dot{z}_{ij-s\,n} \\
- \big(c_{(ij-s)1} + c_{(ij-s)2} + \cdots \\
+ 2\big(c_{(ij-s)1re} .. + c_{(ij-s)\text{т}\,re}\big) \ldots + c_{(ij-s)n\,re}\big)z_{ij-s\,n} \\
- \big(k_{(i1)1re} + .. + k_{(i1)n\,re}\big)\dot{z}_{\,(i1)1\ldots n\,re} \\
= k_{(i1)1}\dot{q}_1 + k_{(i1)2}\dot{q}_2 + \cdots + k_{(i1)1re}\dot{q}_{1re} + .. + k_{(i1)n\,re}\dot{q}_{1re} \\
+ \ldots + k_{(i1)n}\,\dot{q}_n + c_{(i1)1}q_2 + c_{(i1)2}q_2 + \cdots c_{(i1)1re}q_{1re} + c_{(i1)n\,re}q_{n\,re} \ldots \\
+ c_{(i1)n}q_n,
\end{aligned}
$$

If the support has a mover, then it will ride on an uneven road according to the law q_i=hcos(ω_i t), and so for our system the equation will take the form

$$
\begin{aligned}
k_{(i1)1-n}\,\dot{q}_{1-n} + c_{(i1)1-n}q_{1-n} = \omega_1 k_1 \text{h}sin(\omega_1 t) + \\
\cdots \omega_{(i1)n\,re}k_{(i1)n\,re}\text{h}sin\big(\omega_{(i1)n\,re}t\big) \ldots + \omega_{(i1)1re}k_{(i1)1re}\text{h}sin\big(\omega_{(i1)1re}t\big) + \\
\omega_n k_n \text{h}sin(\omega_n t) + c_1\text{h}\cos(\omega_1 \text{t}) + \text{c}_{(i1)1re}\text{h}\cos\big(\omega_{(i1)1re}\text{t}\big) + \\
\text{c}_{(i1)n\,re}\text{h}\cos\big(\omega_{(i1)n\,re}\text{t}\big) + \text{c}_\text{n}\text{h}\cos(\omega_\text{n}\text{t}),
\end{aligned}
$$

$$
\begin{aligned}
m_2\ddot{z}_2 + \big(k_{(i2)1} + k_{(i2)2} + \cdots + k_{(i2)1re} + .. + k_{(i2)n\,re} \ldots + k_{(i2)n\,re}\big)\dot{z}_2 \\
+ \big(c_{(i2)1} + c_{(i2)2} + \cdots + 2\big(c_{(i2)1re} .. + c_{(i2)\text{т}\,re}\big) \ldots \ldots + c_{(i2)n\,re}\big)z_2 \\
- \big(k_{(i2)1} + k_{(i2)2} + \cdots + k_{(i2)1re} + .. + k_{(i2)n\,re} \ldots + k_{(i2)n\,re}\big)\dot{z}_1 \\
- \big(c_{(i2)1} + c_{(i2)2} + \cdots + 2\big(c_{(i2)1re} .. + c_{(i2)\text{т}\,re}\big) \ldots \ldots + c_{(i2)n\,re}\big)z_1 \\
- \cdots \Big(k_{(ij-(s2))1} + k_{(ij-(s2))2} + \cdots \\
+ k_{(ij-(s2))1re} + .. + k_{(ij-(s2))n\,re} \ldots + k_{(ij-(s2))n\,re}\Big)\,\dot{z}_{ij-(s2)n} \\
- \Big(c_{(ij-(s2))1} + c_{(ij-(s2))2} + \cdots \\
+ 2\left(c_{(ij-(s2))1re} .. + c_{(ij-(s2))\text{т}\,re}\right) \ldots \ldots + c_{(ij-(s2))n\,re}\Big)\,z_{ij-(s2)n} \\
- \big(k_{(i2)1re} + .. + k_{(i2)n\,re}\big)\dot{z}_{(i2)1\ldots n\,re} = 0
\end{aligned}
$$

ISSN (E): 2181-4570 ResearchBib Impact Factor: 6,4 / 2023 SJIF 2024 = 5.073/Volume-2, Issue-5

$$m_{v-1}\ddot{z}_{v-1} + \big(k_{(iv-1)1} + k_{(iv-1)2} + \cdots + k_{(iv-1)1re} + .. + k_{(iv-1)\text{т}\,re} + \ldots + k_{(iv-1)n\,re}\big)\dot{z}_{v-1} + \big(c_{(iv-1)1} + c_{(iv-1)2} + 2(\ldots + c_{(iv-1)1re} + c_{(iv-1)1re})\ldots + c_{(iv-1)n}\big)z_{v-1} - \big(k_{(iv-2)1} + k_{(iv-2)2} + \cdots + k_{(iv-2)1re} + .. + k_{(iv-2)n\,re} \ldots + k_{(iv-2)n\,re}\big)\dot{z}_{v-2} - \big(c_{(iv-2)1} + c_{(iv-2)2} + \cdots + 2(c_{(iv-2)1re} .. + c_{(iv-2)n\,re})\ldots\ldots + c_{(iv-2)n\,re}\big)z_{v-2} - \cdots - \big(k_{(ij-1)1} + k_{(ij-1)2} + \cdots + k_{(ij-1)1re} + .. + k_{(ij-1)n\,re} \ldots + k_{(ij-1)n\,re}\big)\dot{z}_{ij-1\,n} - \big(c_{(ij-1)1} + c_{(ij-1)2} + \cdots + 2(c_{(ij-1)1re} .. + c_{(ij-1)\text{т}\,re})\ldots\ldots + c_{(ij-1)n\,re}\big)z_{ij-1\,n} - \big(k_{(iv-1)1re} + .. + k_{(iv-1)\text{т}\,re}\big)\dot{z}_{(iv-1)1\ldots n\,re} = 0,$$

$$m_v\ddot{z}_v + \big(k_{(iv)1} + k_{(iv)2} + \cdots + k_{(iv)1re} + .. + k_{(iv)\text{т}\,re} + \ldots + k_{(iv)n\,re}\big)\dot{z}_v + \big(c_{(iv)1} + c_{(iv)2} + 2(\ldots + c_{(iv)1re} + c_{(iv)1re})\ldots + c_{(iv)n}\big)z_v - \big(k_{(iv-1)1} + k_{(iv-1)2} + \cdots + k_{(iv-1)1re} + .. + k_{(iv-1)n\,re} \ldots + k_{(iv-1)n\,re}\big)\dot{z}_{v-1} - \big(c_{(iv-1)1} + c_{(iv-1)2} + \cdots + 2(c_{(iv-1)1re} .. + c_{(iv-1)\text{т}\,re})\ldots\ldots + c_{(iv-1)n\,re}\big)z_{v-1} - \cdots - \big(k_{(ij)1} + k_{(ij2)2} + \cdots + k_{(ij2)1re} + .. + k_{(ij2)n\,re} \ldots + k_{(ij2)n\,re}\big)\dot{z}_{ijn} - \big(c_{(ji2)1} + c_{(ji2)2} + \cdots + 2(c_{(ij2)1re} .. + c_{(ij2)\text{т}\,re})\ldots\ldots + c_{(ij2)n\,re}\big)z_{ijn} - \big(k_{(iv)1re} + .. + k_{(iv)\text{т}\,re}\big)\dot{z}_{(iv)1\ldots n\,re} = 0,$$

On a relaxation damper. On the relaxation of the lower first subdampers

$$m_{(i1)1re}\ddot{z}_{(i1)1re} + k_{(i1)1re}\dot{z}_{(i1)1re} - k_{(i1)1re}\dot{z}_1 + \text{c}_{(i1)1re}z_{(i1)1re} = k_{(i1)1\,re}\,\dot{q}_{1\,re} + c_{(i1)1\,re}q_{1\,re}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$m_{(i1)n\,re}\ddot{z}_{(i1)n\,re} + k_{(i1)n\,re}\dot{z}_{(i1)n\,re} - k_{(i1)n\,re}\dot{z}_1 + \text{c}_{(i1)n\,re}z_{(i1)n\,re} = k_{(i1)n\,re}\,\dot{q}_{n\,re} + c_{(i1)n\,re}q_{n\,re}$$

The support has the following dependence 〖k_((i1)1-n re) q ̇_(1-n re)+c〗_((i1)1-n re) q_(1-n re) If the support has a mover, then it drive on a rough road according to the law q_(i re)=hcos(ω_(i re) t), and so for our system the equation will take the form

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$k_{(i1)1-n\,re}\,\dot{q}_{1-n\,re} +$
$c_{(i1)1-n\,re}q_{1-n\,re} = \omega_{(i1)n\,re}k_{(i1)n\,re}h\sin(\omega_{(i1)n\,re}t) \dots +$
$\omega_{(i1)1re}k_{(i1)1re}h\sin(\omega_{(i1)1re}t) + c_{(i1)1re}h\cos(\omega_{(i1)1re}t) +$
$c_{(i1)n\,re}h\cos(\omega_{(i1)n\,re}t),$

$m_{(i2)1re}\ddot{z}_{(i2)1re} + k_{(i2)1re}\dot{z}_{(i2)1re} + c_{(i2)1re}z_{(i1)1re} - k_{(i2)1re}\dot{z}_1 +$
$c_{(i2)1re}z_{1+1} = 0,$ ……………

$m_{(i2)n\,re}\ddot{z}_{(i2)n\,re} + k_{(i2)n\,re}\dot{z}_{(i2)n\,re} + c_{(i2)n\,re}z_{(i2)n\,re} - k_{(i2)n\,re}\dot{z}_1 + c_{(i2)n\,re}z_{1+1} = 0,$

$m_{v-1\,1re}\ddot{z}_{v-1\,1re} + k_{(iv-1)\,1re}\dot{z}_{v-1\,1re} + c_{(iv-1)1re}z_{v-1\,1re} - k_{(iv-2)\,1re}\dot{z}_{v-1} +$
$c_{(iv)\,1re}z_v = 0$ ………………..

$m_{v-1\,n\,re}\ddot{z}_{v-1\,n\,re} + +k_{(iv-1)n\,re}\dot{z}_{v-1\,nre} + c_{(iv-1)nre}z_{v-1\,n\,re} - k_{(iv-2)n\,re}\dot{z}_{v-1} + c_{(iv)n\,re}z_v = 0$

$m_{v\,1re}\ddot{z}_{v\,1re} + k_{(iv)1re}\dot{z}_{v\,1re} + c_{(iv)1re}z_{v\,1re} - k_{(iv-2)\,1re}\dot{z}_{v-1} + c_{(iv)\,1re}z_v =$
0 ………………..

$m_{v\,nre}\ddot{z}_{v\,nre} + k_{(iv)nre}\dot{z}_{v\,nre} + c_{(iv)nre}z_{v\,nre} - k_{(iv-2)n\,re}\dot{z}_{v-1} + c_{(iv)n\,re}z_v = 0$

where -is the mass of the corresponding mechanisms; $\ddot{z}$, $\dot{z}$, z- acceleration, speed and displacement; k, k_re – damping and relaxation damping coefficient; c,c_re – coefficient of rigidity and rigidity of relaxation.

Let's consider a number of analytical examples.

Analytical determination of damping of the main parts of a wheeled tractor

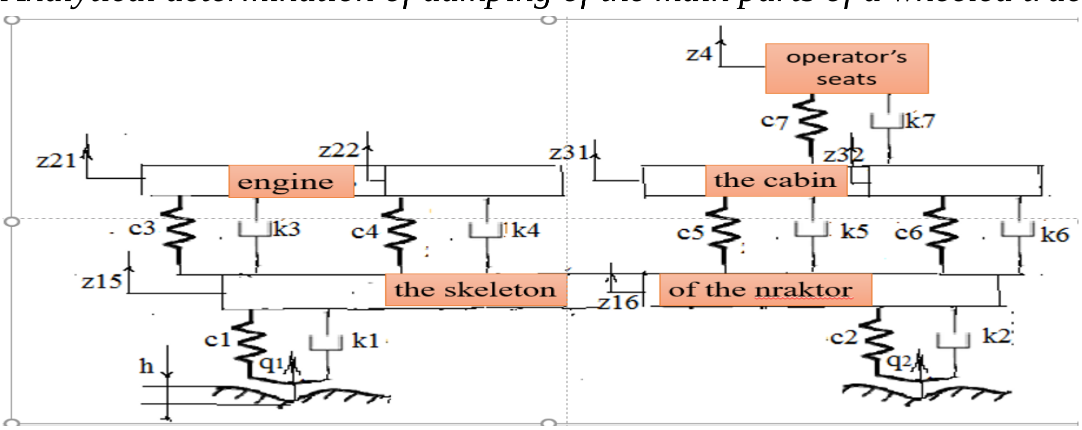

Figure 2 – Equivalent design diagram of damping of the main parts of a wheeled tractor

If $q_1 = h\cos(\omega_1 t)$, $q_2 = h\cos(\omega_2 t)$ то

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$$\frac{1}{3}m_1\ddot{z}_{15}+\left(k_1+\frac{2}{3}k_3+\frac{2}{3}k_4+1/3k_5+1/3k_6\right)\dot{z}_{15}+\left(c_1+\frac{2}{3}c_3+\frac{2}{3}c_4+1/3c_5+1/3c_6\right)z_{15}-\left(\frac{2}{3}k_3+\frac{2}{3}k_4\right)(\dot{z}_{21}+\dot{z}_{22})-(1/3k_5+1/3k_6)(\dot{z}_{31}+\dot{z}_{32})-\left(\frac{2}{3}c_3+\frac{2}{3}c_4\right)(z_{21}+z_{22})-(1/3c_5+1/3c_6)(z_{31}+z_{32})=k_1\dot{q}_1+c_1q_1=\omega_1k_1\mathrm{h}sin(\omega_1t)+c_1\mathrm{h}\cos(\omega_1\mathrm{t}),$$

$$\frac{2}{3}m_1\ddot{z}_{16}+\left(k_2+\frac{1}{3}k_3+\frac{1}{3}k_4+2/3k_5+2/3k_6\right)\dot{z}_{16}+\left(c_2+\frac{1}{3}c_3+\frac{1}{3}c_4+2/3c_5+2/3c_6\right)z_{16}-\left(\frac{1}{3}k_3+\frac{1}{3}k_4\right)(\dot{z}_{21}+\dot{z}_{22})-(2/3k_5+2/3k_6)(\dot{z}_{31}+\dot{z}_{32})-\left(\frac{1}{3}c_3+\frac{1}{3}c_4\right)(z_{21}+z_{22})-(2/3c_5+2/3c_6)(z_{31}+z_{32})=k_2\dot{q}_2+c_2q_2=\omega_2k_2\mathrm{h}sin(\omega_2t)+c_2\mathrm{h}\cos(\omega_2\mathrm{t}),$$

$$\frac{1}{2}m_2\ddot{z}_{21}+\left(k_3+\frac{1}{2}k_4\right)\dot{z}_{21}+\left(k_4+\frac{1}{2}k_3\right)\dot{z}_{22}+\left(c_3+\frac{1}{2}c_4\right)z_{21}+\left(\mathrm{c}_4+\frac{1}{2}\mathrm{c}_3\right)z_{22}-(2/3k_3+2/3k_4+1/3k_5+1/3k_6)\dot{z}_{15}-(1/3k_4+1/3k_3+2/3k_5+2/3k_6)\dot{z}_{16}-(2/3\mathrm{c}_3+2/3\mathrm{c}_4+1/3\mathrm{c}_5+1/3\mathrm{c}_6)z_{15}-(1/3\mathrm{c}_4+1/3\mathrm{c}_3+2/3\mathrm{c}_5+2/3\mathrm{c}_6)z_{16}=0,$$

$$\frac{1}{2}m_2\ddot{z}_{22}+\left(k_4+\frac{1}{2}k_3\right)\dot{z}_{22}+\left(k_3+\frac{1}{2}k_4\right)\dot{z}_{21}+\left(c_4+\frac{1}{2}c_3\right)z_{22}+\left(\mathrm{c}_3+\frac{1}{2}\mathrm{c}_4\right)z_{21}-(2/3k_3+2/3k_4+1/3k_5+1/3k_6)\dot{z}_{15}-(1/3k_4+1/3k_3+2/3k_5+2/3k_6)\dot{z}_{16}-(2/3\mathrm{c}_3+2/3\mathrm{c}_4+1/3\mathrm{c}_5+1/3\mathrm{c}_6)z_{15}-(1/3\mathrm{c}_4+1/3\mathrm{c}_3+2/3\mathrm{c}_5+2/3\mathrm{c}_6)z_{16}=0,$$

$$1/2m_3\ddot{z}_{31}+(k_5+1/2k_6)\dot{z}_{31}+(k_6+1/2k_5)\dot{z}_{32}+(c_5+1/2c_6)z_{31}+(c_6+1/2c_5)z_{32}-(2/3k_3+2/3k_4+1/3k_5+1/3k_6)\dot{z}_{15}-(1/3k_4+1/3k_3+2/3k_5+2/3k_6)\dot{z}_{16}-(2/3\mathrm{c}_3+2/3\mathrm{c}_4+1/3\mathrm{c}_5+1/3\mathrm{c}_6)z_{15}-(1/3\mathrm{c}_4+1/3\mathrm{c}_3+2/3\mathrm{c}_5+2/3\mathrm{c}_6)z_{16}-1/2k_4\dot{z}_4-1/2\mathrm{c}_4z_4=0,$$

$$1/2m_3\ddot{z}_{32}+(k_6+1/2k_5)\dot{z}_{32}+(k_5+1/2k_6)\dot{z}_{31}+(c_6+1/2c_5)z_{32}+(c_5+1/2c_6)z_{31}-(2/3k_3+2/3k_4+1/3k_5+1/3k_6)\dot{z}_{15}-(1/3k_4+1/3k_3+2/3k_5+2/3k_6)\dot{z}_{16}-(2/3\mathrm{c}_3+2/3\mathrm{c}_4+1/3\mathrm{c}_5+1/3\mathrm{c}_6)z_{15}-(1/3\mathrm{c}_4+1/3\mathrm{c}_3+2/3\mathrm{c}_5+2/3\mathrm{c}_6)z_{16}-1/2k_4\dot{z}_4-1/2\mathrm{c}_4z_4=0,$$

$$m_4\ddot{z}_4+k_4\dot{z}_4+\mathrm{c}_4z_4-k_4(\dot{z}_{31}+\dot{z}_{32})-\mathrm{c}_4(z_{31}+z_{32})=0.$$

Analytical determination of damping of the main parts of a wheeled tractor with multi-row relaxation

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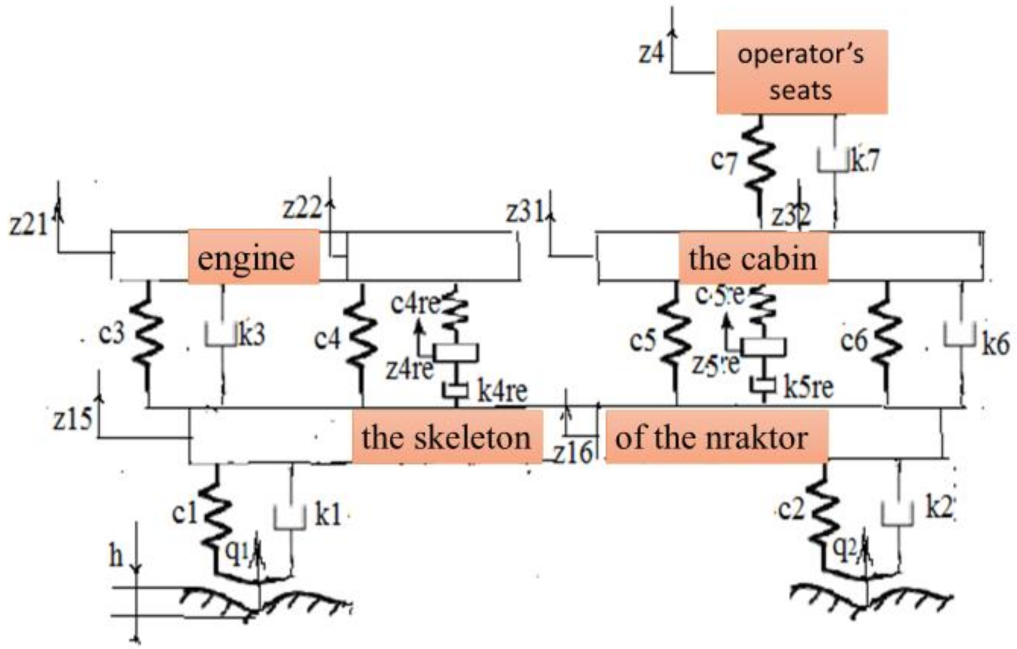

Figure 3 – Equivalent design scheme for damping the main parts of a wheeled tractor with multi-row relaxation

$$\frac{1}{3}m_1\ddot{z}_{15} + \left(k_1 + \frac{2}{3}k_3 + \frac{2}{3}k_{4re} + 1/3k_5 + 1/3k_{6re}\right)\dot{z}_{15} + \left(c_1 + \frac{2}{3}c_3 + \frac{2}{3}c_4 + 1/3c_5 + 1/3c_6\right)z_{15} - \left(\frac{2}{3}k_3 + \frac{2}{3}k_{4re}\right)(\dot{z}_{21} + \dot{z}_{22re}) - (1/3k_5 + 1/3k_{6re})(\dot{z}_{31} + \dot{z}_{32re}) - \left(\frac{2}{3}c_3 + \frac{2}{3}c_4\right)(z_{21} + z_{22re}) - (1/3c_5 + 1/3c_6)(z_{31} + z_{32re}) = k_1\dot{q}_1 + c_1q_1 = \omega_1 k_1 \mathrm{h}sin(\omega_1 t) + c_1\mathrm{h}\cos(\omega_1 \mathrm{t}),$$

$$\frac{2}{3}m_1\ddot{z}_{16} + \left(k_2 + \frac{1}{3}k_3 + 2/3k_5\right)\dot{z}_{16} + \left(c_2 + \frac{1}{3}c_3 + \frac{1}{3}c_{4re} + 2/3c_5 + 2/3c_{6re}\right)z_{16} - \left(\frac{1}{3}k_3 + \frac{1}{3}k_4\right)(\dot{z}_{21} + \dot{z}_{22re}) - (2/3k_5 + 2/3k_6)(\dot{z}_{31} + \dot{z}_{32re}) - \left(\frac{1}{3}c_3 + \frac{1}{3}c_{4re}\right)(z_{21} + z_{22re}) - (2/3c_5 + 2/3c_{6re})(z_{31} + z_{32re}) = k_2\dot{q}_2 + c_2q_2 = \omega_2 k_2 \mathrm{h}sin(\omega_2 t) + c_2\mathrm{h}\cos(\omega_2 \mathrm{t}),$$

$$\frac{1}{2}m_2\ddot{z}_{21} + k_3\dot{z}_{21} + \frac{1}{2}k_{4re}\dot{z}_{22re} + \left(c_3 + \frac{1}{2}c_4 + c_{4re}\right)z_{21} + \left(c_4 + c_{4re} + \frac{1}{2}c_3\right)z_{22re} - (2/3k_3 + 2/3k_{4re} + 1/3k_5 + 1/3k_{6re})\dot{z}_{15} - (1/3k_{4re} + 1/3k_3 + 2/3k_5 + 2/3k_{6re})\dot{z}_{16} - (2/3c_3 + 2/3c_4 + 1/3c_5 + 1/3c_6)z_{15} - (1/3c_4 + 1/3c_3 + 2/3c_5 + 2/3c_6)z_{16} = 0,$$

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$$\frac{1}{2}m_2\ddot{z}_{22} + \frac{1}{2}k_3\dot{z}_{21} + k_{4re}\dot{z}_{22re} + \left(c_4 + c_{4re} + \frac{1}{2}c_3\right)z_{22} + \left(c_3 + c_{4re} + \frac{1}{2}c_4\right)z_{21} - (2/3k_3 + 2/3k_{4re} + 1/3k_5 + 1/3k_{6re})\dot{z}_{15} - (1/3k_{4re} + 1/3k_3 + 2/3k_5 + 2/3k_{6re})\dot{z}_{16} - (2/3c_3 + 2/3c_4 + 1/3c_5 + 1/3c_6)z_{15} - (1/3c_4 + 1/3c_3 + 2/3c_5 + 2/3c_6)z_{16} = 0,$$

$$1/2m_3\ddot{z}_{31} + k_5\dot{z}_{31} + 1/2k_{6re}\dot{z}_{32re} + (c_5 + 1/2c_6 + c_{6re})z_{31} + (c_6 + c_{6re} + 1/2c_5)z_{32} - (2/3k_3 + 2/3k_{4re} + 1/3k_5 + 1/3k_{6re})\dot{z}_{15} - (1/3k_3 + 1/3k_{4re} + 2/3k_5 + 2/3k_{6re})\dot{z}_{16} - (2/3c_3 + 2/3c_4 + 1/3c_5 + 1/3c_6)z_{15} - (1/3c_3 + 1/3c_4 + 2/3c_5 + 2/3c_6)z_{16} - 1/2k_7\dot{z}_4 - 1/2c_7z_4 = 0,$$

$$1/2m_3\ddot{z}_{32} + k_{6re}\dot{z}_{32re} + 1/2k_5\dot{z}_{31} + (c_6 + 1/2c_5 + c_{6re})z_{32} + (c_5 + 1/2c_6 + c_{6re})z_{31} - (2/3k_3 + 2/3k_{4re} + 1/3k_5 + 1/3k_{6re})\dot{z}_{15} - (1/3k_{4re} + 1/3k_3 + 2/3k_5 + 2/3k_{6re})\dot{z}_{16} - (2/3c_3 + 2/3c_4 + 1/3c_5 + 1/3c_6)z_{15} - (1/3c_3 + 1/3c_4 + 2/3c_5 + 2/3c_6)z_{16} - 1/2k_7\dot{z}_4 - 1/2c_7z_4 = 0,$$

$$m_{4re}\ddot{z}_{22} = k_{4re}\dot{z}_{22re} + c_{4re}z_{22} - k_{4re}(\dot{z}_{21} + \dot{z}_{22})/2 + c_{4re}(z_{21} + z_{22})/2,$$

$$m_{6re}\ddot{z}_{32} = k_{6re}\dot{z}_{32re} + c_{6re}z_{32} - k_{6re}(\dot{z}_{61} + \dot{z}_{62})/2 + c_{6re}(z_{31} + z_{32})/2 - 1/2k_7\dot{z}_4 - 1/2c_7z_4.$$

Conclusions. The energy definitions of vertical vibrations with multiple and multi-level damping of mobile machines are analytically modeled, in particular analytically modeled as an example of the action of a wheeled tractor taking into account uneven roads. The influence of the relaxation element on the vibration-protective properties of the suspension with multiple and multi-level damping has been theoretically studied. multi-numerical and multi-level damping, These new analytical modeling will serve to determine the values of vibration and their damping of the complex design of modern mobile machines, which will improve the quality of design and technological work of newly created mobile machines.

BIBLIOGRAPHY

1. 1.Crosby, M.J. The Active Damper – a New Concept for Shock and Vibration Control // 43rd Shock and Vibration Bulletin, Part H, June, 1973. – P. 46–73.

2. Karnopp, D. C. Vibration control using semi-active forse generators // Transactions of the ASME. Journal of Engineering for Industry. – 1974. – Vol. 96. –P. 619–626.

ISSN (E): 2181-4570 ResearchBib Impact Factor: 6,4 / 2023 SJIF 2024 = 5.073/Volume-2, Issue-5

3. Furunzhiev, R.I. Study of some issues of damping vibrations of a car: abstract of thesis. dis. ...cand. tech. Sci. – Minsk, 1965. – 17 p.

4. Valasek M. Extended ground-hook – new concept of semi-active control of truck's suspension // Vehicle system dynamics. – 1997. – Vol. 27, No. 5–6. – P. 289–303.

5. Атаходжаева, Г. А., & Баратова, Д. С. (2017). Состояние качества жизни и толерантности к физической нагрузке больных с хронической сердечной недостаточностью II-III функционального класса при применении антагонистов минералокортикоидных рецепторов. Молодой ученый, (4), 235-239.

6. 5.Analysis of the principles of adjusting damping "skyhook" and "groundhook" in a car suspension / K.V. Chernyshev, I.M. Ryabov, A.V. Pozdeev, T.V. Pylinskaya // Truck. – 2018. – No. 10. – P.3–6.

7. Dmitriev, A.A., Chobitok V.A., Telminov A.V. Theory and calculation of nonlinear suspension systems for tracked vehicles. –Moscow: Mechanical Engineering, 1976. – 207 p.

8. Birger I.A., Mavlyutov R.R. Strength of materials: textbook. – Moscow: Nauka, 1986. – 560 p.

9. Amelchenko, N.P., Kim V.A. Suspension of the driver's seat of a wheeled tractor. – Mogilev: Belarus.-Rus. univ., 2006. – 180 p.

10. Sazonov I.S., Amelchenko, N.P., Kim V.A., Bilyk O.V., Yasyukovich E.I., Linnik D.A. A method for increasing the efficiency of a linear vibration protection system for a tractor driver. // Vestn. Belarus-Ros. un-ta. – 2011. – No. 2 (31). – pp. 96–99.

11. Tarasik V.P. Physical basis of the vibration damping process in a car suspension system. Bulletin of the Belarusian-Russian University. 2019. No. 1(62) – p.62-65.

12. International Journal of Advanced Research in Science, Engineering and Technology Vol. 10, Issue 1, January 2023 Copyright to IJARSET www.ijarset.com 20294 Mathematical Modeling of the Process of Machine Splitting of Nut Shells Bakhtiyor Abdullaevich Yunusov, Farkhod Matqurbonovich Matmurodov https://www.ijarset.com/upload/2023/january/ 04-matmurotov-05.pdf

ISSN (E): 2181-4570 ResearchBib Impact Factor: 6,4 / 2023 SJIF 2024 = 5.073/Volume-2, Issue-5

13. J.Ismatov. F M Matmurodov, J O Khakimov, J. X. Djalilov. Analytical modeling of mass transfer dynamics, velocity, heat transfer and enthalpy in a gas-liquid combustible mixture.

14. Farkhod Matmurodov, Bozorboy Sobirov, Sherzodbek Akhmedov, Isomiddin Tulanov, Esirgap Turapov, and Sayfidin Asamov. Numerical experiment of energy consumption and differences of effective use of mini-grapping and wide-grooving machine-tractor unit.