UDC 629.01 DOI: 10.30977/AT.2019-8342.2022.50.0.02

Parametric synthesis of car suspension

Alexandrov E.[1], Shapovalenko V.[1], Baidala V.[1]

[1]Kharkiv National Automobile and Highway University, Ukraine

Abstract. Problem. *When driving a vehicle with comfortable suspension settings, there is a high probability that such adjustments may, firstly, cause discomfort to the driver and passengers, and secondly, when cornering, there is a high probability that the vehicle will overturn. A stiffer suspension leads to discomfort when driving on bumps. To choose the optimal parameters of the car's suspension, it is necessary to take into account the various parameters of the car's suspension, its settings and the features of the road surface.* ***Goal.*** *The goal is solving the problem of choosing the values of the varied parameters of the car suspension – the coefficients of stiffness of the elastic elements and the average values of the damping coefficients of the shock absorbers, which provide a comfortable state of the driver and passengers while driving.* ***Methodology.*** *The approaches adopted in the work to solve the problems are based on the algorithmic method of parametric synthesis of dynamic systems.* ***Results.*** *The maximum values of generalized coordinates, speeds and accelerations of the sprung part of the car body were obtained, as well as the minimum values of functionalities; with the help of ratios, it is possible to estimate the values of weights of additive functionality based on MathCAD software package. With the help of the algorithmic method of solving the problem of parametric synthesis of a dynamic system it is possible to automate it. Analysis of the process with the specified coefficients allows to detect high efficiency of damping of vertical oscillations of the under-sprung part of the car body. The amplitude of the linear displacement of the center of the body mass does not exceed 0.02 m, and the amplitude of the generalized velocity of the centre of mass of the housing sprung part does not exceed 0.08 m/s^{-1}.* ***Originality.*** *The obtained parameters allow to minimize the time for selection of average values when designing the vehicle suspension.* ***Practical value.*** *The results can be recommended when studying the design features of vehicle suspensions. Thanks to the optimization of the MATLAB software package, modeling with different suspension parameters is possible.*

Key words: *suspension design, car suspension, smoothness, dynamic system.*

Introduction

The car is part of the system "car - driver - environment" (here the "environment" also means the road on which the car moves), and its properties are manifested in interaction with the elements of this system. Therefore, the significance of a certain performance property in the evaluation of the effectiveness of the car depends on the conditions in which this property is manifested, ie on the operating conditions. All performance characteristics are closely related, and the change in the design properties of the car, the improvement of one of the properties, inevitably affects the others. So, for example, stability improves at decrease in the center of weight of the car, however at the same time its passability can worsen. Traction and speed properties determine the maximum speed of the car, but it may be limited due to poor stability or lack of smoothness. Therefore, the final evaluation of the car is carried out taking into account the whole set of performance properties. The smoothness of the car when moving on roads with uneven surfaces depends on the component characteristics of the car, the parameters of the suspension and tires.

Smoothness of the car is a set of its properties that characterize the possibility of prolonged movement on rough roads in the range of operating speeds without disturbing the discomfort and fatigue of the driver and passengers, damage to cargo and the occurrence of excessive dynamic loads in the element's car.

The main indicators of smoothness are the levels of vibration load of the driver, passengers, cargo and characteristic elements of the chassis and body. Estimation of the level of vibration load is performed on the basis of root mean square values of vibration accelerations (vibration accelerations) or vibration velocities (vibration velocities) in the vertical and horizontal directions.

When the wheels of a car hit road bumps, there are dynamic forces that are transmitted to all its elements, the action and the passengers in the car, as well as the goods transported. The main elements that protect the car from the dynamic effects of the road and reduce vibrations and vibrations to an acceptable level are the suspension and tires.

The oscillations of the car caused by the unevenness of the road, usually lead to the deterioration of some of its operational properties, the worse the quality of the road the worse the smoothness of the car. In particular, due to the need to limit speeds, which leads to failures due to high dynamic loads in various parts of the car, the deterioration of smoothness leads to reduced car productivity, increased costs for maintenance and repairs, which ultimately, leads to an increase in the cost of operation of the car. Rapid driver fatigue in cars with poor smoothness significantly affects traffic safety. The acceptability of the level of oscillations that occur in cars during their movement on the road, we are primarily assessed by the effects of these oscillations on the driver and passengers. There are many works aimed at finding gauges and sensors that are used to assess the smoothness of cars. However, as a result of these works, no generally accepted indicators and norms have been developed that would allow a comprehensive assessment of the smooth running of various cars.

An approximate assessment of the smoothness of the course can be made by comparing the measurements of oscillations that occur during the movement of the car on real roads, with the corresponding measurements that characterize the oscillations of man in the process of walking. A person gets used to such oscillations from childhood, and if the indicators of his oscillations in the car do not exceed those occurring when walking, the smoothness of the car will be acceptable.

The estimation of these oscillations can be performed according to two main parameters - frequency and rms vertical acceleration. Scientists consider the limits of oscillations equal to 1.2 - 2 Hz to be the most acceptable. RMS vertical accelerations should not exceed: for comfort - 0.1 g; for the limit of comfortable driving - 0.25 g; at short action - 0,40 g.

Analysis of publications

The task of synthesis of the car suspension system, which corresponds to the choice of such defined parameters, suspension elements, so that perturbation of the suspension part of the body when moving the car on a random traffic surface with specified stochastic characteristics meets certain requirements.

In the first scientific publications on the smoothness of vehicles, the choice of parameters of springs and shock absorbers of vehicles was made by analyzing their impact on the dynamic processes of forced oscillations of the sprung part of the body when hitting a step inequality [1]. In works [2-8] for research of smoothness of the course of wheeled and caterpillar vehicles their disturbance at rectilinear movement on a surface of a sinusoidal profile is found. Attention was paid to the study of resonant phenomena, in which the perturbations acting on the sprung part of the body reach a maximum, and the values of variable parameters of the suspension were selected from the resonance conditions in the operating range of the basic speed. In [9-12] the problem of stochastic modeling of the random surface of the vehicle is considered, and the choice of variable parameters of the suspension is made on the condition of minimal linear and angular deviations of the sprung part of the body from the state of equilibrium.

In [13] the basics of the algorithmic method of parametric synthesis of dynamic systems based on the use of the Optimization Toolbox procedure of the MATLAB software package or the Minimize procedure of the MathCAD software package are presented. Using the algorithmic method, the solution of the problem of parametric synthesis of a dynamic system can be fully automated, including the choice of weights of the additive functional of the quality of the dynamic system, which reflects a set of requirements for the dynamic system.

Purpose and Tasks

The aim is to select the optimal parameters of the car suspension and automate the process of selection of these parameters using the algorithmic method of parametric synthesis of dynamic systems. The process with these coefficients allows to detect high efficiency of damping of vertical oscillations of the sprung part of the car body.

Parameters of the values of the generalized coordinates, speeds and accelerations of the sprung part of a car body, and also the minimum values of functionalities will allow to minimize time for selection of average values at designing of a suspension bracket of the vehicle.

Measuring the zone of soil density when it is punctured by an asymmetric cylindrical tip

The system of differentials, which describe the restless motion of the sprung, parts of the car body, can also look [9]:

$$\ddot{z}_к(t) = -\frac{2gq\delta}{G_к}\dot{z}_к(t) - \frac{2grc}{G_к}z_к(t) - -\frac{g\delta}{G_к}\sum_{j=1}^{2q} l_j\dot{\varphi}_к(t) - \frac{gc}{G_к}\sum_{i=1}^{2r} l_i\varphi_к(t) + F_z(t), \quad (1)$$

$$\ddot{\varphi}_к(t) = -\frac{\sum_{j=1}^{2q} l_j^2}{I_y}\delta\dot{\varphi}_к(t) - \frac{\sum_{i=1}^{2r} l_i^2}{I_y}c\varphi_к(t) - -\frac{\sum_{j=1}^{2q} l_j}{I_y}\delta\dot{z}_к(t) - \frac{\sum_{i=1}^{2r} l_i}{I_y}cz_к(t) + F_\varphi(t). \quad (2)$$

The right-hand sides of the differential equations are generalized forces acting on the sprung part of the car body from the side of the road bumps. The simulation model of external perturbations acting on the sprung part of the body from the road side is the microprofile of the traffic surface on the right and left sides of the car, it is assumed to be the same. Assume that the car is moving on a certain type of soil with known characteristics at a con-stant speed. In this case, random oscillations of the sprung part of the body can be considered stationary, flowing over time relatively uniformly.

In [10, 11], the correlation function and spectral density of a random process h(t) are proposed to be represented as:

$$K(\tau) = De^{-\alpha v\tau}\cos\beta v\tau, \quad (3)$$

$$S(\omega) = D\frac{2\alpha v(\alpha^2v^2 + \beta^2v^2 + \omega^2)}{\omega^4 + 2\omega^2v^2(\alpha^2 - \beta^2) + v^4(\alpha^2 + \beta^2)^2}, \quad (4)$$

where h (t) is the value of the variance of the random process; correlation coefficients. Numerical values for different road conditions are given in Table 1.

Table 1 Numerical values of correlation coefficients and variance of pave-ment irregularities

Type / Coeff.	Asphalt road	Bridge paving	Dirty road
α, $m^{-1}\cdot c$	0.22	0.32	0.47
β, $m^{-1}\cdot c$	0.44	0.64	0.94
D, m^2	$0.144\cdot10^{-3}$	$0.576\cdot10^{-3}$	$0.11\cdot10^{-1}$

where ρ_{max} is the maximum density of the soil in the side wall of the hole, which acts when $x = 0$ and is in the opposite direction from the bevel of the front surface of the cylinder. In [11] the concept of forming a dynamic link is introduced, which means a link with a transfer function, the input of which is given a single uncorrelated "white noise", and the output is a stationary random process h (t), and it is also shown that for the process h (t) with stochastic characteristics (7) and (8) the transfer function of the forming dynamic link is written in the form:

$$W(\overline{\overline{S}}) = \frac{L\{h(t)\}}{L\{\xi(t)\}} = \frac{K}{T_1^2\overline{\overline{S}}^2 + T_2\overline{\overline{S}} + 1}, \quad (5)$$

the values of time constants and gain factors of the forming dynamic link for different road conditions and different speeds of the car are shown in Table 2.

Table 2 Values of the parameters of the forming dynamic link

Speed	Road type		
	Asphalt road	Bridge paving	Dirty road
5 ms^{-1}	K = 0.007m T_1 = 0.3 c T_2 = 2.3 c	K = 0.01m T_1 = 0.2 c T_2 = 1.6 c	K = 0.04m T_1 = 0.2 c T_2 = 0.9 c
10 ms^{-1}	K = 0.005m T_1 = 0.1 c T_2 = 1.6 c	K = 0.008m T_1 = 0.1 c T_2 = 1.1 c	K = 0.03m T_1 = 0.1 c T_2 = 0.6 c
20 ms^{-1}	K = 0.003m T_1 = 0.08 c T_2 = 1.1 c	K = 0.006m T_1 = 0.06 c T_2 = 0.8 c	K = 0.02m T_1 = 0.05 c T_2 = 0.4 c

The differential equation of the dynamic link is written as:

$$T_1^2\ddot{h}(t) + T_2\dot{h}(t) + h(t) = K\xi(t). \quad (6)$$

As a result, the simulation model of external influences acting on the sprung part of the body when moving the car on a random surface is a set of differential equations (10).

Ideal for the car would be a suspension that would provide minimal linear and angular deviations of the sprung body from their values in a state of static equilibrium and minimal dynamic effects on the driver and passengers. Formalization of these requirements leads to the requirement of a minimum of the integral quadratic functional:

$$I(\alpha)=\frac{M}{(j=1,N)}\left\{\int_0^T\left[\beta_1^2 z_{кj}^2(t)+\beta_2^2\dot{z}_{кj}^2(t)+\right.\right.$$
$$\left.\left.+\beta_3^2\varphi_{кj}^2(t)+\beta_4^2\dot{\varphi}_{кj}^2(t)+\beta_5^2\ddot{z}_{кj}^2(t)+\beta_6^2\ddot{\varphi}_{кj}^2(t)\right]dt\right\}\cdot(7)$$
$$\cdot\left(\frac{\pi D^2}{4}+DS_p\right)\rho_{ns}=D\int_0^{S_p}\rho_x dx.$$

Let's make the characteristic equation of a suspension bracket of the car:

$$\det\left[A(\alpha)-es\right]=0. \quad (8)$$

Substitute a matrix into the equation and opening the obtained determinant we obtain the coefficients of the characteristic equation associated with the coefficients of the differential equations.

Algorithmic method for solving problems of parametric synthesis

The problem of parametric synthesis of the car suspension system formulated above belongs to the class of nonlinear programming problems, in which the objective function is calculated according to the following rule. Introducing new components $x_5(t)=h(t)$ $x_6(t)=\dot{h}(t)$ in a dynamic system.

The first step in solving the problem of parametric synthesis of the car suspension is to build a set of allowable values of the parameters of the sus-pension, which vary G_α, you must select a value $\delta_{\max}$ and $C_{\max}$, which limit the area G_α. At the stage of developing a car project, this stage does not cause significant difficulties.

The second stage is the choice of weights of the additive integral quadratic functional, the algorithm of which is as follows. The functional is presented in the form of a balanced sum of private functionals. Through $I_z^*(\alpha), I_{\dot{z}}^*(\alpha), I_\varphi^*(\alpha), I_{\dot{\varphi}}^*(\alpha), I_{\ddot{z}}^*(\alpha), I_{\ddot{\varphi}}^*(\alpha)$ denote the minimum values of private functionals obtained by solving the problem of parametric synthesis, provided that each of the private functionals is minimized separately. The solution is to find the minimum for the $\alpha\in G_\alpha$ functional $I_z(\alpha)$. Any of the known numerical methods for solving the problem of nonlinear programming, including the most common Nelder-Mead method, implemented in the software Optimization Toolbox and Minimize in interactive environments MATLAB and MathCAD, respectively, allows you to find the closest to the starting point, $\alpha\in G_\alpha$ local minimum of functionality. Integral quadratic func-tional has a single minimum on many variable system parameters. Let us denote the minimum value of the private functional at the point $\alpha_z^*\in G_\alpha$ through I_z^*. We will also find the points $\alpha_{\dot{z}}^*\in G_\alpha$, $\alpha_\varphi^*\in G_\alpha$, $\alpha_{\dot{\varphi}}^*\in G_\alpha$, $\alpha_{\ddot{z}}^*\in G_\alpha$, $\alpha_{\ddot{\varphi}}^*\in G_\alpha$ and values of the corresponding functional points $I_{\dot{z}}^*$, I_φ^*, $I_{\dot{\varphi}}^*$, $I_{\ddot{z}}^*$, $I_{\ddot{\varphi}}^*$.

Having obtained the values of the weights of the additive functional, we move on to the third stage - finding the optimal vector of the parameters of the suspension, varying $\alpha_z^*\in G_\alpha$. This is done using the software products Optimization Toolbox and Minimize similar to the optimization of private functionality. As an example, consider the problem of parametric synthesis of the undercut system of the car, the values of mass, inertial and geometric characteristics of which are: $G_к=17\cdot10^3 H$; $I_y=3{,}7\cdot10^3 H$;

$r=2$; $q=2$; $\alpha=\sum_{i=1}^4 l_i=-0{,}076\,m$;

$\mu=\sum_{i=1}^4 l_i^2=8{,}563\,m^2$; $\beta=\sum_{j=1}^4 l_j=-0{,}068\,m$;

$\nu=\sum_{j=1}^4 l_j^2=8{,}539\,m^2$.

Values $\delta_{\max}$ and $c_{\max}$ area G_α selected equal: $C_{\max}=30\cdot10^3 H\cdot m^{-1}$; $\delta_{\max}=8\cdot10^3 H\cdot m^{-1}\cdot c$.

Taking into account the given values of the parameters of the suspension system of the car, the coefficients of the characteristic equation for the example, take the following form:

$a'_{zz}=-2{,}308\cdot10^{-3}\delta$; $a_z z=-2{,}308\cdot10^{(-3)}s$;

$a'_{z\varphi}=0{,}039\cdot10^{-3}\delta$; $a_{z\varphi}=0{,}044\cdot10^{-3}s$;

$a'_{\varphi\varphi}=-2{,}308\cdot10^{-3}\delta$; $a_{\varphi z}=0{,}0205\cdot10^{-3}\ s$.

Substitute into the characteristic equation and make a replacement in it. Let's separate the real and imaginary parts and equate them to zero.

We write down the relations for the boundary of the stability region of a dynamic system in the plane of varying parameters (δ, c) c=1,65δ^2.

Let us distinguish the region of stability in the plane (δ, c) bounded by a parabola and the lines $c_{\max}$ and $\delta_{\max}$. The shading is directed inside the area of stability. Thus, the area has the form shown in Fig.1.

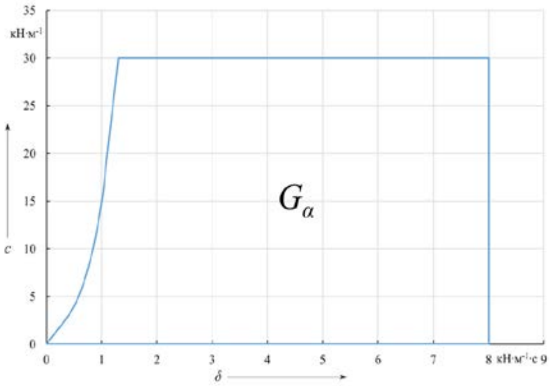

Fig. 1 The range of parameters of the suspension, which varies

By choosing the values of the varied parameters of the suspension, corresponding to different points of their allowable values in the field, you can estimate the maximum values of the generalized coordinates on the solutions of the system.

In the example, the values of these coordinates are: z_{kmax}=0,15 m; $\varphi_{\text{кmax}}$ =0,15; $\dot{z}_{\text{kmax}}$=0,45 ms^{-1}; $\dot{\varphi}_{\text{кmax}}$ =0,42 s^{-1}; $\ddot{z}_{\text{kmax}}$=2 ms^{-2}; $\ddot{\varphi}_{\text{кmax}}$ =0,42 s^{-2}.

The next stage in the process of parametric synthesis of the car pi drive is the search for the minimum values of the functionalities using the software products Optimization Toolbox or Minimize. In the assessment of private functionalities, the condition was introduced that the movement of cars near the asphalt concrete at a speed 10 ms^{-1}. Using the obtained maximum values of generalized coordinates, velocities and accelerations of the sprung part of the car body, as well as the minimum values of private functionals, with the help of relations we estimate the values of weights of the additive functional. Finally, the last stage of the process of parametric synthesis is the search in the Ga region for the minimum of the additive integral quadratic functional. Minimizing the value using the algorithm described above x_7 (T, c, δ), for the example under consideration, we obtain the optimal values of the parameters of the suspension δ*=4,012·103 $H{\cdot}m^{-1}{\cdot}c$ and c*=15,01·103 $H{\cdot}m^{-1}$.

In Figure 2 shows a cross section of the function I (c, δ) by a variable value δ and at c=c*.

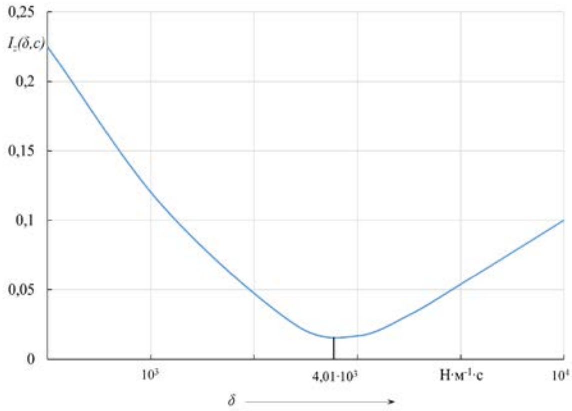

Fig. 2 The intersection of the function I (c, δ) on the variable value of δ

In fig. 3 shows random processes of coordinate change $x1(t)=zK(t)$ and $x2(t)=zK(t)$ when moving the car on the asphalt pavement at speed 10 $m{\cdot}s^{-1}$ with the selected optimal values of the parameters of the suspension system. The analysis of processes allows to draw a conclusion about high efficiency of damping of vertical oscillations of the sprung part of a car body. The amplitude of the linear displacement of the center of mass of the body does not exceed 0,02 m, and the amplitude of the generalized oscillation speed of the center of mass of the sprung part of the housing does not exceed 0,08 $m{\cdot}s^{-1}$.

Conclusion

The suspension system of the car should not be too rigid to avoid increased dynamic effects on the driver, passengers and goods transported, and should not be too soft to avoid seasickness in the driver and passengers.

The formalization of the requirements for the car suspension leads the solution of the problem of parametric synthesis of the suspension to explain the minimum of additive integration quadratic functional with unknown weights calculated by the mathematical model of perturbed motion of the sprung part of the car body on the software product Optimization Toolbox or Minimize, with simultaneous estimation of values of weights of the minimized additive functionality.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

1. Тарасик, В. П. (2019). Фізичні основи процесу демпфування коливань в системі підресорювання автомобіля. Вісник Білорусько-Російського університету №1(62). Tarasik V., (2019). Fizichni osnovi procesu dempfuvannya kolivan' v sistemi pidresoryuvannya avtomobilya. [Physical basics of the process of damping oscillations in the system of vehicle suspension] Visnik Bilorus'ko-Rosijs'kogo universitetu №1(62). [in Ukraine].
2. Нгуен Х. Т., (2019). Исследование влияния параметров системы подвески и условий эксплуатации на плавность движения автомобиля. Вестник Машиностроение и машиноведение №19. Nguyen H. (2019). Issledovanie vliyaniya parametrov sistemy podveski i uslovij ekspluatacii na plav-nost' dvizheniya avtomobilya [Study of the influence of the parameters of the suspension system and operating conditions on the smoothness of the vehicle] Vestnik Mashinostroenie i mashinovedenie №19. [in Russian].
3. Неволин Д. Г. (2018). Повышение устойчивости, управляемости и плавности хода автопоездов. Сборник статей. Автомобильная индустрия №3. Nevolin D. (2018). Povyshenie ustojchivosti, upravlyaemosti i plavnosti hoda avtopoezdov [Improvement of stability, controllability and ride trains due to improvements] Sbornik statej. Avtomobil'naya industriya №3. [in Russian].
4. Горелов В. А. (2019). Методика прогнозирования ресурса торсионных валов систем подрессоривания транспортных машин. Сборник трудов. Машиностроение и транспорт: теория, технологии, производство №4 (127). Gorelov V. (2019). Metodika prognozirovaniya resursa torsionnyh valov sistem podressorivaniya transportnyh mashin [Method of evaluation of service life of torsional shafts within the suspension of transport vehicles] Sbornik trudov. Mashinostroenie i transport: teoriya, tekhnologii, proizvodstvo №4 (127). [in Russian].
5. Жилейкин М. М. (2019). Математические модели транспортных систем Сборник. Инновации и инвестиции №8. Zhileikin M. (2019). Matematicheskie modeli transportnyh sistem [Mathematical models of vehicle systems] Sbornik. Innovacii i investicii №8. [in Russian].
6. Тарасик В. П., Пузанов О. В. (2018). Оптимизация параметров подвески легкового автомобиля. Вестник. Белорусско-Российского университета №2(59). Tarasik V., Puzanova O. (2018) Optimizaciya parametrov podveski legkovogo avtomobilya [Optimization of the suspension parameters of a passenger car]. Vestnik. Belorussko-Rossijskogo universiteta №2(59). [in Russian].
7. Степанов Е. В. (2019). Оценка плавности хода автомобиля с гидроэластомерной подвеской. Труды НГТУ им. Р.Е. Алексеева №3(130). E.V. Stepanov (2019). Ocenka plavnosti hoda avtomobilya s gidroelastomernoj podveskoj [Evaluation of car ride comfort with hydroelastomer suspension] Trudy NGTU im. R.E. Alekseeva №3(130). [in Russian].
8. Александров Е. Е. (2014). Математическое моделирование, системный анализ и синтез динамических систем. Учебное пособие. Харьков. НТУ «ХПИ». Aleksandrov E. E. (2014). Matematicheskoe modelirovanie, sistemnyj analiz i sintez dinamicheskih sistem. [Mathematical modeling, system analysis and synthesis of dynamic systems]. Uchebnoe posobie. Har'kov. NTU «HPI». [in Russian].
9. Александрова Т. Е. (2013). О единственности решения задачи параметрического синтеза линейной динамической системы с интегральным квадратичным критерием оптимальности. Весник Системы обработки информации. №7(114). Aleksandrova T. (2013). O edinstvennosti resheniya zadachi parametricheskogo sinteza linejnoj dinamicheskoj sistemy s integral'nym kvadratichnym kriteriem optimal'nosti. [On the uniqueness of the solution of the problem of parametric synthesis of a linear dynamical system with an integral quadratic optimality criterion] Vesnik Sistemy obrabotki informacii. №7(114). [in Russian].
10. Александрова Т. (2004). Выбор оптимизируемого функционала в задачах параметрического синтеза систем стабилизации. Весник НТУ «ХПИ». Серия. Транспортное машиностроение №29(1305). Aleksandrova T. (2004). Vybor optimiziruemogo funkcionala v zadachah parametricheskogo sinteza sistem stabilizacii [The Choice of the Optimized Functional in Problems of Parametric Synthesis of Stabilization Systems]. Vesnik NTU «HPI». Seriya. Transportnoe mashinostroenie №29(1305). [in Russian].

Evgeniy Aleksandrov[1], D.Sci. (Eng.) Prof. of the Department of automobiles named after A. Gredeskula, e-mail: aleksandrov.ye.ye@gmail.com, Phone.: +38 (050) 625-68-40,
ORCID: https://orcid.org/0000-0001-7525-6383,

Vladyslav Shapovalenko[1] Assistant, Department of automobiles named after A. Gredeskula, e-mail: vladislav-shapovalenko@ukr.net,
Phone.: +38-097-161-77-40,
ORCID: https://orcid.org/0000-0002-5770-0740.

Baidala Vladyslava[1] postgraduate student of the Department of Mechanical Engineering and Machine Repair Technology, e-mail:vlada.baidala@gmail.com
Phone.: +38(095)355-88-90,
ORCID: https://orcid.org/ 0000-0001-8836-6784.

Параметричний синтез підвіски автомобіля

Анотація. Проблема. *Під час руху транспортного засобу з комфортними налаштуваннями підвіски велика ймовірність того, що такі налаштування можуть привести по перше до дискомфорту водія та пасажирів по друге в поворотах є велика ймовірність перевороту автомобіля. Більш жорстка підвіска призводить до дискомфорту під час руху по дорожніх нерівностям. Для вибору оптимальних параметрів підвіски автомобіля необхідно враховувати різні параметри підвіски автомобіля її налаштування та особливості дорожнього покриття.* ***Ціль.*** *Вирішення задачі вибору значень варійованих параметрів підвіски автомобіля - коефіцієнтів жорсткості пружних елементів і середніх значень коефіцієнтів демпфування амортизаторів, які забезпечують комфортний стан водія і пасажирів під час руху транспортного засобу.* ***Методологія.*** *Підходи прийняті в роботі для рішення поставлених задач ґрунтуються на алгоритмічному методі параметричного синтезу динамічних систем.* ***Результати.*** *Отримані максимальні значення узагальнених координат, швидкостей і прискорень підресореної частини корпусу автомобіля, а також мінімальні значення функціоналів, за допомогою співвідношень можливо оцінити значення вагових коефіцієнтів адитивного функціоналу заснованого на використанні процедури Optimization Toolbox програмного пакета MATLAB або процедури Minimize програмного пакету MathCAD. За допомогою алгоритмічного методу рішення задачі параметричного синтезу динамічної системи можливо повністю автоматизувати. Аналіз процесу з заданими коефіцієнтами дозволяє виявити високу ефективність демпфірування вертикальних коливань підресореної частини кузова автомобіля. Амплітуди лінійного переміщення центру мас корпусу не перевищує 0,02 м, а амплітуда узагальненої швидкості коливань центру мас підресореної частини корпусу не перевищує величини 0,08 м·с-1.* ***Оригінальність.*** *Отримані параметри дозволяють мінімізувати час на підбір середніх значень при проектуванні підвіски транспортного засобу.* ***Практична цінність.*** *Результати можуть бути рекомендовані під час вивчення особливостей проектування підвісок транспортних засобів. Завдяки оптимізації програмного пакета MATLAB можливе моделювання при різних параметрах підвіски.*

Ключові слова: *проектування підвіски, підвіска автомобіля, плавність руху, динамічна система.*

Александров Євген Євгенович [1], д.т.н., проф. каф. автомобілів ім. А.Б. Гредескула, e-mail: aleksandrov.ye.ye@gmail.com,
тел. +38 (050) 625-68-40,
ORCID: https://orcid.org/0000-0001-7525-6383
Шаповаленко Владислав Олексійович [1], асистент, каф. автомобілів ім. А.Б. Гредескула, e-mail vladislav-shapovalenko@ukr.net,
тел.: +38-097-161-77-40,
ORCID: https://orcid.org/0000-0002-5770-0740.
Байдала Владислава Юріївна [1], аспірант кафедри технології машинобудування та ремонту машин, e-mail: vlada.baidala@gmail.com,
тел.: +38-095-355-88-90,
ORCID: 0000-0001-8836-6784.
[1]Харківський національний автомобільно-дорожній університет, вул. Ярослава Мудрого, 25, м. Харків, Україна, 61002.