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ABOUT A POSSIBILITY OF A GYROSCOPIC STABILISATION OF THE VIBROISOLATION SYSTEM

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Summary: *It is analyzed a gyroscopic stabilization of the vibroisolation system of an ambulance couch. There is deduced the extended system with seven degrees of freedom and its cyclic first integrals.*

1. Introduction

Up till now the analyzed vibroisolation system of the ambulance couch (parallelogram + double Cardan suspension) with three degrees of freedom (kinematic schema see Fig. 1) has been realized by standard pneumatic springs (see [1], [2], [3]). By the general position of the human body on the couch is the equilibrium state reached with the help of the program controlling of the pressure in all the springs. If we apply accessible wave springs, the natural frequencies are higher then we need (2.2, 3.8 and 4.2) Hz. According to the fact, that the first natural frequency of the undercarriage is in interval 1.5-2Hz, the applications of additional volumes is necessary (see. [3]). However, there is a difficult problem in their design realization (specially their placement near the springs). Owing to our experience, there is a possibi- lity to reach a good vibroisolation – the application of the gyroscopic stabilization (see [6], [7], [8]) of the second Cardan frame.

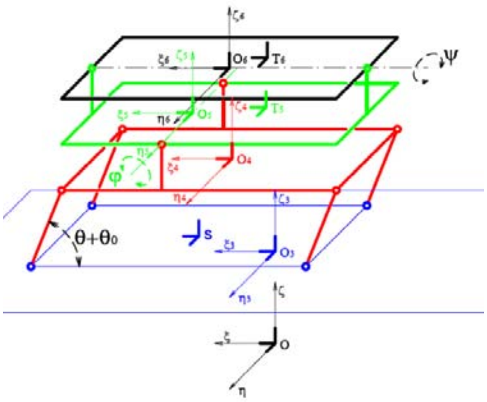

Fig. 1

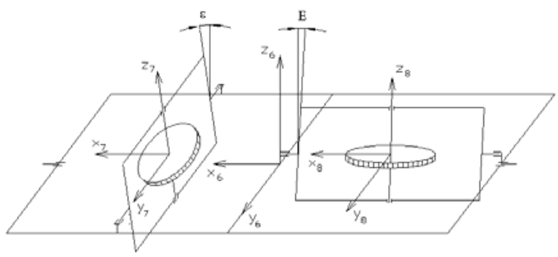

Fig. 2

2. Preliminary consideration

There are two possibilities of this stabilization – with vertical (see Fig. 2) or horizontal axes of gyroscopes.

The original system (three differential equations of the second order for the moment equilibrium and ten of the first order for equilibrium of the mass flows in the entries of air springs

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and additional volumes) will be extended of four differential equation of the second order for moment equilibrium on the axes of precessions frames and of gyroscopes.
We come from relations for absolute velocity (deduced in [1]). We introduce the further coordinates: the angles γ resp. Γ of own rotation of the first resp. second gyroscope and the angle deflections ε resp. E of their precession frames. We suppose that the both frames and also both gyroscopes are statically and dynamically balanced. According to the fact that the basic decomposition is made in the mass centers of gyroscopes, resp. frames the kinetic energy (see Königs theorem) will be

$$T_{rg} = \sum_{j=7}^{10} T_j \qquad T_j = \frac{1}{2} m_j \vec{v}_{j3}^2 + \frac{1}{2}\left(J_{jx}\Omega_{jx}^2 + J_{jy}\Omega_{jy}^2 + J_{jz}\Omega_{jz}^2\right) \quad j = 7,8,9,10 \tag{1}$$

If we include only gravity forces in the potential energy will be for potential energy

$$U_{rg} = g\sum_{j=7}^{10} m_j z_{0j} \qquad U_j = m_j g \cdot z_{0j} \qquad j = 7,8,9,10 \tag{2}$$

3. Lagrange equations of the second sort and cyclic first integrals

We introduce vector of general coordinates $\vec{q}(\vartheta,\varphi,\psi,\varepsilon,\mathrm{E},\gamma,\Gamma)$ and we denote M_{pi} moment of pneumatic springs, M_{di} of hydraulic dampers, M_{ri} moments of passive resistances, M_{ki} moments of radial correction and M_{gi} driving moments of gyroscopes. The Lagrange equations will be

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{q}_i} - \frac{\partial T}{\partial q_i} + \frac{\partial U}{\partial q_i} = M_{pi} + M_{di} + M_{ki} + M_{ri} \quad i = 1..5 \tag{3}$$

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{q}_i} - \frac{\partial T}{\partial q_i} + \frac{\partial U}{\partial q_i} = M_{gi} + M_{ri} \qquad i = 6..7 \tag{4}$$

After the activation of gyroscopes, the moment M_{ri} is balanced with driving moment M_{gi} during a few seconds. According to the fact, that the potential and kinetic energy are independent of the angle coordinates γ and Γ, the first integrals relevant to these both cyclic coordinates are

$$J_9(\dot{\gamma} + \dot{\psi}\sin\varepsilon - \dot{\varphi}\cos\varepsilon\sin\psi) = H_9 \quad J_9(\dot{\Gamma} - \dot{\varphi}\sin(\psi + \mathrm{E}) = H_{10} \tag{5}$$

4. Linearised system

If we restrict the on the small angles and small angle velocities, we can make a trigonometric and power linearization and such system we can write in the matrix form

$$\mathbf{A}\ddot{\vec{q}} + (\mathbf{B}_0 + \mathbf{B}_1(t) + \mathbf{G})\dot{\vec{q}} + (\mathbf{C}_0 + \mathbf{C}_1(t) + \mathbf{K})\vec{q} = \vec{E}_0 + \vec{E}_1(t) \tag{6}$$

where is $\mathbf{A}$ matrix of mass, $\mathbf{B}_0$ matrix of damping, $\mathbf{B}_1(t)$ matrix of parametric excitation, $\mathbf{C}_0$ matrix of stiffness, $\mathbf{C}_1(t)$ matrix of parametric excitation, $\vec{E}_0$ vector of gravity forces and moment of pneumatic springs, $\vec{E}_1(t)$ vector of external kinematic excitation, $\mathbf{G}$ anti-symmetrical matrix of the gyroscopic effect and $\mathbf{K}$ is antisymmetrical matrix of the radial correction.

5. Equilibrium state

We adjust this state at the horizontal position of the loading area of the automobile $(\alpha = 0, \beta = 0, \zeta = 0)$. It is defined in such a way that the static components of the gravity moment (given by null-members in the Taylor expansion) are balanced with the help of the appropriate position controllers by means of static components of pneumatic springs moments. This state is expressed by the condition:

$$\vec{E}_0 = 0 \tag{7}$$

6. Characteristic equation of the system and some results of numerical experiments

We demand, that the real parts of the all roots of characteristic equation will be negative

$$Det\ \left[\mathbf{A}\cdot\lambda^2+\left(\mathbf{B_0}+\mathbf{G}\right)\cdot\lambda+\left(\mathbf{C_0}+\mathbf{K}\right)\right]=0 \qquad (8)$$

We will change the angle velocity of gyroscopes and the parameters of radial correction. The middle value is 20.000 revolutions per minute, this is $\omega_g = 20000\,\frac{2\pi}{60}\left[\frac{rad}{s}\right]$.

For the initial numerical experiment there was choused a rotor of gyroscope from a plain instrument (Jg = 0,00834 kg.m^2, Je = 0,00556 kg.m^2, f = 20.000 revolutions per minute, this frequency was change in interval 2.000-20.000-200.000), the parameters of radial correction are changed in interval 0,2 – 2 Nm.rad^{-1}. There was analyzed the dependency of the roots of the characteristic equation of this parameters. Above all was demonstrated, that the all roots are complex and it is possible to distribute them in to two groups: the first three doublets of the roots correspond with roots of the original system without gyroscopes, the second group is formed by two doublets of roots with correspond wit a precession motion of the gyroscope frames.

1) By growth of the turning frequency the imaginary parts of first and second roots increase, the real part remains constant (see Fig.3 – 4). The third root remains practically constant (see Fig.5).

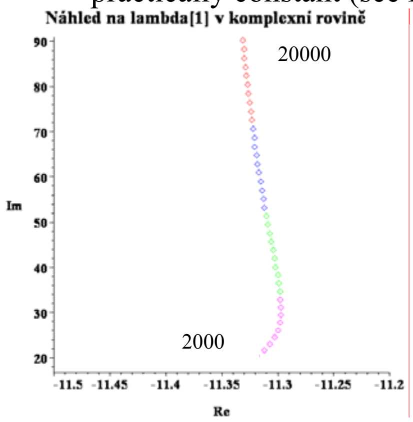


Fig.3a

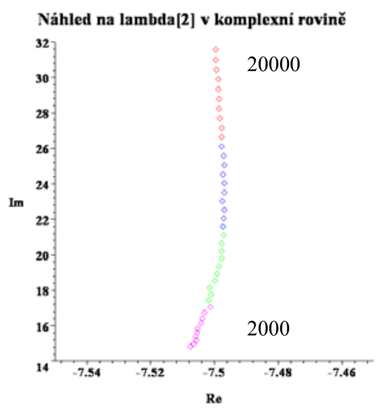


Fig.4a

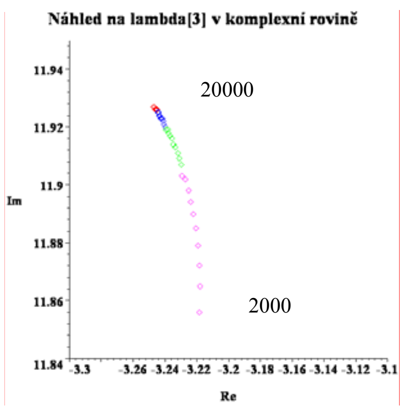


Fig.5a

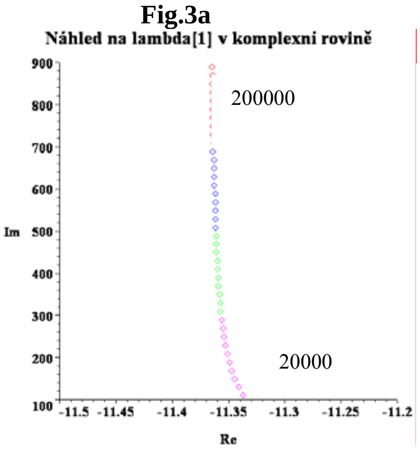


Fig.3b

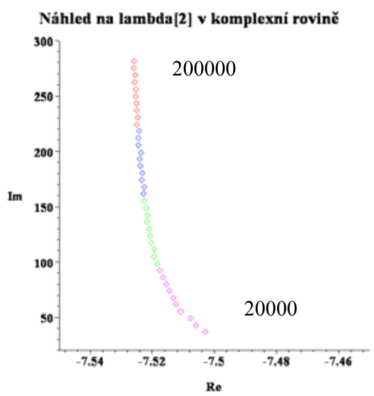


Fig.4b

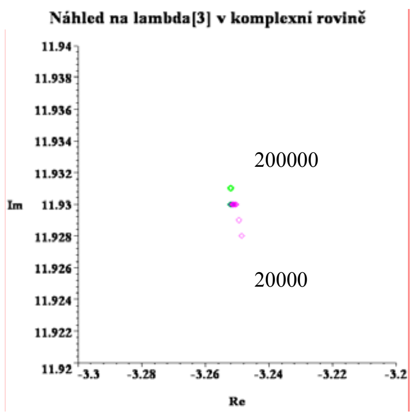
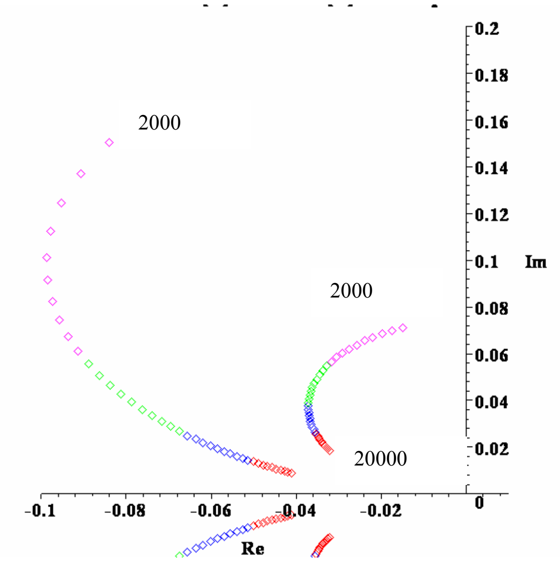


Fig.5b

2) By growth of the turning frequency decrease the imaginary parts of fourth and fifth roots, the real parts change, but not monotonously (see Fig.6).



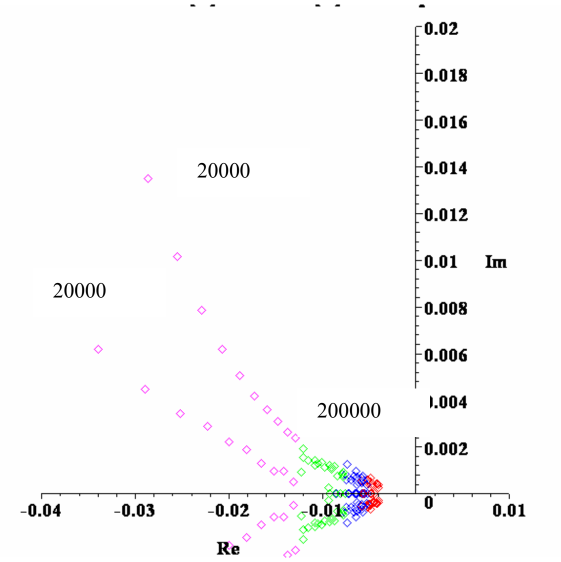


Fig.6a **Fig.6b**

3) By growth of radial correction parameters the first three roots remain practically but the real and imaginary parts of fourth and fifth root increase.

7. Conclusions

In case, that the precession axes are horizontal and the axes of the gyroscopes vertical (in the basic position), from the demand of correct gyroscopic stabilization results the necessity of opposite rotations of the gyroscopes.

8. Acknowledgment

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