International Conference
ENGINEERING MECHANICS 2010
Svratka, Czech Republic, May 10 – 13, 2010

RADIAL CORRECTION COEFFICIENTS OF GYROSCOPIC STABILIZER

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Summary: *This paper presents a part of research of the gyroscopic stabilizer and describes a gyroscopic stabilizer correction and compensation system. Consequently identification of the effect of correction and compensation system parameters settings for the system behavior is described. Estimation of a concrete compensation and correction settings are presented in this study.*

1. Introduction

A part of the one-axis gyroscopic vibration-isolation platform project is the estimation of the correction and compensation system coefficients (k_1, k_2). These coefficients represent a proportional feedback between the displacement of the gyroscope precession frame or stabilizer deflection from the vertical post and the compensation or correction torque. These torques act on the precession frame (correction – k_2) and stabilizer frame (compensation – k_1). For the determination of the proportional members magnitude of the feedback there was created a mathematical model in the Maple environment. For this model verification there was created another mathematical model in the MapleSim environment. The system motion simulations during various maneuvers help to identify the impact of the proportional feedback coefficients on the system behavior, and it is possible to estimate the concrete magnitude of these parameters by the comparison with desired behavior of mechanical system.

2. System and simulations description

Model of system is schematically viewed in Fig. 1. System consists of a foundation (black) which provides three-dimensional general motion (translations in direction of three axes and rotations around these axes). There is a frame (blue) which provides rotational motion around longitudinal axis (its angle displacement is represented by coordinate q_1) mounted on the foundation. The frame is supported by spring and damper which are mounted between the foundation and the frame and represented in the model by the torsion spring and damper. Precession frame of the gyroscope (green) is mounted on the frame and provides rotation around transversal axis (its angle displacement represented by coordinate q_2). The gyroscope (pink) with a vertical rotation axis (rotation represented by angle coordinate q_4) is mounted in bearings on the precession frame. Dissipative forces between frame and precession frame and also between the precession frame and the gyroscope are not considered. A sensor (yellow) of

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frames displacement from absolute vertical is mounted on the frame. The sensor is modeled as a mathematical pendulum (its displacement from the frame's normal post is represented by angle coordinate q_3) and there is considered passive resistance in pivot which is formulated as a small torsional damping. Compensation torque motor (bigger red cylinder) is mounted on the rotation axis of frame between the foundation and the frame and is driven by angular displacement of the gyroscope precession frame. Correction torque motor (smaller red cylinder) is mounted on the precession frame rotation axis between the frame and the precession frame of gyroscope and is driven by signal from the sensor (angular displacement of mathematical pendulum). The sensor or its model pendulum in this system indicates an angular displacement of the frame from absolute vertical.

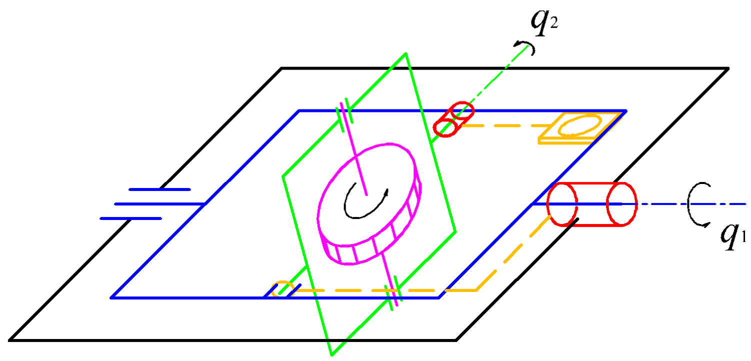

Fig. 1 Scheme of gyroscopic stabilizer model

For identifying behavior of the system were designed two numerical experiments:

a) Systems time response for excitation by sudden change of the torque on the frame rotation axis (from zero magnitude to constant value) and simulations start in equilibrium state. It represents sudden change of frame gravity center.
b) Time response for excitation by acceleration in transversal direction. This experiment represents, for example, centrifugal acceleration during steering maneuver of car.

In case a) the impact of compensation system coefficient on time response was watched. In case b) the impact of both coefficients was observed. Compensation system acts on the frame rotation axis and it balances the system to the zero displacement of frame. The correction system acts on the gyroscope's precession frame and is driven by signal from the sensor mounted on the frame. The balancing frame to reach the apparent vertical post (which is direction of gravity and centrifugal accelerations resultant) is purpose of the correction system. If the centrifugal acceleration generates the torque on the frame the correction motor acts torque on the precession frame rotation axis due to deviation of apparent vertical indicated by sensor, gyroscope generates the gyroscopic torque around longitudinal axis due to correction torque and consequently frame vertical reaches the apparent vertical. But gyroscope precession frame is displaced due to torque generated by springs which are mounted between frame and foundation and due to this the compensation system acts a torque of the same direction as gyroscopic torque on frames rotation axis and helps to accelerate reaching the apparent vertical post.

3. Results and their interpreting

For purposes of numerical experiments the intervals of coefficients k_1 and k_2 were determined by using Hurwitz conditions of stability. For simulations there were used the values of k_1 and k_2 coefficients inside the determined intervals.

The results of simulations of numerical experiments in case a) are shown in Fig. 2. The surface is composed of the time response simulations for various coefficients k_1 and k_2 magnitudes. The surface plot on the left demonstrates the impact of compensation torque feedback coefficient k_1 to velocity of system stabilizing and magnitude of angular displacement of the precession frame in new equilibrium state. The surface plot on right demonstrates dependency of stabilization time on coefficient k_1 magnitude. Steady state of displacement is reached more quickly for higher magnitudes of k_1 and also its higher magnitude is required for smaller precession frame displacement. Satisfactory magnitude seems to be $k_1 > 300$ in this case.

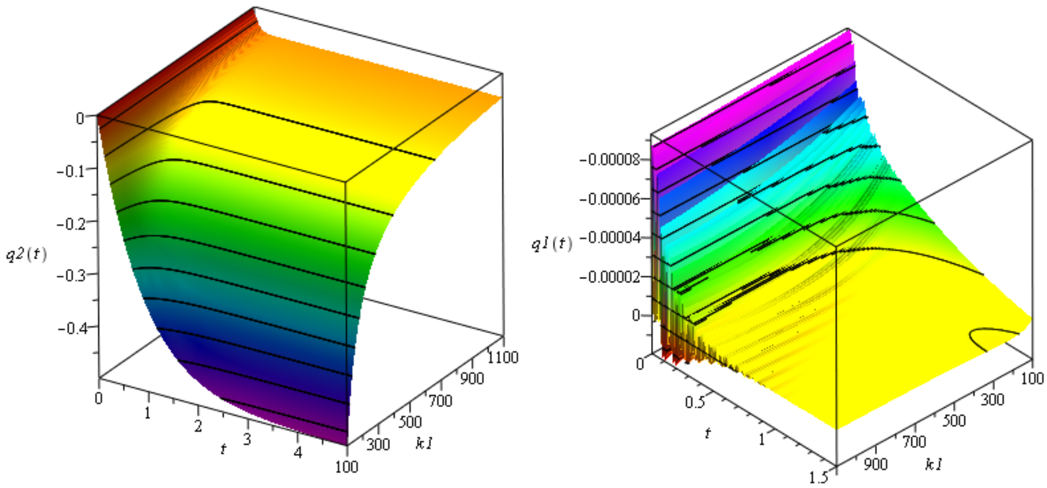

Fig. 2 The time responses surfaces for disturbance torque response simulations

The surface plots composed of the time responses on excitation by constant acceleration 3ms^{-2} in duration 5s are shown in Fig. 3. Surface plot on left demonstrates that the magnitude of k_1 must be also more than 300 for favorable behavior during reaching the apparent vertical by the frame. Dependencies of the precession frame angular displacement are shown by surface plot on right. It is required the magnitude of the precession frame displacement to be small preferably $(q_2)_{max} = 0{,}5$rad due to precession frame design restriction. It is obvious the $k_1 > 500$ for this reason but because of stability must be less than approximately 1800.

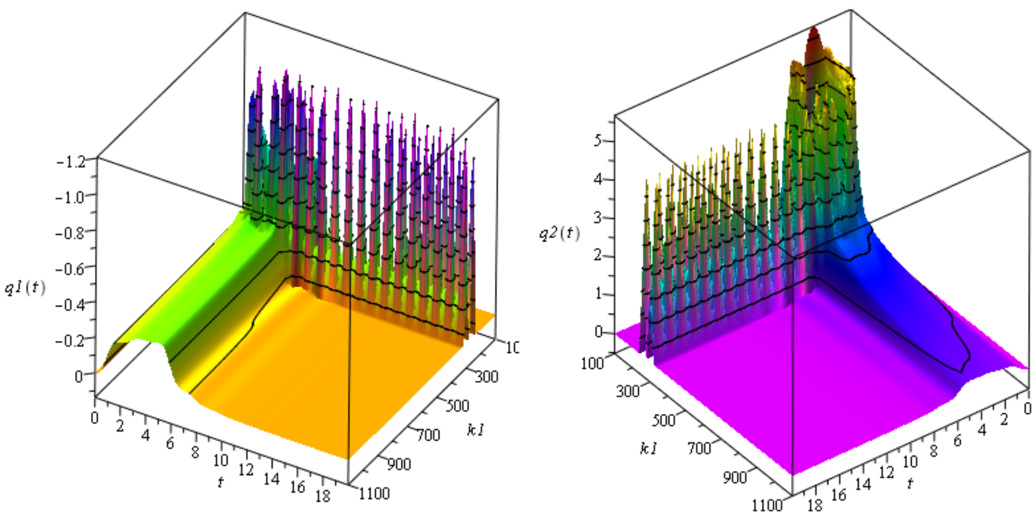

Fig. 3 The time responses for transversal acceleration dependency on k_1

The simulations presented above were provided with constant magnitude $k_2 = 50$. The time response simulations for transversal acceleration made for various magnitudes of k_2 are shown in Fig. 4 ($k_1 = 700$ was chosen from interval determined above). On right is shown system behavior change due to increasing magnitude of k_2. The maximum value of q_1 (angular displacement of the frame) shown in surface plot corresponds to apparent vertical post deviation during the simulated transversal acceleration. Reaching this magnitude of the frame displacement is desirable but not strongly required. It is better to choose compromise between reaching close to apparent vertical and less vibratory motion. For this reason is better to chose magnitude of coefficient k_2 in the middle of shown interval (around 50). And the plot on right proofs the choice of this value is favorable for the maximum displacement of the precession frame q_2.

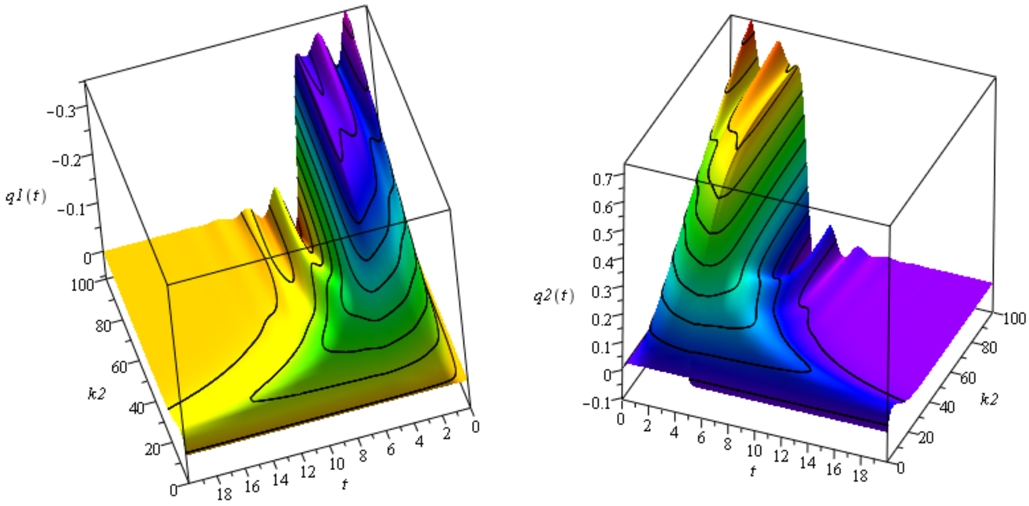

Fig. 4 The time responses for transversal acceleration dependency on k_2

4. Conclusion

The intervals of the correction and compensation coefficients magnitudes for which the system provides a stable vibration motion were determined by system analysis. From numerical experiments which are described above, it was estimated closer interval of these coefficients for which the system provides desired behavior.

5. Acknowledgement

The research has been supported by project GAČR 101/09/1481 “Gyroskopická stabilizace vibroizolačního systému“.

6. References

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