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Stabilization of Platform using Gyroscope

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Abstract

This paper deals with gyroscopic stabilization of platform. The platform consists of parallelogram, cardan frame and two contra-rotating gyroscopes. The whole system is described with five generalized coordinates and with two cyclic coordinates. We created a prototype of platform, which rotate around one axis. The prototype is designed with respect to a simple way to extend the rotation about the second axis and paralelogram. The rotary frame is driven by the gyroscope. Pneumatic motors are used to actuating gyroscopes. Pneumatic springs are used to actuating rotating frame. This paper shows also control system of platform and it introduces reached results of stabilization.

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Keywords: active suspension; gyroscope; vibroinsulation; LabView; pneumatic instability; aerostatic bearing

1. Introduction

Research of gyroscopic stabilization of platform follows the research of active ambulance stretcher with magnetorheological dampers. This is described in [1] and [2]. Generally the platform consists of paralelogram and two rotating frames, Fig.1. A prototype of stabilized plate consists of frame rotating around one axis only, Fig.2. The auxiliary base frame is placed on the floor. Outer upper frame can be excited by hands or put on hydraulic pistons. Upper frames are propelled by pneumatic springs. Pressures in both springs are controlled by electrical proportional valves. Two gyroscopes with vertical rotation axis are mounted to upper inner frame. Gyroscopes have the air bearing support in precession frames. Gyroscopic stabilizer mechanical system was completely described in [3, 5]. Gyroscope with the mass about 3.5kg is driven by air turbine and has design speed over 30.000 rpm. Real speed 12000 rpm was tested with industrial compressor, which can supply air with pressure 9 bars and sufficient flow.

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Making of gyroscopes with aerostatic bearings is described in [6, 7]. Speed of gyroscope is measured with magnetic contact sensor. Speed is calculated from frequency of pulses. The torque motor of radial correction is mounted on precession frame axis between upper inner stabilizer and precession frame. This pneumatic torque motor is actuating device of correction and compensation system. It was described in [4] including characteristics and simulation model. Pneumatic springs and motors are controlled by electrical servo valves.

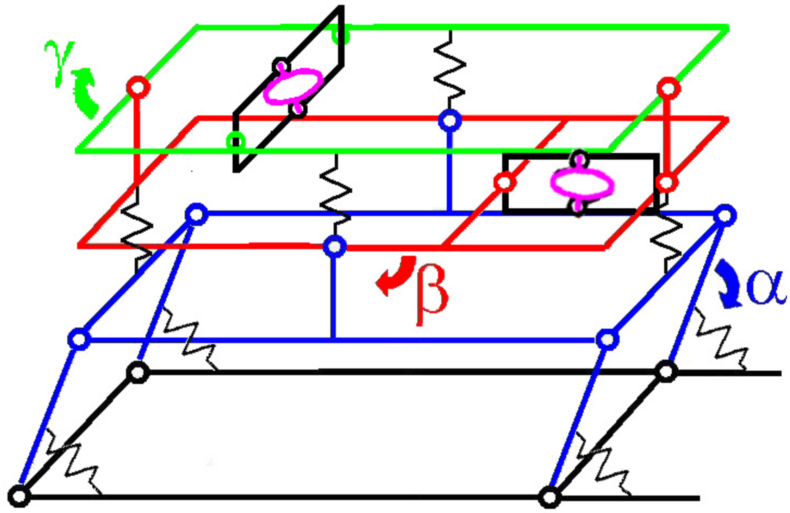

Fig. 1. Scheme of whole stabilized platform.

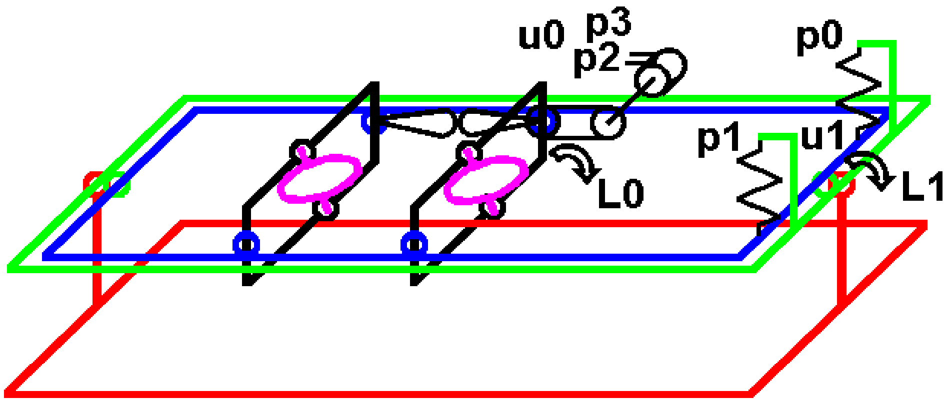

Fig. 2. Scheme of one-axis prototype.

2. Stabilized plate and its control circuit

A photograph of prototype is in Fig.3. The scheme of stabilized plate is in Fig.2. Auxiliary frame, which is laid on the ground, is red. Base frame is green. This frame can be inclined. Upper inner stabilized frame is blue. This frame is propelled by pneumatic springs. Precession frames of gyroscopes are mounted on blue frame. They are driven by pneumatic motor trough the gears. Problems and advantages of using tandem of gyroscopes and effects of friction are solved in [8,9].

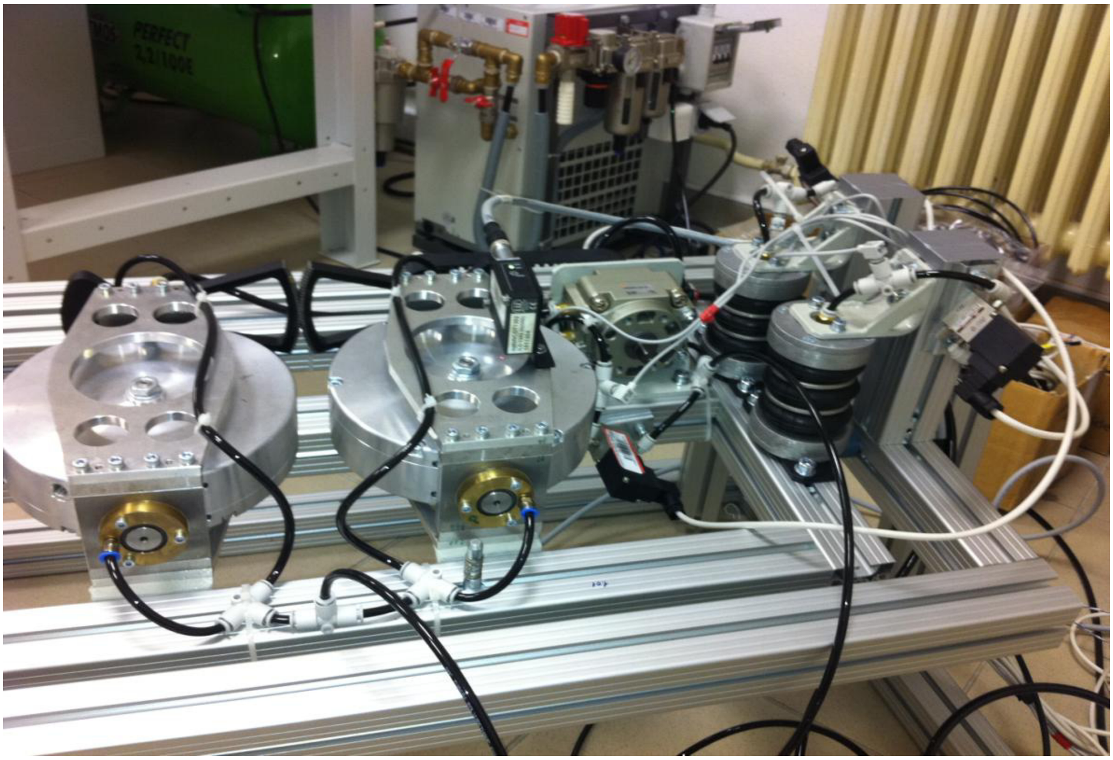

Fig. 3. Prototype of stabilized plate.

The system is controlled to horizontal position of blue rotating frame. Correction and compensation systems consist of two proportional feedbacks with PID controllers. Correction torque motor on precession frame axis is driven by feedback from sensor of stabilized frame position. It indicates direction of an apparent vertical. Compensation system has feedback, which applies the torque on stabilized frame. It is driven with respect to magnitude of precession frame angular displacement. The scheme of control circuit is in Fig. 4.

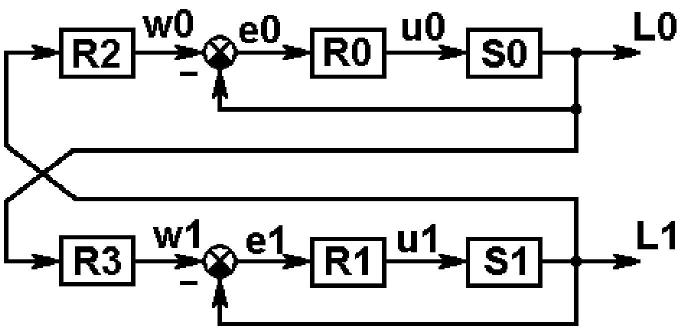

Fig. 4. Structure of control circuit.

2.1. Mathematical model and its optimization

The basis of model is set of motion equations, which are derived from Lagrange equations of second kind with external torques on their right sides.

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{q}_i} - \frac{\partial T}{\partial q_i} + \frac{\partial U}{\partial q_i} = M_{s_i} + M_{d_i} + M_{pas_i} + M_{cor_i} \qquad i = 1..3 \tag{1}$$

Stabilized frame has index i=1 with angle displacement q1. Precession frame has index i=2 with angle displacement q_2. Sensor of apparent vertical has index i=3. q_3 is angle between apparent vertical and z-axis of stabilized frame. M_{Si} are torques of air springs. M_{ti} are torques of dampers, M_{pasi} are torques of passive resistances and M_{cor2} is torque of correction motor. It is only on the precession frame axis. The whole model moreover contains air spring models and models of electric valves.

Control circuit consists of two feedbacks with two PID controllers R0 and R1, Fig 4. Their parameters were optimized with integral criterion

$$J_i = \int_0^{t_{end}} \left[t^n (e_i)^2 + k (y_i')^2 \right] dt \tag{2}$$

e_i are control deviations., y_i are controlled values, n and k are optional weighting coefficients. Parameters of crosslink gains R2 and R3 were adjusted experimentally.

2.2. Results of control

Results of control are shown in Fig.5 and Fig.6. There are positions of each frame in upper chart. Absolute rotation against the surrounding is in the chart below. In Fig.5 it is control of excitations of base frame by hands. In Fig.6 it is control with changing of wanted values.

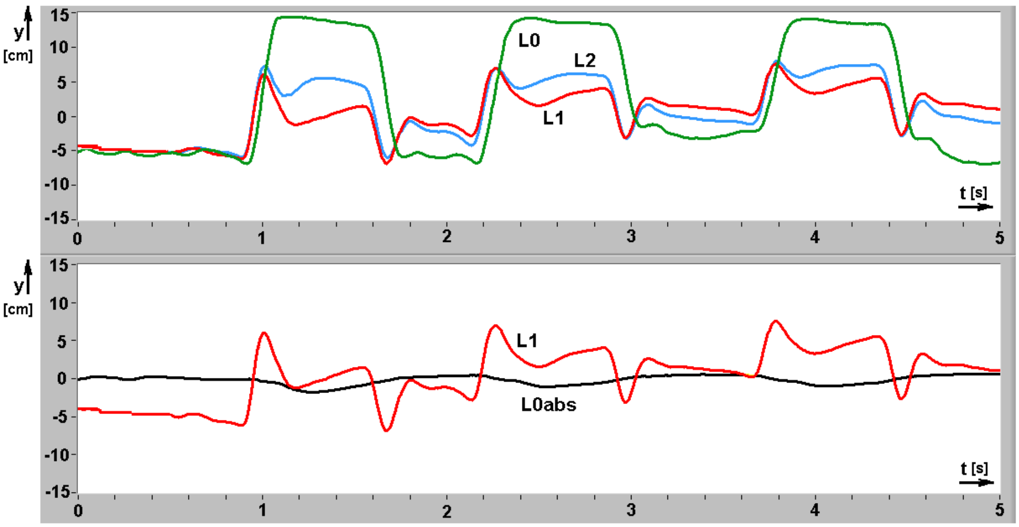

Fig. 5. Control to stabilized position, excitation by hands.

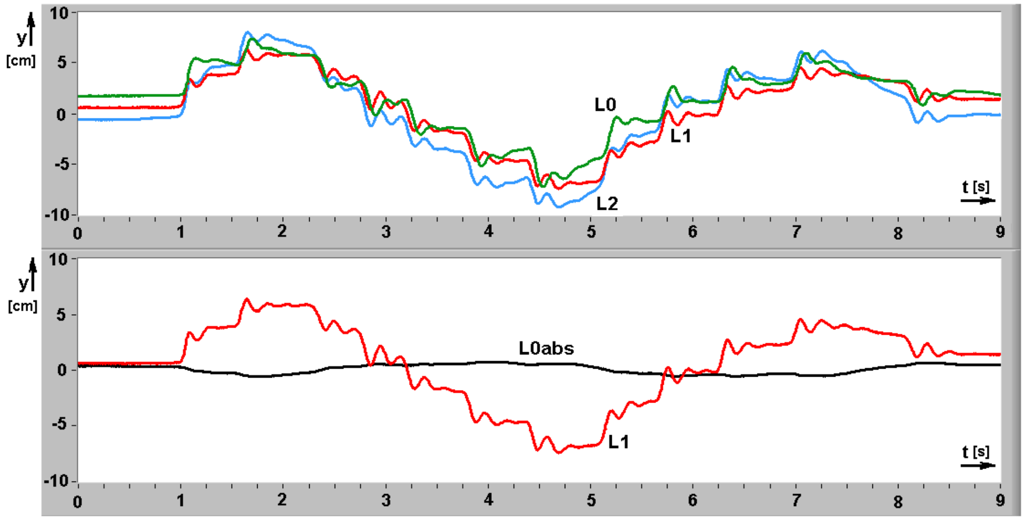

Fig. 6. Control to stabilized position, changing of wanted value.

3. Conclusion

The control system of stabilized plate with gyroscopes was designed and realized. Its mathematical model was created and used for optimization of controller parameters. All parameters of control circuits were adjusted and optimized. Satisfactory results of control were introduced. Simulation results were verified on real prototype of stabilized platform. Theoretical consideration of gyroscopic stabilization has been successfully verified on real system. For technical reasons it was not possible to achieve the required speed gyroscopes. Increasing speed gyroscopes would be their stabilizing effect even higher. Now we are going to extend platform with two axes mechanism and apply gyroscopic stabilization to prototype of ambulance stretcher.

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