

## Dynamic behavior of the gyroscope with liquid damper under the action of external moment

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Gyroscope is a part of many complex constructions. Main goal of gyroscopes operation is aircraft vehicles space orientation stabilization during motion. Undesirable angular velocities may appear during change of vehicle space orientation that are to be suppressed. Damping is included into gyroscope for this suppression. In the current paper dynamic behavior of gyroscope with fluid damping system for nutation oscillations suppression is studied. Gyroscope during change of vehicle space orientation under control moment is considered.

At Fig. 1 general view of gyroscope in gimbal suspension (left) is shown. Gyroscope with liquid damper is shown at Fig. 2. The rotor rotates with constant frequency equal to 100 Hz. Control moment is applied about motionless axis of gyroscope (x-axis at Fig. 1).

Three cases of the applied forces were analyzed:

1. Under the action of gravity load
2. Under the action of control moment
3. Under the action of both gravity and control moment.

The liquid damper is a torus-like volume partly filled with viscous liquid (for example, quicksilver).

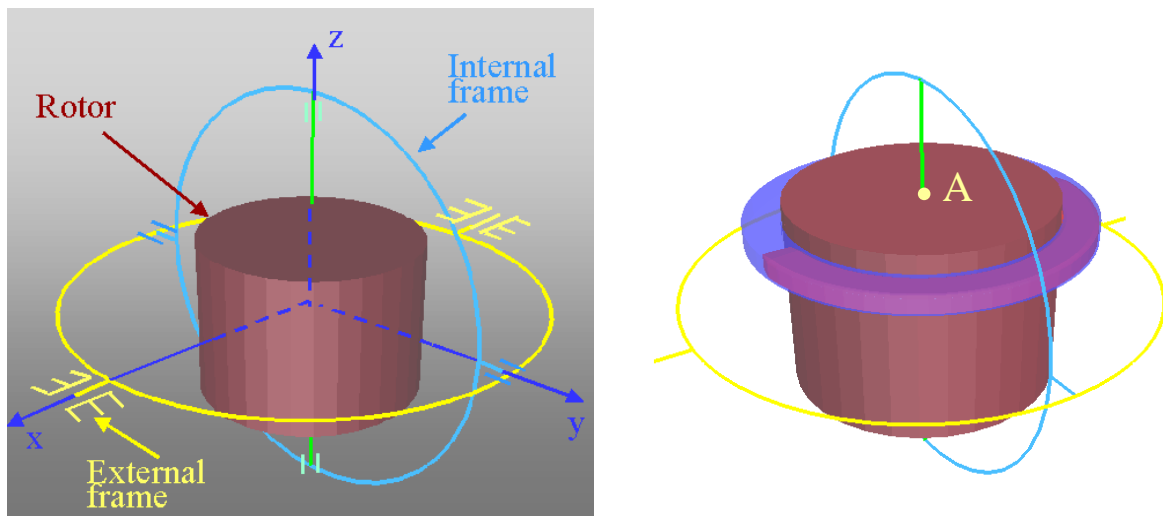
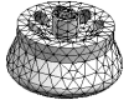


Fig. 1

For simulation of fluid-structure interaction ALE formulation was used with initial void option. Rigid material properties (MAT\_RIGID) were used in the analysis for rotor and frames and Null material (MAT\_NULL) was applied for liquid and void. Liquid fills half of the damper volume at initial time (see Fig.1, right; Fig 4,  $t = 0$  s). Also for modeling fluid there was used equation of state in the Gruneisen form (EOS\_GRUNEISEN):

$$p = \rho_0 C^2 \left( \frac{\rho}{\rho_0} - 1 \right),$$

where  $C$  – sound speed equal to 150 m/s;  $\rho$  – initial density 13 500 kg/m<sup>3</sup>;  $\rho_0$  – density in actual state;  $p$  – pressure.



The `CONSTRAINED_LAGRANGE_IN_SOLID` option was used for contact interaction between damper surface and liquid with friction equal to 1. Surface tension wasn't modeled to simplify problem statement. At Fig. 2 the dependence of external moment vs. time is shown. It is described by the following law:

$$M_x = 0.01 \cdot H(t - 0.02) \cdot H(0.06 - t),$$

where  $H(t)$  – Heaviside function.

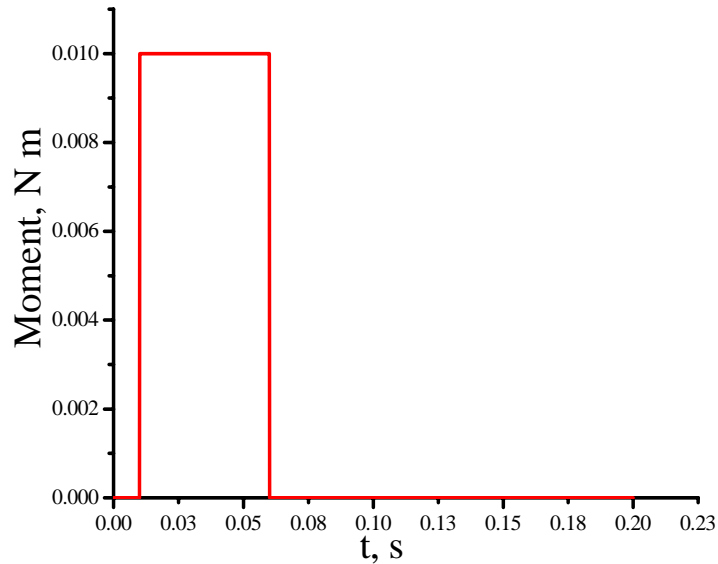


Fig. 2

Fig. 3 presents the dependency of coordinate X of point A (see Fig. 1). Analysis of this figure shows that the gyroscope axis deviates under loading of moment (from 0.02 to 0.06 s) and remains in this position after removal of the moment as it is described by the theory.

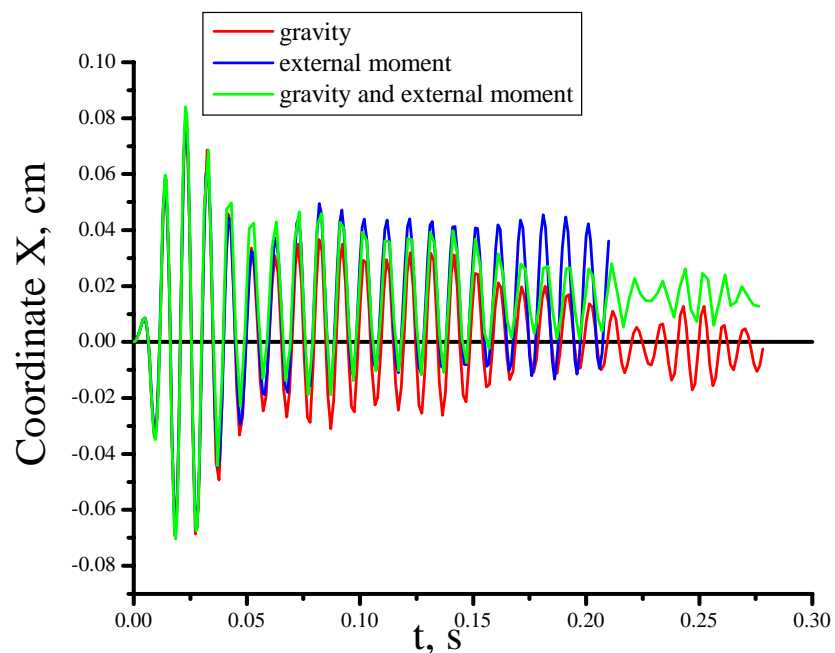


Fig. 3

At Fig. 4 liquid shapes at the different moments of time are shown.

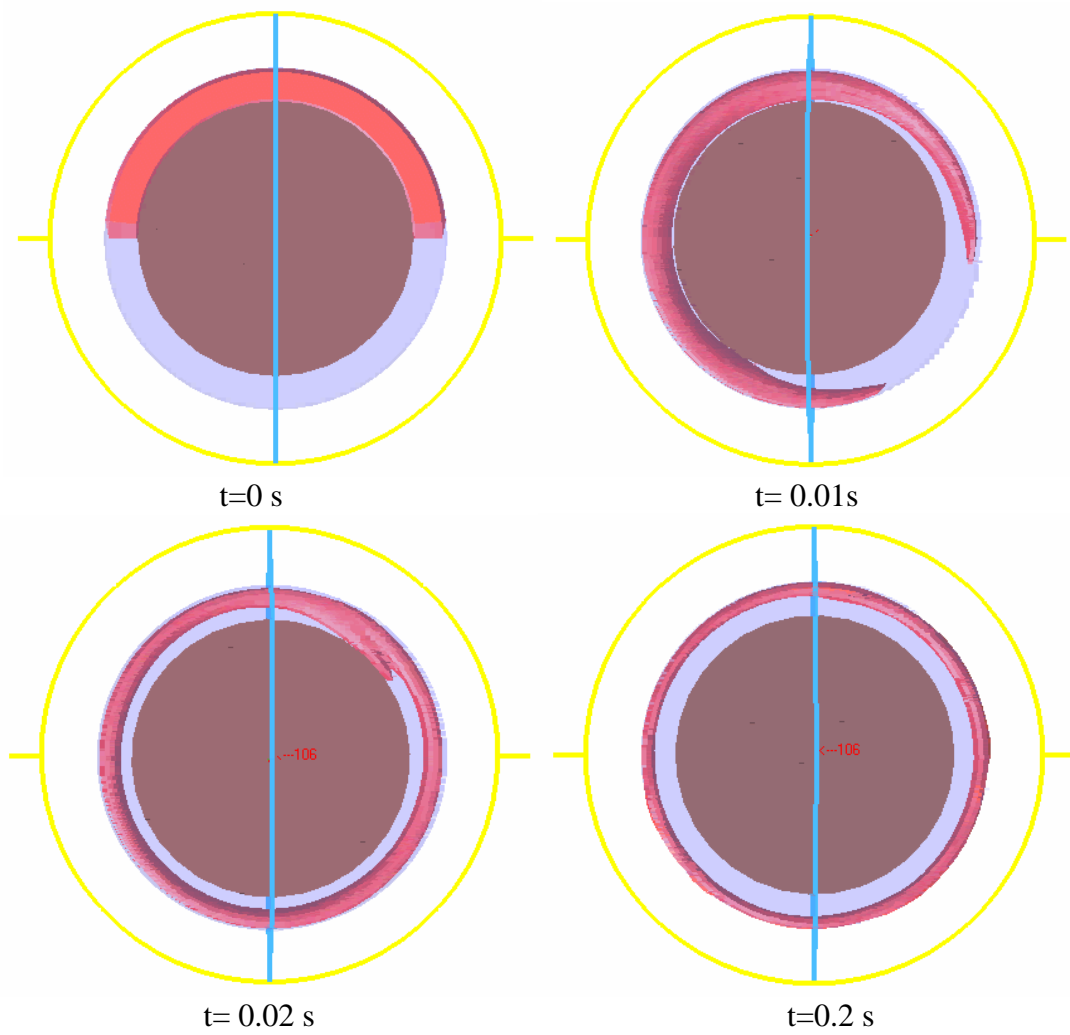


Fig. 4