Gyro-Ring: Dynamics and Steady Precession of Ring on a Vertical Smooth Rod

Li, XinRui (School: Hwa Chong Institution)

Interesting motion arises when a ring-like object (e.g., washer) is rotated on a vertical, smooth rod. Intuitively, the ring will simply slide down the rod once its weight overcomes friction. However, experiments show that under certain release conditions, the ring can achieve steady precession (600-2000 rpm) and travel downwards at a terminal velocity, seemingly defying gravity. Two distinct regimes of motion were observed experimentally. 1) Oscillatory motion when the ring has 1 contact with the rod (transient motion). 2) Steady state (terminal velocity) when the ring has 2 sticking contacts (instantaneously stationary) with the rod. This project aims to study these two regimes and the transition between them through qualitative, analytical and numerical means. One key feature of the steady-state motion is energy dissipation through rolling friction and air drag, which were modelled theoretically (coefficients independently characterized). Our model predicted that steady-state motion occurs only when certain geometric conditions (ratio of radii of ring and rod, tilt angle) are fulfilled. To study the transient regime, a comprehensive numerical model accounting for the stick-slip transition at the contact point is formulated using the Runge-Kutta Method. As the double-contact configuration was often found to be the preferred final state, dynamic stability of single-contact was investigated through bifurcation and phase space analysis. Theoretical models are in good agreement with experimental data across all experiments. The study of this phenomenon is useful for various engineering applications, such as studying the vibrational detachment of threaded fasteners and developing gravity-driven centrifuges.

Awards Won:
Second Award of $2,000