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Paradoxes

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ABSTRACT

Many paradoxes are recorded in the history of Mechanics. A few, mostly from recent times, are included in this paper.

Congratulations

It is a pleasure to contribute to this celebratory issue and to offer my congratulations to Erskine on reaching his hundredth birthday.

Erskine was a leading founder of IFToMM. From the inaugural meeting in Zakopane through many decades of development, no-one worked harder for the Federation than Erskine. Fortunately, he could hold his own in several languages — an essential feature during the multilingual and occasionally disputatious meetings of the Council! He led the way forward with great distinction.

Others will be more familiar with his many scientific contributions to our fields of interest. I simply wish to express my warmest regard for his friendship and support over the years.

HAPPY BIRTHDAY, ERSKINE.

1. Introduction

The Oxford Dictionary defines "Paradox" as "a seemingly absurd though perhaps actually well-founded statement". The illustrations that follow come from a variety of sources and fields, including private communications. Enigmas were never far away.

2. Gyroscopes

(a) Fig. 1 shows a familiar two-axis gyroscope made up of a symmetric rotor mounted in two connected gimbals that allow the axis of the rotor to adopt any position in space within the mechanical limits of the assembly. If the rotor spins at high speed, it tends to retain its orientation in space. If the assembly is given a transient impulse, any small departure from its original position will be accompanied by a vibration, called nutation, in which the axis of the rotor executes a conical path at a predictable frequency. Yet, paradoxically, there is no spring, mechanical or otherwise, involved in the system. It is purely a matter of dynamics.
Another unexpected aspect of the vibration can occur if light viscous friction exists in the bearings of the gimbals. Free vibration will then be damped, but, if a certain relationship exists between the viscous damping coefficients and the moments of inertia of the parts, a paradoxical result [1] follows — the frequency of the damped vibration remains the same as that of the undamped vibration.

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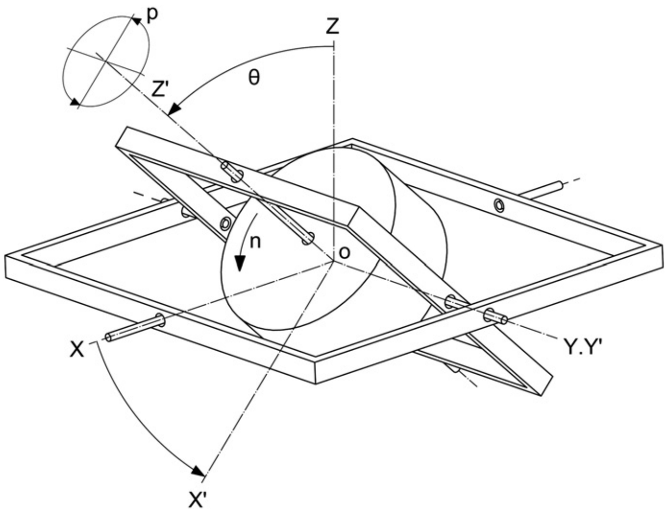

Fig. 1. Symmetric rotor in gimbals.

(b) Advances in space technology began soon after WW2 when detailed information on the German V-2 rocket was acquired by the West and also by the Soviet Union. The V-2 included early forms of inertial navigation incorporating gyroscopes and accelerometers, although their performance was variable. A serious problem was "vibrational drift", an unexpected departure of the gyroscopes and of the V-2 from the reference direction. The first analysis of this phenomenon seems to have been carried out during the war by two researchers at the German Institute of Aircraft Equipment.
Later, in Newcastle [2], experiments were carried out on a scaled-up two-axis gimbaled gyroscope mounted on a vibrating table. The responses to free and to forced vibration in every conceivable configuration (Fig. 2) were recorded, including the drift-rates that emerged from a second-order analysis. The results, including drift-rates, corresponded closely with our predictions. The paradox lay in the neglect of second-order terms in the original analysis.

3. Vibration

An unexpected effect was noticed in an experimental development of an apparatus designed for the fatigue testing of turbine blades (Fig. 3). It consisted of a magnetostrictive stack of laminated plates driving a so-called mechanical amplifier, a piece of steel

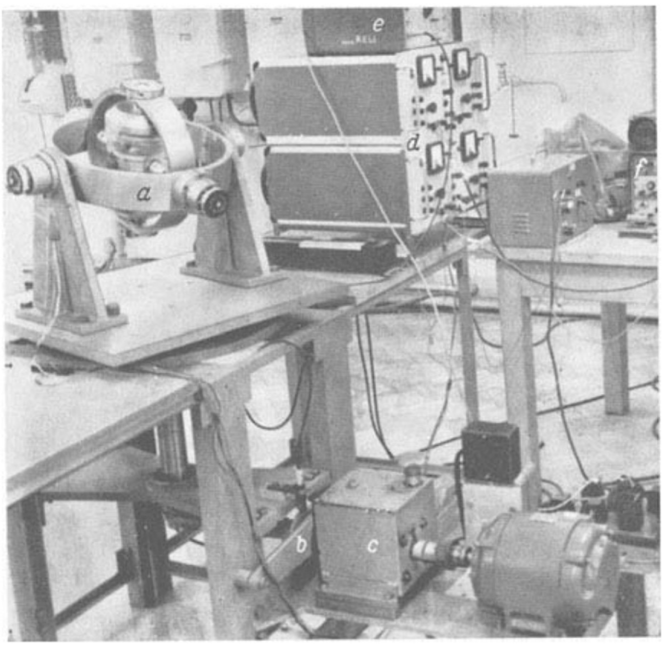

Fig. 2. Gyroscopic equipment on vibrating table.