Gyroscope-Weighing Experiment with a Null Result

J. E. Faller, W. J. Hollander, P. G. Nelson, and M. P. McHugh
Joint Institute for Laboratory Astrophysics,
National Institute of Standards and Technology and University of Colorado, Boulder, Colorado 80309-0440
(Received 18 January 1990; revised manuscript received 2 February 1990)

A recent experiment reporting an anomalous weight reduction for a spinning gyroscope weighed on a pan balance has been repeated in our laboratory. We find no anomalous weight changes of the magnitude reported that depend on rotor speed and/or rotational sense about the vertical axis.

PACS numbers: 04.80.+z, 04.90.+e

A recent Letter by Hayasaka and Takeuchi[1] reports finding an anomalous weight change (reduction) of rotors having spin vector pointed down (in the right-handed sense), and no weight change for spin-vector-up rotations. In spite of the fact that they observed similar effects for three different gyros, it is still very difficult to think of any fundamental reason for their observed effects. Motivated by this, we reperformed the experiment with a slightly different apparatus. To aid our thinking about the possible sources of error that could affect an experiment of this type, we experimented with a few different gyroscope and scale combinations, which led to the development of the gyroscope described below.

The air-driven and jeweled-bearing–supported brass, hardened steel, and nylon rotor (Fig. 1) in our experiment weighs 451 g. The two jeweled support bearings for the rotor shaft are soft (spring) mounted in order to provide the horizontal compliance necessary to accommodate the (inevitable) machining errors, rotor-geometry imperfections, and density inhomogeneities. The rotor is enclosed in a Lucite container and O-ring sealed —but not evacuated—while the weighings are being made. The use of a transparent Plexiglas housing permits simple "viewing" of the rotor to track its speed and offers a thermal impedance to the warming of the container's outside surface by the warmed (because of the stirring) inside gas. The rotor is blown up to speed—either with the spin pointed up or with the spin pointed down—by blowing on a nylon gear on the top of the rotor with compressed nitrogen. On reaching 8000 rpm, the hoses are removed from the unit and the sealing cover is placed on. A small threaded hole in the top permits gas to escape while putting the lid on. A small thumbscrew with an O-ring under its head is then screwed into this hole to seal the unit. (Preliminary data taken using an unplugged bleeder hole showed continuous weight changes after the rotor had stopped, which corresponded to several-milligram changes over the measuring times.) Hayasaka and Takeuchi emphasize their use of a vacuum to exclude fluid effects of air on the weight of the gyroscope. Since we know of no steady-state effect of internal air currents on the weight of a sealed system, we decided a simple O-ring seal on the cover of our gyro was sufficient. On being sealed, the unit is placed on our single-pan Mettler (H315) balance. The rotor's speed is measured during a weighing run with a stroboscope (half of the rotor is blackened with a magic marker). The rotor decayed from 6000 rpm to a stop in just over 11.5 min (the time interval between removing the hoses, sealing the unit, and finally placing it on the balance "cost" 2000 rpm).

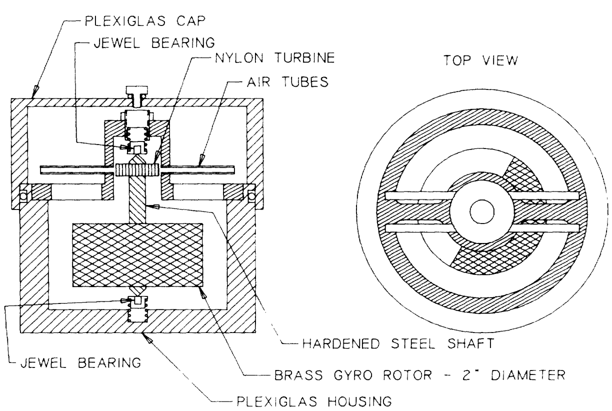

FIG. 1. Schematic of apparatus.

Our balance has a weight limit of 1000 g and a last digit sensitivity of 0.1 mg. With that in mind, we designed our total system weight to be somewhat below 1 kg so as not to be at the exact limit of the balance's (knife-edge) capabilities. Our total apparatus mass was roughly 800 g. We affixed to the pan scale a thin (2 mm) piece of dense foam rubber in order to achieve some degree of high-frequency-vibration isolation. Near 2000 rpm the balance was always unreadable as the gyro went through a resonance.

The important features of our experiment are the recognition that an evacuated vessel is not needed, and the use of a system free from external connections once the rotor was spun up. Having the gyroscope isolated means that it is identical for both senses of spins (i.e., no motor drive currents are changing signs, etc.), and one achieves the full benefits of the balance's knife-edge sus-

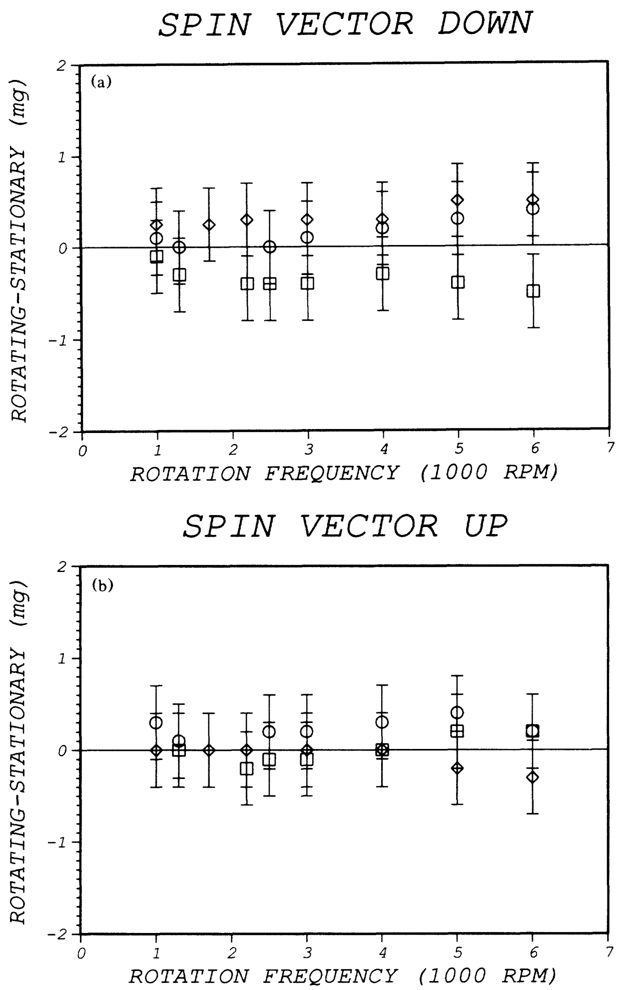

FIG. 2. Rotating weight minus stationary weight vs rpm for (a) spin-vector-down and (b) spin-vector-up orientations. Diamonds represent the runs taken with the first set of bearings, circles and squares represent runs taken with the second set. The weight change expected from simply scaling the results of Hayasaka and Takeuchi would be a linear decrease to −13.7 mg at 6000 rpm for the spin-vector-down case and no change for the spin-vector-up case.

pension.

Figure 2 represents the results of six data runs, for both spin senses of the gyroscope. Two (one in each direction) of the data runs were made—having plugged the aforementioned bleeder hole—before the initial set of bearings failed. The other four were made after we replaced the bearings with new ones.

In the paper by Hayasaka and Takeuchi, a 175-g rotor of similar geometry as the one in this work appeared to experience—for one direction of spin—a weight loss proportional to rotation speed amounting to about 11 mg at 12000 rpm (5.5 mg at 6000 rpm). This occurred only when rotating in the spin-pointing-down sense. No weight change was observed with the rotor spinning in the opposite direction. Our rotor mass being approximately 2.5 times greater should give us a sensitivity 2.5× greater (though since there is no theory for this effect, it is not clear whether it should scale with mass, rotor moment of inertia, etc.). We conclude that within our experimental sensitivity, which is approximately 35 times larger than needed to see the effect reported by Hayasaka and Takeuchi, there is no weight change of the type they described. By continuing the weighing after the rotor had stopped, an unexplained instrumental drift of a few tenths of a milligram per run, uncorrelated with the rotation direction, was measured. In Fig. 2 we show actual data without any attempt to correct the data for drift. Based on the scatter between runs of the *same* rotation sense, and making allowances for the effects of instrument drift, we assign an error estimate of ±0.4 mg to each of our measurements.

We cannot say what possible systematic error or errors would account for the results of Hayasaka and Takeuchi. What we can say is that for our spinning rotor and to the limit of our experimental sensitivity, there is no observed weight change that depends on either the angular speed or sense of rotation.

Salary support for this work comes from National Institute of Standards and Technology, National Geodetic Survey, U.S. Air Force Geophysical Laboratory, and Fort Belvoir Research Development, and Engineering Center.

[1]H. Hayasaka and S. Takeuchi, Phys. Rev. Lett. **63**, 2701 (1989).