THE GYROSCOPE-WEIGHING EXPERIMENT REVISITED -- WITH A NULL RESULT

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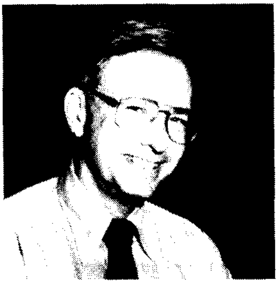

ABSTRACT

A recent experiment that reported finding an anomalous weight reduction for a spinning gyroscope weighed on a pan balance has been repeated during six days in our laboratory. We found no anomalous weight changes of the magnitude reported that depended on rotor speed and/or its direction of rotation about the vertical axis.

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In a recent paper in Physical Review Letters, Hayasaka and Takeuchi[1)] reported finding an anomalous weight change (reduction) of rotors having their spin vector pointed down (in the right-handed sense), and no weight change for the spin vector up sense of rotation. In spite of the fact that they observed similar effects with three different gyros, it is still very difficult to think of any fundamental reason for their observed effects. We note -- with some puzzlement -- the existence of a 1978 theoretical paper by Hayasaka on this subject which was not referenced in their Physical Review Letters paper. Intrigued by this report, we re-performed the experiment with a slightly different apparatus. To help us think about the various sources of error that could affect an experiment of this type, we first experimented for about a day with a few different lecture demonstration gyroscopes and laboratory scale combinations. This initial experimentation guided the design and construction of the gyroscope described below.

The air-driven and jeweled bearing-supported brass, hardened steel, and nylon rotor (Fig. 1) made for our experiment weighs 451 grams. The two jeweled support bearings for the rotor shaft are soft (spring) mounted in order to provide the necessary horizontal compliance to accommodate the (inevitable) machining errors, rotor geometry imperfections, and density inhomogeneities. Our rotor was enclosed in a lucite container which was sealed using an o-ring -- but not evacuated -- while the weighings were being made. Our use of a transparent plexiglass housing permitted simple "viewing" of the rotor to track its speed while offering a thermal impedance to the warming of the container's outside surface by the warmed (because of the stirring) inside gas. The rotor was blown up to speed -- either with the spin pointed up or with spin pointed down -- by blowing on a nylon gear on the top of the rotor with compressed nitrogen. (The laboratory air supply contained far too much water.) On reaching 8,000 rpm, the hoses were removed from the unit and the sealing cover was placed on. A small threaded hole in the top permitted gas to escape while putting the lid on. A small thumbscrew with an o-ring under its head was then screwed into this hole to seal the unit. [Preliminary data taken using an unplugged bleeder hole showed continuous (monotonic) weight changes after the rotor had stopped, which corresponded to several-milligram changes over the measuring times. Subtracting the large drift that was seen with an unplugged bleeder hole nevertheless yielded a null result, but with somewhat larger error bars than those obtained when the hole was plugged.] Hayasaka and Takeuchi emphasized 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 was placed

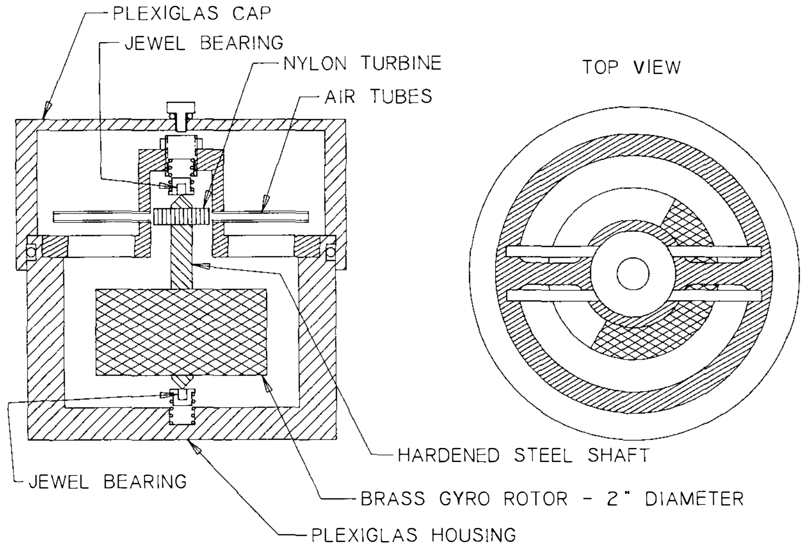

Fig. 1. Schematic of apparatus.

on our single-pan Mettler (H315) balance. The rotor's speed was measured during a weighing run with a stroboscope (half of the rotor was blackened with a magic marker). The rotor decayed from 6000 rpm to a stop in just over 11 1/2 minutes (the time interval between removing the hoses, sealing the unit, and then placing it on the balance "cost" 2000 rpm).

Our balance has a weight limit of 1000 grams 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. Still, 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 was 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 suspension.

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 -- with the aforementioned bleeder hole plugged -- before the initial set of bearings failed. The other four were made after we replaced the bearings with new ones.

In the experiment reported by Hayasaka and Takeuchi, a 175 g rotor of geometry similar to that of the one used in this work appeared to experience -- for one direction of spin -- a weight loss proportional to rotation speed amounting to about 11 mg at 12,000 rpm (5.5 mg at 6,000 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 provide us a sensitivity 2.5 times greater (although 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 was approximately 35 times larger than needed to see the effect reported by Hayasaka and Takeuchi, there was 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 the actual data uncorrected 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 do not know what possible systematic error or errors could account for the results of Hayasaka and Takeuchi. (It is always difficult to comment on someone elses work because while they report on what they think they did, this may not be exactly what they actually did.) What we can report is that for our spinning rotor and to the limit of our experimental sensitivity, we found no observed weight change that depended on either the angular speed or sense of rotation.[3)] We note that Quinn and Picard,[4)] at the Bureau International des Poids et Measures, redid this experiment subsequent to our work, and also found no effect.

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References

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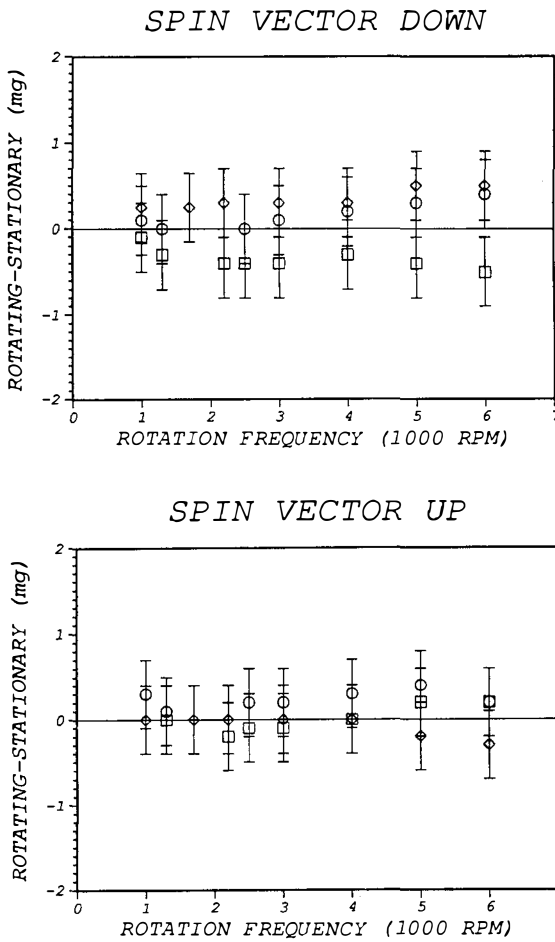

Fig. 2. Rotating weight minus stationary weight vs. rpm for (a) spin vector down and (b) spin vector up orientations. Diamonds represent the runs taken with the first set of bearings, circles and squares represent runs taken with the second set. The weight change expected from simply scaling the results 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.