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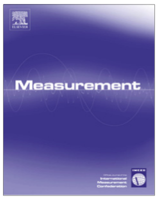

Identification of error sources in high precision weight measurements of gyroscopes

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ABSTRACT

A number of weight anomalies have been reported in the past with respect to gyroscopes. Much attention was gained from a paper in Physical Review Letters, when Japanese scientists announced that a gyroscope loses weight up to 0.005% when spinning only in the clockwise rotation with the gyroscope's axis in the vertical direction. Immediately afterwards, a number of other teams tried to replicate the effect, obtaining a null result. It was suggested that the reported effect by the Japanese was probably due to a vibration artifact, however, no final conclusion on the real cause has been obtained. We decided to build a dedicated high precision setup to test weight anomalies of spinning gyroscopes in various configurations. A number of error sources like precession and vibration and the nature of their influence on the measurements have been clearly identified, which led to the conclusive explanation of the conflicting reports. We found no anomaly within $\Delta m/m < 2.6 \times 10^{-6}$ valid for both horizontal and vertical orientations.

1. Introduction

A number of weight anomalies have been reported in the past with respect to gyroscopes, starting from the claims of Laithwaite in the 1970s, who designed a propellantless propulsion system using a special arrangement of spinning gyroscopes [1]. Much attention was gained from a paper in Physical Review Letters, when Japanese scientists announced that a gyroscope loses weight up to 0.005% when spinning only in clockwise rotation when viewed from above with the gyroscope's axis in the vertical direction [2]. In their setup, the gyroscope was encapsulated in a vacuum container measured on a counter-weight chemical balance. Immediately afterwards, a number of other teams tried to replicate the effect using a standard electronic balance all obtaining a null result [3–7]. It was suggested that the Hayasaka and Takeuchi effect was probably due to a vibration artifact [6,7], however, no final conclusion on the real cause has been obtained. On the other hand the data from Quinn and Picard [6] showed that small anomalies were present in some of the measurements which showed dependence on rotational speed. These authors suggested that vibration, friction torque and temperature drifts would be the cause for the measured anomaly. Also Dmitriev and Snegov reported a clear change of the mass of rotating bodies as a function of rotational speed [9]. The major cause for these anomalies was attributed to sensor drift and/or vibration, but in this case detailed analyses that would confirm these assumptions were absent.

A series of experiments has been designed in order to obtain a definite explanation of the conflicting reports. A summary of the most relevant previously published experimental results can be seen in Table 1.

2. Description and results

Our first setup reproduced the experiment of Hayasaka and Takeuchi [2] in which the measurement device was a counterbalance. The second reproduced the follow-up

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Table 1
Summary of relevant published experiments.

Experiment	$\eta = \lvert\delta M/M\rvert$	Measurement method	Orientations	Comments
Hayasaka–Takeuchi [2]	Up to 6.8×10^{-5}	Counter-weight balance	Vertical	Anomalies measured
Faller et al. [4]	$<9 \times 10^{-7}$	Counter-weight balance	Vertical	No anomalies measured
Quinn–Picard [6]	$<2 \times 10^{-7}$	Flexure strip balance	Vertical	Anomalies present
Nitschke–Wilmarth [5]	$<5 \times 10^{-7}$	Electronic scale	Vertical North–south	No anomalies measured
Imanishi et al. [8]	$<2.5 \times 10^{-6}$	Electronic scale	Vertical	No anomalies measured
Dmitriev–Snegov [9]	Up to 2.8×10^{-6}	Electronic scale	Counter-rotating gyroscopes Vertical/horizontal	Anomalies present in horizontal orientation

experiments in which the gyroscopes were measured directly on an electronic balance. In both experiments the same gyroscope was used as the test mass, which was a commercially available precision gyroscope [from Brightfusion Ltd, model name: "Super Precision Gyroscope"], comprised of a brass rotor with a mass of 112 g and a standard DC motor with which a maximum rotation speed in excess of 25,000 RPM could be reached for relatively short periods (seconds) and approx. 19,000 RPM for longer periods (minutes) [13,000 RPM for Hayasaka and Takeuchi [2]].

Since in the reports of Hayasaka and Takeuchi [2] the results varied in function of rotational direction, we performed each measurement for six rotational vector orientations: up, down, north, south, east and west.

Here we will refer to the counter-balance layout as a balance and the electronic balance as a scale for convenience.

2.1. Counter-balance experimental set-up

Fig. 1 shows the schematic layout of the balance, where we can observe the solutions for the elimination of first order error sources. They comprise a sealed container which would restrict any airflow from within the measurement system to the outside environment and a wireless data interface. In all of the previously published experiments a sealed container was also considered a necessity in order to restrict airflow; in some, the container was also evacuated in order to minimize the effects of airflow. We decided that a sealed environment would be sufficient without evacuation.

In previous experiments wires were used for the control of the gyroscopes but we considered that this solution introduces an error source; hence we implemented a wireless control interface with the power supply (batteries) and control electronics for the gyroscope all placed inside the container. For the actual weight measurements we applied an electronic precision scale [Sartorius AX 224] with a maximum range of 220 g and a 0.1 mg resolution that was placed under the counter-weight holder. The output of the scale is a selectable unit of mass (grams in our case) hence the actual internal algorithm through which the device computes the mass from the force applied on top of the measuring plate is unknown.

We observed that the scale was also influenced by the position of the contact point between the object to be measured and the scale's plate. In order to eliminate this possible error source that would originate from the surface imperfections of two larger plates (undefined contact points), the physical connection between the counter-weight holder and the scale was realized through

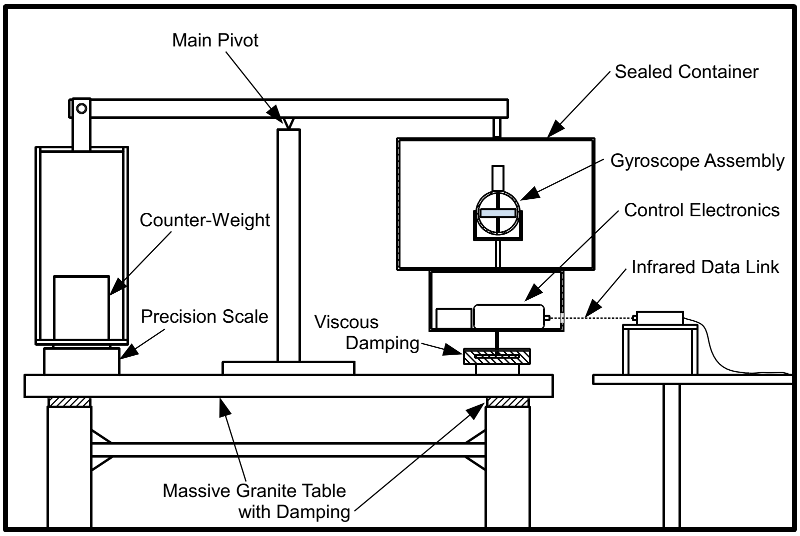

Fig. 1. Schematic setup using balance arm and counter-weights (counter-balance setup).