Evidence of Lift Force on Gyroscope

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Abstract

Experimental evidence is presented showing that a rapidly rotating gyroscope experiences a lift force opposing gravity. The theory is derived by considering the centrifugal forces (with the Earth's center as the origin) that act on a cylindrically symmetric, rapidly rotating rigid body. Under normal circumstances, this effect is completely negligible compared to other forces acting on the gyroscope. Therefore, this experiment was designed for a rapidly spinning mechanical gyroscope by placing it on a sensitive scale in a vacuum chamber. Experimental methods and data analysis methods are also presented. The data shows that the effect is much larger than anticipated by the theory, and that the effect seems to be enhanced through interaction with electromagnetic (EM) fields. Our conclusion is that the data indicated that our theory is partially correct, but incomplete, and likely to be missing at least one effect related to electromagnetism.

Keywords: Gyroscope, gravity, centrifugal, angular momentum, lift, orbit

I. Introduction

Gyroscopes are fascinating. If you have ever put a gyroscope on a scale, you may have been disappointed to observe no change in weight. However, on June 25, 2021, the US Government released a report about Unidentified Ariel Phenomena (UAP). The report stated "*Some UAP appeared to remain stationary in winds aloft, move against the wind, maneuver abruptly, or move at considerable speed, without discernable means of propulsion*"[1]. Although, previously dismissive of evidence of UAPs, I was intrigued by the official endorsement and the challenge to figure out how they could possibly maneuver like that. Why is the stereotypical UAP disk-shaped? Could their propulsion system be related to rotational energy? These questions lead me to revisit an experiment to place a gyroscope on a scale.

II. Theory

Consider a cylindrically symmetric rigid body of mass m in the gravitational field of a dominant body M such that $m \ll M$, and rotating at angular distance r and angular velocity ω about the $\hat{z}$ axis. For an arbitrary differential mass dm in this body, moving at velocity $\vec{v} = \omega r\hat{\theta}$, the force acting on it is given by the sum of centrifugal and gravitational forces[2].

$$\overrightarrow{dF} = dm\left[\frac{v^2}{r}\hat{r} + \left(\frac{v^2}{z} - \frac{GM}{z^2}\right)\hat{z}\right], \qquad dm = \rho_{(r,z)}\, rd\theta\, dr\, dz$$

Where $\rho_{(r,z)}$ is the local density. Since the body is cylindrically symmetric, the integral over the radial $\hat{r}$ component evaluates to zero, leaving only the components along the $\hat{z}$ axis.

$$\vec{F} = \int \overrightarrow{dF} = 2\pi \iint \left[\frac{\omega^2 r^2}{z} - \frac{GM}{z^2}\right]\hat{z}\,\rho_{(r,z)}\, r\, dr\, dz \quad (1)$$

Consider the case where the overall size of the rigid body is very small so that $r \ll R$, and R is the object's distance from the origin. Further, assume the body has an internal and external radius of r_1 and r_2, then the density function is:

$$\rho_{(r,z)} = \begin{cases} \rho h \delta_{(z-R)}, & r_1 \le r \le r_2 \\ 0, & else \end{cases}$$

Where $h \ll R$ is the thickness of the body along the $\hat{z}$ axis, and $\delta_{(z-R)}$ is the Dirac delta function. Then equation (1) simplifies:

$$\vec{F} = \rho h 2\pi \int_{r_1}^{r_2} \left[\frac{\omega^2 r^2}{R} - \frac{GM}{\mathrm{R}^2}\right] r\, dr\hat{z} = \rho h\pi \left[\frac{\omega^2 r^4}{2\mathrm{R}} - \frac{GMr^2}{\mathrm{R}^2}\right]_{r_1}^{r_2}\hat{z}$$

$$m = \rho h\pi(r_2^2 - r_1^2), \qquad \vec{F} = m\left[\frac{\omega^2}{2R}(r_2^2 + r_1^2) - \frac{GM}{R^2}\right]\hat{z} \quad (2)$$

The positive term in equation (2) is the lift force under investigation in this experiment. Notice that if we set $r_2 = r_1$ such that all the mass were to be concentrated in a rotating ring, then we can determine the angular velocity required to counteract gravity and produce a stationary orbit.

$$Assume \begin{matrix} |\vec{F}| = 0 \\ r_2 = r_1 = r \end{matrix}, \qquad \frac{\omega^2 2r^2}{2R} = \frac{GM}{R^2}, \qquad \omega r = \sqrt{\frac{GM}{R}} \quad (3)$$

Equation (3) is the same equation for the circular orbital velocity of a point particle about the dominant body M. Therefore, just as a point particle will remain in a stable circular orbit at this orbital velocity, so too will a rotating ring remain in orbit, if it is rotating such that each part of it is moving at this same orbital velocity. For the case where $r \ll R$, this kind of orbit could look like levitation since the ring may seem to remain stationary.

III. Experimental Methods

Using equation (2) and the geometry of the gyroscope, one can calculate the theoretical lift force as a function of angular velocity. Our experimental setup used a gyroscope with two rotating parts. The main part of the gyroscope was the heaviest portion and would always be spinning the fastest. The shell part would start at rest but would gain angular velocity due to friction with the main portion. For our gyroscope, the

[1] US Gov. UAP Report, p 5

[2] Taylor, p 344-347

theoretical lift force (measured by the scale as a reduction in mass) is:

$$\Delta Mass \approx \left[(2.5)\omega_{M(t)}^2 + (1.5)\omega_{S(t)}^2\right] 10^{-9} s^2\ g \pm 5\%$$

For example, consider the case where

$$\omega_M = 1000\ s^{-1},\ \ and\ \omega_S = 500\ s^{-1}$$

$$\Delta Mass = \ (2.5\ E^6 + 3.8\ E^5)\ E^{-9}\ g \approx 0.003\ g$$

This small effect requires a high-quality gyroscope, a scale sensitive to at least 0.001g, a vacuum chamber large enough to fully contain the scale and the gyroscope, and a vacuum pump powerful enough to generate a vacuum much faster than the gyroscope would lose its rotational energy due to friction.

The experiment also required a reliable way to spin up the gyroscope to high initial angular velocities of approximately 25,000 RPM. Once spinning, the gyroscope must quickly be placed upon the scale, the vacuum chamber sealed, and data collection begins. Further, one must be careful to shield the experiment from EM fields, as these seemed to cause significant noise in the data.

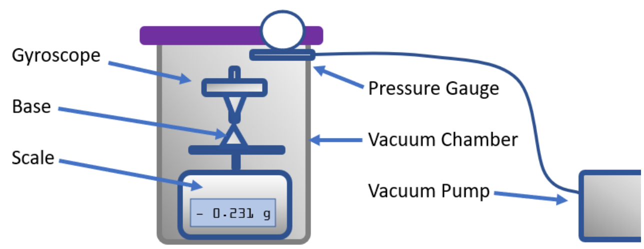

Figure 1: Experimental setup with a gyroscope on a sensitive scale, in a high quality vacuum.

Data was collected using a video camera placed over the vacuum chamber's glass lid. The air pressure and the angular velocity were measured manually using a pressure gauge and a tachometer, respectively. These values were recorded in the video as an audio input. The data was then manually transferred to spreadsheets for further analysis.

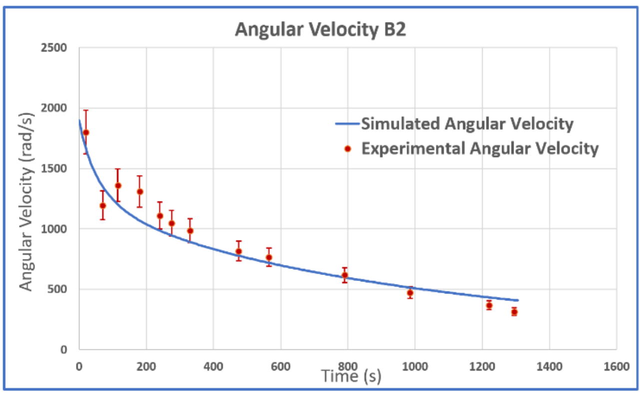

Figure 2: Angular velocity and air pressure measurements were used to calibrate the simulation.

A computer model of the experiment was written in C# to model differential equations for 1) how the rotational velocity of the gyroscope's main part and shell part would change, 2) how the air pressure would decrease toward a vacuum, and 3) account for the fluid dynamics effects that would dominate until the vacuum was sufficiently high quality.

The model's parameters were calibrated by using the measured values for the angular velocity, the air pressure, and the initial change in weight caused by fluid dynamics effects.

The computer model was then used to identify what the data ought to look like with and without the lift force from the centrifugal lift effect in equation (2). These predictions were contrasted with the data. In order to account for our inability to measure the quality of the vacuum below $10^{-3}\ atm$, the model assumed that the air pressure was only reduced by a factor of $10^{-4}\ atm$, which is a very conservative assumption compared to the pump quality claim of $2.9 * 10^{-6} atm$.

When the data collection starts, the gyroscope is spinning at its maximum angular velocity, however it is not yet in a vacuum. The gyroscope has a shell on the bottom that partially shields it from fluid dynamics effects on the bottom side. Since the top of the gyroscope is spinning much faster than the bottom portion, this generated a significant lift force upwards from the Bernoulli effect[3]. Flipping the gyroscope over created a roughly equal and opposite effect pushing downwards on the gyroscope, whereas reversing the spin direction had no effect, and so we are confident that this initial weight reduction is entirely due to the Bernoulli effect.

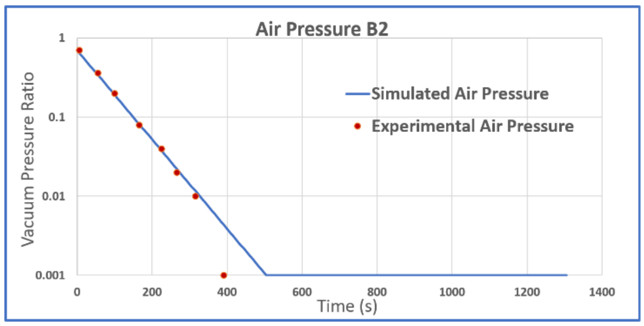

Figure 3: Our setup required about 300 seconds to get to a vacuum quality sufficient to neutralize the Bournoulli effect.

During this first 300 seconds the vacuum pump has not yet established a sufficient quality vacuum and the pressure differences from the Bernoulli effect are the dominant cause of the initial weight reduction. However, the weight reduction persisted long after the vacuum was established, as our theory predicted.

As a control, we tested a non-spinning gyroscope to verify that the change in weight was not caused by the equipment calibration drifting or the lack of buoyancy from the atmosphere. We were unable to collect significant data for when the gyroscope's vertical orientation was flipped because it would keep falling off the base after a few minutes. We also tested both directions of spin, which made no discernable difference.

[3] Taylor, p 725-726

IV. Results and Analysis

There were several iterations of data acquisition, and this series “B2” gave the cleanest data. The green line is our control data from the simulation. The blue line is the theory’s prediction. The red line is the experimental data, which clearly shows the effect is much larger than anticipated.

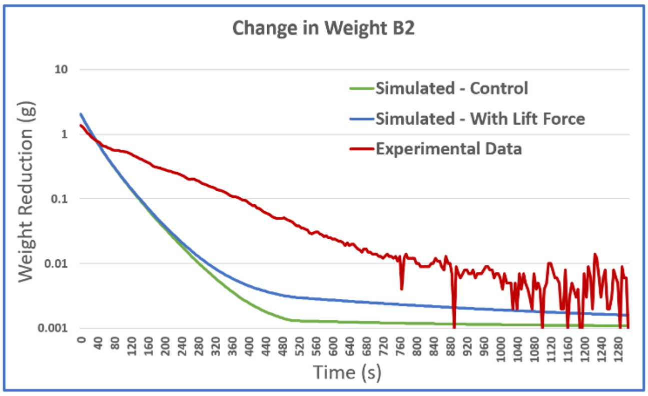

Figure 4: Experimental data showing reduction in measured mass.

Although this deviation is unexpected, it could be quite valuable once understood. The effect seems to increase the magnitude of the lift force significantly. When we first discovered that the effect was much larger than anticipated, we tried collecting more data and tried adding more EM shielding. These changes significantly reduced the noise in the data, which can be seen by comparing the “B2” and “A2” series of data. The “A2” series was obtained prior to adding the extra shielding, and obviously has more noise.

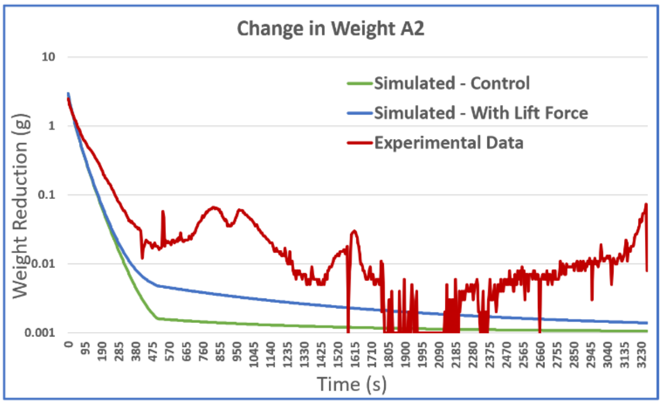

Figure 5: The data prior to adding abundant EM shielding.

Since the mass reduction in the “A2” series has gradual peaks and valleys that occur as the angular velocity of the gyroscope gradually decreased, and since additional EM shielding significantly reduced this response, we concluded that there is an effect related to electromagnetic resonance in the data that was not accounted for in our theory.

Our theory assumed that the gyroscope is a completely electromagnetically neutral rigid body. However, our gyroscope is primarily composed of stainless-steel, conducts current, and is rapidly rotating in unknown EM fields. Unfortunately, we are unable to explain the deviation and leave that investigation for future experiments.

There are many ways to repeat this experiment with higher quality equipment. For example, using an industrial-grade, magnetically levitating flywheel instead of a gyroscope would be ideal as we would be able to achieve much higher angular velocities in a consistent high-quality vacuum.

This experiment is repeatable at the undergraduate level, and does not require expensive equipment. A step-by-step guide for repeating this experiment, along with additional documentation, a copy of our raw data, and the C# program used for data simulation is publicly available here: https://github.com/cjQuinlan/GyroscopeLiftForce

V. Acknowledgements:

Thanks to my lab assistant Kirana Bahls for manually transcribing the data from video. Also, my sincere thanks to all those that have helped to review this paper and offered feedback.

VI. Conclusion:

Using our understanding of centrifugal forces, we theorized that a rotating body ought to experience a lift force away from the Earth proportional to the square of its angular velocity. Our experiment tested this hypothesis by placing a rapidly rotating gyroscope on a sensitive scale within a vacuum chamber, and then measured the change in weight as the gyroscope gradually slowed down.

The data showed a significantly stronger effect than what was expected. Although the effect is larger, our data is consistent with our initial theory. Adding EM shielding seemed to reduce the noise in the data, but not the average values of the data. While supporting the theory, the data also demonstrated that it is an incomplete explanation that is likely missing consideration of EM effects.

We believe that this data is evidence that there is at least one additional mechanism by which a lift force can be generated from rotational energy without the use of propellant or aerodynamics. This may be part of the explanation for the propulsion systems of some UAPs.

References

Government, U. (2021, June 25). *Preliminary Assessment: Unidentified Aerial Phenomena.* Retrieved April 22, 2022, from https://www.dni.gov/files/ODNI/documents/assessments/Prelimary-Assessment-UAP-20210625.pdf

Taylor, J. (2005). *Classical Mechanics.* Sausalito, California: University Science Books.