Inertial propulsion Part III: A note on Laithwaite's engine

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Abstract

In this paper, using Newtonian mechanics, we show that under the assumption of small motion about the horizontal plane, the famous Laithwaite's engine operates like an ideal harmonic oscillator. It was found that the frequency of the aforementioned oscillation is higher than the frequency of the vertical driving main spindle, the difference depending on the ratio of the product mass×axle's length×radius (*mlR*) of the forced precession over the moment of inertia (I_1) of the gyro with respect to an axis passing through the pivoting point and being normal to the axle.

Keywords: Laithwaite, forced precession, small displacements.
Method: rigid body motion analysis

1. Introduction

In a previous paper [1] we have reported on the topic of 'inertial propulsion'. Inertial propulsion through concentrated rotating eccentric masses has been thoroughly demystified by Provatidis for space [2-4], ground [5, 6] and water [7] applications. Also, an electromagnetic equivalent of Dean's drive has been presented [8]. As an extreme thought application, it has been shown that if two hydrogen molecules were to cooperate in the setup of a Dean drive, then the maximum height they could reach would be 72 km [9]. Concerning alternative configurations, the figure-eight (8 or ∞) shaped drive has been analyzed [10, 11].

Besides Dean drive, i.e. instead of using concentrated masses, the so-called Laithwaite's engine uses two spinning flywheels at the end of two axles. The configuration can be found in Clarke's encyclopedia [12] (Fig. 1 has been partially extracted from its Greek translation, the only available to the author). The term "*Laithwaite engine*" has been derived from the (antigravity) book of Childress [13] as well as the mainstream book of Millis and Davis [14] (see, Fig. 2).

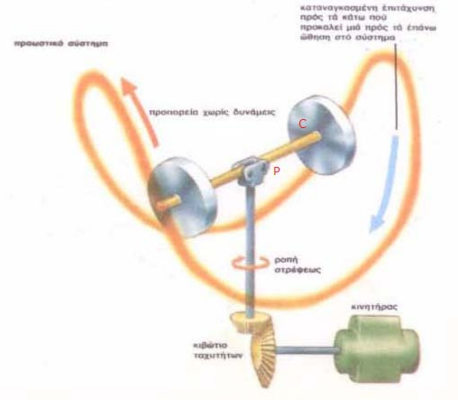

Figure 1: The operation of Laithwaite's engine (From [12])

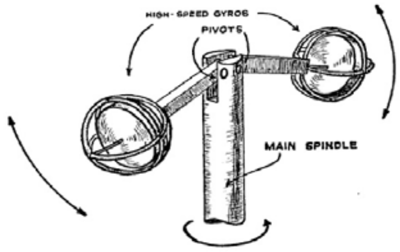

Figure 2: The original Laithwaite's engine (From [13,14])

The subject has been analyzed in 2013 by the author [15] in the context of Newtonian mechanics, while other authors have proposed non-Newtonian approaches with a modified Newton's law [16, 17], or new physics of forces by replacing relativistic, quantum and string theories with process models, so they claim [18].

Despite the above studies the topic remains still unclear, although [15] has come to some conclusions, however extracted from several calculations based on the accurate numerical solution of Euler's equations of motion. Nevertheless, not a simple expression for the description of the motion of the two flywheels has been presented so far. As the level of mechanics in [15] is rather high, it is the purpose of this paper to explain the procedure we followed to derive the equations of motion, then to present a simple formula that describes the motion of the axles, and finally to obtain some conclusions.

2. Euler equations of forced precession in a spinning wheel supported on a rotating pivot

Many books of physics such as French (1971) and classical mechanics such as Goldstein et al. (2011, and older), deal with the case of a spinning top or a flywheel that rotates around a *fixed* point. This case has been extensively studied even from the time of Lagrange (1811). In contrast, Laithwaite engine (see, Figs. 1 and 2) includes two flywheels that do *not* rotate around fixed points. In more details, each of the two pivots shown in Figs. 1 and 2 are located at a short distance *R* from the axis of the vertical spindle. In other words, each axle of the corresponding flywheel is attached to the circumference of an (imaginary) 'circular table' of radius *R* that rotates at an angular velocity, ω. The key point to write down the Euler equations of motion is to decide about the *type of the joint* between each axle and the table. Reference [15] studies two characteristic cases: (i) a ball joint and (ii) a hinge joint. In the particular case of Laithwaite's engine shown in Fig. 1 and Fig. 2, we can clearly notice *hinge* joints only.

A hinge joint transfers a shear force and also moment components except of the one that refers to the axis of the pivot. Since the pivoting point P follows the circumference of a circle of radius *R*, the *torsional* option of second Newton's law (torque = change rate of momentum) must be taken with respect to the *center of mass* C and not the pivot P. However, this fact requires the knowledge of internal shear force at the pivot P. In order to determine the before-mentioned shear force, it becomes necessary to apply the *translational* option of second Newton's law (force = mass times acceleration at the centroid). If this procedure is followed, then lengthy expressions for the Euler equations are derived (see, [15]).

Having previously tested the accuracy of numerical analysis of the classical spinning top about a fixed point [19] (as a benchmark for which the analytical solutions are known), we apply the same type of numerical solution for Laithwaite's engine as well. Each of the following assumptions has been thoroughly examined and validated using the aforementioned full numerical solution as well.

Following [15], for the particular case of a vertical spindle that rotates at a *constant* angular velocity, ω, the three Euler equations become:

Equation-1: $$2(I_1^C + ml^2)\omega\dot{\theta}\cos\theta - I_3\dot{\theta}\left(\omega\cos\theta + \dot{\psi}\right) = -M_{\text{int},1} \quad (1)$$

Equation 2: $$\boxed{(I_1^C + ml^2)\ddot{\theta} - (I_1^C + ml^2)\omega^2\sin\theta\cos\theta + I_3\omega\sin\theta\left(\omega\cos\theta + \dot{\psi}\right) = -ml[-R\omega^2\cos\theta - g\sin\theta]} \quad (2)$$

Equation-3: $$I_3\left(-\dot{\phi}\dot{\theta}\sin\theta + \ddot{\psi}\right) = M_{\text{int},3} \quad (3)$$

where ϕ is the azimuthal angle, θ is the inclination angle, and ψ is the spinning angle.

The triplet (ϕ, θ and ψ) consist the so-called Euler angles, see for example, Goldstein [21].

Due to the hinge joint $M_{\text{int},2} = 0$, and due to the fact that no torsional moment influences the behavior of the gyro (only elastic deformation is possible but here is neglected) $M_{\text{int},3} = 0$.

Under these circumstances Eq. (3) depicts that (remind that ω = constant):

$$\omega_3 = \dot{\phi}\cos\theta + \dot{\psi} = \dot{\psi}_0 = \text{const.} \quad (4)$$

Therefore, Eq. (2) becomes the *governing* ordinary differential equation that describes the whole phenomenon. After its solution, Eq. (1) merely determines the internal moment $M_{\text{int},1}$.

3. Simplified equations

Following [20], we investigate the particular case in which the initial position of the two axles (PC and P´C´) is perfectly horizontal ($\theta = \pi/2$) and the axles are at rest. Assuming that during the entire motion the amplitude is small (e.g. less than 5 degrees) so that:

$$\cos\theta \cong \frac{\pi}{2} - \theta \qquad \text{and} \qquad \sin\theta \cong 1, \quad (5)$$

and considering that $\dot{\phi} \equiv \omega_m$ (the index '*m*' stands for the driving motor), after manipulation Eq. (2) takes the form

$$\ddot{\theta} + \omega^2\theta = b \quad (6)$$

where

$$\omega = \omega_m\sqrt{1 + \frac{mlR}{I_1^C + ml^2}} \quad (7)$$

and

$$b = \frac{\pi}{2}\omega^2 - \frac{I_3\omega_m\omega_3 - mgl}{I_1^C + ml^2} \quad (8)$$

For the abovementioned initial conditions the general solution of the ordinary differential equation (6) is:

$$\theta(t) = \frac{\pi}{2} - \delta(1 - \cos\omega t) \quad (9)$$

with

$$\delta = \frac{I_3\omega_m\omega_3 - mgl}{\omega^2(I_1^C + ml^2)} \quad (10)$$

4. Discussion

Despite the limitation imposed by the assumption (5), it was clearly shown that Laithwaite's engine can operate like a harmonic oscillator with a natural frequency given by

Eq. (7). Since $\omega > \omega_m$ (cf. eq. [7]), $T < T_m$. Therefore, during a full rotation of the vertical main spindle (see Fig. 2) by 360 degrees, the two axles of the flywheels have *already* completed a full period of their harmonic oscillation. Conclusions about reaction forces and totally energy consumed are reported in [20], and hopefully will be extended in a future paper.

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