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Research Article

Physics of Gyroscope's "Antigravity Effect"

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The physics of gyroscopic effects are more complex than presented in existing mathematical models. The effects presented by these models do not match the real forces acting on gyroscopic devices. New research in this area has demonstrated that a system of inertial torques, which are generated by the rotating mass of spinning objects, acts upon a gyroscope. The actions of the system of inertial forces are validated by practical tests of the motions of a gyroscope with one side support. The action of external load torque on a gyroscope with one side support demonstrates that the gyroscope's upward motion is wrongly called an "antigravity" effect. The upward motion of a gyroscope is the result of precession torque around its horizontal axis. The novelty of the present work is related to the mathematical models for the upward and downward motions of gyroscopes influenced by external torque around the vertical axis. This analytical research describes the physics of gyroscopes' upward motion and validates that gyroscopes do not possess an antigravity property.

1. Introduction

The applied theory of gyroscopes emerged mainly during the twentieth century due to the vast application and intensification of the rotation of numerous spinning objects in engineering [1–4]. Gyroscope properties are used in many engineering calculations related to rotating parts in aerospace, shipbuilding, and other industries, and numerous publications have been dedicated to gyroscopic effects [5, 6]. Fundamental textbooks and publications about classical mechanics describe gyroscopic effects in Euler's term of the change in angular momentum [7–9]. Nevertheless, previous analytical approaches are based on several assumptions and simplifications that lead to theoretical uncertainty about gyroscopic effects [10, 11]. Mathematical models for gyroscope properties in publications do not match the practical applications of gyroscopic devices [12–15]. All rotating objects of movable mechanisms manifest gyroscopic effects that should be computed using engineering methods. From this, researchers have coined artificial terms such as gyroscopic effects and gyroscope couples, and they have established noninertial, nongravitational properties that contradict the principles of physics.

The physics of gyroscopic effects are more complex than presented in the literature. The external torque applied to the gyroscope produces a system of eight inertial torques generated by centrifugal, common inertial, and Coriolis forces, as well as by the change in the angular momentum of the spinning rotor. The actions of the system of inertial torques around the axes of the gyroscope are interrelated and manifest all gyroscopic properties that were previously unexplainable. Today, the physics and mathematical models of gyroscopes' inertial torques are well described and have been validated [16–20]. However, the new analytical approach still has some mathematical errors. Some publications point out mathematical models' inaccuracy when dealing with the inertial torques acting on a gyroscope [20]. In engineering, several load torques of gyroscopic devices can act in different directions around their axes of rotation. The interrelated actions of the internal and external load torques on the gyroscope pose a solvable scientific and engineering problem. The novelty of the present work describes an accurate mathematical model for gyroscope upward motion under the action of external torque and explains the physics of the gyroscopic effect that has wrongly been called an "antigravity" property.

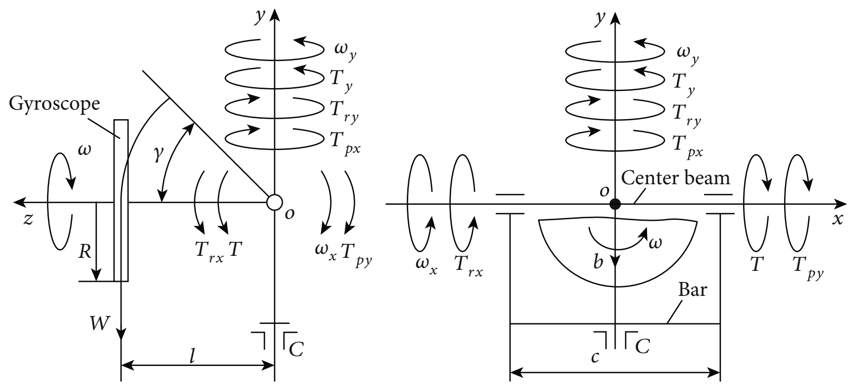

Figure 1: The torques and motions acting on the gyroscope with one side support.

2. Methodology

Recent investigations into the physical principles of gyroscopic effects have led to mathematical models that can be used to assess a system of inertial forces acting on a gyroscope. New mathematical models of internal torques have described new gyroscope properties and behaviours of gyroscopic devices. The action of external load on a gyroscope generates resistance and precession torques originated by the rotation of the mass-elements of the spinning rotor. The mathematical models for the inertial torques acting on a gyroscope are presented in several publications [16–20]. One publication contains incorrect mathematical models for the interrelation of external and internal torques acting on a gyroscope [20]. The action of the system of interrelated inertial torques around the axes of the gyroscope should be considered carefully. Analyses of the interdependent sequence action of the external and inertial torques enable the physical principles of the gyroscope motions to be formulated. The actions of the system of torques and their effects on the gyroscopic stand have been considered, and the related technical data have been published [20]. The mathematical models for gyroscope motions are presented via two examples of the actions of external and internal torques on the gyroscope with one side support for its horizontal location. For simplicity, the actions of frictional forces on the supports and pivot are not considered. Two mathematical models of gyroscope motions provide a clear picture of the physics of the acting external and internal torques. The first mathematical model considers the action of the external load torques, described as the torque T_y acting on the gyroscope around axis *oy* and the torque T of the gyroscope weight W acting around axis *ox* in a counterclockwise direction. The second mathematical model considers the external loads described as the action of the torque T_y in the clockwise direction around axis *oy* and the action of the torque T of the gyroscope weight in a counterclockwise direction around axis *ox*. This constructional peculiarity of the gyroscope stand generates a unique combination of acting inertial torques and different motions.

2.1. Case Study 1. The mathematical model for the gyroscope motions considers the action of the load torque T_y around axis *oy* in a counterclockwise direction and the load torque $T = Wgl$ generated by the weight W of the gyroscope around axis *ox*. Under these conditions, the action of the external load torque T_y generates a system of inertial torques that act around the axes of the gyroscope (Figure 1). The action of the load torque T_y generates the following inertial torques:

(a) The resistance torque $T_{r.y} = T_{ct.y} + T_{cr.y}$ generated by the action of centrifugal $T_{ct.y}$ and Coriolis forces $T_{cr.y}$ around axis *oy* in a clockwise direction (i.e., in the opposite direction of the action of load torque T_y)

(b) The procession torque $T_{p.y} = T_{\text{in}.y} + T_{am.y}$ generated by the common inertial forces $T_{\text{in}.y}$ and the change in the angular momentum of the spinning rotor $T_{am.y}$ originated at axis *oy* but acting around axis *ox* in a clockwise direction (i.e., in the opposite direction of the action of the gyroscope weight T). The value of the torque produced by the gyroscope weight T is lower than the value of the resulting inertial torques $T_{rstx} = T_{p.y} - T_{r.x} - T$ acting around axis *ox*. The latter (T_{rstx}) causes the upward motion of the gyroscope

(c) The procession torque $T_{p.y}$ around axis *ox*, in turn, generates the resistance torque $T_{r.x} = T_{ct.x} + T_{cr.x}$ of centrifugal $T_{ct.x}$ and Coriolis forces $T_{cr.x}$ around axis *ox*. These torques move in a counterclockwise direction and augment the action of the gyroscope weight T

The action of the resulting torque $T_{rstx} = T_{p.y} - T_{r.x} - T$ around axis *ox* produces the precession torque $T_{p.x} = T_{\text{in}.x} + T_{am.x}$ generated by the common inertial forces $T_{\text{in}.x}$ and the change in the angular momentum $T_{am.x}$ originated on axis *o x* but acting around axis *oy* and added to the resistance torque $T_{r.y}$ around axis *oy*, which results in the resistance torque $T_{rst.y} = T_{r.y} + T_{p.x}$.

The actions of loads T_y and T change the values of interrelated inertial torques acting around two axes. The action of the external torque T_y generates precession torque $T_{p.y}$, which acts around axis *ox*, which is opposite to the action of the gyroscope weight T. This situation leads to decreases in the value of the resulting inertial torque $T_{rst.x}$ and the precession torque $T_{p.x}$ acting around axis oy. The changes in the values of the inertial torques are equal because they express the internal kinetic energies. This change is expressed by the coefficient of the change in the inertial torques around one axis and is explained by the following expression:

$$\eta = \frac{T_{p.y} - T}{T_{p.y}} = 1 - \frac{T}{T_{p.y}} = \left[1 - \frac{Wgl}{((2\pi^2 + 9)/9)J\omega\omega_y}\right], \quad (1)$$

where expressions of the inertial torques [16] and the torque produced by the gyroscope weight are substituted into Equation (1). All components are as specified above.

The coefficient η represents the decrease in the value of precession torque acting around axis oy when the value of inertial torque around axis ox decreases. This dependency reflects the interrelation of the inertial torques acting around two axes. An analysis of Equation (1) results in the following values of the coefficient η:

(i) The absence of the load torque T acting around axis ox means that the coefficient is $\eta = 1.0$ (i.e., there is no change in the value of the inertial torques acting around two axes)

(ii) The action of the load torque T means that the coefficient is $\eta < 1.0$ (i.e., the values of the inertial acting torques around two axes decrease)

(iii) When the load torque is equal to the precession torque ($T = T_{p.y}$), the coefficient is $\eta = 0$ (i.e., the gyroscope does not turn around axis oy but instead turns around axis ox under only the action of the gyroscope weight).

This peculiarity should be represented in equations of the gyroscope motions around two axes. A mathematical model has been developed to assess a gyroscope's motions that are caused by the action of the external and internal torques. This model involves corrections based on the interrelated action of the inertial torques and is presented by the following Euler's differential equations:

$$J_y \frac{d\omega_y}{dt} = T_y - T_{ct.y} - T_{cr.y} - (T_{\text{in}.x} + T_{am.x})\eta, \quad (2)$$

$$-J_x \frac{d\omega_x}{dt} = T - T_{\text{in}.y} - T_{am.y} + T_{ct.x} + T_{cr.x}, \quad (3)$$

where ω_x and ω_y are the angular velocities of the gyroscope around axes ox and oy, respectively; $T_{ct.x}$, $T_{ct.y}$, $T_{cr.x}$, $T_{cr.y}$, $T_{\text{in}.x}$, $T_{\text{in}.y}$, $T_{am.x}$, and $T_{am.y}$ are the internal torques generated by the centrifugal, Coriolis, and common inertial forces and the change in the angular momentum acting around axes ox and oy, respectively [16]. The sign (-) of Equation (3) means that the motion occurs in a clockwise direction. All other components are as specified above.

Equations of inertial torques [16] and Equation (1) are substituted into Equations (2) and (3). The components of the torques generated by centrifugal $T_{ct.y}$ and inertial $T_{\text{in}.x}$ forces that have the same expression are removed from Equations (2) and (3). The simplification and modification of these equations are similar to the solution presented in the manuscripts [17, 18], wherein this process is justified in detail. Modified equations are presented by the following system:

$$J_y \frac{d\omega_y}{dt} = T_y - \left(\frac{2\pi^2 + 8}{9}\right) J\omega\omega_y - J\omega\omega_x \times \left[1 - \frac{Wgl}{((2\pi^2 + 9)/9)J\omega\omega_y}\right], \quad (4)$$

$$-J_x \frac{d\omega_x}{dt} = T - \left[\left(\frac{2\pi^2 + 9}{9}\right) J\omega\omega_y - \frac{8}{9} J\omega\omega_x\right], \quad (5)$$

$$\omega_x = \left(4\pi^2 + 17\right)\omega_y, \quad (6)$$

where Equation (6) represents the dependency of the angular velocities of the gyroscope around axes ox and oy that were added to Equations (4) and (5). This solution is presented in manuscripts [17, 18] that use similar analytical approaches. All other parameters are as specified above.

Substituting Equation (6) into the first Equation (3) and transformation gives the following equation:

$$J_y \frac{d\omega_y}{dt} = T_y - \left(\frac{2\pi^2 + 8}{9}\right) J\omega\omega_y - \left(4\pi^2 + 17\right) J\omega\omega_y \times \left[1 - \frac{Wgl}{((2\pi^2 + 9)/9)J\omega\omega_y}\right], \quad (7)$$

where all components are as specified above.

2.1.1. Working Example. The components of a gyroscope with one side support move under the action of the load torques T_y and T, which are generated by the gyroscope weight and act around axes oy and ox, respectively. The value of the first torque T_y is half the value of torque T (i.e., $T_y = 0.5Wgl$). The actions of the torques and motions are presented in Figure 1. The technical data related to the gyroscope is presented in the manuscript ([20], Table 1). Equation (7) is the equation of the gyroscope motion around axis oy. The ratio of the angular velocities around two axes is calculated using Equation (6). The angular velocity around axis oy is defined by the following solution. Substituting the initial data of the gyroscope [20] and the data presented above into Equation (7) yields the following equation:

$$\begin{aligned}
&3.38437\times10^{-4}\frac{d\omega_y}{dt}\\
&\quad=0.5\times0.146\times9.81\times0.0355\\
&\qquad-\left(\frac{2\pi^2+8}{9}\right)\times0.5543873\times10^{-4}\\
&\qquad\times\omega\omega_y-\left(4\pi^2+17\right)\times0.5543873\times10^{-4}\\
&\qquad\times\omega\omega_y\left[1-\frac{0.146\times9.81\times0.0355}{((2\pi^2+9)/9)\times0.5543873\times10^{-4}\times\omega\omega_y}\right].
\end{aligned}\tag{8}$$

Equation (8) can be simplified as follows:

$$0.102495748\frac{d\omega_y}{dt}=280.049918886-\omega\omega_y.\tag{9}$$

Equation (10) arises by separating the variables to simplify and transform Equation (9):

$$\frac{d\omega_y}{(280.049918886/\omega)-\omega_y}=9.756502262\omega dt.\tag{10}$$

Equation (11) is the integral form of Equation (10):

$$\int_0^{\omega_y}\frac{d\omega_y}{(280.049918886/\omega)-\omega_y}=9.756502262\omega\int_0^t dt.\tag{11}$$

The left integral of Equation (11) is tabulated and presented as the integral $\int(dx/(a-x))=-\ln x+C$. The right integral is simple. Solving the integrals yields the following equation:

$$-\ln\left(\frac{280.049918886}{\omega}-\omega_y\right)\Big|_0^{\omega_y}=9.756502262\omega t\Big|_0^t,\tag{12}$$

thus giving rise to the following:

$$\begin{aligned}
&\ln\left(\frac{280.049918886}{\omega}-\omega_y\right)-\ln\left(\frac{280.049918886}{\omega}\right)\\
&\quad=-9.756502262\omega t.
\end{aligned}\tag{13}$$

Equation (13) can be transformed into the equation of angular velocity for the gyroscope around axis oy:

$$\left(1-\frac{\omega_y}{280.049918886/\omega}\right)=e^{-9.756502262\omega t}.\tag{14}$$

The right component of Equation (14) contains the expression $e^{-9.756502262\omega t}$, which has a small value of the high order by which the angular velocity ω of the spinning rotor is around $n=10000\cdots30000$ rpm. Hence, this component of the equation can be neglected. Solving Equation (10) yields the following equation:

$$\omega_y=\frac{280.049918886}{\omega},\tag{15}$$

where all components are as specified above.

The angular velocity ω of the gyroscope around axis oy is defined according to the rotor's speed of $n=10000.0$ rpm. Substituting n into Equations (15) and (6) yields the angular velocities of the gyroscope around axes oy and ox:

$$\begin{aligned}
\omega_y&=\frac{280.049918886}{\omega}=\frac{280.049918886}{(10000\times2\pi)/60}\\
&=0.267427973\ \text{rad/s}=15.322494^\circ/\text{s},
\end{aligned}\tag{16}$$

$$\begin{aligned}
\omega_x&=-\left(4\pi^2+17\right)\omega_y=-\left(4\pi^2+17\right)\times0.267427973\\
&=-15.103908738\ \text{rad/s}=-865.390224^\circ/\text{s},
\end{aligned}\tag{17}$$

where the sign (-) of Equation (17) means the gyroscope precession around axis ox is in the clockwise direction, i.e., the gyroscope moves upward.

The torque T_y acting around axis oy leads to slow counterclockwise rotation around axis oy and causes the intensive precessed clockwise rotation of the gyroscope around axis ox. The gyroscope moves upward from its horizontal location. This effect serves as practical evidence of the absence of the antigravity property.

2.2. Case Study 2. The mathematical model for the gyroscope's motions is considered for the same gyroscope stand and technical parameters presented in Section 2.1, Case Study 1. The difference is the clockwise action of the load torque T_y around axis oy. Under this condition, the actions of the gyroscope internal torques and motions are as follows:

(i) The load torque T_y generates the resistance torque T_{ry}, which acts in a counterclockwise direction around axis oy and the precession torque T_{py}, which acts around axis ox in a counterclockwise direction. This coincides with the action of the load torque T

(ii) The action of the torque produced by the gyroscope weight T generates the resistance T_{rx} and precession T_{px} torques. The resistance torque T_{rx} acts in a clockwise direction around axis ox. The precession torque T_{px} acts in a counterclockwise direction around axis oy as the torque T

All acting torques and motions of the gyroscope with one side support are illustrated in Figure 2.

The equations of the gyroscope torques and motions around axes ox and oy are represented by the following expressions:

$$-J_y\frac{d\omega_y}{dt}=-T_y+T_{ct.y}+T_{cr.y}+(T_{\text{in}.x}+T_{am.x})\eta,\tag{18}$$

$$J_x\frac{d\omega_x}{dt}=T+\left(T_{\text{in}.y}+T_{am.y}-T_{ct.x}-T_{cr.x}\right),\tag{19}$$

Table 1: Technical data of the test stand with Super Precision Gyroscope, "Brightfusion Ltd.".

Parameters	Mass (kg)	Mass moment of inertia around axes *ox* and *oy* (J kg m^2)
Spinning rotor with shaft (m_r)	0.1159	$J = m_r R^2/2 = 0.5543873 \times 10^{-4}$ (around axis *oz*)
Gyroscope (M)	0.146	$J_{iM} = (2/3) m_f r_f^{\,2} + m_f l^2 + (m_r R^2{}_c/4) + m_r l^2 = 2.284736^* 10^{-4}$
Centre beam with journals and screw (b)	0.028	$J_{bx} = m_b r^2{}_b/2 = 0.00224 \times 10^{-4}$ (around axis *ox*) $J_{by} = m_b l^2{}_b/12 = 0.2105833 \times 10^{-4}$ (around axis *oy*)
Mass $E = M + b$	0.174	$J_{Ex} = J_{xM} + J_{bx=} 2.286976 \times 10^{-4}$ (around axis *ox*)
Bar with screws (b_s)	0.067	$J_{bs} = m_{bs} l^2{}_{bs}/12 = 0.51456 \times 10^{-4}$ (around axis *oy*)
Arm (a)	$2 \times 0.009 = 0.018$	$J_a = m_a r^2{}_a/2 + m_a l_a^{\,2} = 0.41553 \times 10^{-4}$ (around axis *oy*)
Total $A = M + b + bs + a$	0.259	$J_y = J_{yM} + J_b + J_{bs} + J_a = 3.38437 \times 10^{-4}$ (around axis *oy*)

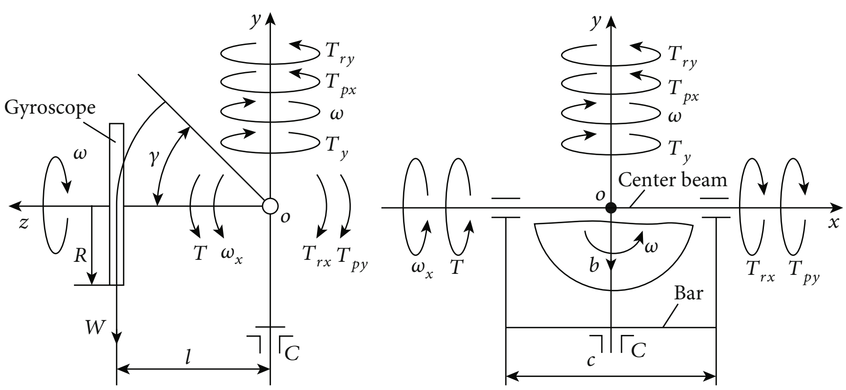

Figure 2: Internal torques and motions when the load torque T_y acts in the clockwise direction around axis *oy*.

where the sign (-) of Equation (18) indicates a clockwise movement. All other components are as specified above.

The coefficient η represents the proportional increase of the precession torque $T_{p.x}$ around axis *oy*. The coefficient η is expressed as the ratio of the sum of the precession $T_{p.y}$ and load T torques to the precession $T_{p.y}$ torque, which acts around axis *ox*. The expression η is obtained in a similar way as in Equation (1) and is represented by the following equation:

$$\eta = \frac{T_{p.y} + T}{T_{p.y}} = 1 + \frac{T}{T_{p.y}} = \left[1 + \frac{Wgl}{((2\pi^2 + 9)/9) J\omega\omega_y}\right], \quad (20)$$

where η is the coefficient of the proportional increase of the value of the precession torque $T_{p.x}$ acting around axis *oy*. All other parameters are as specified above.

The coefficient η denotes the increase in precession torque $T_{p.x}$ around axis *oy* when the value of the resulting torque $T_{rst.x}$ around axis *ox* also increases. Equation (20) demonstrates the following values of the coefficient η:

(i) The absence of the load torque T acting around axis *ox* means that the coefficient $\eta = 1.0$ (i.e., there is no change in the values of the inertial torques acting around two axes)

(ii) The action of the load torque T means that the coefficient is $\eta > 1.0$ (i.e., the values of the inertial torques acting around two axes increase)

(iii) When the load torque of the gyroscope weight is equal to the precession torque ($T = T_{p.y}$), the coefficient $\eta = 2$ (i.e., there is an increase in the value of the resulting resistance torque $T_{rtst.y}$ acting around axis *oy*)

Equations for inertial torques—that is, Equations (17) and (20)—are substituted into Equations (18) and (19). Equations (21)–(23) are simplified and transformed in the same manner as Equations (4)–(6):

$$-J_y \frac{d\omega_y}{dt} = -T_y + \frac{2}{9}\left(\pi^2 + 4\right) J\omega\omega_y + J\omega\omega_x \times \left[1 + \frac{Wgl}{((2/9)\pi^2 + 1) J\omega\omega_y}\right], \quad (21)$$

$$J_x \frac{d\omega_x}{dt} = T + \left[\left(\frac{2}{9}\pi^2 + 1\right) J\omega\omega_y - \frac{8}{9} J\omega\omega_x\right], \quad (22)$$

$$\omega_x = \left(4\pi^2 + 17\right)\omega_y, \quad (23)$$

where all parameters are as specified above.

Regarding the motion around axis *ox*, the acting torques are represented by the combined action of the gyroscope weight T with the precession torques $T_{p.y}$ and of the resistance torques $T_{r.x}$ in the opposite direction. The torques acting around axis *oy* are represented by the action of the load torque T_y and the combined resistance torques $T_{r.y}$ with precession torques $T_{p.x}$ acting in the opposite direction. The following solution for Equations (21)–(23) is the same as presented in Section 2.1, Case Study 1. Equation (21) can be solved by substituting the defined equation and utilising transformations to yield the following equation:

$$-J_y \frac{d\omega_y}{dt} = -T_y + \frac{2}{9}\left(\pi^2+4\right)J\omega\omega_y + \left(4\pi^2+17\right)J\omega\omega_y \times \left[1 + \frac{Wgl}{((2/9)\pi^2+1)J\omega\omega_y}\right], \quad (24)$$

where all components are as specified above.

2.2.1. Working Example. The motions of the gyroscope with one side support are conducted under the clockwise action of the load torque T_y around axis *oy*. The sketch of the action of the torques and motions is presented in Figure 2. Equation (24) is the equation of the gyroscope motion around axis *oy*. The angular velocities of precessions around the two axes should be defined. Substituting the initial data of the gyroscope ([20], Table 1) into Equation (24) and making transformations yield the following equation:

$$\begin{aligned}
&-3.38437 \times 10^{-4} \frac{d\omega_y}{dt} \\
&= -0.5 \times 0.146 \times 9.81 \times 0.0355 + \frac{2}{9}\left(\pi^2+4\right) \\
&\quad \times 0.5543873 \times 10^{-4} \times \omega\omega_y + \left(4\pi^2+17\right) \\
&\quad \times 0.5543873 \times 10^{-4} \times \omega\omega_y \\
&\quad \times \left[1 + \frac{0.146 \times 9.81 \times 0.0355}{((2/9)\pi^2+1) \times 0.5543873 \times 10^{-4} \times \omega\omega_y}\right].
\end{aligned} \quad (25)$$

Equation (25) is simplified. Then, the steps of solutions similar to the steps presented in Section 2.1, Case Study 1, are carried out. All comments related to the solutions of the equations are omitted.

$$\begin{aligned}
&-0.102495748 \frac{d\omega_y}{dt} = 264.651454335 + \omega\omega_y, \\
&\frac{d\omega_y}{\omega_y + (264.651454335/\omega)} = -9.756502262\omega dt, \\
&\int_0^{\omega_y} \frac{d\omega_y}{\omega_y + (264.651454335/\omega)} = -9.756502262\omega \int_0^t dt, \\
&\ln\left(\omega_y + \frac{264.651454335}{\omega}\right)\Big|_0^{\omega_y} = -9.756502262\omega t\Big|_0^t, \\
&\ln\left(\omega_y + \frac{264.651454335}{\omega}\right) - \ln\left(\frac{264.651454335}{\omega}\right) \\
&= -9.756502262\omega t, \\
&\left(1 + \frac{\omega_y}{264.651454335/\omega}\right) = e^{-9.756502262\omega t}, \\
&\omega_y = -\frac{264.651454335}{\omega},
\end{aligned} \quad (26)$$

where the sign (-) indicates a clockwise movement.

$$\begin{aligned}
\omega_y &= -\frac{264.651454335}{10000 \times (2\pi/60)} = -0.252723522 \text{ rad/s} \\
&= -14.479991^\circ/\text{s}, \\
\omega_x &= \left(4\pi^2+17\right) \times 0.252723522 \\
&= 14.273424613 \text{ rad/s} = 817.806989^\circ/\text{s}.
\end{aligned} \quad (27)$$

The torque T_y acting around axis *oy* causes the slow clockwise rotation around axis *oy* and the intensive counterclockwise rotation of the gyroscope around axis *ox*. These rotations result in a counterclockwise torque around axis *ox*.

3. Results and Discussion

Mathematical models for the gyroscopic effects lead to equations for the motions of the gyroscope with one side support for the main external torque acting around the vertical axis. The models of the gyroscope motions around two axes are based on the actions of the external and internal torques that are generated by centrifugal, common inertial, and Coriolis forces. They are also based on the change in angular momentum. The new analytical approach to the gyroscopic problem demonstrates that the action of the external load torque around the vertical axis generates the precession torques that turn the gyroscope upward or downward around the horizontal axis. These motions depend on the direction of the rotation of the spinning rotor. Mathematical models for the motions of a gyroscope with one side support in which actions carried out by external and internal torques around two axes are confirmed by observations made during practical tests.

4. Conclusion

Previous mathematical models for gyroscopic effects contain many assumptions and simplifications that have not been validated in practice. This new study of gyroscopic effects examines the actions of the system of inertial torques generated by the known inertial forces of classical mechanics. The mathematical models for the motions of a gyroscope with one side support and the action of counterclockwise and clockwise load torques around the vertical axis explain the gyroscope's upward and downward motion. The upward motion of the gyroscope is not an antigravity property, as was once thought, but is the result of the action of the precession torque generated by the load torque. The value of the precession torque is greater than the value of the torque produced by the gyroscope weight. The analytical models for the gyroscope's upward and downward motions clearly describe the physics of such gyroscopic effects.

Nomenclature

g:	Gravity acceleration
e:	Base of the natural logarithm
i:	Index for axes *ox* or *oy*
J:	Mass moment of inertia of a rotor's disc
J_i:	Mass moment of inertia of a gyroscope around axis i
l:	Distance between gyroscope centre mass and one side support
l_i:	Length of gyroscope component i
m:	Mass of rotating components
R:	External radius of a rotor
r_i:	Radius of gyroscope component i
T:	Load torque generated by gyroscope weight
T_y:	Load torque applied to axis *oy*
$T_{am.i}$, T_{cti}, $T_{cr.i}$, $T_{\text{in}.i}$:	Torque generated by the change in angular momentum, centrifugal, Coriolis, and inertial forces, respectively, and acting around axis i
$T_{r.i}$, $T_{p.i}$:	Resistance and precession torque, respectively, acting around axis i
t:	Time
W:	Weight of gyroscope
γ:	Angle of inclination of spinning axle
η:	Coefficient of the change in value internal torques
ω:	Angular velocity of a rotor
ω_i:	Angular velocity of precession around axis i.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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