Robotics & Automation Engineering Journal
ISSN: 2577-2899

Juniper Publishers
key to the Researchers

Review Article
Volume 5 Issue 3 - January 2023
DOI: 10.19080/RAEJ.2023.05.555664

Robot Autom Eng J

Comparative Analysis of the Pendulum and Gyroscope Oscillations

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Submission: December 19, 2022; **Published:** January 25, 2023

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Abstract

The physics of the pendulum and gyroscope oscillations is the same and are presented by the fundamental principles of the potential and kinetic energies and their conversions. The potential energies of the pendulum and gyroscope can be demonstrated by the action of their weight and the external load. The manifestation of their kinetic energies is different. The pendulum's kinetic energy is demonstrated by the variable velocity of its oscillation under the action of the weight. The gyroscope's kinetic energy oscillation is demonstrated by the action of the weight and the torques generated by the centrifugal and Coriolis forces and the change in the angular momentum of the rotor's rotating mass. The external torques acting on the gyroscope generates the composition of inertial torques, which are interrelated by the closed-loop circuit with the feedback and the dependency of its angular velocities around axes of rotation. The pendulum and gyroscope oscillations express the change in the mechanical energy of their rotation around axes. The oscillation of the gyroscope of one side support and with a stopped rotor demonstrates properties of the simple pendulum that well described in the textbooks of classical mechanics. This short communication considers the comparative analysis of the change in the mechanical energies of the pendulum and gyroscope oscillations.

Keywords: Gyroscope Theory; Physics of Gyroscope Oscillation; Change in Mechanical Energy

Introduction

The machine dynamics methods of engineering mechanics are applied for the mathematical modeling of motions of mechanical objects. The physics of the pendulum oscillations is well described in the textbooks of classical mechanics which is presented by the fundamental principles of the potential and kinetic energies and their conversions. The potential energies of the pendulum and gyroscope are demonstrated by the action of their weight and the external load. The manifestation of their kinetic energies is different. The recent publications show the fundamental principles of gyroscope motions contain two components. The first one is the system of the eight inertial torques generated by the centrifugal and Coriolis forces and the change in the angular momentum of the one rotating mass of the spinning rotor. The second component is the interrelated dependency of the angular velocities of the gyroscope rotation around axes. The action of the inertial torques around axes is implemented by the closed-loop circuit with feedback. Both components express the gyroscope motions and the change in the kinetic energy of its rotation around axes [1,2]. The action of all torques and motions of the gyroscope with one side support are demonstrated in the 3D Cartesian coordinate system Σ*oxyz* (Figure 1). The gyroscope of one side support and with a stopped rotor presents the simple pendulum with its properties of mechanical energy. The action of the inertial toques on the gyroscope is presented by the resistance T_r and precession T_p torques around axes *ox* and *oy* with the angular velocities ω_x and ω_y, respectively. The motions of the gyroscope under the action of the external torques about axes of rotation are based on the mechanical energy conservation law [1]. The potential energy of the gyroscope weight is converted into inertial torques and kinetic energy of its motions around axes. Table 1 represents the fundamental principles of the gyroscope theory which are the expressions of inertial torques and the dependency of a gyroscope motion around axes. Table 1 contains the following symbols: ω_i is the angular speed of the spinning disc motion about axis *i*; ω is the spinning velocity of the disc; *J* is the moment of inertia of the spinning disc. All inertial torques are proportional to the toque of the change in angular momentum $T_{am.i}$.

The fundamental principles of the gyroscope theory enable deriving mathematical models for the motion of the gyroscope with one side support, "anti-gravity effect", inversion of the top, and so forth [3-5]. There are phenomena of the nullification of the inertial torques for the gyroscope motion around one axis and others. All of them are related to the mechanical energy of gyroscope motions, which have an indistinct presentation. The reason for such incomplete information in publications was unsolved analytically gyroscopic effects that give rise antiscientific expressions and conclusions. Finally, the problem of gyroscopic effects was solved recently and today is the time for print run of the new knowledge. This process is inertial and is connected with the complexity of the action of the external and internal torques, and interrelated rotational motions of the gyroscope around three axes. The simple examples of the physical principles of classical mechanics in the textbooks make it difficult for their application to complex problems. The sophisticated, multi-parametric, and multifunctional dependencies are always hardly perceived and associated with the physical principles of classical mechanics. [6 -10]. The parameters of the mathematical models should have clear physical contents. This short communication considers the physics of the change in the kinetic energy for the gyroscope with one side support and clearly describes the nature of their inertial torques.

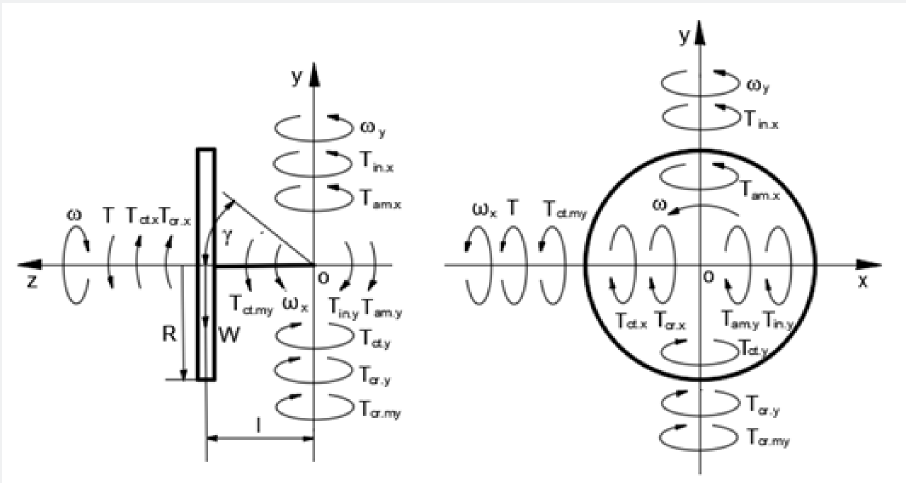

Figure 1: Schematic of acting torques on the gyroscope with one side support.

Table 1: Fundamental principles of the gyroscope theory.

Fundamental Principles of the Gyroscope Theory		Action	Equation, kg.m²/s²
Inertial torques generated by	Centrifugal forces	Resistance	$T_{ct.i} = (4\pi^2/9)J\omega\omega_i$
		Precession	
	Coriolis forces	Resistance	$T_{cr.j} = (8/9)J\omega\omega_i$
	change in angular momentum	Precession	$T_{am.i} = J\omega\omega_i$
Principle of mechanical energy conservation	Dependency of angular velocities of the spinning disc about axes of rotation: $\omega_y = (8\pi^2 + 17)\omega_x$		

Methodology

The known publications of last year's well describe the physics of the gyroscopic effects manifested by the action of interrelated inertial torques on the rotating objects [1]. The method of causal investigatory connections defined the system of inertial torques generated by the centrifugal and Coriolis forces of the rotating mass elements, and the change in the angular momentum of the spinning objects and the dependence of the angular velocities of their rotation around axes. The mathematical models for gyroscope oscillations axes are well-founded by the mechanical energy conservation law and validated by practical tests [5]. The external torques, which are the action of the weight

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of the gyroscope with one side support, the extra torque of the short time action, and its spinning rotor generate the composition of the eight inertial torques acting around axes of motions. The external torques T generates the two compositions of the inertial torques (Figure 1). The first group is the resistance torque $T_r = -T_{ct.x} - T_{cr.x} - T_{ct.y} - T_{am.y}$ acting around axis *ox.* The second group is the precession torque $T_p = T_{ct.x} + T_{am.x} - T_{ct.y} - T_{cr.y}$ acting around axis *oy.* The signs (±) of inertial torques mean the action in the counter and clockwise directions, respectively. The action of the resistance T_r and precession T_p torques is interrelated by the closed feedback loop circuit and manifested by the gyroscope rotations around axes *ox* and *oy* with the angular velocities ω_x and ω_y, respectively. The potential energy of gyroscope weight and external torque is converted into its kinetic energies, which are presented by the inertial torques rotating of the gyroscope around axes *ox* and *oy* with the angular velocities ω_x and ω_y, respectively.

The gyroscope of the horizontal disposition, in which the rotor does not spin, is the classical pendulum oscillating around one axis. The potential energy of the pendulum's bob weight and the extra torque of the short time action is converted into its kinetic energy of its oscillation [6-9]. The forms of the kinetic energies of the pendulum and the gyroscope with one side support are different. The kinetic energy of the pendulum's motion manifests its rotational motion around one axis. The kinetic energies of motions for the gyroscope with the spinning rotor and the one-side support manifest the action of its inertial torques and rotational motions around the two axes. The studies of their oscillating around axes show the following properties:

-The blocking of the pendulum rotation leads to the nullifying of its kinetic energy.

-The gyroscope with the spinning rotor rotates around two axes under the action of the system of the inertial torques.

The blocking of the gyroscope motion around the axis *ox* ($\omega_x = 0$) yields the nullifying of its kinetic energies around two axes (Figure 1). All inertial resistance T_r and precession T_p torques are nullified because there is no rotation around axis *ox*, ($\omega_x = 0$). The nullification of the inertial torques is presented in the publications by the term of their deactivation [3]. The blocking of the gyroscope motion around axis *oy* does not stop its rotation around axis *ox*, but leads to the nullifying of its kinetic energy around axis *oy.* Then, the precession torques generated by the gyroscope motion around the axis of *oy*, i.e., $T_{ct.x}$, T_{cty} , $T_{cr.x}$, and $T_{am.y}$ are nullified (Figure 1). The rotation of the gyroscope around axis *ox* is continued with nullified inertial torques generated by the rotated distributed mass. Their nullifications are conditioned by the principle of the equality of the kinetic energies around two axes, *ox* and *oy*, respectively. The absence of the inertial torques acting around one axis yields the absence of the inertial torques acting around another one because of the maintenance of their interrelations by a closed feedback loop system [1, Chapter 4]. The action of the gyroscope weight and rotation of the rotor center mass generates the inertial torque, $T_{am.x.}$ At the condition of the absence of the resistance inertial torques T_r, the gyroscope rotates with the high angular velocity ω_x around axis, *ox*. The inertial torque $T_{am.x.}$ does not nullify and acts around axis oy because of the maintenance of the principle of mechanical energy conservation that was validated by the practical test. The conducted analysis shows the difference in the manifestation of the kinetic energies of the pendulum rotation and the gyroscope motions around axes. The kinetic energy of the gyroscope is expressed by the system of the action of the inertial torques and motions around axes.

Conclusion

The recent publications of the inertial torques generated by the rotating mass of the gyroscope and its motions about axes described the physics of gyroscopic effects. The potential energies of the gyroscope are converted into kinetic energies of its inertial torques and interrelated motions around axes. The blocking of the action of external torques on the gyroscope yields the nullification or deactivation of all inertial torques generated by the rotating masses acting around two axes. The blocking only of the gyroscope precessed motion yields nullification of the inertial torques acting around two axes by the principle of the equality of their kinetic energies about the two axes. It is necessary to point, the precessed torque, generated by the center mass does not nullify by the principle of kinetic energy conservation. The action of the inertial torques generated by the spinning object explains the physics of the gyroscope motions around two axes by the principles of mechanical energy conservation. The action of the interrelated inertial torques and their kinetic energies enables a better understanding the physics of the complex gyroscope motions in space.

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How to cite this article: Ryspek U. Comparative Analysis of the Pendulum and Gyroscope Oscillations. Robot Autom Eng J. 2023; 5(3): 555664. DOI: 10.19080/RAEJ.2023.05.555664