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Corrected Physics of Deactivation of Gyroscopic Inertial Torques

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Abstract

The main property of gyroscopic devices is maintaining the axis of a spinning rotor in space. All gyroscopes manifest the action of the inertial torques and motions which mathematical models based on the principle of the mechanical energy conservation. New studies show the external force to the spinning rotor generates the net of the interrelated inertial torques acting around axes of its rotation. The four centrifugal, two Coriolis torques and two torques of the change in the angular momentum are looped around two axes and express the resistance and precession torques of the spinning rotor. Blocking of the gyroscope precessed motion leads to the vanishing of inertial torques around two axes except the precessed torque-generated by the center mass of the spinning rotor. The vanish of inertial torques of the running gyroscope is not well described in known publications that needs clarification. This paper represents the detailed explanation of the physics of the vanish of inertial torques for the case of the blocking of gyroscopic precessed motion.

Keywords: gyroscope theory; spinning disc property; inertial torque

Introduction

The study of gyroscopic effects which means the action of unexplainable forces on the spinning object and its motion begins with the times of the Industrial Revolution. The famous mathematician L.Euler described only one gyroscopic effect, which is the precessed torque generated by the rotating center mass of the spinning disc. Other gyroscopic effects remained without mathematical models for around three centuries. The simplified gyroscope theories with mathematical models emerged at the beginning of the twenty century, but the practice did not validate them [1-3]. Unsolved gyroscopic effects attract scientists and researchers that publish numerous manuscripts until our time [4-6]. Fundamental textbooks of classical mechanics contain chapters with simplified solutions to gyroscopic problems that do not accept by engineering industries which prefer to use the numerical models for the gyroscopic effects. All publications explain gyroscopic effects only by the terms of the precessed toque and motion of the spinning rotor [7-10]. The intuitive explanation of the physics of other inertial forces acting on the gyroscopic devices does not find mathematical models [10-12]. The action of unexplained forces on the rotating object and its motions have spawned artificial terms among researchers such as gyroscope resistance, gyroscope couple, gyroscope mystery, and fantastic properties like non-inertial, non-gravitational, and so on.

Recent investigations of the physical principles of gyroscope motions show the action on the spinning disc the net of the eight torques generated by centrifugal and Coriolis forces and the precession torque around axes of its rotation [13, 14]. The dependency of gyroscope rotations around axes of the 3D coordinate system is interrelated with the action of inertial torques (Fig. 1). Mathematical models describe the physical principles of gyroscope rotations [16].

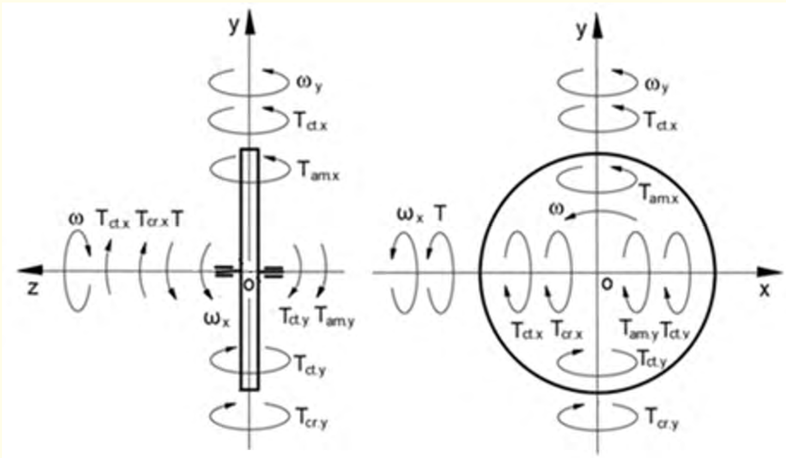

Figure 1: The action of the external and inertial torques on the spinning disc around axes of the 3D coordinate system.

Figure 1 contains the following symbols: T is the external torque; $T_{ct.x}$ and $T_{ct.y}$ is the inertial centrifugal torques acting around axis ox and oy, respectively; $T_{cr.x}$ and $T_{cr.y}$ is the Coriolis inertial torques acting around axis *ox* and *oy*, respectively; $T_{am.x}$ and $T_{am.y}$ is the precession torque acting around axis *ox* and *oy*, respectively; ω is the spinning velocity of the disc, ω_x and ω_y is the disc rotation velocity around axes ox and oy, respectively.

The developed system of the eight inertial torques interrelated by the dependency of the angular velocities of the gyroscope motions around axes of rotations by the principle of the kinetic energy conservation are the fundamental principles of the gyroscope theory [15, 16].

The expressions of inertial torques and the dependency of a gyroscope motion around axes are represented in Table 1. The practice validated the analytical models for the gyroscope motions around axes on the Super Precision Gyroscope model "Brightfusion Ltd".

Fundamental principles of the gyroscope theory		***Action***	***Equation***
Inertial torques generated by	Centrifugal forces	Resistance	$T_{ct.i} = (4\pi^2 / 9)J\omega\omega_i$
		Precession	
	Coriolis forces	Resistance	$T_{cr.i} = (8/9)J\omega\omega_i$
	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 $\omega_y = (8\pi^2 + 17)\omega_x$		

Table 1: Fundamental principles and expressions of inertial torques of the gyroscope theory.

Table 1 contains the following symbols: ω_i is the of the disc angular velocity about axis i; ω is the disc spinning velocity; *J* is the disc moment of inertia. The expressions of the inertial torques and the interrelation of the spinning disc motions about axes of rotation are the basis for the analytical modeling of motions for any gyroscopic device by the known methods of machine dynamics. This paper describes the physics of inertial torques deactivation in case of the blocking the gyroscope precessed motion.

Methodology

The mathematical models of inertial torques acting on a spinning disc are shown in Table 1. These torques are interrelated and act around axes of the 3D coordinate system. The external torque T activates the net of the centrifugal and Coriolis torques and the precession torques of the rotating center mass (Fig. 1). Analysis of the expressions of the inertial torques shows all of them contain the product ($\omega\omega_x$) of the spinning disc velocity *ω* and the angular velocity ω_x of its rotation around axis *ox*. The kinetic energies of spinning disc rotation around axes are equal which express its inertial torques. The equality of the kinetic energies of spinning disc rotation about axes is a fundamental principle validated analytically [16].

The inertial torques $T_{ct.x}$, $T_{cr.x}$, $T_{ct.y}$ and $T_{am.y}$ of the centrifugal and Coriolis forces and the precession torque (*ct. cr*, and *am* indices) are originated around axis *ox* and *oy* (*x* and *y* indices), respectively. The inertial torques $T_{ct.x}$, $T_{am.x}$, $T_{ct.y.}$ and $T_{r.y}$ are generated by the same dynamic components with indices acting around axis *oy*. The action of these inertial torques is looped by the interrelated chain and results in the gyroscope velocities ω_x and ω_y around axis *ox* and *oy*, respectively. The gyroscope velocity around axis *ox* is many times less than around axis *oy* that shown by their dependency presented in Table 1.

The picture of the gyroscope motion with one side support is changed drastically if to block the motion around axis *oy*. The tests demonstrate the vanishing of the inertial torques but the precession torque of the rotating center mass is acting. The vanishing of the inertial torques yields the high speed of the gyroscope rotation around axis *ox* under the action of its weight and the action of the precession torque around axis *oy*. The precession torque creates the frictional torque at the support.

The following analysis of the physical components involved in the process of its motion explains the phenomena of the gyroscopic inertial torques vanishing. The work of the potential and kinetic energy of the spinning disc expresses the action of the external and inertial torques on the gyroscope. The product $\omega\omega_x = \varepsilon_y$ is the acceleration of the gyroscope around axis *oy* expresses the action of the resulting torque ($T_{r.y} = T_{ct.x} + T_{am.x} - T_{ct.y} - T_{r.y}$) around the same axis. The angular velocity ω_x expresses the action of the resulting torque ($T_{r.x} = T - T_{ct.x} - T_{cr.x} - T_{ct.y} - T_{am.y}$, Fig. 1). The absence of the gyroscope rotation around axis *oy* expresses the absence of the kinetic energy and inertial torques around the same axis. In such case, the principle of the equality of their kinetic energies yields the absence of the kinetic energies about two axes [16]. The principle of the kinetic energy conservation yields the increase of the velocity of rotation ω_x of the spinning disc under the action of the external torque *T* (Fig. 1). The expression $\omega\omega_x$ is constant and the precession torque will have a new value for the spinning disc velocity rotation around one axis.

Results and Discussion

The external and inertial torques acting on a spinning disc express its mechanical energy around axes *ox, oy*, and *oz*. The mechanical energy of the spinning disc is manifested by its motions around axes. The vanish of the kinetic energy about one axis leads to the vanish of the kinetic energy about another one by the principle of the equality of their kinetic energies. The principle of mechanical energy conservation is maintained and spinning disc energy is transformed proportionally to its angular velocities around axes. The vanishing of the gyroscopic inertial torques is described by the principles of physics mechanics.

Conclusion

The theory of gyroscopic effects opened a new light and showed new properties of the rotating object that enable mathematical modeling for all problems of gyroscopic devices. Among the gyroscopic effects, there is the vanishing of the inertial torques when the spinning disc rotates around one axis. Engineering industries use gyroscopic mechanisms with rotation about one axis whose parameters must be clearly described for the proper work. The physical principles of mechanical energy conservation described the imaginary vanishing of the inertial torques generated by the spinning rotor.

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