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Short Communication

Theory of Gyroscopic Effects for Rotaining Objects

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The first SI Edition of the Theory of Gyroscopic Effects for Rotating Objects was written to provide scientists, lecturers, students of universities and practitioners from industries with clear and thorough presentation of the gyroscope theory and application in engineering mechanics. To the ample gyroscope problems were added the new chapters and arranged in the book with an increasing level of difficulty. It was done with the aim to describe mathematically the physics of gyroscopic effects of the spinning object that were unsolvable for the long time. The text of the first edition of the book was prepared for the short time given by the publisher. Such tense frame of time reflected on the incorrect mathematical processing of multi-integral expressions that distorted results of computing of some parameters for gyroscopic effects. The new edition will present the best book in the gyroscope theory with the precise expression of mathematical models, clarity in the physics of the gyroscopic effects and validated by the practical tests.

Gyroscopic effects in form of the spinning tops and boomerangs were interested in an inquisitive population of different civilizations from the ancient time. Beginning from the Industrial Revolution, famous scientists and ordinary researchers of all ranks studied intensively the phenomena of gyroscopic effects. They published probably tons of manuscripts and dozens of simplified theories dedicated to the gyroscopic problems. Practical tests validated none of them. Unexplainable motions in the space of the spinning objects created the term as gyroscopic effects that express the action of their inertial torques. One torque, that is the change in the angular momentum, was described by the famous mathematician L. Euler and presented in classical mechanics. Other inertial torques acting on the spinning objects were defined intuitively without mathematical models. This is the reason that scientist could not describe the physics of gyroscopic effects and the absence of the exact gyroscope theory.

It is necessary to note that the famous physicists and mathematicians of past centuries could not develop the gyroscope theory in principle. The nature of gyroscopic effects is based on the several physical laws. The science developed the fundamental physical concepts and properties of the matter at different times that take in about two hundred years, namely from the middle of the seventeen century and to middle of nineteen one. Scientists and researchers of the 17 -19 centuries did not have the physical bases to solve problems of gyroscopic effects. The scientists of the following centuries could not unify the action of the several physical laws that express gyroscopic effects of the spinning objects. For the practical applications of the gyroscopic devices, they developed severe and expensive numerical models for gyroscopic effects with the software and simplified theory for the educational processes. The latter one does not yield exact results and the physics of gyroscope phenomena are explained vague. Today, basic gyroscope problems solved and presented in this book containing the fundamental principles of gyroscope theory that are the system of the inertial torques interrelated by the kinetic ratio of the gyroscope motion about axes of rotation.

The gyroscopic effects are subject to the dynamics of rotating objects that is a crucial part of the knowledge in engineering. The movable, spinning components of different mechanisms manifest gyroscopic effects. The spinning disc and other rotating objects are the parts of numerous mechanisms and machines that call gyroscopic devices in different industries. Such rotating movable

objects created many problems in computing acting inertial forces and motions. These parts can be the aircraft's, helicopter's and ship's propellers, gas turbines, projectiles, wheels, cones, rotors, spheres, paraboloids, etc. The action of gyroscopic effects results in motions of rotating objects in space. These motions should be analytically described and explained the physics of acting forces.

The gyroscopic effects of the simple spinning disc did not describe mathematically for over two centuries. This is an unusual reality in the science of classical mechanics which methods can solve more complex problems. Unsolved gyroscopic effects forced researchers to spawn artificial terms and anti-scientific statements that gyroscopic devices possess non-inertial and non-gravitational properties, etc.

Contemporary machines and mechanisms are characterized by the intensification of the work and functioning that lead to increasing the values of the acting inertial forces. This trend will be kept in the future of engineering. The inertial forces of the rotating object can damage it and gyroscopic devices lose properties at the condition of the high angular velocity. For solving these problems, engineering needs exact solutions for gyroscopic effects. Recent investigations and detailed analysis of the inertial forces acting on the rotating objects discovered the action of the system of interrelated inertial torques. These torques are generated by centrifugal, and Coriolis forces of the rotating mass elements, as well as the change in the angular momentum, which are well known in classical mechanics. The Euler's principle of the change in the angular momentum makes up less than the tenth part of all torques acting on the rotating objects and does not play a significant role in gyroscopic effects. This fact is the reason that all known gyroscope theories did not match practical tests. The new system of inertial forces of the spinning objects mentioned above makes up the fundamental principles of the gyroscope theory. The new principles based on casualty dependencies of the acting interrelated internal torques and used for processing the mathematical models for the gyroscope motions. The principles of the gyroscopic effects have formulated for the simple spinning disc, but they are universal and can be applied to any designs of rotating objects. The mathematical models for the inertial torques will be different that depend on the geometry of rotating objects.

Obtained results show the physics of the gyroscopic effects are more complicated in mathematics than presented in known publications with simplifies analytical models and correction coefficients. The reason for a delusion of all researchers, scientists, and scholars is mathematical modeling of acting forces and motions based on the center mass of rotating objects. They did not pay attention to the action of the distributed masses of the objects in which geometries can have different designs. For example, the distributed masses of the spinning disc are located on the 2/3 of its external radius that well known in the textbooks. The rotating objects with lengthened designs have distributed masses located on their radii and lengths that manifest their gyroscopic effects. The fundamental principles of gyroscopic effects opens the new direction in the dynamics of rotating objects in classical mechanics.

The theory of gyroscopic effects considers the dynamics of the rotating objects in which mathematical models for the inertial forces and motions are presented in the Euler's form. The analytical approaches were treated by the methods of mathematical analysis. This type of presentation enables for easy understanding and avoiding the cumbersome mathematical models that expressed by 3D Lagrange's and Euler's angles method. The analytic approaches are based on the vector and differential analysis methods and assumed that the reader knows these mathematical basis. The exact and straightforward treatment for motions of gyroscopic devices is considered in the standard system of coordinate axes throughout the book. Formulation of the theory of gyroscopic effects and solutions do not contain analytic approximations and simplifications for mathematical models to fit with practical results.

The manifestation of the gyroscopic effects expresses the action of the external and inertial torques on the gyroscopic devices. These torques include the operation of frictional forces on the supports of gyroscopic mechanisms. The analysis shows the action of minor frictional forces can drastically reduce the kinetic energy of the inertial torques generated by masses of the rotating objects. The external torques acting around different gyroscope's axes are considered in several examples that resulting in the change in the kinetic energy of the rotating objects that lead to the gyroscope's lift up, oscillation, and nutation. The design features of rotating objects considered in working examples and assisting in clarify-

ing the mathematical method for solving gyroscopic effects for the spinning disc. The mathematical models tested on the most unsolvable cases of the gyroscope with spinning rotor suspended from the flexible cord and with one side pivoted support. The results of the practical tests perfect match the mathematical models of the gyroscope motions. This fact is the best validation of their correctness.

The gyroscope theory for rotating objects has formulated by multi-stepped analytical approaches. The reason for such a statement is interrelations of the inertial torques acting around three axes. The mathematical modelling of the complex problem is a routine process with omissions and improvements in science and engineering solutions. All gyroscopic effects that ascribed to rotating objects are finally can be solved analytically. However, all mistakes are, of course, solely the author's responsibility. It would appreciate any comments, suggestions, or problems related to any matters that will improve the content of this work.

The object of this work is to give fundamental principles of the theory of gyroscopic effects. It presents mathematical methods and models for inertial forces and motions, which can be used for solving the vast engineering problems generated by the rotating objects. The new analytical approach has enabled for writing the complete theory of gyroscopic effects that is accurate, systematic, and clear in physical processes. The mathematical models for gyroscopic forces and motions are concerned with fundamental principles of physics. Accurate treatment for gyroscopic effects, solutions in working examples, and practical tests are used in the SI system. Derived theory of gyroscopic effects included important components from publications of previous research and collected information that assisted in writing this book. Each chapter contains references to the essential publications dedicated to gyroscope problems. The content of the book planned by the principle from the simple to complex.

The gyroscope theory for rotating objects opens a new direction in dynamics chapter of classical mechanics. Science and engineering receive a powerful analytical tool to solve gyroscopic problems and to enhance the quality of the education at universities. The author hopes this book will be helpful for the scientists, lecturers, and students of the Mechanical Engineering Faculties of Universities. Some sections and examples can be used in lectures, tutorials and practical studies in basic and special courses of physics-mechanics and machine dynamics. The practitioners and engineers from corresponding industries engaged in the field of the gyroscopic effects can find useful knowledge.