

Preface

This book is the result of my long-time investigation and interest in the field of dynamics of mass variable systems. In this book, the terms ‘mass variable system’ and ‘mass variation’ include change of mass, but also variation of moment of inertia.

A significant number of real systems exist where mass and moment of inertia are varying in time. Let us mention some of them: celestial bodies (earth, moon), but also machines like centrifuges, pumps, fans, turbines, sieves, transportation mechanisms and rotors used in textile, cable, paper industry, etc. Mass variation affects some special phenomena which are not known in dynamics of bodies with constant mass. The book treats these occurrences and has an intention to explain them. The problem of mass variation is divided into two groups: discontinual and continual.

For discontinual mass variation, a particle or a body is separated or is added to an initial system during infinitesimal short time. This type of mass variation occurs in nature, but also in machines and mechanisms in everyday use. Due to this occurrence, velocity and angular velocity have a jump-like variation which may be the reason for serious malfunctions and even harmful damages in machines. In the text, methods for obtaining dynamic characteristics of the final system after mass variation are treated. Procedures are based on the well-known principle of momentum and principle of angular momentum. The problem is also solved using statements of analytic mechanics. Theoretical results are applied for a rotor which part is separated, for in-plane separation of the beam, for particle separation of a four-particle system and a shovel disjoint of a wind turbine. Knowledge of dynamics of discontinual mass variation provides us valuable information about motion of systems and gives the possibility of preconception of motion properties.

In systems with continual mass variation, mass-time function is a continual and monotone one. Due to mass variation, reactive force occurs which depends on relative velocity of mass addition or separation. In this book the reactive torque, as a result of time variation of the moment of inertia and relative angular velocity of body variation, is introduced. Influence of reactive force and of reactive torque on motion of the system is analysed. Results of investigation are applied for a mass

variable rotor: a drum on which the band is winding up. This model is useful in machines in textile, paper, cable industry, etc. Research on energy distribution in this type of nonconservative systems is very important. Lagrange's equations of motion, which include generalized force due to reactive force and reactive torque, are formed and considered. As one of the results, energy variation of mass variable system is obtained. Noether's theorem and Killing's equations are adopted for determining of first integrals and conditions for existence of conservation law in such nonconservative system.

In the book, special attention is directed toward oscillatory motion of mass variable systems. In investigation, the nonlinear properties of the system are included. Methods for determination of oscillations of nonlinear systems with variable mass are developed. Analytic solving procedures, based on the Ateb and trigonometric functions, are introduced. Interaction between reactive force and damping force is determined. Vibrations of truly nonlinear oscillator, Duffing oscillator, oscillator with fifth order of nonlinearity, and of Van der Pol oscillator are presented. Theoretical results are applied on solving the problem of vibration of a Jeffcott rotor and a two-body system with nonlinear connection.

The book is an extension of Dynamics of bodies with constant mass to Dynamics of bodies with mass variation, with specifications of phenomena which are the result of mass change in time. The book is suitable to be used by researchers in dynamics of mass variable systems in all fields of science, for example: mechanics, mechanical devices, electromechanical systems, electric circuits, physics, chemistry, biology, medicine, etc. Besides, it is applicable for engineers and technicians for solving practical problems in matter and to approve designs and eliminate the possible collapse of machines. The book is assigned also as a textbook for students in dynamics of mass variable systems.

This book is the extended version of my MTA dissertation awarded from the Hungarian Academy of Sciences.

Novi Sad

Livija Cveticanin

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Cveticanin, L.

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