Application of Multibody System Dynamics in Marine Machinery

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Abstract. Multibody system dynamics has been developed into a mature discipline, widely used in mechanical design and manufacturing in all aspects. This paper introduces the development of multibody mechanics, summarizes the application of the multibody mechanics in the field of ship mechanics, and puts forward the understanding of the development of the future.

Introduction

The multibody system dynamics is to establish mathematical model suitable for computer program to solve the kinematics and dynamics analysis, and seek the efficient and stable numerical method, its fundamental purpose is computer application technology for dynamic analysis and simulation of complex mechanical system.

Through the computer to solve the multibody system dynamics problems, engineers the main work only need to according to the reality of the situation build suitable dynamics model, and submit to the computer solution. Moreover, the computer can also provide the results analysis, the extremely difficult complex mechanical problems which cannot even solve can now use computer calculation function to facilitate the solution.

In the early days, the multi-body system dynamics is only applicable to the aviation machinery and robot, and now, with the continuous deepening of its theory, multibody system dynamics has a wide range of applications in the ship mechanical design. Below, we first briefly introduce the basic theory of multi-body system dynamics, and then focus on the application of multi-body system dynamics in the ship mechanical design.

Review of the Rigid Body System Dynamic

Multi rigid body dynamics from the 60's to the present, multi rigid body system dynamics is a new branch of science, and it has a number of research directions. The method of vector mechanics by Newton-Euler equation as the representative of the general motion of a rigid body in space decomposition with a point on the translation and rotation around this point. Lagrange method from the view of system, establish the differential-algebraic equation\cite{1}. Roberson-Wittenburg method characteristics the structural characteristics of multi rigid body system to describe some concepts of graph theory applied in discrete mathematics, the different structure of the system can be described by a unified mathematical model. Kaine method is a common method to set up the general multi degree of freedom dynamic equations of discrete system, which is characterized by the pseudo velocity as independent variables to describe the system the movement is not only suitable for the complete system, but also to
incomplete system. Gauss minimum constraint principle method does not need to establish
the system dynamic equations, used the acceleration as a variable, according to the extreme
value of the function, the system can be used to solve the real acceleration at each moment of
the coordinate and velocity value, so as to determine the motion law of the system.

**Review of Flexible Body Dynamics**

Multi flexible body system dynamics can be regarded as a natural extension of multi rigid
body system dynamics. According to the features of flexible multibody systems, general to
study of multi rigid body system dynamics based on using discrete method, modal analysis
method, shape function method or the finite element method to process different flexible body
in the system, and combined the research results of flexible body and multi rigid body.

In the study of the dynamics of flexible body, the direct path method was proposed by Ho
in 1977[2]. Singh[3] using the Kane equation, the modal function of the element is used to
represent the elastic deformation of the object, and the general equation of the flexible body
dynamics is derived.

Meirovitch and Quinn[4] using perturbation method and the flexible multi body system of
high order nonlinear equation group separation of zero order, low dimensional rigid body
motion and relative motion of rigid body first, high dimension number, and time related to the
elastic motion. Modi using Lagrange equation and the direct path of thought is an applicable
to spacecraft, general flexible multibody system dynamics equation.

Shabana[5] with consistent finite element method of deformation body is discretized, Haug
lumped mass finite element method of deformation body of discrete, and they are used in the
first Lagrangian method establishment of flexible multibody system of programming
dynamics model.

For multi-body system rotating component dynamics stiffening, Simo, Wall rap, Shabana
etc. in the study are introduced nonlinear stiffness matrix and mass formula. For large multi
body system, considering the geometric stiffness matrix computation, Banerjee [6] put
forward "motion induced stiffness matrix, geometric stiffness matrix of the degrees of
freedom are reduced, thereby reducing the dimension of the system.

**Dynamics of Multi Body Systems in Ship Mechanical Engineering**

Multi-body system dynamics has become the most active field of general mechanics.
Adams, etc. 10 kinds of quite impact of commercial software, engineers use such kind of
software production of complex mechanical system "prototype", true motion simulation
process and quickly compared a variety of parameters, until get the optimum performance,
thereby greatly less expensive.

**In the Application of Vibration and Noise Reduction of Ship Machinery**

The vibration characteristics of marine machinery relate to its reliability, service life,
balance, noise. Severe vibration of marine machinery can reduce its durability and affect the
service life of the whole machine [7]. The effect of flexible body is not considered in the
dynamic modeling of the mechanism, but in the actual mechanical system, the flexibility of
the system is very important to the movement of the whole system. At present, the study of
dynamic performance is often limited to the research of a sports organization, and lack of
research on the equipment.
Liu Yun established a multi cylinder diesel engine body finite element entity model, by ADANS dynamics simulation software to simulate the computer excitation force, in accordance with the piston stroke of discrete equivalent applied, the exciting force is more in line with the actual working conditions.

Zhang Zhaoqiang fully consider the constraint relation between agencies, and fully considering the influence of flexible body on the whole, obtained the frequency change with the rotation curve of crankshaft system of diesel engine.

Zhang Junhong using multibody dynamics simulation of internal combustion engine vibration and noise analysis, high quality of finite element model and the simulation model is established, with nonlinear damping spring simulation between moving parts connected by engine surface vibration velocity to evaluate radiation noise, improved engine structure, increased local stiffness.

Guo Xijing, combined the multi-body dynamics method, finite element method, acoustic boundary element method in one, predicted structure vibration and radiated noise characteristics systematically numerical and analysis of the work, through the modal test data revised engine components and combination structure finite element model.

Huang Yingyun research on the impact resistance of engine generator established linear vibration model, and correctness of the model is experimentally verified. On the basis of the construction unit of the nonlinear vibration isolation system, and the unit rated condition and impact condition, the dynamic characteristics of vibration system analysis.

Tan Wenjie, introduced the internal combustion engine crankshaft vibration response analysis based on multibody system dynamics method, including flexible crankshaft and rotate with the crankshaft parts of rigid body, the crankshaft system can be established by comprehensive use of CAD modeling and finite element analysis and mechanical system simulation technology model to calculate the interaction between parts of the analysis crankshaft dynamic deformation.

In the Application of Anti-impact Dynamics Analysis of the Mechanism

Marine life is a necessary condition for the ship to preserve itself and exert its own perational capability, and the anti-impact performance of the ship is the core content of its vitality. The international research on the vitality of ships has attracted great attention of all the countries in the world, and has made some achievements.

Ma Bingjie based on multi-body dynamics and finite element method, diesel engine crank and connecting rod mechanism as the research object, considering the institutions into the complexity of the internal contact, spindle bearing oil film stiffness and nonlinear factors, respectively in the diesel engine in rated condition and static condition, institutions anti impact performance were evaluated.

Zhang Yunbo introduces the theory of multi rigid body dynamics and contact dynamics, oriented object analysis and design method is used in contact impact model analysis, modeling and implementation process, to contact module constitute elements of the model of object oriented analysis, model element classification table is obtained.

Zhu Xiaoping has studied ship propulsion shafting system, considering in under the action of impact speed for the response of the shaft under shock effect, but also consider the transverse movement and rotation coupling effect, the multibody dynamics modeling tool derived dynamic equations in nonlinear partial differential equations describing the ship main propulsion shaft and with the classical theory of the discrete, the Runge Kutta method is used
in the numerical simulation, case analysis and points out that the speed for the response of the shaft under shock effects cannot be ignored.

**In the Research of Marine Mechanical System Dynamics Modeling and Simulation**

Multibody system dynamics simulation is an effective method for mechanism and machine dynamics research. It can not only accurately movement mechanism simulation, and can easily change mechanism parameters, so as to analyze the influence of the change of these parameters on the dynamic characteristics. In addition, the method does not need to establish a complex mathematical model, without the need to write lengthy simulation program, easy for design engineers to accept.

Si Hongzhu combined Pro-E and Working model 3D, made a single cylinder diesel engine crank connecting rod mechanism of the multibody system dynamics analysis model, using the model simulation of S195 diesel engine crank connecting rod mechanism under the rated speed dynamic balance, design of diesel engine balance analysis and calculation of the balance device provides a new approach.

Ma Bingjie applications such as multibody system dynamics theory of the excitation characteristics research, provide input condition for the gear finite element dynamic response analysis, gear finite element analysis model is established in completes the transmission device of multi body dynamics simulation analysis of foundation.

Chen Hong established the coupled dynamics of the hydraulic control system of diesel engine model analysis to analyze correctly and add constraints between components of the model, initial conditions and boundary conditions, and the dynamic connecting rod, for example to build the rigid flexible hybrid dynamics model, based on simulation speed machine working process and the dynamic characteristics were analyzed.

Niu Wenbo takes a 165F diesel engine as the research object, focuses on the dynamic characteristics of the diesel engine valve mechanism, and establishes the traditional single degree of freedom model, multi degree of freedom model.

Shao Kangyong used ADAMS simulation engine crank connecting rod mechanism dynamics, the engine crankshaft, crank connecting rod mechanism and machine were dynamics simulation analyzed, the key parts of the motion and force parameters and vibration response is obtained, providing reference for improvement of structure design.

Wang Boxing in the development of complex mechanical dynamics simulation analysis software of Intel-Dyna, parameterized driving technology is introduced into the modeling of complex mechanical system dynamics, using the object oriented analysis method, established the basic parameterized model of complex mechanical system dynamics.

Gao Anjin introduced the basic theory of multi rigid body system dynamics, studied the method of using ADAMS software to build the dynamic model of multi rigid body.

**Summary**

Multibody dynamics is a necessary means for design and performance optimization in mechanical engineering. It not only can realize the virtual design of the product, but also can predict the dynamic characteristic. Multibody not only can be used as a powerful tool for design optimization and manufacturing, but also has become the support of the rapid development of mechanical engineering.

Ship machinery structure is complex, changeable force, poor working environment, maintenance and inspection management inconvenience, requirements of equipment life
higher special situation and requirements, it is necessary for us to strengthen the design and research of ship machinery, multibody system dynamics is used to more accurately the modeling, which can greatly reduce physical experiment, improve the design efficiency and can obtain more accurate experimental data, to greatly simplify the design process. Using the multibody dynamics software can effectively simulate a variety of conditions, the object of study of fault mechanism and the vibration and noise, and fundamentally to find the source of the fault, which can in advance to take measures to solve, prolong the service life of equipment.

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