論文の内容の要旨

Abstract

Title of Dissertation

Nonlinear Dynamic Strength of Ship Structure and Structural Optimization

（船体構造の非線形動的強度と構造最適化）

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本文

This dissertation is to take nonlinear dynamic strength of a containership into account in extreme waves. As the name suggests that extreme wave is a kind of single wave whose wave height is very giant, giant wave height has a huge destructive power for maritime structures, nonlinear dynamic strength should be addressed. The nonlinear dynamic strength suggests that structural nonlinearities including material nonlinearity and geometrical nonlinearity are considered when ship is impacting into extreme wave. Therefore, ultimate strength and collapse of ship structure could be induced. On one hand, traditional ultimate strength evaluations are is mainly undertaken by making a carried out in quasi-static assumption and the no dynamic wave effect is not considered. On the other hand, the dynamic response of a ship as induced by a wave is studied on the basis of the hydroelasticity theory so that the no nonlinear ship structural response of the ship can be obtained for in large waves. Therefore, the nonlinear dynamic strength of ship calculated by nonlinear dynamic FEM combining with

strip method and hydroelasto-plasticity is addressed and compared with linear static strength.

Chapter 1 firstly presents the motivation and background of the current study through statistics of ship accidents due to extreme waves. Then several studying methods to wave load and dynamic strength and response of ship induced by wave are introduced. Moreover two researches with respect to this dissertation are explained and compared with this dissertation. Finally contributions and structure of dissertation are listed and explained.

Chapter 2 uses a FEM beam with a channel section simplified a containership to simulate ship strength under a large slamming force at the bow of ship. Slamming load is generated when extreme wave or large wave is impacting to bow of ship, and some important and sensitive structural responses are resulted in. A typical slamming case derived from realistic hydroelastic computation was calculated by transient nonlinear FEM to obtain dynamic elastic-plastic responses of ship beam. In addition, a number of critical slamming cases which resulted in the initial plastic and ultimate plastic moments are computed, with the analysis of simulation results, the rules of magnitude of slamming load curve which can provide constructive suggestions for container ship designer are obtained.

Chapter 3 proposes a computational method which calculates dynamic structural strength taking into account of material nonlinearity and geometric nonlinearity and evaluate dynamic ultimate strength of 500TEU containership model in extreme waves. Three extreme waves are selected to study motion response and linear VBM. And then nonlinear dynamic FEM computation is performed, a half of whole FEM container ship is modeled to perform the nonlinear dynamic strength, consequently deck buckling which is primary failure mode can be regarded. Finally, the nonlinear dynamic VBM, which is dependent on structural nonlinearity, is calculated using a combination of quasi-static and dynamic nonlinear analyses based on FEM. The nonlinear and linear VBMs are then compared to assess how they differ.

Chapter 4 proposes a 2D hydroelastoplasticity method to study nonlinear dynamic responses of a containership in extreme waves. The method which take the coupling between time-domain wave and nonlinear ship beam into account is proposed. This method contains hydroelasticity method and simplified progressive collapse method to combine wave load and structural nonlinearity. Simplified progressive collapse method which considers plastic nonlinearity and buckling effect of stiffened is used to calculate ultimate strength and nonlinear relation between bending moment and curvature, so nonlinear relation between rigidity and curvature is obtained as well. Dynamic reducing rigidity related to deformation could influence strength and curvature of ship beam, so it is inputted to dynamic hydrodynamic formula rather than a constant structural rigidity in hydroelastic equation. A number of numerical extreme wave models are selected for computations of hydroelastoplasticity, large deformation is resulted in and nonlinear dynamic VBM is obtained when ship is impacting to large extreme waves. Four extreme wave patterns including extreme wave height, regular wave height, Froude number of encountering wave, and wave length ratio are studied to get common conclusions, a number of results of hydroelasto-plasticity including nonlinear VBM, deformational curvature are computed and compared with results of hydroelasticity, some difference and conclusions are obtained.

Chapter 5 performs the work of structural optimization of 500-TEU containership based on ultimate strength evaluation criterion in extreme waves. Firstly objective function is looking forward to obtain minimum structural cost, and structural cost is determined structural weight cost. 500-TEU containership is used to model optimization model, 56 designing variables are defined, nine basic stiffened plate elements and two plate elements are included. Nonlinear curvature constraint which makes sure that nonlinear dynamic maximum curvature calculated by hydroelasto-plastic code should be smaller than the critical curvature at ultimate bending moment calculated by Smith code. The nonlinear constraint optimization function fmincon provided by optimization toolbox of Matlab is used to calculate the structural optimization based on ultimate strength in extreme waves. The optimization function provides SQP method solving a sequence of optimization subproblems, each of which optimizes a quadratic model of the objective subject to a linearization of the constraints. Allowed extreme wave height is given to design different external wave conditions, the tendency of optimal results of ship model are studied.

Chapter 6 summarizes the originalities and work of whole thesis and presents the future work. The 2D hydroelasto-plasticity method is proposed to be a originality to study nonlinear dynamic strength of ship induced by extreme wave. Compared with previous studying method as nonlinear dynamic FEM, short computational time and high efficiency could be obtained for hydroelasto-plastic method. Extreme wave is new studying field to induce nonlinear dynamic strength of real ship structure. On one hand, previous researches were performed for tank extreme wave and linear strength of ship model. In this dissertation, extreme ocean wave is used to study nonlinear dynamic strength of actual ship structure. On the other hand, although nonlinear strength of ship induced by head wave was studied by earlier researches, the extreme wave topic is a new studying field, extreme wave is different from common big wave, it is a single wave whose wave height is very large, the nonlinear dynamic strength and response of ship induced by extreme is different from common big wave necessarily. Nonlinear dynamic strength has been addressed as a new studying field in present dissertation. A nonlinear dynamic structural evaluation criterion, which makes sure that the maximum nonlinear dynamic strength calculated by hydroelasto-plasticity is smaller than ship ultimate strength, is proposed and compared with a linear static structural evaluation criterion, which makes sure that linear strength calculated by hydroelasticty is smaller than ship ultimate strength. The extreme wave height which induces ultimate bending moment is 1.35D for case 3 based on the nonlinear dynamic structural evaluation criterion, while another extreme wave height which arrives the value of ultimate bending moment by hydroelasticity is around 1.55D for case 3, it is obvious that the extreme wave height based on the nonlinear dynamic structural evaluation criterion is smaller than based on the linear static structural evaluation criterion.

Based on above studying results, several conclusions are obtained. The extreme wave height inducing ultimate strength and collapse of ship by nonlinear dynamic methods including nonlinear FEM and hydroelasto-plasticity is smaller than the extreme wave height inducing the value of ultimate VBM by linear dynamic methods such as strip method and hydroelasticity. The extreme wave speed leading to ultimate strength of ship by nonlinear dynamic methods is also smaller than the speed resulting the value of ultimate VBM by linear dynamic methods. Furthermore, according to the hydroelasto-plastic computations of ship for extreme wave patterns, large deformation is generated depends to a large extent extreme wave height rather than regular wave height. Extreme wave length ratio plays a important role to influence a ship's strength.Maximum VBM is occurred around λ / L=1, the VBM calculated by hydroelasto-plasticity method has a larger value than hydroelasticity method around λ / L=1.