Mathematical models of the dynamics of marine facilities

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This section discusses the current trends in the approaches, methods and models of the dynamics of the ship in the interaction with the external environment, including complex (extreme) conditions, as well as the modeling of environmental conditions (wind and waves) Exploitation of the Sea of dynamic objects. The main emphasis is on the model of buoyancy, stability, flooding, and pitching ship. Issues relating to the strength of the ship, which is closely related to the definition of the forces acting on the vehicle, refer to the structural mechanics of the ship and are not considered in this report. All the qualities of ships covered in this report, are studied under the assumption that the ship is strong enough that we can consider it as an absolutely solid.

Introduction

The main objectives of the dynamics of the vessel under the influence of external conditions is to ensure that the ship qualities will best ensure its proper use. These are the seaworthiness of the ship, which are understanding set of properties that determine the behavior of the ship as a floating structure as a whole in different environments and under different external influences (including extreme). Design and analysis of models of the dynamics of the vessel focused primarily on the identification and study of the objective laws which describe the interaction of the ship with the environment, which is equally inherent seaworthiness of ships, regardless of their individual differences. Knowledge of these laws (especially in the form of well-tested methods and models) makes it possible to predict the behavior of a ship in a variety of conditions, as well as identified those preventive measures that should be taken to avoid the disastrous consequences for the ship, which is of great importance both for shipbuilders and navigators. Depending on the task model of the dynamics of the vessel may describe the behavior of the ship in calm water without an analysis of its movement during the transition from one position to another (static consideration of the various provisions of the ship), and also directly on the move. Despite significant progress in addressing these challenges, progress in the last decade, which consists in replacing the general experimental research in experimental pool of computer experiment requires a systematic study of existing models of the dynamics of vessels under the influence of the environment.

Mathematical modeling of the dynamics of the vessel

A study of the dynamics of the vessel under the influence of the environment involves the construction of mathematical models of rational pitching. There are four categories of models of the dynamics of marine facilities:

- Spectral linear and linear model of the dynamics of the ship.
- Non-linear asymptotic model of the dynamics of the ship.
- Non-linear numerical model of the dynamics of the vessel based on the equations of classical mechanics.
- Non-linear numerical model of the dynamics of the vessel based on the equations of fluid mechanics.

Spectral linear and linearized model of the dynamics of the vessel

The main assumptions of the linear hydrodynamic theory of pitching is the relative smallness of the amplitudes of the incident waves and the movements of the vessel.Currently, these models are the basis of a number of regulations and procedures, for example [2,3]. In some cases, they can be generalized to the case of linear models of pitching. [1] However, in view of the assumptions about the relatively low amplitude of the incident waves and the movements of the vessel, these models are not applicable to the study of the dynamics of the vessel in extreme situations.

Nonlinear asymptotic model of the dynamics of the vessel

In that case, if the dynamics of the vessel is described by the classical equations of mechanics, for a number of non-linear systems, in some cases you can build their solutions on the basis of asymptotic (analytic) methods. To obtain analytical solutions in the formulation of the problem in the form of the equations of mechanics certain assumptions are made: linearization of the basic equations and boundary conditions in the small parameter - the Froude number, approximate allowance for vertical and longitudinal angular fluctuations of the vessel, etc. [4]. However, this approach is of limited applicability, and can lead to loss of new solutions whose form is unknown in advance. However, the variety of non-linear factors to take into account the general mathematical model of pitching, in some cases, cannot identify the root cause of the occurrence of unusual vibrations or loss of stability.

Non-linear numerical model of the dynamics of the vessel based on the equations of classical mechanics

The use of numerical methods have enabled through extensive research to solve the problem of strongly nonlinear regimes pitching that led to intensive development of a family of models and corresponding software implementations: illustrative of [5,6], on the basis of isolated equations with constant coefficients, to a sufficiently detailed, with variables coefficients are calculated directly in the modeling process by integrating the hull under the waterline of the current each time [7,8].

However, in most models, which are useful for the analysis of nonlinear vibrations onboard, broaching phenomenon

cannot be described. In order to study these phenomena special models are built. Nonlinear models pitching and modifications are widely used as base models for studies of the dynamics of liquid cargo in the vessel [9,10], to investigate the effectiveness of Stabilizers and develop algorithms for their control [11,12,13], to study the effect of parametric resonance [14].

Non-linear numerical model of the dynamics of the vessel based on the equations of fluid mechanics

The approach to modeling the dynamics of the ship, based on the equations of classical mechanics does not account for the influence of the presence and movement of the ship on the distribution of the hydrodynamic pressure in the agitated liquid, which does not provide a complete description of the process of pitching and allows to take into account only the hydrostatic forces and the main part of the disturbing forces. Currently, such hydrodynamic model to ship tasks can be realized not only through specialized software systems, but also by calculating the dynamics of packets continuum of general purpose, such as Fluent (may be noted here, and domestic development Flow Vision [15]) . However, in the latter case, a fundamental aspect is how to correctly set the boundary conditions on the surface, given the physical and statistical properties of sea waves [16].

Another method of modeling the interaction of the vessel and the liquid can serve as smoothed particle hydrodynamics (Smoothed particle hydrodynamics) [17]. SPH method is a method of solving problems of the dynamics of fluids and solids.SPH method allows us to solve the problem of simulating shock waves, decaying waves, calculation of the lava flow flooding, etc.

Conclusion

The main problem of mathematical modeling of the dynamics of the vessel is related to the sustainability of its movement and is formulated as a definition of the state space of the vessel, the relevant requirements of the operation, the search for the boundaries of this region and the relation between the parameters of the vessel with critical operating parameters perturbation [1]. The research in this formulation can be made only on the basis of the analysis of the ship, being under the influence caused by the forces of wind and waves. For this reason, to solve the problem of constructing models of the dynamics of the vessel under the influence of the environment in the extreme conditions necessary to divide the proper mathematical (simulation) model variability of the environment and the model of the dynamics of marine object in it.

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