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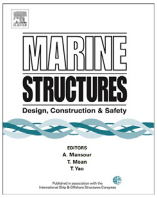

A new approach for coupling external dynamics and internal mechanics in ship collisions

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ABSTRACT

This paper proposes a new model, which efficiently couples the external dynamics and internal mechanics in ship collision accidents. This method is especially useful for design purposes since the detailed ship hull profile is not needed.

Ship motions in the horizontal plane are considered. The collision forces are calculated using the explicit nonlinear finite element code LS-DYNA. The hydrodynamic forces in surge, sway and yaw are calculated using a traditional ship maneuvering model with a series of nondimensional coefficients determined from experiments. These forces are applied to the center of gravity (COG) of the ship with the user defined load subroutine in LS-DYNA and are solved together with structural response analysis during simulation.

The proposed 3DOF coupled method was applied to calculations of an offshore supply vessel colliding with a rigid plate and a submersible platform. The results were compared with those predicted by a decoupled method. Ship motions with the proposed method compared reasonably with SIMO simulations. The advantages and limitations of the method were further discussed in the view of the equivalent added masses.

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1. Introduction

The aim of this paper is to present a coupled procedure in ship collisions to predict the detailed structural damage together with reasonable global motions. This method is especially useful for design purposes since the detailed ship hull profile is not needed.

Ship collisions and groundings are highly nonlinear, coupled dynamic processes involving large structural deformations and fluid structure interactions. It is challenging to include all the effects in one simulation. Various methods have thus been proposed since Minorsky [1] presented a simplified decoupled solution. In this method, the collision process is decoupled into two independent parts: external dynamics and internal mechanics. The external dynamics part deals with motions of the striking and struck ships. A basic assumption in the external dynamics is that the effects of fluid are represented by constant added masses. The velocities after collision can then be determined by the conservation of momentum principle. Pedersen and Zhang [2] proposed a closed form theoretical model for the planar external dynamics problem. Stronge [3] developed an advanced solution for 3D impacts. Liu and Amdahl [4] extended Stronge's work for 3D impact cases in a local coordinate system, allowing the geometric shape of vertical contact and objects with 3D eccentricities such as icebergs to be considered.

For the simplified analytical models of external dynamics, knowing the velocities of the striking and struck ships before and after collisions, the energy lost during a collision can be obtained. This lost kinetic energy is dissipated by structural deformations. In the internal mechanics analysis, the struck ship is normally fixed in space, and the striking ship moves along a prescribed path. The final penetration is obtained when the area under the force-penetration curve equals the energy loss resulting from the external dynamic calculations. Nonlinear finite elementcodes such as LS-DYNA or ABAQUS are often used to determine the force-penetration curve; An alternative is to use simplified methods, which allow for fast estimation of the force-penetration curve with reasonable accuracy. Examples of simplified analytical methods can be found in Hong and Amdahl [5], Simonsen [6], Yu et al. [7], etc.

The decoupled method is well suited for a right angle collision when the struck ship is initially motionless. However, often a ship collision does not take place at a right angle, in which case the exact ship path cannot be specified beforehand. Tabri [8] compared the penetration predicted by the decoupled approach with model test results. He found that for unsymmetrical ship collisions, the decoupled approach failed to predict the penetration paths, and the error could be very large. He also found that the dissipated energy given by the decoupled method was typically within a reasonable range, but for cases when the struck ship had a forward speed, the error of the energy dissipation could be considerable. In addition, Motora et al. [9] found that the assumption of constant added masses was often not a good approximation. He showed both experimentally and analytically that the equivalent added masses depended on the collision duration and the variation of collision forces with time. Collisions with longer durations would yield larger equivalent added masses. These effects are not captured in the decoupled approach.

For a more accurate prediction of ship motions and structural responses, a few researchers have turned to the coupled solution. Samuelides [10] developed a code to solve the coupled right-angle collisions. Petersen [11] suggested a coupled simulation procedure, taking into account the transient effects of hydrodynamic loads. The strip theory was used and sectional added masses and damping were calculated using an approximate method. Ship motions were restricted to be in the horizontal plane. Tabri et al. [12] extended the simulation technique to full 6DOF for models of both the striking and struck ships. Brown [13] developed a Simplified Collision (SIMCOL) Model, which was capable of coupling the internal and external mechanics in planar motions. SIMCOL was especially useful in the preliminary design stage. Mitsubishi developed a program entitled MCOL to deal with rigid body dynamics. LeSourne [14] coupled the MCOL code and the super-element method [15] to tackle the internal and external mechanics simultaneously.

These methods emphasized more on external dynamics while the collision forces were simplified. For example, Petersen [11] simplified the collision forces with four nonlinear springs. Tabri et al. [12] assumed homogeneity of ship stiffness and represented the collision forces by integrating the