Abstract

In the present thesis, a hybrid solution algorithm is developed to study nonlinear violent sloshing inside tanks by considering the coupling effects between ship motions and sloshing, each influencing the other. The algorithm combines a potential flow based weakly-nonlinear seakeeping solution with a viscous multiphase flow based fully-nonlinear sloshing solution. A three-dimensional transient Green function based boundary element method (BEM) is used for the seakeeping solution while an open-source finite volume method (FVM) solver OpenFOAM which is based on interface capturing volume of fluid (VOF) method is adopted for the sloshing solution. Effective coupling between the potential-flow based external hydrodynamics solver for the ship motions and the CFD based internal slosh flow solvers is not trivial due to the widely disparate time steps necessary for the two solvers which are run in serial and parallel modes respectively. A robust, efficient and effective coupling algorithm is developed here in which the BEM solver is considered the parent process while the CFD solution is the child process. Within a BEM time step for ship motions, there are many mini and adjustable time steps for the CFD solver decided based on an algorithm to retain numerical stability. This and several other numerical details that are found necessary for an effective and optimized coupling between the solvers are described.

The developed method is verified and validated against available experimental results as well through comparisons against other numerical results reported in literature. Initially the two solvers are validated independently (i.e. for sloshing impact pressures and ship motions) followed by validation of the coupled algorithm. The present method is found to provide predictions in overall fair agreement with experiments and other numerical results.

Studies are next made to determine the influence of several parameters such as incident wave steepness, fill conditions in the tank, ship speed and heading etc. on the slosh coupled ship motion behaviour as well as on the interior sloshing. Other aspects such as sway-roll coupling, effect of nonlinearity in seakeeping and correlation of various sloshing modes on ship motions and sloshing are also studied when coupling is considered between interior sloshing and external hull motions.

Further, the application of the algorithm in the assessment of design slosh-induced pressures under extreme wave conditions is presented. For this purpose, a methodology is devised for evaluation of extreme pressure statistics based on long duration sloshing analysis.

Overall, the present study suggests that consideration of slosh coupling on seakeeping is important and thus essential if realistic sloshing loads are to be evaluated.

The developed tool is found to produce predictions within acceptable engineering accuracy, which can assist in the evaluation of design slosh loads.

Keywords: slosh coupled ship motions, sloshing, seakeeping, transient Green function method, BEM, FVM, OpenFOAM, weakly-nonlinear, F-K nonlinear