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Numerical and Experimental Studies of Simple Geometries in Slamming

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The aim of this paper is to present a numerical and experimental study of slamming phenomena experienced by ships in service when their bottoms hit the water with a high velocity. Ship-bottom slamming is more often to the rapid ships, but large ocean-going vessels with big block coefficients may also be affected, especially in the ballast condition. The research work covers the finite element modeling of the impact between a rigid body and a free water surface, using 3 numerical approaches based on the finite element code ABAQUS, as well as the experimental slamming tests for validation.

INTRODUCTION

Initially studied for seaplane floats (von Karman, 1929; Wagner, 1932), the slamming phenomenon quickly began to be important in the naval field. This dynamic, random and nonlinear impact induces local and global harmful effects. A global response is described by a shear force and an additional bending moment, which commonly introduce vibrations of the ship hull girder. The local damages are more especially due to repeated impacts on the exterior hull. These responses negatively affect passenger comfort, crew preparedness and the integrity of onboard equipment. Thus it is important to accurately predict the applied forces for a correct and optimal design.

This paper treats only the bottom slamming, i.e. impact between the interior hull structure and the free water surface. We limit our study to simple rigid geometries and 2D flows as a first step in developing numerical models for deformable and 3D cases. Then, we take into consideration wedges (2D) and cones (pseudo-3D). Slamming forces depend on the deadrise angle formed between the generatrix of the body and the still-water surface. Complex air trapping phenomena are present if the deadrise angle becomes smaller than 4° (Portemont et al.), the mechanism of impact having become more complex.

Because our model, based on Wagner's theory, is not adapted for small angles, only deadrise angles between 4° and 45° will be considered. The velocity and displacement flow potentials are computed within a Finite Element model, while Tassin et al. (2010) employed a Boundary Element formulation. A lot of quasi-analytical approaches can be found in the literature, Korobkin (2004) and Mei et al. (1999) being important contributors.

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KEY WORDS: Slamming, shock machine, fluid-structure interaction, ABAQUS/Explicit, coupled Eulerian-Lagrangian (CEL) simulations.

ABAQUS/STANDARD APPROACH

Mathematical Formulation

In order to describe the mathematical formulation, we consider the impact problem of a body on a free water surface, as presented in Fig. 1. The fluid problem is developed within potential flow theory for an ideal fluid (incompressible, inviscid, irrotational), initially at rest. We assume small disturbances for the fluid and the solid domain, and we neglect the gravity. The structure has no forward speed and the current is zero. The flow is analyzed using Eulerian variables and must fulfill the conservation of mass and the momentum equation. The velocity vector anywhere in the fluid domain is obtained as $V = \mathbf{grad}\,\Phi$ and the velocity potential $\Phi(x, y, z, t)$ must satisfy the continuity, sliding, free-surface condition and decay conditions, respectively, Eqs. 1∼4. Eq. 3 represents the 1st-order zero pressure condition characterizing the free water surface.

$$\Delta\Phi = 0 \quad \text{in the fluid domain } \Omega_f \tag{1}$$

$$\mathbf{grad}\,\Phi \cdot \mathbf{n} = V_s \cdot \mathbf{n} \quad \text{on the wetted surface } \Gamma_B \tag{2}$$

$$\Phi = 0 \quad \text{on the free surface } \Gamma_L \tag{3}$$

$$\mathbf{grad}\,\Phi = 0 \quad \text{far from the body } \Gamma_\infty \tag{4}$$

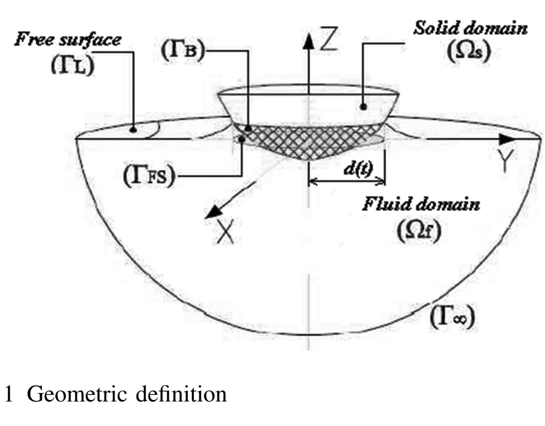

Fig. 1 Geometric definition