
Modeling Fluid-Structure Interaction in Naval Architecture (CAIMS)
Modélisation des interactions fluides-structures en architecture navale (SCMAI)
(Org: **Serguei Iakovlev** (Dalhousie))

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Simulation of structural failure from contact underwater explosions

A numerical method for performing large-deformation two-way coupled fluid-structure interaction simulations has been developed to model a wide class of problems in which structural response significantly influences subsequent fluid flow, through motion-induced cavitation, structural failure or both. We demonstrate the suitability of the approach to such events by applying our method to the early-time response of plates to contact and near-contact underwater explosions in three dimensions. The plates exhibit a variety of behaviors including petalling failure with venting of explosive products through the resulting holed plates. The deformation and failure patterns of the plates are compared with experimental data from trials performed by Defense Research Development Canada at Suffield.

SERGUEI IAKOVLEV, Dalhousie University, Halifax, Nova Scotia, Canada
Modeling shell-shock interaction in a multi-fluid environment

A fluid-filled submerged cylindrical shell is considered for the most general case of contact with fluid, i.e., when the internal and external fluids are different. It is shown that the interaction in this case is very different from the case of two identical fluids. Specifically, it is demonstrated that the response of the system is much more complex in terms of the fluid-structure interaction effects, and that a wider variety of shock wave reflection phenomena is observed. The ratio of the acoustic speeds in the internal and external fluids is shown to be the single most important parameter determining the main features of the interaction. Depending on the value of the ratio, four qualitatively different regimes of interaction are shown to exist. Each regime has its unique dynamic features of which the most notable is the possibility of observing different reflection-focusing sequences for the pressure wave inside the shell. The practical relevance of the fluid-structure interaction effects observed is discussed.

This is a joint work with Garrett Dooley, Bryan MacDonald and Jonathan Gaudet.

CEDRIC LEBLOND ET JEAN-FRANÇOIS SIGRIST, Service Technique et Scientifique, DCNS Propulsion / LEPTIAB, Université de La Rochelle
Semi-analytical methods for the study of transient fluid-structure interaction problems

We study semi-analytical methods related to the effects of highly transient loads on underwater vehicles. Firstly, simple fluid-structure interaction models are derived so as to highlight the physical phenomena occurring in this problem. More precisely, interactions between circular thin shells or elastic structures and the radiated field by an underwater explosion are considered. The approach is based on the classical methods of Laplace transform in time, Fourier series expansions and separation of variables in space. Secondly, an extension of this approach is proposed for more complex geometries. It is based on Laplace transform in time, in vacuo eigenvector expansion with time-dependent coefficients for the structural dynamics and boundary-integral formulation for the fluid. The projection of the fluid pressure on the in vacuo eigenvectors leads to a fully coupled system involving the modal time-dependent displacement coefficients, which are the problem unknowns. They are simply determined by matrix inversion in the Laplace domain. This fluid-structure numerical method is exact in the sense that classical early-time or doubly asymptotic approximations are not made. This appears to be a versatile approach which can be efficiently and extensively used for design purposes, once part of the numerical resolution has been performed one time for a given geometry.

JULIE YOUNG, Princeton University

Numerical Investigation of Shock and Blast Loads on Composite Marine Structures

A strongly coupled 2D/axisymmetric Eulerian–Lagrangian numerical solver is presented for the modeling of shock and blast loads on composite marine structures. An overview of the numerical formulation is given for the compressible multiphase fluid, the generalized continuum solid, and the fluid-fluid and fluid-solid interface coupling methodology using modified versions of the ghost fluid method. The resulting strongly coupled Eulerian–Lagrangian solver is able to efficiently capture nonlinear fluid-structure and shock-bubble interactions involving strong shocks, gas bubble dynamics, cavitation inception and collapse, and complex stress and deformation fields of anisotropic, composite marine structures. Analytical, numerical, and experimental validation studies are shown. The objective of this work is to use the newly developed coupled Eulerian–Lagrangian method to study the transient response of composite marine structures subject to shock and blast loads. Special attention is given to quantify the influence of surface and core material elasticity/plasticity, boundary conditions, surface curvature, and strain-rate dependency on the fluid-structure interaction response caused by planar shocks and underwater explosions.

The goal is to develop parametric curves that can assist the design of general composite structures subject to shock and blast loads, and to explore potential shock mitigation strategies.