HYDRO-ELASTIC NUMERIC ANALYSES OF A WEDGE-SHAPED SHELL STRUCTURE IMPACTING A WATER SURFACE

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Abstract— **The fluid structure interaction is simulated during the impact of a 2-d wedge on a water surface. The analysis combines the assumption of small displacements for the ideal fluid and the solid with an asymptotic formulation for accurate pressure evaluation on the wet surface boundary. Wedge deadrise angles β above approximately 30° do not fulfill this hypothesis. A fluid-heat analogy is used to obtain the regular displacement, velocity and pressure fields in the fluid domain with ABAQUS/Standard finite element code. PYTHON and FORTRAN languages are employed to connect fluid and structure data. Two methods are developed. The first method employs a weak fluid-structure coupling. The average discrepancy between our numerical results and experiments was 22% for the peak pressures for conical shell structures. The wet surface velocity was well predicted. The second method (implicit fluid-structure coupling using a convergence criterion) is more accurate. Recent results with an improved, numerical hydrodynamic model based on CFD are also presented.**

Keywords— **Hydroelastic analysis, water impact, wedge.**

I. INTRODUCTION

The fluid-structure impact problem is important in many engineering applications. The slamming phenomenon implies, in general, very large forces because a considerable mass of water is displaced in a very short time.

Slamming is particularly important for fast ships:

- Slamming loads are often the largest loads and determine structural dimensions, particularly sensitive for light-weight, fast ships
- Even if each impact load is small, frequent impact loads accelerate fatigue failures of hulls
- Fast ships usually transport passengers and slamming loads affect passenger comfort.

A fully satisfactory theoretical treatment of slamming has been prevented so far by the complexity of the problem:

- Slamming is a strongly non-linear phenomenon which is very sensitive to relative motion and contact angle between body and free surface
- Predictions in natural seaways are inherently stochastic; slamming is a random process in reality
- Since the duration of wave impact loads is very short, hydro-elastic effects are large
- Air trapping may lead to compressible, partially supersonic flows where the flow in the water interacts with the flow in the air
- Most theories and numerical applications are for two-dimensional rigid bodies (infinite cylinders or bodies of rotational symmetry), but slamming in reality is a strongly three-dimensional phenomenon.

Bertram (2000) gives an overview of the most important analytical approaches to slamming, pointing out that in the end only computational fluid dynamics (CFD) methods are expected to bring considerable progress, while classical theories work well in two-dimensional flow for certain geometries.

We focus here on the aspect of hydro-elasticity, limiting the study to simple geometries and 2-d flows, as a first step to develop more sophisticated 3-d numerical methods.

II. MATHEMATICAL FORMULATION

We consider the problem of impact of a 3-d body on a water surface, Fig. 1. The fluid problem is formulated within potential flow theory for an ideal fluid (incompressible, inviscid and irrotational).

The velocity vector anywhere in the fluid domain follows from v = *grad* Φ. Φ(x,y,z,t) is the velocity potential. We assume small disturbances both for the solid and the fluid.

Then, the velocity potential must satisfy the following conditions:

$$\Delta\Phi = 0 \qquad \text{in } \Omega_f \qquad (1)$$

$$grad\ \Phi \cdot \mathbf{n} = \dot{\boldsymbol{u}}_s \cdot \mathbf{n} = \frac{\partial \boldsymbol{u}_s}{\partial t} \cdot \mathbf{n} \quad \text{on the wetted surface} \quad (2)$$

$$\Phi = 0 \qquad \text{on the free surface} \qquad (3)$$

Equation (3) expresses the condition of zero relative pressure on the free surface. Everywhere at the free surface and at all times, the pressure corresponds to atmospheric pressure. The linearized Bernoulli equation gives then, at the free surface: $\partial\Phi/\partial t - g_z = 0$.

Neglecting gravity (wave making) for high impact speeds, we then obtain: $\partial\Phi/\partial t = 0$, thus Φ = const. As only derivatives of the potential are of interest here, we can set the constant arbitrarily to zero.

The fluid is initially at rest:

$$\Phi(x_0, y_0, z_0, 0) = 0 \qquad (4)$$