TEST CASE DOCUMENTATION
AND TESTING RESULTS

TEST CASE ID ICFD-VER-3.1

Liquid sloshing

Tested with LS-DYNA® v980 Revision Beta

Friday 1st June, 2012

Document Information	
Confidentiality	**external use**
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1 Introduction

1.1 Purpose of this Document

This document specifies the test case ICFD-VER-3.1. It provides general test case information like name and ID as well as information to the confidentiality, status, and classification of the test case.

A detailed description of the test case is given, the purpose of the test case is defined, and the tested features are named. Results and observations are stated and discussed. Testing results are provided in section 4.1 for the therein mentioned LS-DYNA® version and platforms.

2 Test Case Information

Test Case Summary	
Confidentiality	external use
Test Case Name	Liquid Sloshing: 2D free surface flow oscillating in a tank
Test Case ID	ICFD-VER-3.1
Test Case Status	Under consideration
Test Case Classification	Verification
Metadata	FREE SURFACE

Table 1: Test Case Summary

3 Test Case Specification

3.1 Test Case Purpose

The purpose of this test case is to study the "sloshing" phenomena i.e the frequency of a liquid oscillating in a partially filled tank.

3.2 Test Case Description

The sloshing effect consists in a liquid with a free surface in a partially filled tank that is given an initial slope so as to trigger its periodic oscillating under the influence of gravity. The sloshing phenomenon is of great practical importance to the safety of the liquid transport and is probably one of the most classical examples of free surface analysis ([2]). Figure (1) offers a sketch of the problem. In the case of inviscid flows, the free surface elevation η above the initially undisturbed free surface height is given by [1] :

$$\eta = A\sqrt{\frac{\epsilon}{gD}}sin(t\sqrt{\frac{g\epsilon}{D}})cos(\frac{2\pi}{\lambda}x) \tag{1}$$

where :

$$\epsilon = \frac{2\pi}{\lambda}Dtanh(\frac{2\pi}{\lambda}D) \tag{2}$$

with A the initial amplitude, g the acceleration of gravity, D the undisturbed free surface height, and λ the initial wavelength, in our case two times the width of the container.

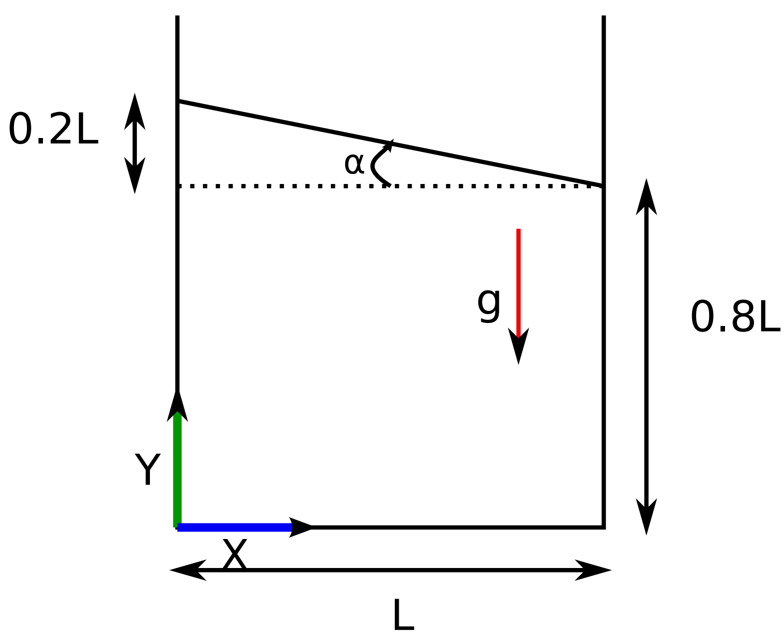

Figure 1: Test Case Sketch

3.3 Model Description

Figure (2) offers a view of the geometry and mesh. Table (2) describes the mesh and Table (3) gives the physical parameters that will be used. The model consists of two phases, the phase located at the bottom represents the fluid while the upper phase represents the air or vaccum. Therefore the physical parameters given correspond to the fluid's parameters only.

Model information	
Surface Element size	0.0125
Volume Nodes	6638
Volume Elements	12962

Table 2: Test Case Mesh Information

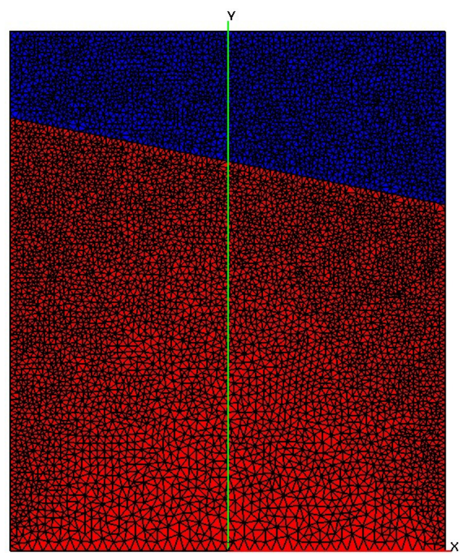

Figure 2: Test Case Mesh

Model physical parameters	
Fluid Density	1000
Viscosity	0.001
Gravity	10

Table 3: Test Case Parameters

4 Test Case Results

4.1 Test Case observations

The sloshing behavior of the fluid can be observed in Figure (3). The good conservation of the fluid's interface can be noted. Figure (3) shows a good agreement between the numerical and the analytical solution with an frequency error of less then 3%. The differences in the amplitude can be explained through the slight damping effect that occurs when approaching the boundaries (See Figure (3)).

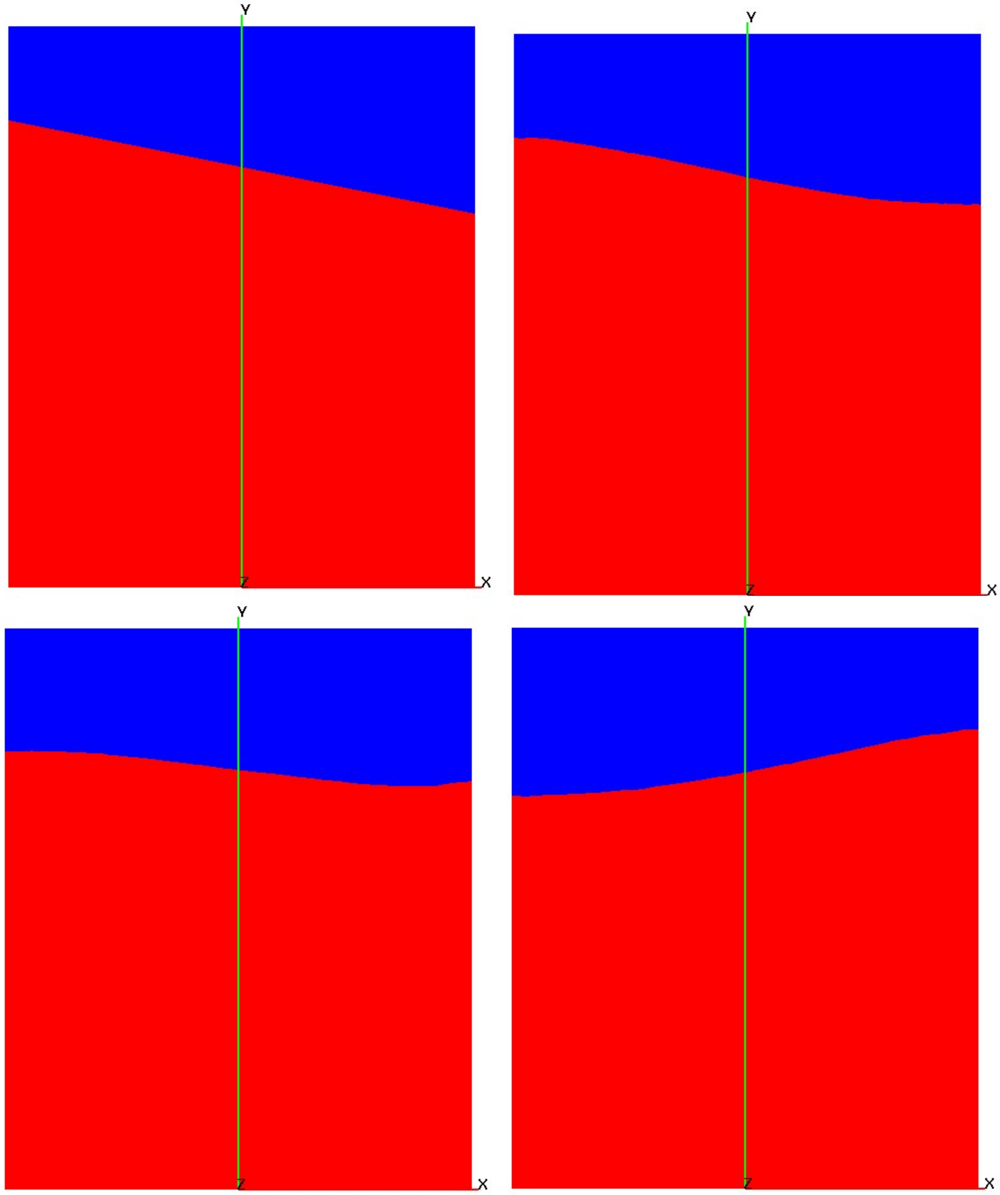

Figure 3: Fringes showing the sloshing behavior of the tank

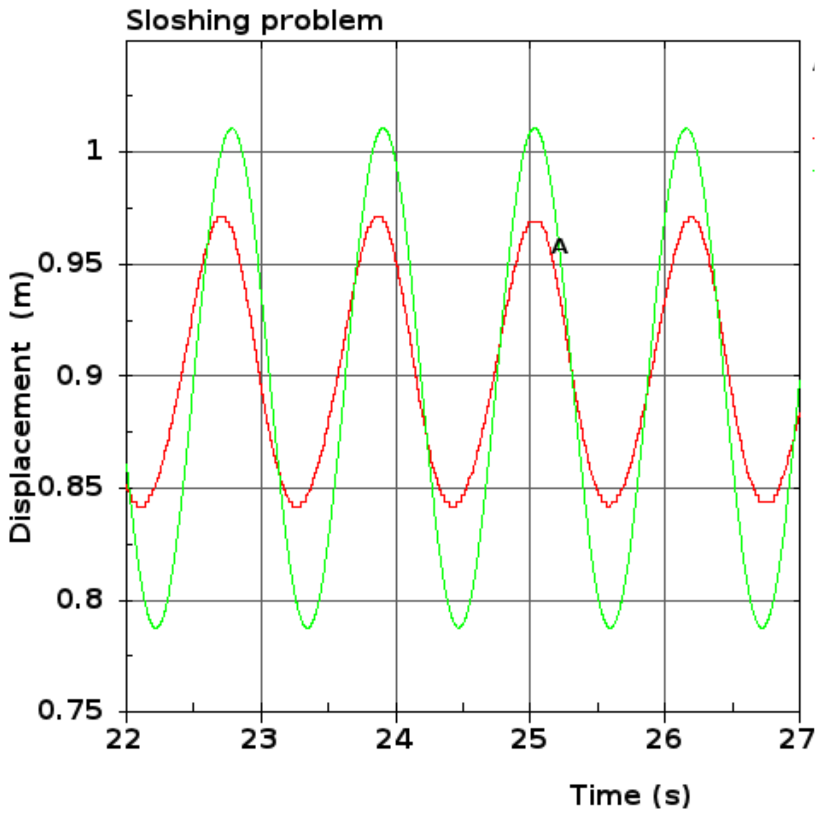

Figure 4: Superimposition of both numerical (in red) and analytical (in green) solutions for 4 periods of oscillation.

References

[1] F. D. PIN, *The Meshless Finite Element Method Applied to a Lagrangian Particle Formulation of Fluid Flows*, PhD thesis, 2007.

[2] Z. H. K. M. Z. SAOUDI, C. MNASRI, *Standing wave induced by free liquid sloshing in rectangular tank*, International Renewable Energy Congress, (2010).