# TEST CASE DOCUMENTATION
# AND TESTING RESULTS

## TEST CASE ID ICFD-VAL-7.1

# 3D Fluid Elastic Body Interaction Problem

Tested with LS-DYNA® R7 Revision Beta

Thursday 15th May, 2014

LSTC
Livermore Software
Technology Corp.

| Document Information | |
|---|---|
| Confidentiality | **external use** |
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## Disclaimer:

# Contents

# 1 Introduction

## 1.1 Purpose of this Document

This document specifies the test case ICFD-VAL-7.1. 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 | 3D Fluid Elastic Body Interaction Problem |
| Test Case ID | ICFD-VAL-7.1 |
| Test Case Status | Under consideration |
| Test Case Classification | Validation |
| Metadata | FSI |

Table 1: Test Case Summary

# 3 Test Case Specification

## 3.1 Test Case Purpose

This test case is part of the SPHERIC benchmark library and is a combination of a free surface problem with a FSI problem and is therefore a perfect candidate to highlight the capabilities of the ICFD solver.

## 3.2 Test Case Description

The reference experiment (see [1]) is based on a strong interaction between a free surface sloshing flow in a rectangular tank where an elastic body is clamped in either the bottom or top center. The clamped beam experiments have been run with oil while for the hanging beam experiment, water has been used. Due to the high viscosity of oil, no breaking waves are generated due to the obstacle.

The tank is rectangular with a rotation center at mid bottom. Schematic tank and elastic body deformation is presented in Figure (1). Two beam lengths will be studied (shallow beam length of 57.4 mm and mid depth length of 114.8 mm). In both cases the water will initially be at the beam level. For the hanging beam case, the beam will have a length of 287.1 mm and will be touching the surface of the water. Beam thickness is 4 mm in all cases.

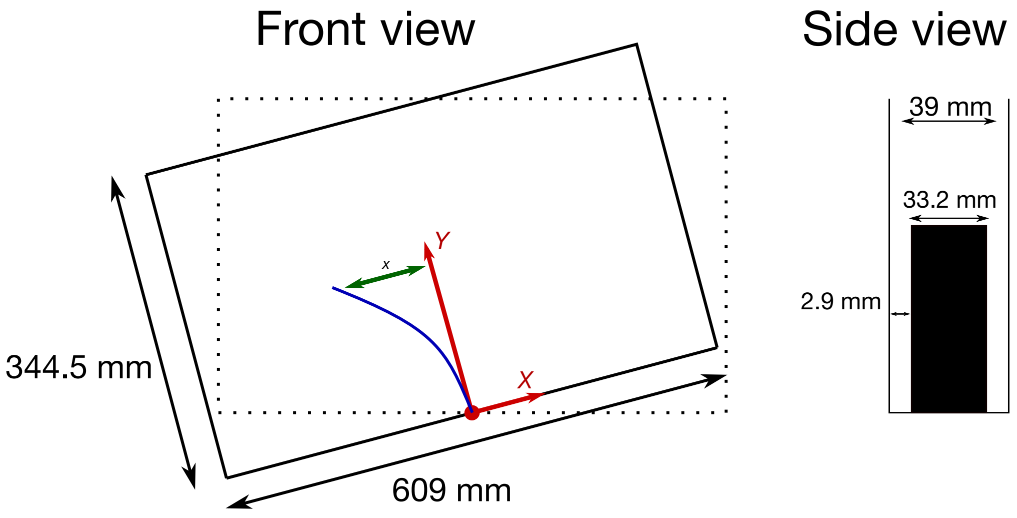

Figure 1: Test Case Sketch

### 3.3 Model Description

This case was treated as a 2D problem by [3] and [2] and indeed, with a small gap between the beam and the tank (2.9 mm), it is a valid assumption. However, in this analysis, the complete 3D model will be used.Due to the very small gap between the beam and the tank, frequent dynamic remeshing will occur which will increase the complexity but also the value of this validation test case.

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 numerical characteristics for the beam and the fluid have been extracted from [2].

The time steps used correspond to a CFL number between 1 and 3 i.e a timestep chosen between 2 and 5 milliseconds.

| Model information | |
|---|---|
| Beam Surface Element size | 1 mm |
| Volume Nodes (approx.) | 1 M |
| Volume Elements (approx.) | 6 M |

Table 2: Test Case Mesh Information

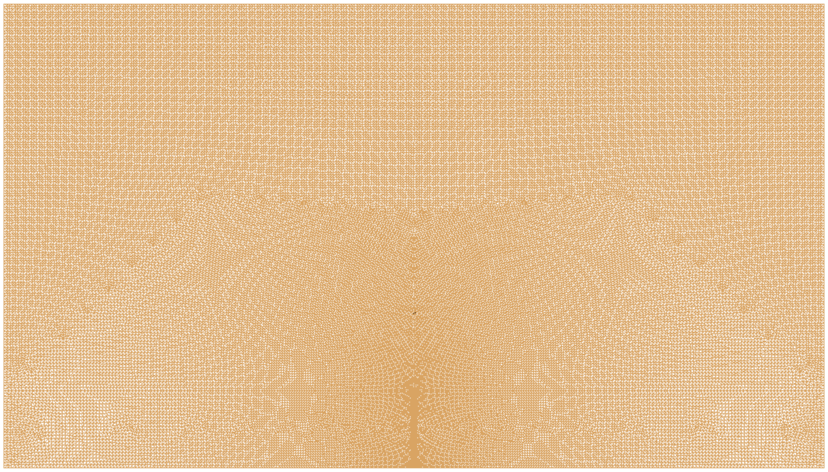

Figure 2: Test Case Mesh

| Model physical parameters | |
|---|---|
| Oil Density $[kg/m^3]$ | 917 |
| Oil Viscosity $[Pa.s]$ | 0.04585 |
| Water Density $[kg/m^3]$ | 998.2 |
| Water Viscosity $[Pa.s]$ | 0.001 |
| Clamped Beam Density $[kg/m^3]$ | 1100 |
| Clamped Beam Young's modulus $[GPa]$ | 6 |
| Hanging Beam Density $[kg/m^3]$ | 1900 |
| Hanging Beam Young's modulus $[GPa]$ | 4 |
| Beam Poisson coefficient [-] | 0.49 |
| Gravity $[m/s^{-2}]$ | 9.81 |

Table 3: Test Case Parameters

# 4 Test Case Results

## 4.1 Test Case observations

The first two examples consist of a clamped beam immersed in a shallow or deep oil flow. Figure (3) and Figure (4) show some snapshots of the displacements at different instants. It can be observed that the deep oil case is a complicated example in which the interaction between the fluid and the elastic beam is very strong. Figure (5) shows the results for the beam tip displacements for both cases and offers a comparison with the experimental results. For the deep oil case, results are in good agreement and close to those of [3] and [2]. For the shallow oil case, the differences between the numerical and experimental results are larger but still similar and close to those obtained by [2]. An explanation provided by [2] is that the measurement error from the experiment is relatively large for the clamped beam in shallow oil because the displacements are an order of magnitude smaller than for the clamped beam in deep oil. The pressure forces are generally not used for comparison in this case but are shown in Figure (6) for the sake of completeness.

According to [3], the hanging elastic beam with shallow water is the most difficult and impressive example. Indeed, the beam is hanging from the upper wall in such a way that the interaction with the fluid can be attained only due to the waves produced. Figure (7) shows some snapshots at different times of the beam's behavior while Figure (8) offers a comparison on the beam displacements at the tip, at 0.75% beam length and at the midpoint. Results are similar to those of [3] and [2] and the agreement between the numerical results and the experimental ones are very good, taking into account the complexity of the example. Again Figure (9) shows the drag forces applied on the beam. It is interesting to note the various water impacts on the beam, the first one starting shortly after 2 seconds and then increasing in intensity.

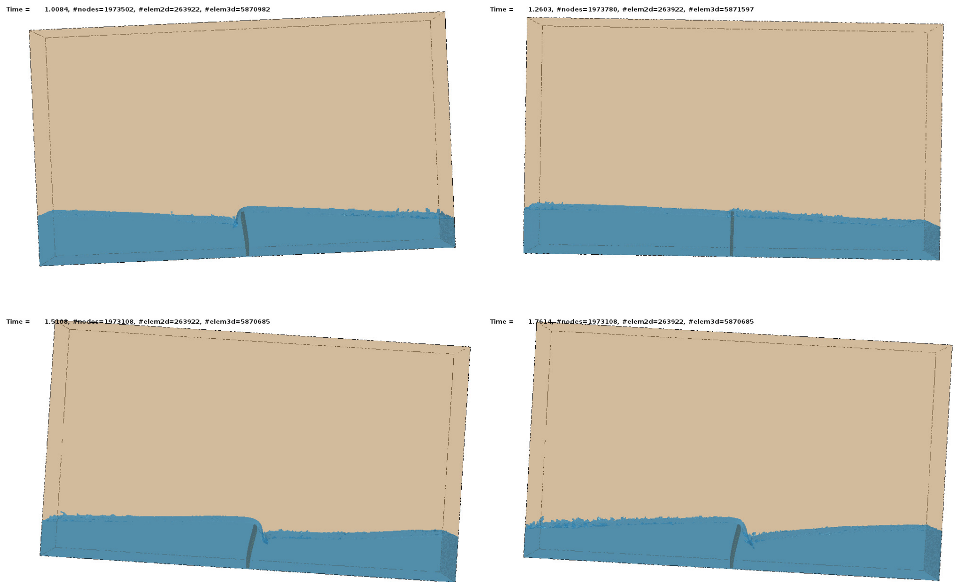

Figure 3: Clamped elastic beam in shallow oil : t=1, 1.25 ,1.5 ,1.75 [s].

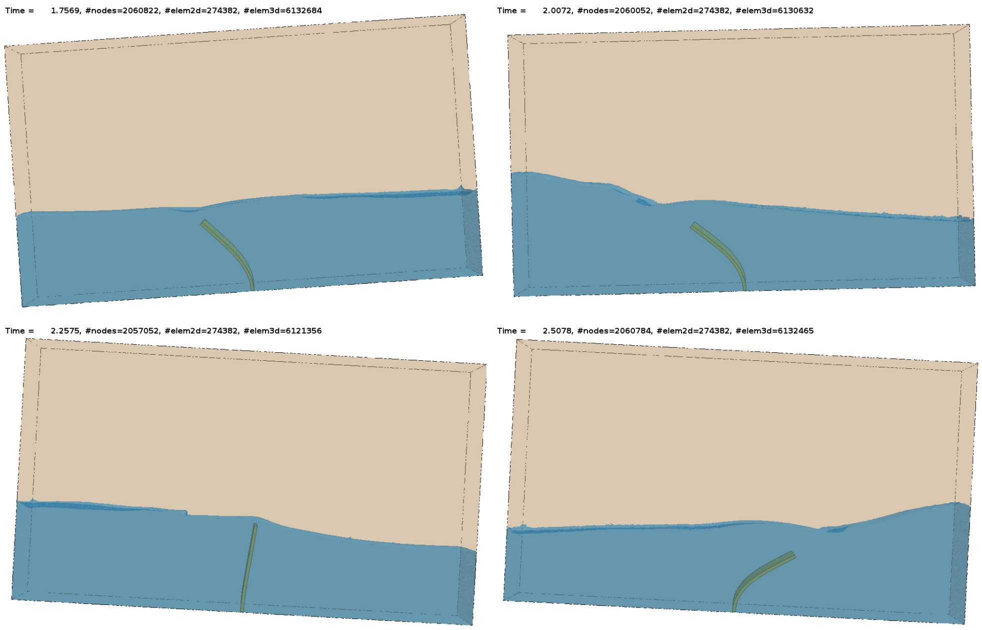

Figure 4: Clamped elastic beam in deep oil : t=1.75, 2.00 ,2.25 ,2.50 [s].

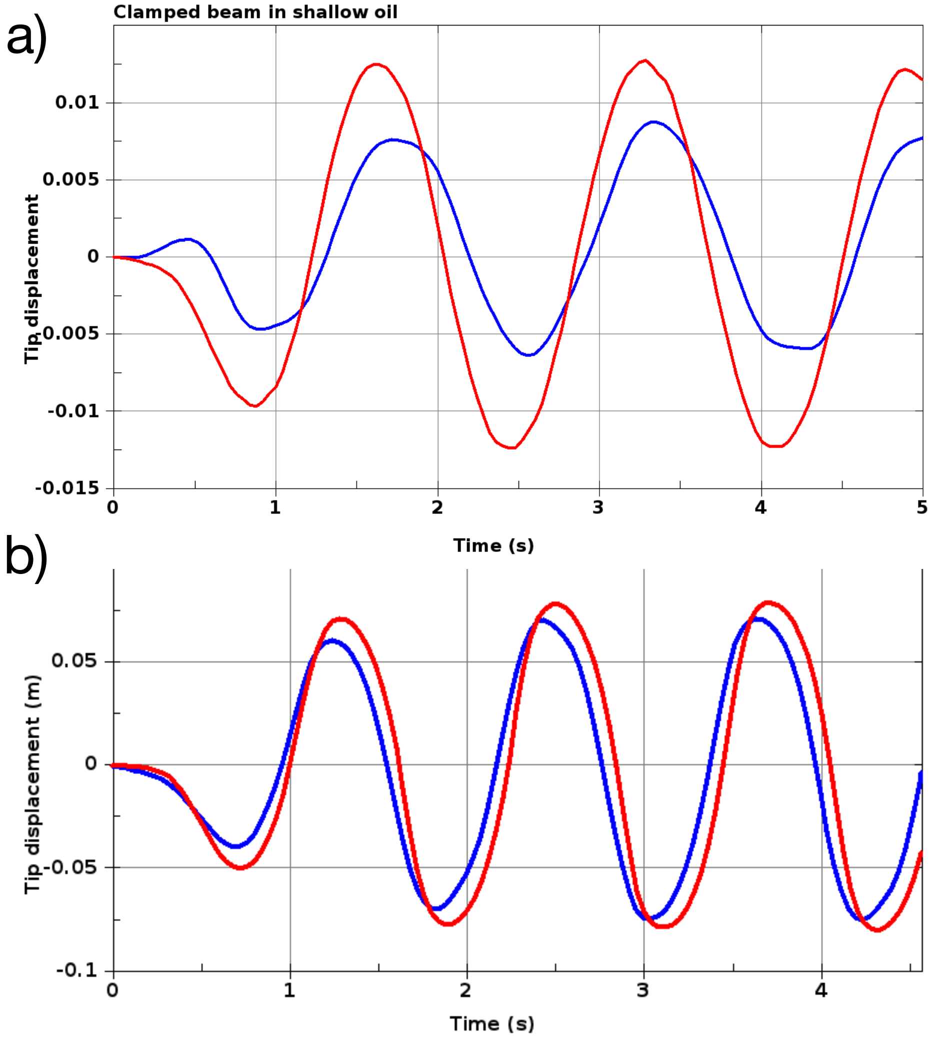

Figure 5: Clamped beam tip displacement comparison between numerical results (in red) and reference results (In Blue)([1]) : a) Shallow oil level, b) Deep oil level.

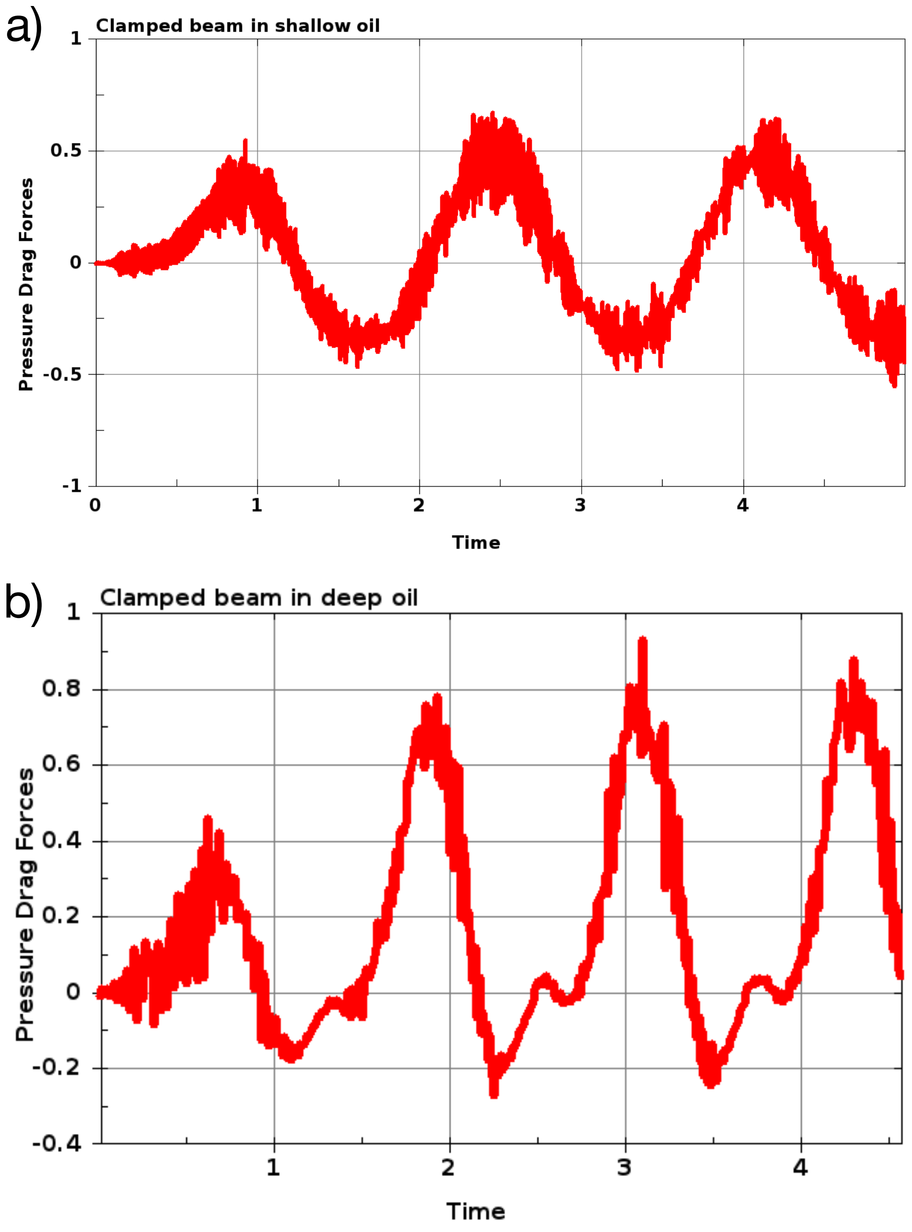

Figure 6: Pressure drag forced applied on immersed clamped beam : a) shallow oil level, b) deep oil level.

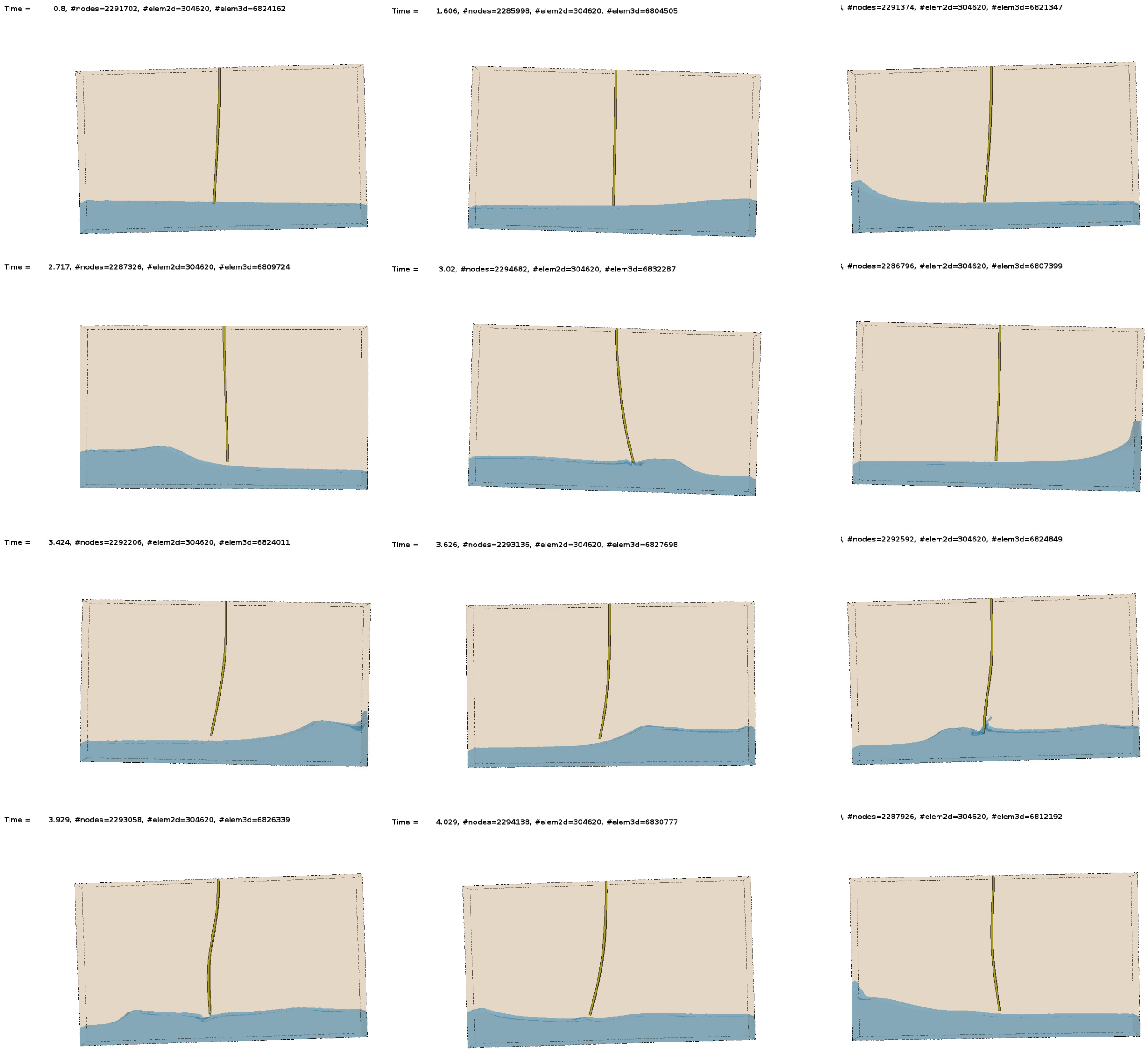

Figure 7: Hanging elastic beam in shallow water : t=0.8, 1.7 ,2.4 ,2.7 ,3.0 ,3.3 ,3.4 ,3.6 ,3.8 ,3.9 ,4.0 ,4.2 [s].

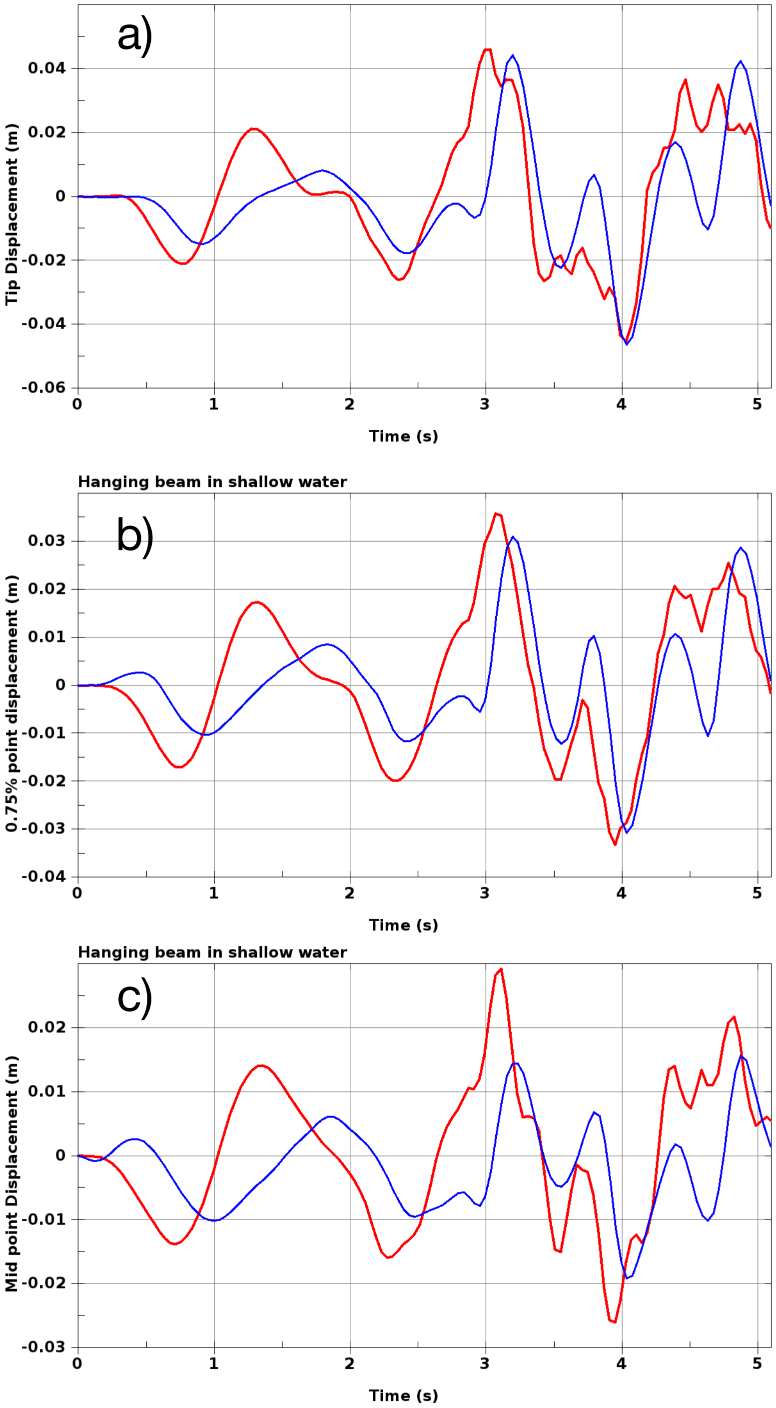

Figure 8: Hanging elastic beam in shallow water: a) Beam tip, b) 75% of beam tip, c) Mid point. Comparison between numerical results (in Red) and experimental results (in Blue).

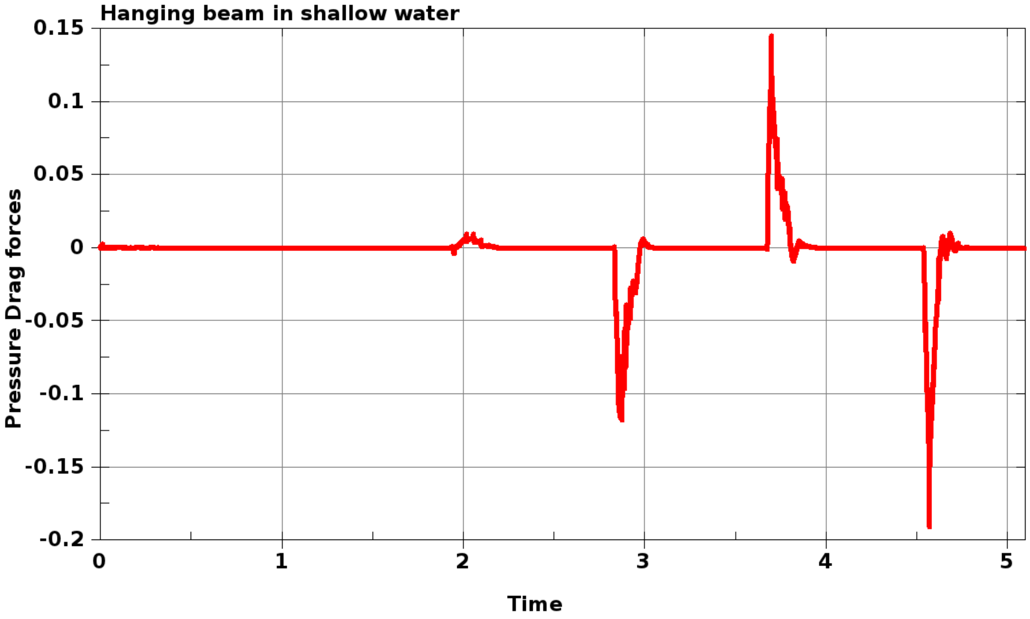

Figure 9: Pressure force applied on the beam function of time.

# References

[1] E. Botia-Vera, A. Souto-Iglesias, A. Bulian, and L. Lobovsky, *Three sph novel benchmark test cases for free surface flows*, 5th ERCOFTAC SPHERIC workshop on SPH applications.

[2] J. Degroote, A. Souto-Iglesias, W. Van Paepegem, S. Annerel, P. Bruggeman, and J. Vierendeels, *Partitioned simulation of the interaction between an elastic structure and free surface flow*, Computer Methods in Applied Mechanics and Engineering, 199 (2010), pp. 2085–2098.

[3] S. Idelsohn, J. Marti, A. Souto-Iglesias, and E. Onate, *Interaction between an elastic structure and free-surface flows: experimental versus numerical comparisons using the pfem*, Computational Mechanics, 43 (2008), pp. 125–132.