Example 22 – Ditching using SPH

Summary
The ditching of a specimen into a is studied using SPH and CEL approaches. The simulation results are compared to the experimental data and to the analytical results. Furthermore, the study is performed using different impact velocities. The specimen is modeled using a triangular section. In the first approach, a SPH model is used for water. This example deals with the problem of an interface definition between the two parts. First, the SPH boundary and type 7 interface are used. Moreover, the specimen undergoes a linear elastic law; the water being defined by the hydrodynamic viscous fluid law 6. The results are compared with regard to the pressure and acceleration outputs. The OUTLET boundary conditions provide appropriate results. In the second approach, the water is modeled with an ALE mesh while the structure is Lagrangian. The interface type 18 is used to treat the fluid-structure interactions. The results compared to Von Karman theory, illustrate the robustness and stability of the CEL method.

<table>
<thead>
<tr>
<th>Title</th>
<th>Ditching using SPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>22.1</td>
</tr>
</tbody>
</table>

| Brief Description | Impact of a simple specimen on water. |
| Keywords         | SPH modeling, hexagonal net |
|                  | Hydrodynamic viscous fluid law (/MAT/LAW6), impact on water modeling |
|                  | Type 7 interface |
**RADIOSS Options**

- Rigid body (/RBODY)
- Initial velocity (/INIVEL)
- Accelerometer (/ACCEL)
- Gravity (/GRAV)
- Interface (/INTER)
- SPH outlet (/SPH/INOUT)

**Compared to / Validation Method**

- Experimental data provided by Politecnico di Milano (Polytechnic University of Milan) [1]
- Analytic solution proposed by Von Karman [2]

**Input File**

- **Impact_velocity=3.5m/s:**
  <install_directory>/demos/hwsolvers/radioss/22_Ditching/Impact_velocity_35/SPH_EX351*

- **Impact_velocity=6.8m/s:**
  <install_directory>/demos/hwsolvers/radioss/22_Ditching/Impact_velocity_68/SPH_EX681*

- **Impact_velocity=11m/s:**
  <install_directory>/demos/hwsolvers/radioss/22_Ditching/Impact_velocity_110/SP HEX110*

**RADIOSS Version**

44m

**Technical / Theoretical Level**

Skilled
Overview

Physical Problem Description
The problem consists of a simple specimen falling into water simulating the ditching of a helicopter.

Units: mm, ms, N, MPa, g.

Impact of a triangular section specimen on water is performed and the results are compared qualitatively [2], also using the experimental data obtained from the Politecnico di Milano [1].

The computation is performed using several impact velocities: 3.5 m/s, 6.8 m/s and 11 m/s.

The material used for the specimen follows a linear elastic law (/MAT/LAW1) with the following characteristics:

- Initial density: $7.8 \times 10^{-3}$ g.mm$^{-3}$
- Reference density: $7.8 \times 10^{-3}$ g.mm$^{-3}$
- Young modulus: 210000 MPa
- Poisson ratio: 0.3

The material law for water is a hydrodynamic viscous fluid law (/MAT/LAW6) with the following characteristics:

- Initial density: $1 \times 10^{-3}$ g.mm$^{-3}$
- Reference density: $1 \times 10^{-3}$ g.mm$^{-3}$
- Pressure cutoff: -0.1 MPa
- Pressure shift: 0 MPa
- Kinematic viscosity: 0
- Initial energy / unit of volume: 0 mJ/mm$^3$
Analysis, Assumptions and Modeling Description

Modeling Methodology

The specimen is modeled using shell elements with an average mesh size of 15 x 15 mm².

The water is modeled using SPH particles having a hexagonal compact net with a smoothing length \( h_0 \) equal to 28.2843 mm. Each particle of the net represents a volume equal to 16 mm³ and weighs 16 g. This part uses 36075 SPH cells.

The size of the water block is adapted to the shape of the specimen for the purpose of reducing the model’s size and the simulation’s CPU time.

RADIOSS Options Used

• Rigid body:

  The specimen is modeled using a rigid body, and a mass of 23042.2 kg is added to the rigid body’s master node (ID: 287002).

• Initial velocity:

  An initial velocity, in accordance with the Z axis, is set on the rigid body’s master node and its value is set successively at 3.5 m/s, 6.8 m/s and 11 m/s.

• Gravity:

  A gravity load \( g_z = -9.81 \text{ m.s}^{-2} \) is applied to the specimen.

• Accelerometer:

  An accelerometer is set on the rigid body’s master node.
• **SPH outlet:**

The parallelepiped water mesh is surrounded on five faces by Outlet SPH boundary frontier absorbing conditions. A control surface is placed at a distance equal to $2 \times h$, inside the water. This surface shown in green on Fig 2, is oriented so that its normal vector points face the interior of the domain. On this outlet surface, specific silent boundary conditions are applied to the SPH cells.

• **Interfaces:**

One type of contact occurs in the simulation. Contact between the skin structure (shell finite elements) and the water (SPH cells) is modeled using a sliding interface (type 7). The gap between the surface skin and the SPH cells is equal to 1 mm. After optimization, a scale factor on the Penalty stiffness interface equal to 0.1 is used for controlling the interface forces between the rigid specimen and the water.

Fig 2: SPH outlet boundary conditions (green).
Simulation Results and Conclusions
Curves and Animations
Output Pressure
The SPH module does not enable output pressure time history values; only the animation values may be compared to the experimental data. Figures 3 and 4, show a variation in the pressure when the wedge ditches into the SPH water, corresponding to an impact velocity of 6.8 m/s. In order to attain a representative pressure gradient, the pressure range has been fixed at -0.01 MPa for the minimum value and 0.08 MPa for the maximum value. In comparison to the experimental data, the pressure values are basically the same, the wave propagation being well described.

Fig 3: Ditching simulation (from the beginning to 3 ms).
Output Acceleration

For the specimen, an accelerometer is set on the master node of the corresponding rigid body. The acceleration values expressed in g units are compared to both the experimental values [1] and the analytic solution proposed by Von Karman [2]. The signal is filtered using a CFC 60 (-3db) filter frequency after calculation. The filtering reduces discrepancy between the peaks.

The following diagrams indicate the time history acceleration results at the wedge specimen’s rigid body’s master node for three cases of impact speed: 3.5, 6.8 and 11 m/s.
Fig 5: Deceleration of the wedge for an impact velocity of 3.5 m/s.

Fig 6: Deceleration of the wedge for an impact velocity of 6.7 m/s.
For these three cases, the SPH approach using the OUTLET SPH boundary conditions indicates a good deceleration. For an impact velocity nearing the 8 m/s of the Helicopter ditching configuration, the deceleration is in correlation with the experimental data [1] and also with the analytic solution proposed by Von Karman [2].

Conclusion
The simulations show that the SPH approach using the OUTLET option developed in RADIOSS V4.4, allows the ditching of simple specimens to be modeled without any numerical problems. The SPH and OUTLET results are very close to the experimental test results and also to the analytical solution. In conclusion, to achieve ditching simulations with the correct results, it is necessary to model the water block using the SPH method with the OUTLET boundary conditions.

References
[1] CAST Deliverable 5.5.1 Generic Water Impact Tests performed at Politecnico di Milano (Polytechnic University of Milan)