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SeaFEM - Validation Case 8

Dynamics of a vertical pile

SeaFEM

Version
15.1.0

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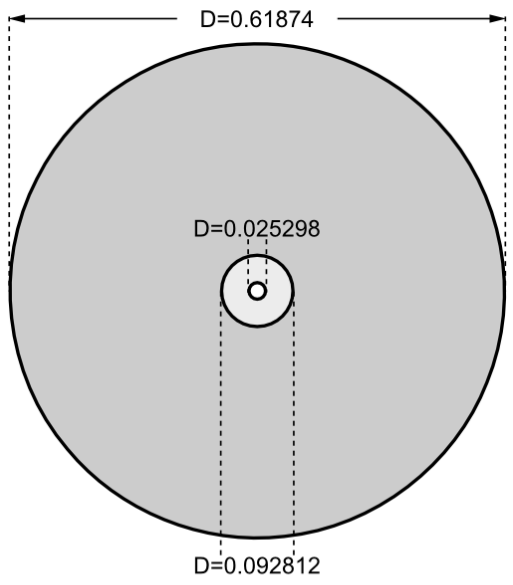
1 Validation Case 8 - Dynamics of a vertical pile

The present test case analyzes the dynamics of a slender vertical cylinder. The goal of this study is to compare the results obtained using two different approaches to evaluate the forces on the cylinder; the diffraction-radiation solver of SeaFEM, and the Morison's equations.

Therefore, two different models will be created. The first one will be used to solve the problem using the diffraction-radiation solver. The geometry on the left hand side below shows the whole computational domain with the cylinder located at the center (all length units in meters). This geometry was constructed based on that defined in reference [1].

The second one, on the right hand side below, shows the whole computational domain, but it doesn't include the cylinder model, since the necessary data to define the cylinder characteristics will be defined in a TCL script.



The main dimensions of the geometry are:

- T = 1.68 s
- L = 3.734 m
- H = 0.074 m
- d = 0.618 m
- D = 0.025 m
- ρ = 999.8 kg/m^3

Problem description

- Geometry

Vertical cylinder of diameter 0.0252984 m and 0.618744 m draught.

- Domain

Cylindrical domain of diameter 0.618744 m and depth 0.86874 m.

- Fluid Properties

For the present analsyis, water density was taken to be ρ = 1025 kg/m^3.

- Problem description

Bathymetry: infinite depth

Absorption factor: 1.0

Beach: 0.075 m

- Seakeeping environment

Wave spectrum type: Monochromatic wave

Wave amplitude: 0.0372 m

Period: 1.68 s

Wave direction: 180.0 deg

- Body properties

The center of gravity is set to 0.0, 0.0, -0.5 m.

Only pitch and heave degrees of freedom are free.

- Time data and solver parameters

Time step: 0.0154 s

Simulation time: 80 s

Initialization time: 40 s

Symmetric solver: Deflated conjugate gradient (tolerance = 1.0E-7) with an ILU preconditioner

Morison-type forces

The inertial force on slender slements is calculated in SeaFEM as [4]:

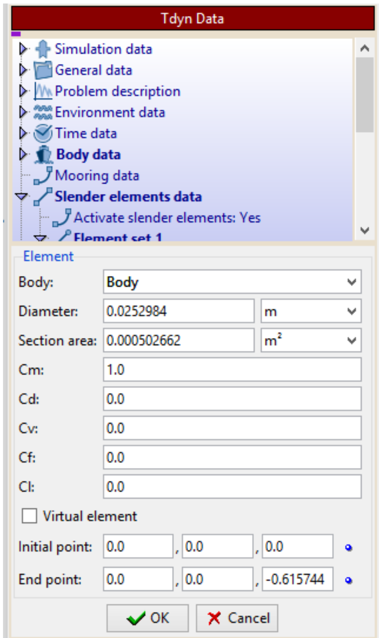
$$F_M = (1 + C_M) \cdot \rho \cdot S \cdot (\mathbf{l} \; x \; \mathbf{a}^{\mathbf{w}} x \; \mathbf{l}) - C_M \cdot \rho \cdot S \cdot (\mathbf{l} \; x \; \mathbf{a}^{\mathbf{b}} x \; \mathbf{l})$$

The first term in the right hand side of the above equation, includes the Froude-Kriloff force (i.e. undisturbed wave pressure force) and the diffraction inertial force, while the second term represents the radiation inertial force. It is well known that the potential theory results gives a mass coefficient C_M=1.0 for a circular cylinder, where half the contribution comes from the Froude Kriloff force and the other half comes from the diffraction force [2]. Therefore, we will use this value to calculate the forces acting on the cylinder using Morison's formulae.

A TCL script is used to insert the data required by SeaFEM. The script shown below defines the characteristics of the vertical cylinder with a mass coefficient C_M=1.0. Furthermore, it switches off the diffraction-radiation solver to accelerate the calculations in this case.

```
proc TdynTcl_StartSetProblem { } {
    TdynTcl_Add_Morison_Element 1 0 0.0 0.0 0.0 0.0 0.0 -0.618744 0.0252984 0.000502662
1.0 0 0 0 0
    TdynTcl_Configure_Analysis Solve_Dif_Rad 0
}
```

It should be noted that SeaFEM v13.6 and above allows the definition of slender elements through the GUI.



Definition of an slender element

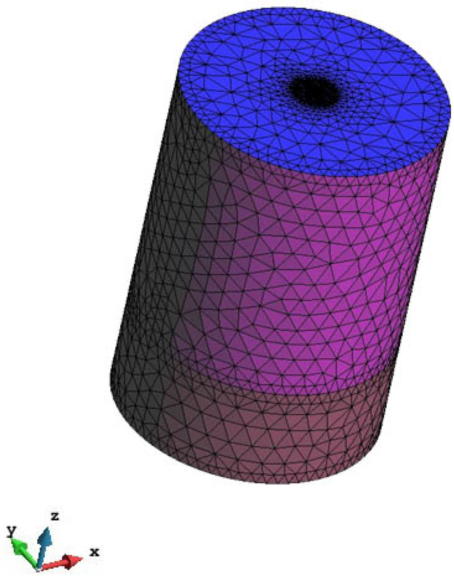
In that case, the definition of the slender element used in this case is done as shown in the picture above. See reference [5] for further information.

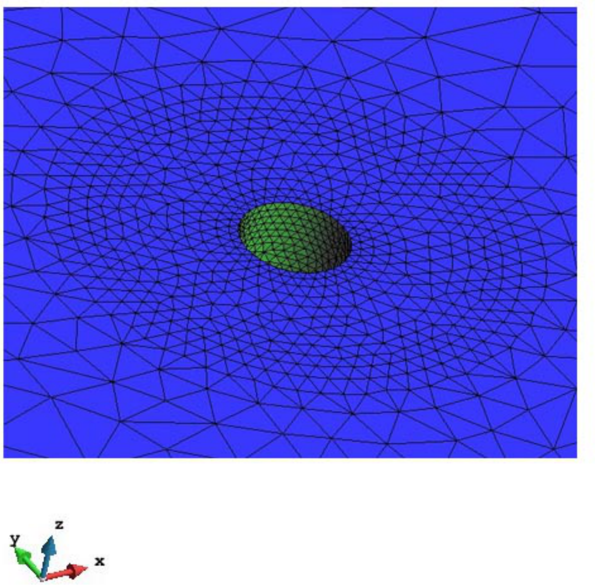
Mesh

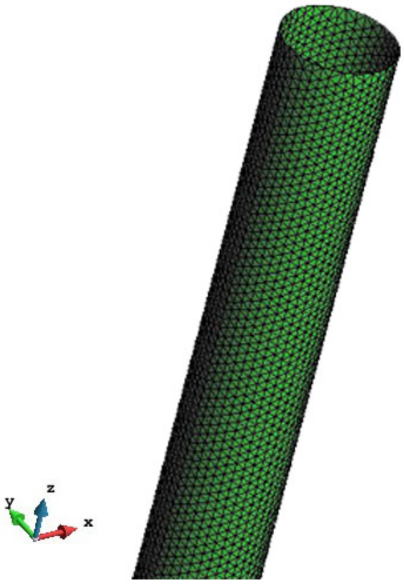
Mesh properties for the analysis using the diffraction radiation solver are summarized in the following table:

Mesh properties	
Min. element size	0.00216
Max element size	0.028
Inner free surface element size	0.00432
Mesh size transition	0.5
Number of tetrahedra	38,621
Number of nodes	75,139

The following figures show first a global view of the mesh used in this case, and next, details of the cylinder mesh as well as the free surface mesh close to the structure location.





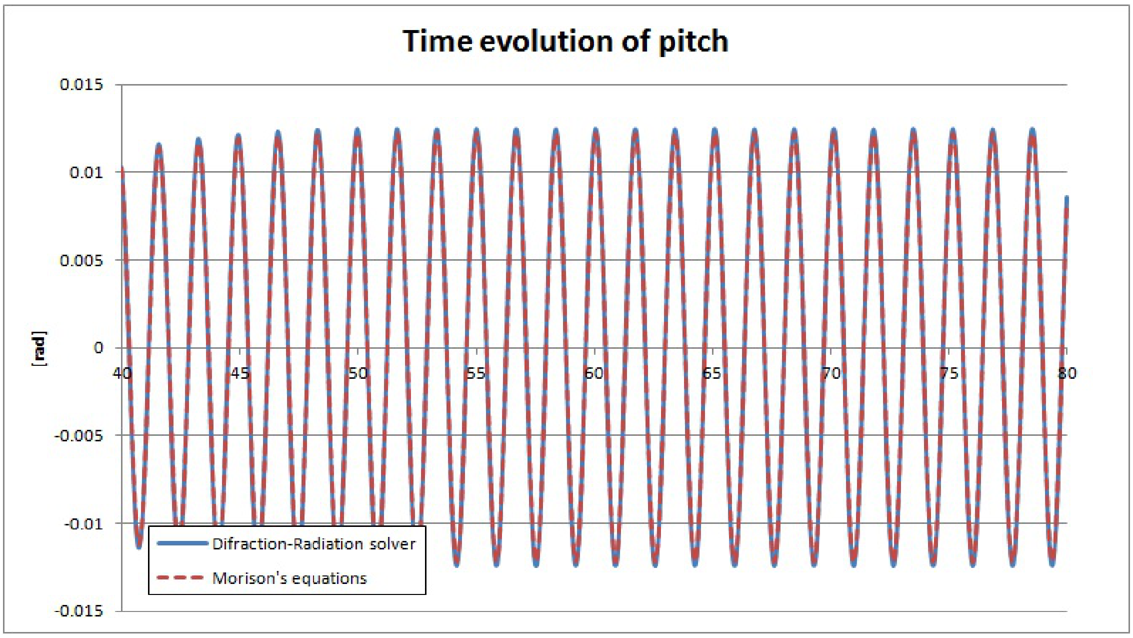


In the case of the analysis using Morison's equations, a uniform mesh of maximum size 0.05 is created, resulting in the following mesh properties.

Mesh properties	
Min. element size	0.05
Max element size	0.05
Inner free surface element size	0.05
Mesh size transition	0.5
Number of tetrahedra	4,770
Number of nodes	23,504

Results

In the present analysis, the pitch movement for the two different cases is compared. The following graph shows the time history for the las 40 s of simulation of the pitch movement in both cases. As can be seen, both signals are almost identical, as expected.



References

[1] Morison J. R., O'Brien M. P., Johnson J. W., and Schaaf S. A., 1950, "The force exerted by surface waves on piles”, Petroleum Transactions, American Institute of Mining Engineers, 189, pp. 149–154.

[2] Faltisen, O.M., "Sea loads on ships and offshore structures", Cambridge University Press (1998).

[3] R. McCamy and R. Fuchs, Wave forces on piles: a diffraction theory. Tech. Memo No. 69, U.S. Army Corps of Engrs, 1954

[4] SeaFEM Theory Manual. Available to download at http://www.compassis.com/compass/en/Soporte.

[5] SeaFEM User Manual. Available to download at http://www.compassis.com/compass/en/Soporte.

Validation Summary

CompassFEM version	15.1.0
Tdyn solver version	15.1.0
RamSeries solver version	15.1.0
Benchmark status	Successfull
Last validation date	27/11/2018