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SeaFEM - Validation Case 6

Wave force on a vertical pile

SeaFEM

Version
15.1.0

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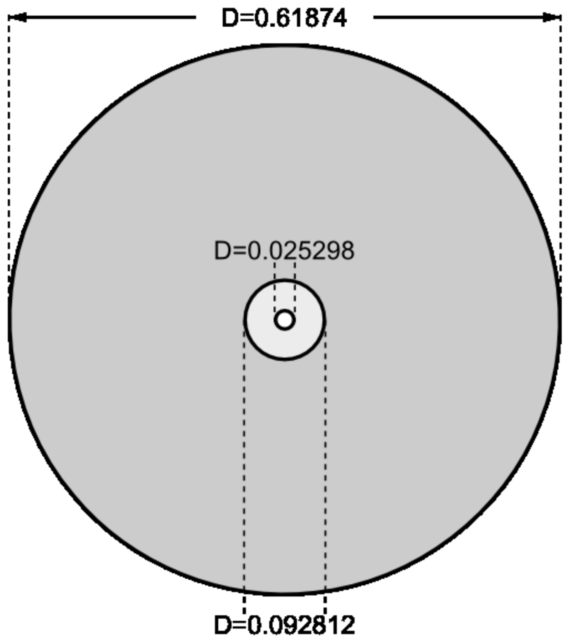
Table of Contents

1 Validation Case 6 - Wave force on a vertical pile

The present test case analyzes the force exerted by an unbroken surface wave on a cylindrical pile, which extends from the bottom upward above the wave crest. The GiD geometry below shows the whole computational domain with the pile structure located at the center (all length units in meters). Next, details of the geometry are presented. This geometry was constructed based on that defined in reference [1].



The results will be compared to those obtained experimentally in [1] for the following case:

- 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

Where T, H and L are the wave period, height and length, repectively, d is the still water depth, D is the pile diameter and the density of the water.

Problem description

- Geometry

Vertical cylinder of diameter 0.025 m, extended from the top to the bottom of the domain.

- Domain

Cylindrical domain of diameter and depth 0.619 m.

- Fluid Properties

For the present analsyis, water density was taken to be ρ = 999.8 kg/m^3.

- 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, -0.619 m.

- Time data and solver parameters

Time step: 0.01 s

Simulation time: 10 s

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

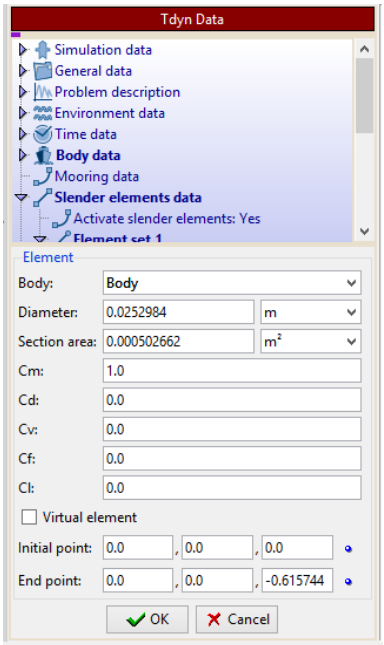
- Morison-type forces

A TCL script is used to insert the data required by SeaFEM to evaluate drag forces and improve evaluation of the diffraction added mass accounting for viscous effects.

The script shown below, defines the characteristics of the vertical cylinder, a coefficient for correction of added mass due to viscous effects of -1.69, and a drag coefficient of 1.32 (see [1] and [2]).

```
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 -1.69 1.32 0.0 0.0 0.0
}
```

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



Definition of an slender element

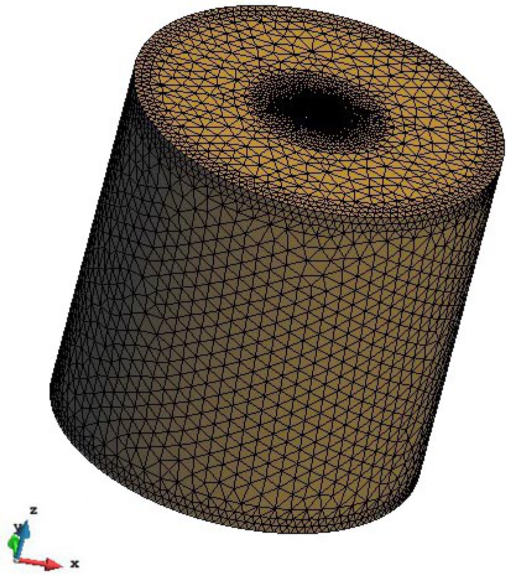
In that case, the definition of the slender element used in this case is done as shown in the picture above. See reference [5] for further information.

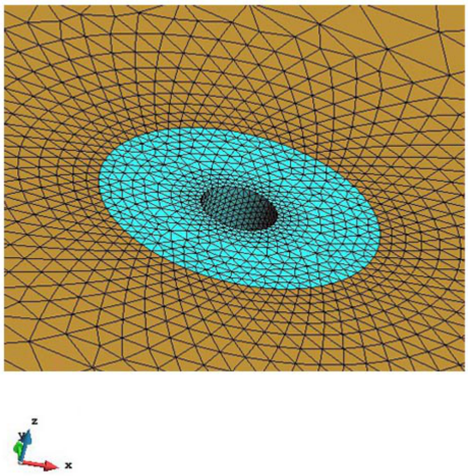
Mesh

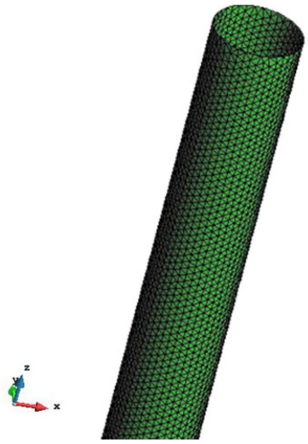
Mesh properties for the present analysis are summarized in the following table:

Mesh properties	
Min. element size	0.00216
Max element size	0.028
Inner free surface element size	0.00432
Mesh size transition	0.3
Number of tetrahedra	397,180
Number of nodes	75,139

The following figures show the mesh used for the present analysis. First a global view is presented. Next, details of the pile mesh are shown as well as the free surface mesh close to the structure location.







Results

In the present SeaFEM calculation, the moment exerted by the wave force on the bottom of the pile will be compared to the experimental and analytical values obtained in by Morison et al. [1].

As shown in reference [1], the dimensionless moment coefficient, M^*, exerted by the wave force about the bottom of the pile can be estimated by:

$$M^* = -\frac{\pi}{4} \cdot C'_M \cdot \frac{D}{H} \cdot K_1 \sin(\varpi t) \; + \; C_D K_2 \cos(\varpi t) \cdot |\cos(\varpi t)|$$

where the first term corresponds to the inertia term (Froude-Krylov force plus hydrodynamic mass force) and the second is the momentum of the drag force. In the above equation, C'_M is the inertia coefficient, C_D the drag coefficient, w the wave angular frequency, t the physical time and K_1 and K_2 two coefficients that can be evaluated from the wave and pile characteristics [1].

The dimensionless moment coefficient is related to the moment M, by

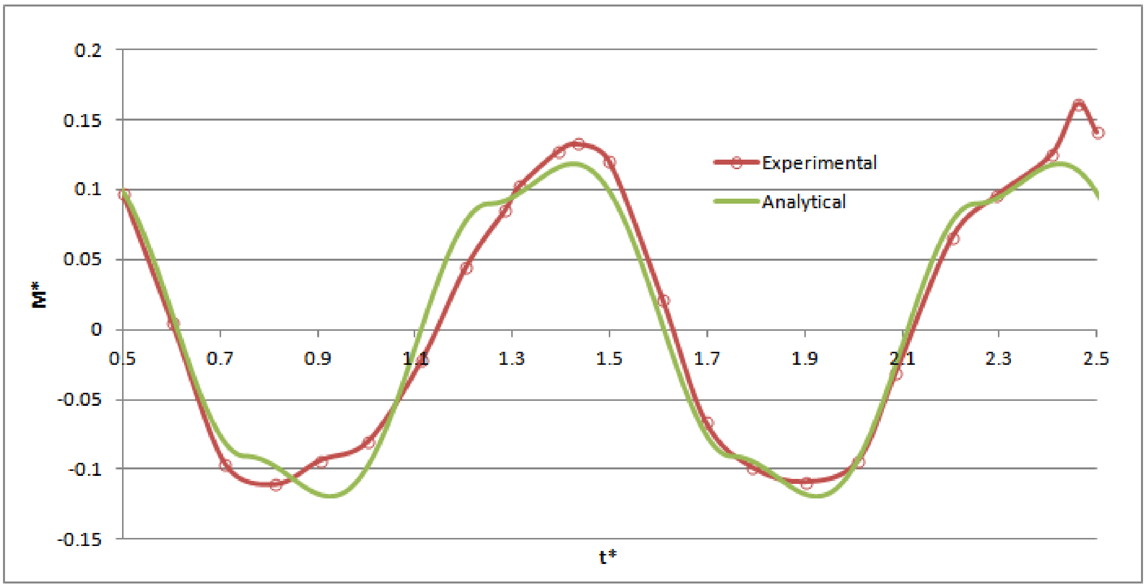
$$M^* = \frac{M\,T^2}{\rho\,D\,H^2 L^2}$$

In reference [1], the experimental data for this case is presented, and C'_M and C_D are calculated from the experimental data to be 1.20 and 1.32, respectively. These values results in K_1 = 0.2815 and K_2 = 0.07440.

Is it important to remark that the inertia coefficient used in SeaFEM, C_M, is related to C'_M by [4]:

$$C_M = C'_M - 1$$

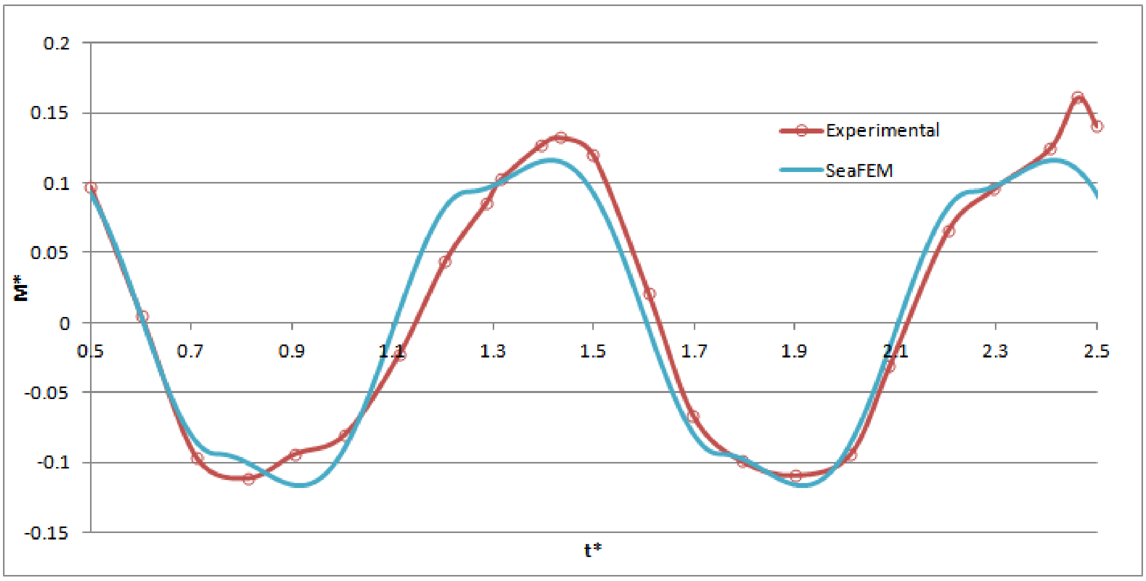
The following graph shows the comparison of the experimental results from reference [1] and the analytical data obtained from the above equations. The horizontal axis shows the dimensionless time, t*=t/T.



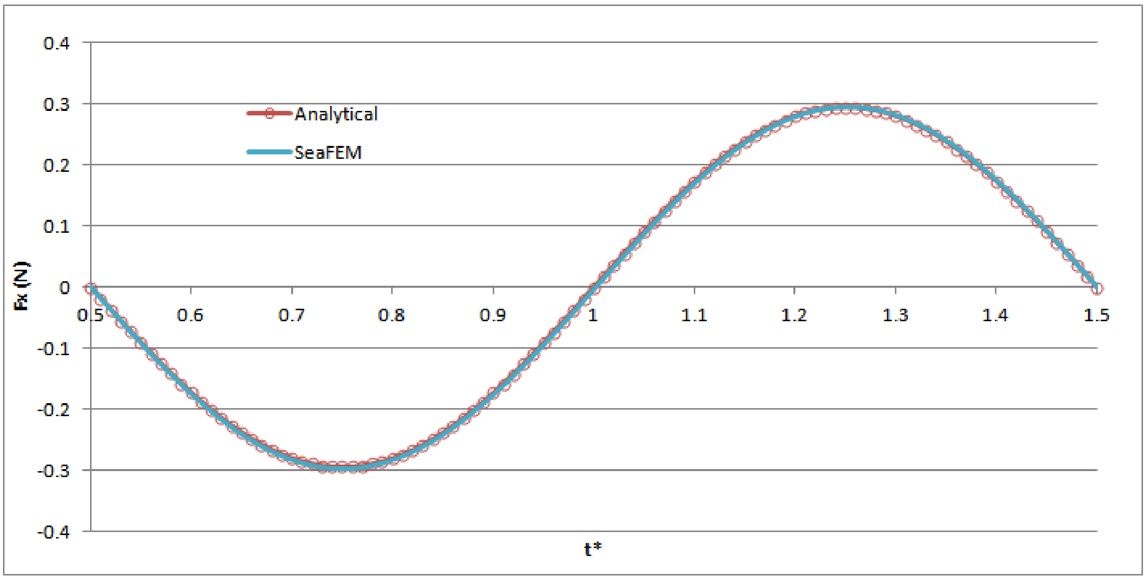
SeaFEM is able to compute the non-viscous forces, by integrating the pressure field on the pile surface. This term is composed of the force introduced by the unsteady pressure field generated by undisturbed waves (Froude-Krylov force) and the diffraction force due to the body disturbing the waves. Furthermore, SeaFEM can estimate the viscous drag forces, and correct the diffraction added mass due to viscous effects by using the analytical formula presented in [1]. For this purpose, the required data must be defined in a TCL script as indicated in previous sections.

Further information on this matter can be found in the Theory and User Manuals of SeaFEM.

The following graph shows a comparison of the SeaFEM moment computation, including drag force and diffraction force correction due to viscous effects.



Finally, the non-viscous horizontal force exherted by the incident waves over the pile and computed by SeaFEM is compared herein with the corresponding analytical solution shown in [3].



It is emphasized that SeaFEM will always calculate the inertia term by integrating the pressure field on the body surface. This will result in the evaluation of the Froude-Krylov force plus diffraction force. On the other hand, it is well known that viscous effects can reduce the amplitude of the diffraction force, and in most of the cases SeaFEM calculation will result in overprediction of this value [2]. Therefore, it could be advisable to improve the computational prediction of this force, by setting a suitable value of C_M by using auxiliary slender elements, based on experimental information.

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