

## SeaFEM - Validation Case 10

Buoys joined with an inelastic catenary



# SeaFEM

**Version**  
**15.1.0**



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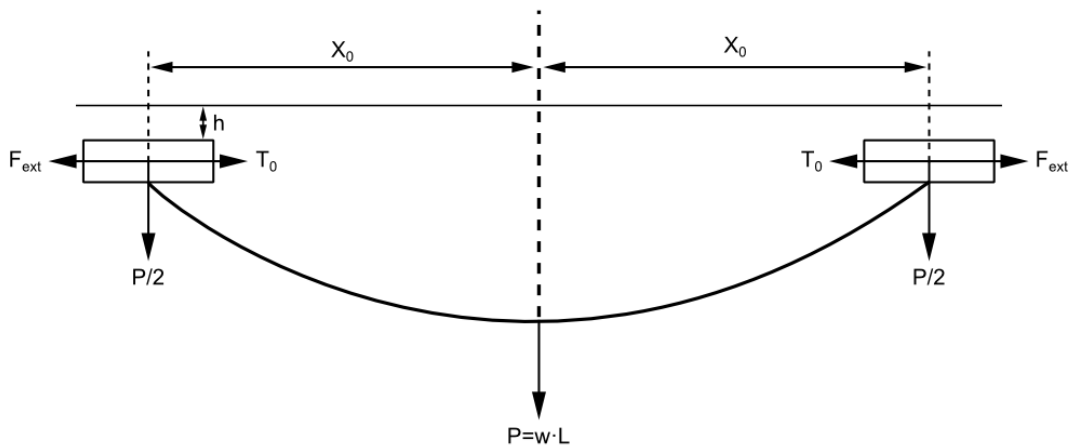
## 1 Validation Case 10 - Buoy inelastic catenary

This validation case analyses the dynamic behavior of two buoys connected by an inelastic catenary. This simple model is aimed to verify some of the mooring capabilities of SeaFEM, in particular the inelastic catenary type of mooring segments.

For the sake of validation, we start from an equilibrium configuration consisting of two cylindrical bodies joined by a catenary segment. In order to enforce the equilibrium, both bodies are subjected to external forces that exactly compensate the horizontal component of the catenary force. An additional surge displacement is imposed initially and both bodies are further released causing an oscillation about the equilibrium configuration. The weight of the catenary causes an additional heave displacement that can be also predicted and validated. No wave effects are taken into account. Hence, incident waves do not exist and the diffraction-radiation problem is not solved.

Equilibrium configuration of the catenary

The assumed equilibrium configuration and problem parameters are shown in the following sketch:



$$x_0 = 6 \text{ m}$$

$$w = 1000 \text{ N/m}$$

$$L = 15 \text{ m}$$

The equation of the inelastic catenary is given by the following expression:

$$z = \left( \frac{T_0}{w} \right) \cdot \cosh \left( x \cdot \frac{w}{T_0} \right)$$

where  $T_0$  is the horizontal component of the catenary tension force (which is constant along the catenary) and  $w$  the effective weight (actual weight minus buoyancy) per unit length of the catenary.

On the other hand, the length of a differential element of the catenary is given by:

$$ds = (dx^2 + dz^2)^{\frac{1}{2}} = \left(1 + \frac{dz}{dx}\right)^{\frac{1}{2}} \cdot dx$$

By differentiation of the catenary equation and further substitution into the previous equation we end up with the following expression.

$$ds = \left(1 + \sinh\left(x \cdot \frac{w}{T_0}\right)\right)^{\frac{1}{2}} \cdot dx$$

Integrating between both ends of the catenary we obtain the total length  $L_0$ .

$$L_0 = 2 \cdot \left(\frac{T_0}{w}\right) \cdot \sinh\left(x_0 \cdot \frac{w}{T_0}\right)$$

By solving this transcendental equation, it is possible to evaluate the value of  $T_0$  and consequently the value of the external forces necessary to enforce the equilibrium. In our particular case, it results in:

$$T_0 = 5073 \text{ N}$$

The additional heave displacement due to the weight of the catenary chain attached to the bodies can be also evaluated analitically and compared to the numerical results. To this aim, note that such an additional displacement will cause an extra buoyant force which must exactly compensate half the effective weight ( $P/2$ ) of the chain (since two bodies are supporting the total length of the catenary). From this, the vertical displacement can be evaluated as:

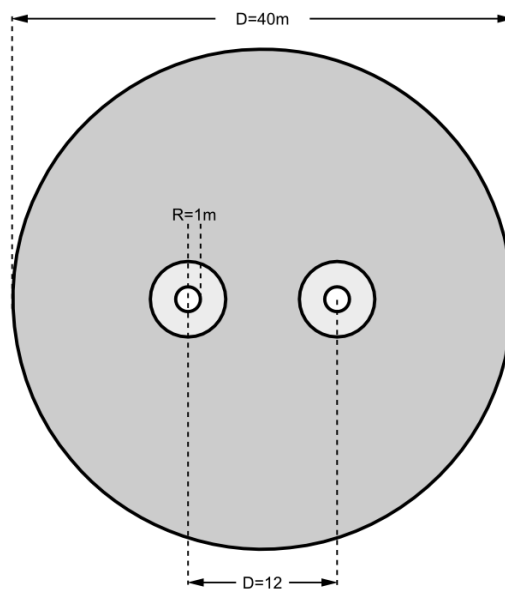
$$h = \frac{P}{2 \cdot \rho_w \cdot g \cdot A}$$

where  $\rho_w$  is the water density,  $g$  is the gravity acceleration and  $A$  is the cross section area of the cylinder. In the present simulation,  $\rho_w = 1025$  which corresponds to sea water, and  $A = 3.1416 \text{ m}^2$  (cylinder radius  $R=1 \text{ m}$ ). This provides a vertical displacement:

$$h = 0.2374 \text{ m}$$

Since the initial configuration of the model does not take into account the weight of the catenary, and the masses of the floating bodies are calculated by SeaFEM imposing an initial hydrostatic equilibrium, the numerical simulation will result in a vertical oscillation of the two bodies around the vertical equilibrium position  $z = -h = -0.2374 \text{ m}$ .

The following image shows a top view of the computational domain. The two cylinders have identical radius ( $R=1\text{m}$ ) and initial draft ( $h=0.5 \text{ m}$ ) resulting in a displacement about  $1.57 \text{ m}^3$  and a body mass about  $1610 \text{ Kg}$  (water density  $\rho = 1025 \text{ Kg/m}^3$ ).

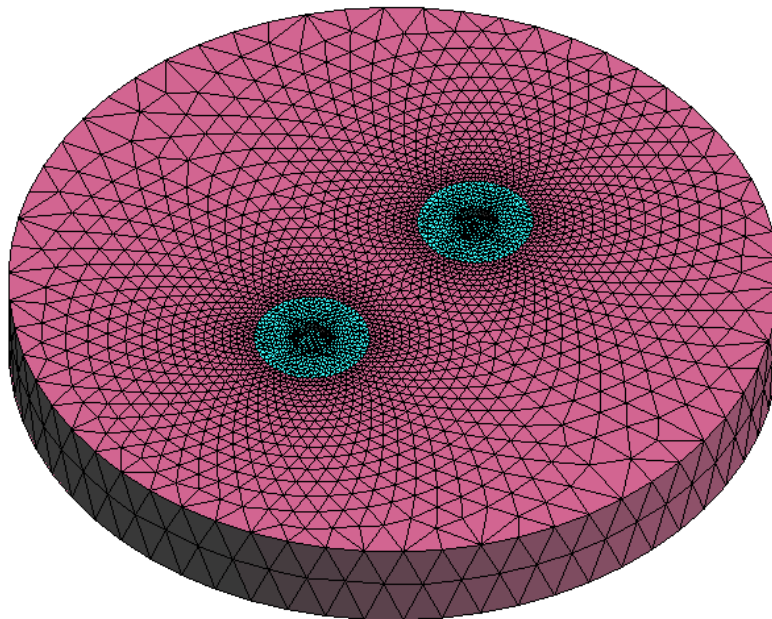


## Mesh

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

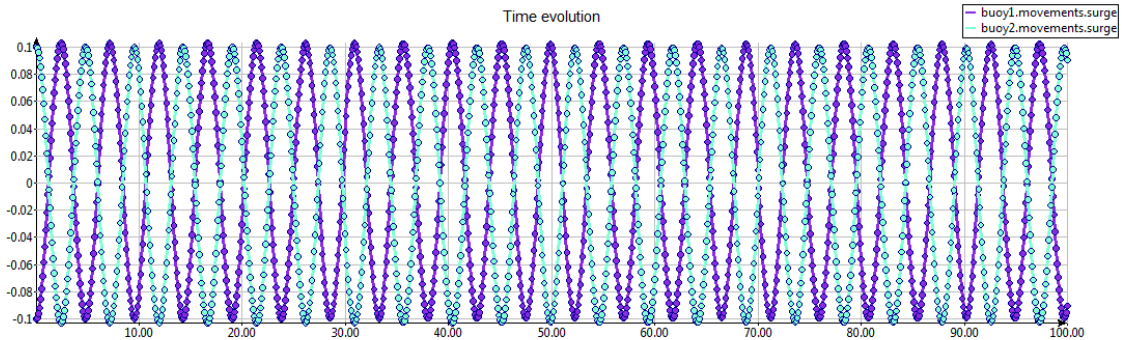
Mesh properties	
Min. element size	0.2
Max element size	5
Mesh size transition	0.2
Number of elements	127355
Number of nodes	21845

Next picture shows an isometric view of the whole domain mesh used for the present analysis.



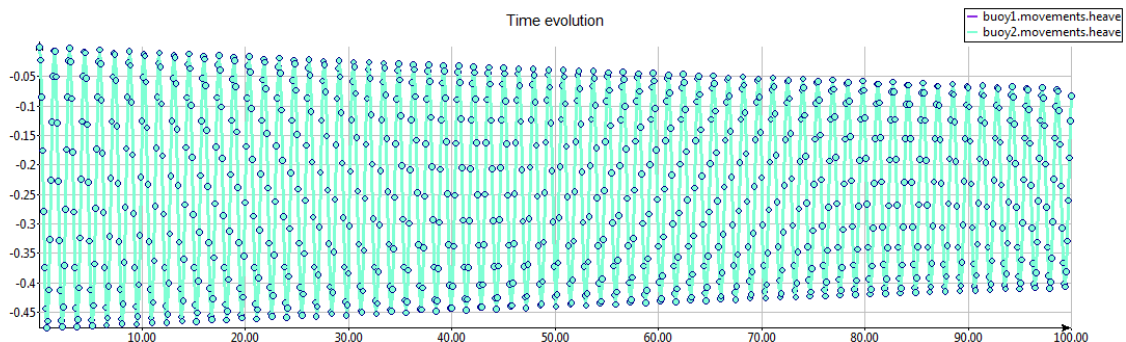
## Results

The following picture shows the surge displacement response of the two floating bodies when they are initially pulled apart 0.1 meters from their equilibrium position:



As it was expected, both bodies oscillate in surge with the same phase around the equilibrium position corresponding to null surge.

The following picture shows the heave displacement of the two bodies when they are initially located in their free hidrostatic equilibrium position. As it was expected, both bodies oscillate around the equilibrium position given by the additional displacement caused by the weight of the catenary ( $z = -0.2374$  m). The damping observed in the vertical oscillation is simply due to the numerical dissipation of the dynamic solver algorithm).





## Appendix

The following code describes the tcl script used for the present analysis. TdynTcl\_InitiateProblem is simply used to deactivate the numerical calculation of the diffraction-radiation problem. On the other hand, TdynTcl\_CreateMooring procedure is used to create the catenary line and to link it to the floating bodies.

Note that in newer versions of the program mooring lines can be already defined using the graphic user interface of SeaFEM. In this case, the TdynTcl\_CreateMooring procedure must be commented in the Tcl script to avoid mooring duplication. On the contrary, TdynTcl\_InitiateProblem procedure must remain active within the Tcl script to configure the solver so that the diffraction-radiation problem is not effectively solved.

```
proc TdynTcl_InitiateProblem { } {  
    configure_analysis Solve_Dif_Rad 0  
}  
  
proc TdynTcl_CreateMooring { } {  
    set area 0.015158  
    set L 15.0  
    set w 1000.0  
  
    set seg1 [TdynTcl_Create_Mooring_Segment 2 -6.0 0.0 -0.5 6.0 0.0 -0.5 $w $L $area  
2.10E+11 0]  
  
    TdynTcl_Create_Mooring_Link $seg1 2  
  
    TdynTcl_Message "TdynTcl_CreateMooringLine finished!!!" notice  
}
```

**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