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RamSeries - Validation Case 14

Non-Linear Dynamic Analysis with SeaFEM Wave Loads

RamSeries

Version
15.1.0

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Model Description

This test case is a simple analysis produced in order to test RamSeries Non-Linear (geometric) dynamic capabilities, combined with wave pressure loads coming from previously performed diffraction-radiation calculations using SeaFEM.

Test model has a simple geometry, consisting on a solid cylinder with the following dimensions:

R_{cyl} = 1.0 m

h_{cyl} = 0.7 m

RamSeries model:

First, the hidrostatic equilibrium for the initial configuration is stablished by checking de displacement calculated in SeaFEM, and adjusting the specific weight (ρ) in RamSeries, so the cylinder has its floating line in z = 0 (this means a depth of d=0.5 m).

Displacement (SeaFEM): Δ_{SF} = 15693 N

Cylinder volume: V_{cyl} = 2.19 m^3

Then, the specific weight for the material is evaluated as $\rho_{cyl} = \Delta_{SF}/(V_{cyl} \cdot t_{cyl})$ = 7136 N/m3

Therefore, the volume is assigned with a material of the following properties (the material is assumed to be linear elastic):

E = 2.1e11 N/m2

μ = 0.3

ρ_{cyl} = 7136 N/m3

- Loads:
  The model is loaded with the dynamic pressures coming from the SeaFEM analysis results, plus the standard hydrostatic pressure load, and the self-weight. Dynamic wave load pressures are applied to the geometry below the floating line, while hydrostatic pressures are also applied above the waterline, to account for its variation,

  The self-weight load is applied to the whole model.

- Constraints:
  The model has its displacement restrained in the direction transversal to the advancing irection of the wave system (Y axis). This condition is applied to the points A(0.0,-1.0,-0.5) and B(0.0,1.0,-0.5).

Also, an elastic constraint has been applied at the point P(-1.0,0.0,-0.5). The stiffness value is K=100 N/m. This condition is also applied in the SeaFEM model, to make them equivalent.

- Dynamic and Non-Linear analysis parameters:
  The following parameters have been used:

  $\Delta t = 0.1$ s

  Num. Steps: 600

  Integration Method: Energy Conserving/Decaying

  $\alpha_{E\text{-}C/D} = 0.0$ (High frequency dissipation parameter)

  Matrix storage: Consistent

  Initial conditions: None

  Damping (Rayleigh):

  $\alpha_M = 0.4426$

  $\alpha_K = 0.0$

The damping coefficient, α_M, has been defined to be the 5% of the critical damping for the heave motion. The calculation procedure is showed next:

$\xi=C/C_c=1$

with:

$C=M\cdot\alpha'_M$

$C_c=2\cdot M\cdot\omega_c$

So:

$\alpha'_M = 2\cdot\omega_c$

The natural frequency of the heave motion is calculated as:

$\omega_c = (K_{33}/M)^{1/2} = 4.415\ s^{-1}$

with:

$K_{33} = \rho\cdot g\cdot A_{flot} = 31557.3$ N/m

and being M, the total mass of the floater. And finally,

$\alpha_M = 0.05 \cdot (2 \cdot \omega_c) = 0.05 \cdot \alpha'_M = 0.4426$

SeaFEM model:

The geometry of the model for SeaFEM is the same, but for the part of the cylinder over the free surface (Z= 0), which is neglected (not necessary for SeaFEM analyses). Details of the generation of this model are described in the SeaFEM Manual.

- Enviroment data.
  The simulation is performed for monochromatic wave system in the advancing along the positive X axis direction (0.0 deg), with the following parameters:

  A_{wave} = 0.1 m

  T_{wave} = 6.0 s

- Body data:
  The body data corresponds to the geometric properties of the solid cylinder, which have been obtained with RamSeries tools:

```
Center of Gravity

(xG,yG,zG) = (-9.33527e-006,-3.20587e-011,-0.149999) [L]

Total weight = 15669.4 [N]

Moments of Inercia respect to ortogonal axis passing through the Center of Gravity

(Ixg,Iyg,Izg) = (4656.38,4658.74,7991.03) [F*L^2]

Radii of gyration respect to ortogonal axis passing through the Center of Gravityn

(rxg,ryg,rzg) = (0.545128,0.545266,0.714127) [F*L^2]
```

Center of gravity: CDG=(0.0,0.0,-0.15).

Radii of gyration:

R_{xx} = R_{yy} = 0.5451

R_{zz} = 0.7141

Three degrees of movement are free: surge, heave and pitch.

External forces have been added:

1 .Elastic spring (same as in RamSeries):
F_x = -100*dx[-1.0,0.0,-0.5]

2 .Compensating moment:

This moment is applied so it compensates the moment which will appear in RamSeries due to the elastic restriction.

M_y = -100*dx[-1.0,0.0,-0.5]*(0.5-0.15)

- Irregular frequency removal = 0.05.
  A 5% of the critical damping factor has been considered here, in order to make the analysis equivalent to the RamSeries one.

Results

For the sake of validation, a simulation was run using the properties, loads and problem conditions described in the previous chapter.

Mesh:

An unstructured mesh of linear triangles has been used.

Number of elements:2440

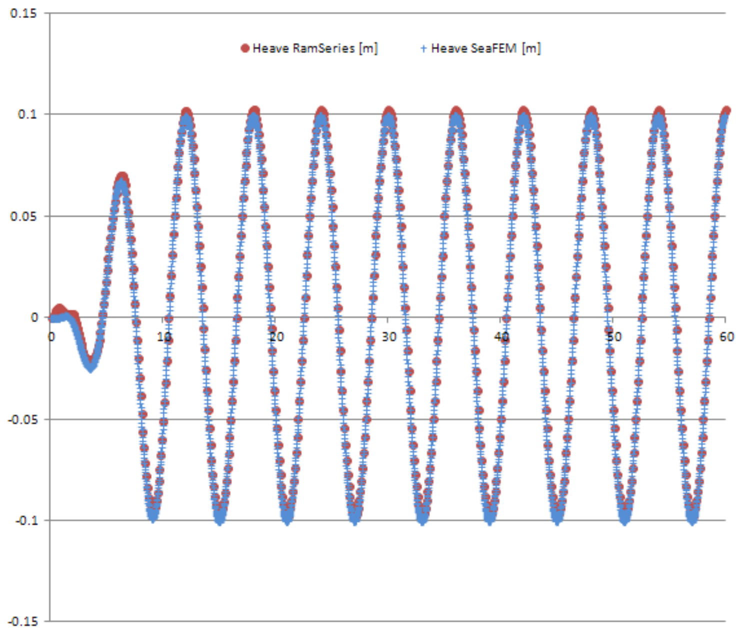
Number of nodes:9800

Displacements results:

The main goal of this test is to validate that the dynamics of RamSeries follows the dynamic imposed by the pressure results obtained in SeaFEM.

The following images show the comparison of both codes solution for the main movements (heave, surge and pitch).

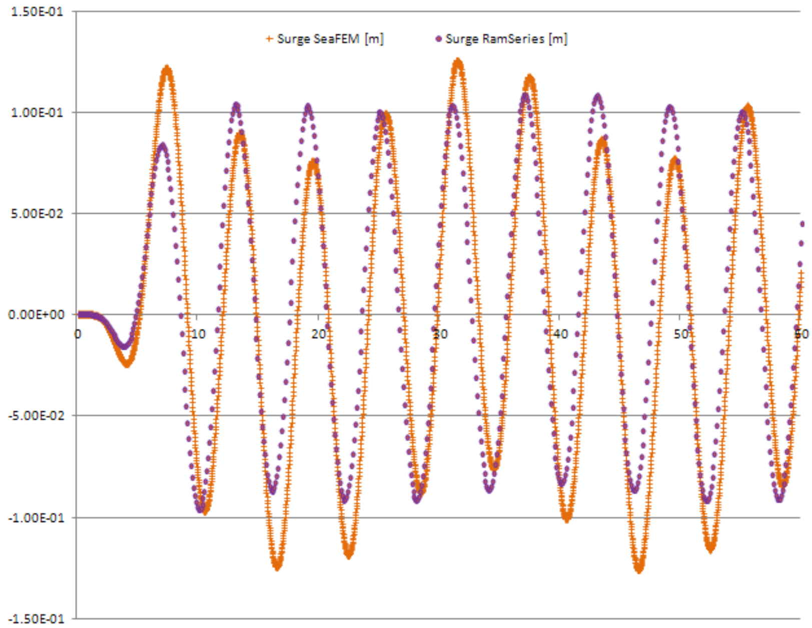
- Heave movement of the Center of Gravity:



Heave movement [m] for point (0,0,-0.15)

As can be seen, both signals follow each other perfectly.

- Surge movement of the Center of Gravity:



Surge movement [m] for point (0,0,-0.15)

For this movement, an offset appears in the amplitude of the signals. This is produced by the initial transitory which is not exactly the same in both simulations.

Nevertheless, it is very important to remark that both signals follow the two main movements periods:

- T_w = 5 s (wave period)
- T_k = 25.33 s (spring natural period)

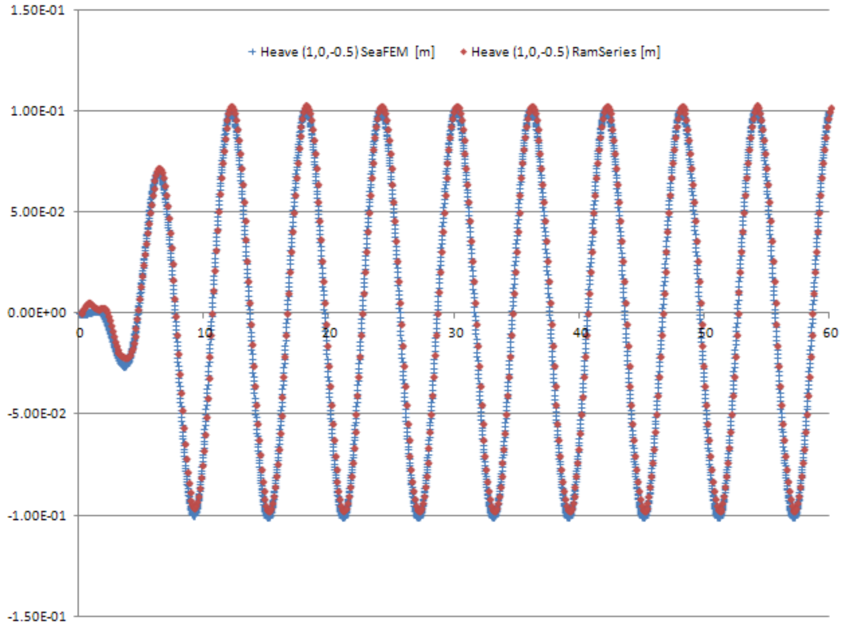
The spring period is calculated as follows (it includes the critical damping percentage inserted in RamSeries model):

$$\omega_K = \sqrt{(K/M - (\xi/2)^2)}$$

$$T_K = 1/\omega_K$$

Being M the total floater mass, K=100 N/m the spring constant, and ξ = 0.05 (5%) the percentage of the critical damping considered.

- Heave movement of a point different from the CDG:
  The heave motion of a point different from the CDG (point [1,0,-0.5])is also compared for both codes solution. The coincidence of both signals grants that the pitch motion (rotation around the Y axis) is also coincident.

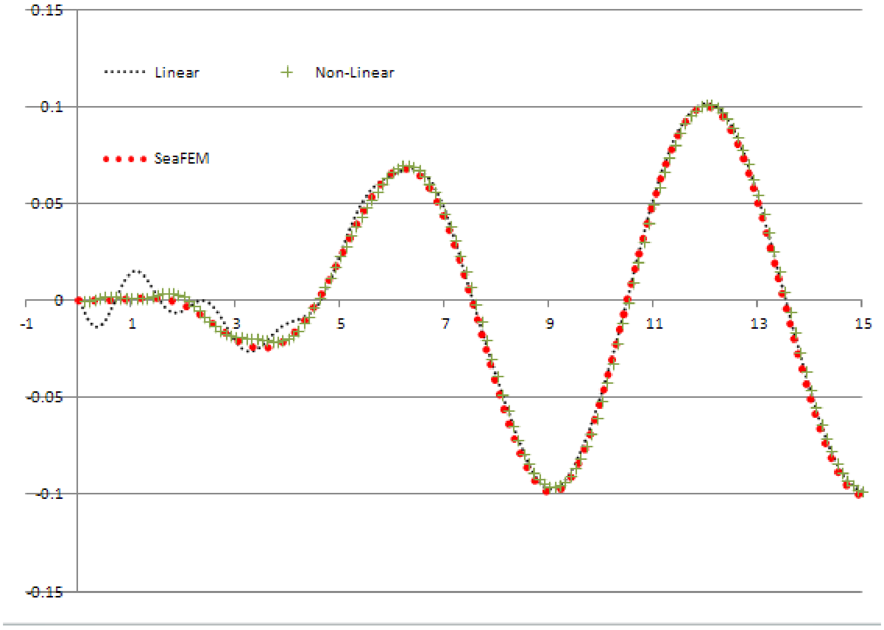


Heave movement [m] for point (1,0,-0.5)

Linear results

A linear analysis has also been performed, in order to compare results. If small movements are expected, it may be quite convenient and advisable to perform a linear analysis instead of the non-linear, for it runs faster.

The obtained signal is showed in the following image:



References

[1] B. Serván. SeaFEM Manual. CompassIS (2012).

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