Validation of a simplified method for the crashworthiness of offshore wind turbine jackets using finite elements simulations

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Context

- Wind farms
  - More, larger and closer to traffic lanes
- Ships
  - Commercial, passenger and maintenance vessels

Probability of collision ↗

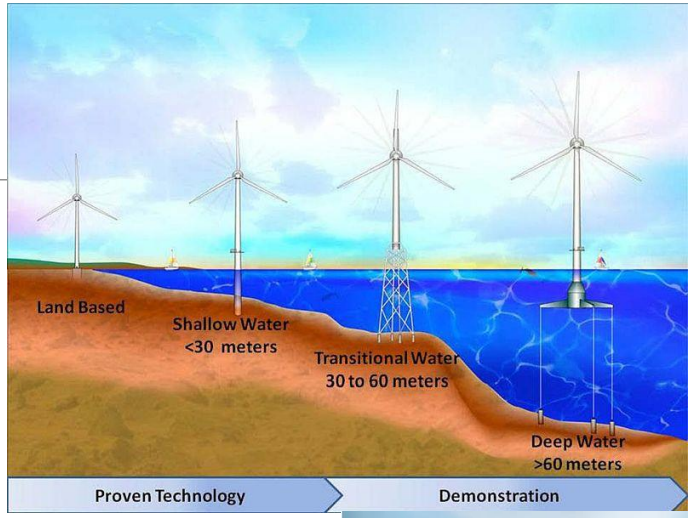
[offshorewindindustry.com]

[ship-technology.com]

[maritimejobs.org]

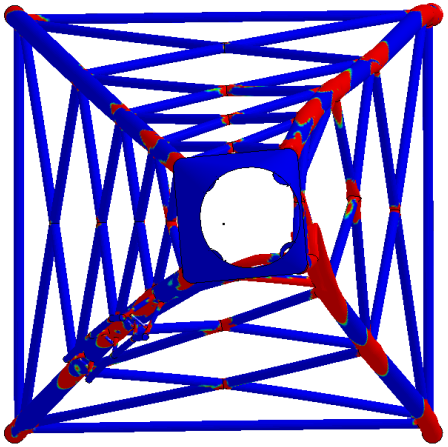
Context

- Several types of wind turbine supporting structures
  - Monopile
  - Tripod
  - **Jacket**
  - Floating
- Finite elements: accurate but time demanding
- Need a faster method for pre-design stage
  - Analytical developments
    → Continuous Elements Method

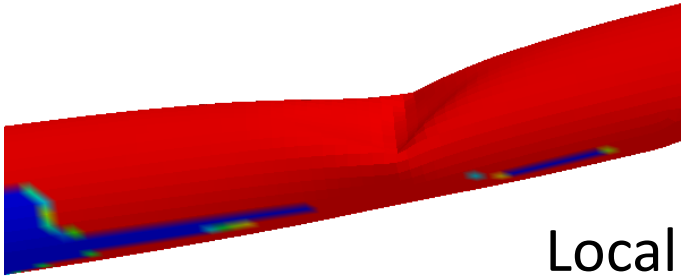


[boem.gov]
[researchgate.net]

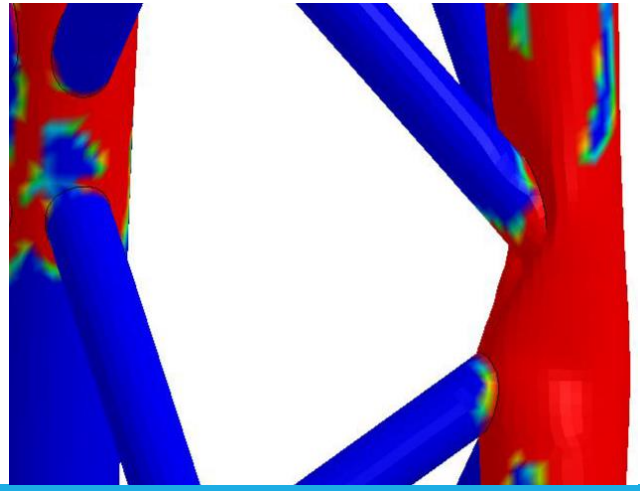
Deformation modes



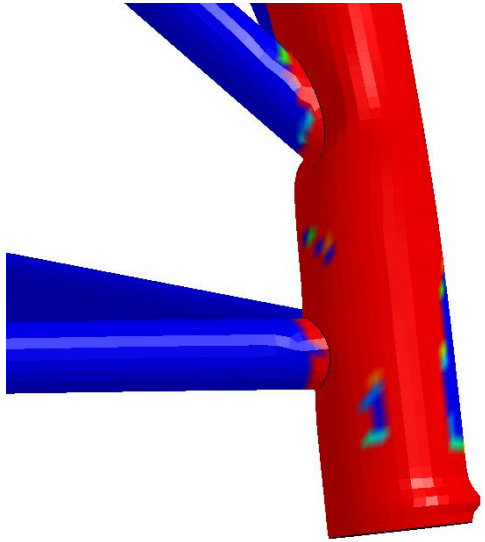
Overall motion



Local crushing



Punching



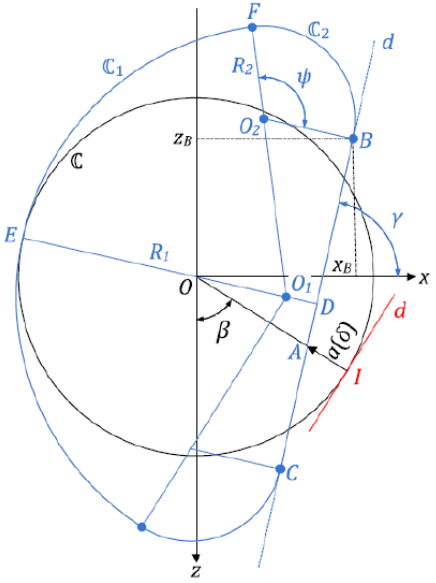
Base of jacket

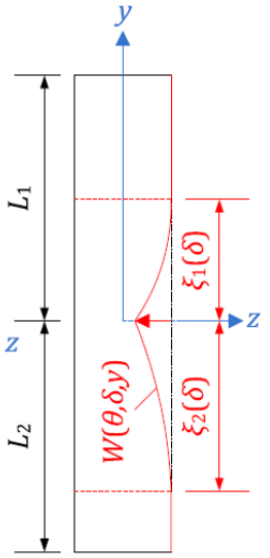
Analytical developments

- Use of the virtual work principle, in combination with the upper-bound theorem (Jones, 2003)

$$F \times \dot{\delta} = \dot{E}_{int}$$

- Example for local crushing

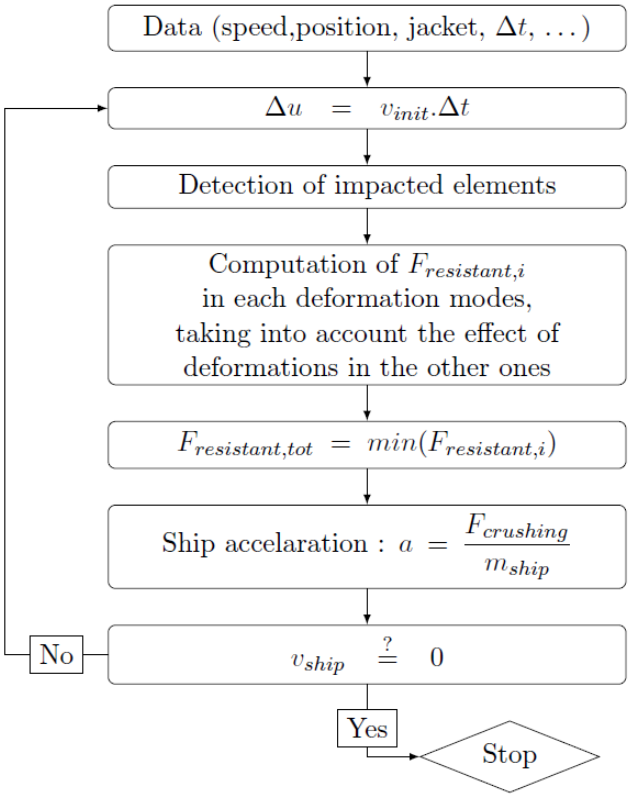




Buldgen L., Le Sourne H. and Pire T. 2014. Extension of the super-elements method to the analysis of a jacket impacted by a ship. Marine Structures, 38.

General algorithm

- Combine all deformation modes



Le Sourne H., Pire T., Hsieh J. R. and Rigo P. 2016. New analytical developments to study local and global deformations of an offshore wind turbine jacket impacted by a ship. Proceedings of International Conference on Collision and Grounding of Ships, Ulsan, Korea.

Numerical modelling

- Parameters
  - Dynamics of tower and nacelle
  - Effect of gravity
  - Soil structure interaction
  - Wind, waves, current

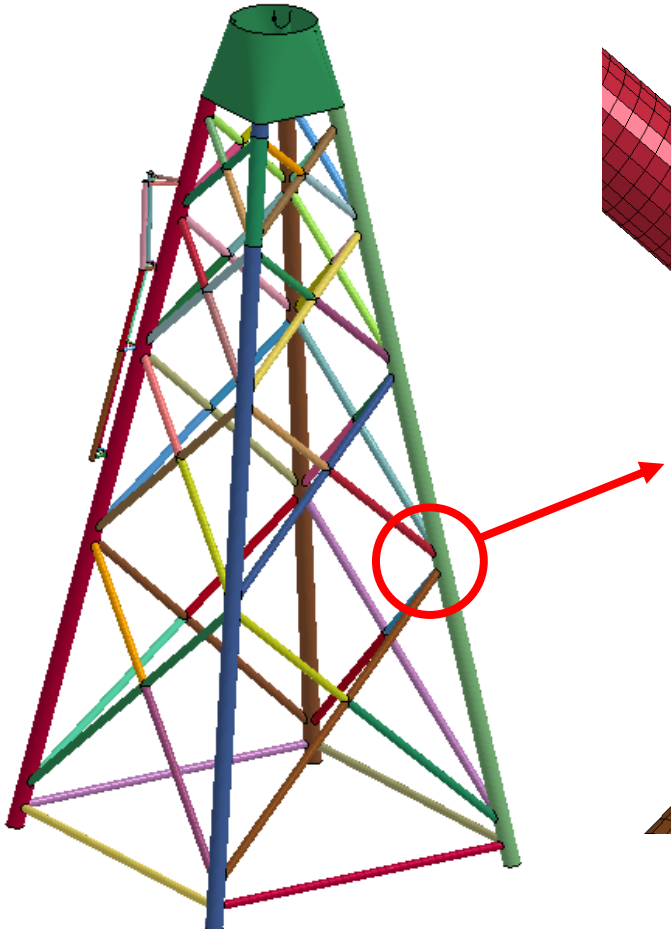
  } Neglected

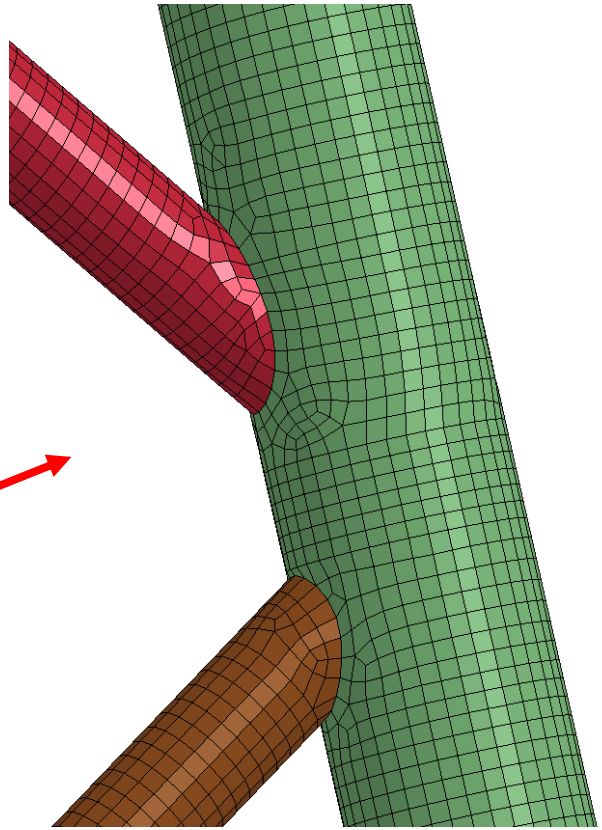
- Ship stiffness influence
  - Consider here rigid colliding ships

- Large energy impact
  - Direction of tower collapse

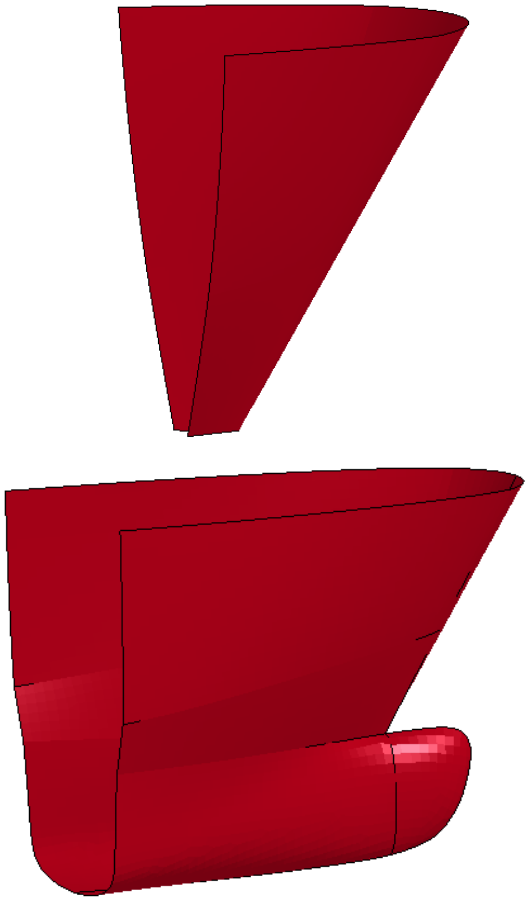
Le Sourne H., Barrera, A. and Maliakel J. B. 2015. Numerical crashworthiness analysis of an offshore wind turbine jacket impacted by a ship. Journal of Marine Science and Technology, 23(5).

Finite elements models

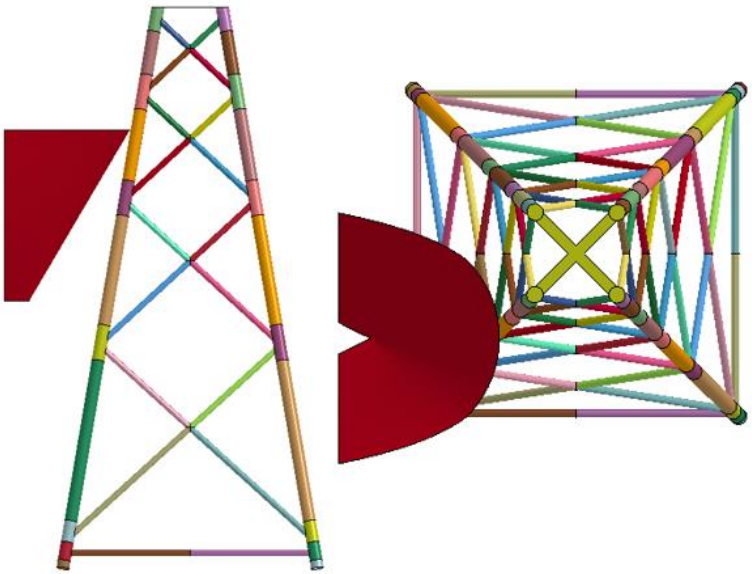


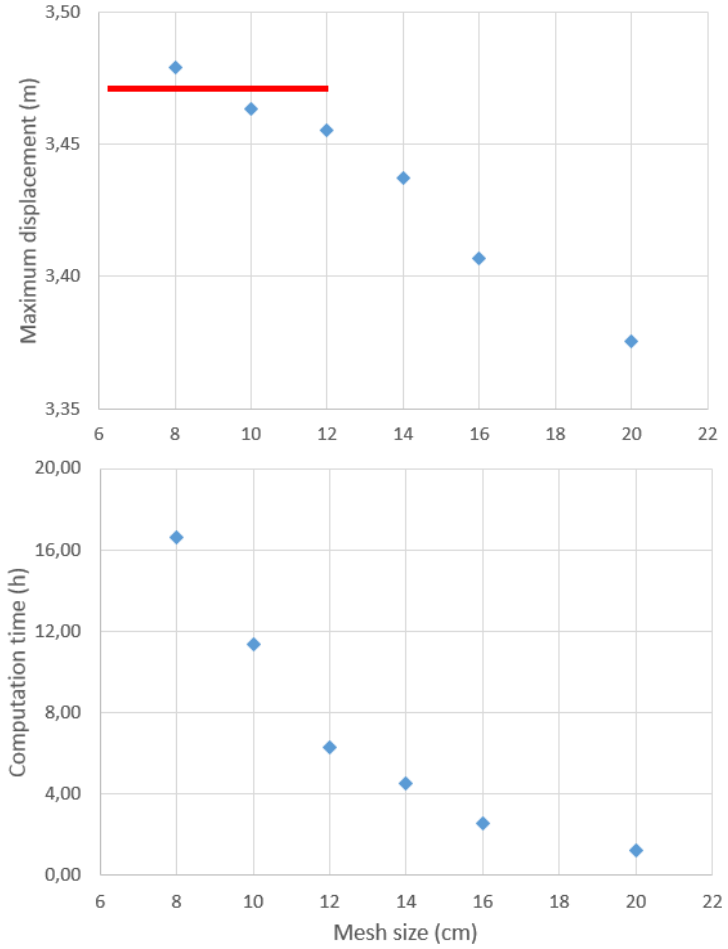


Mesh: 10cm



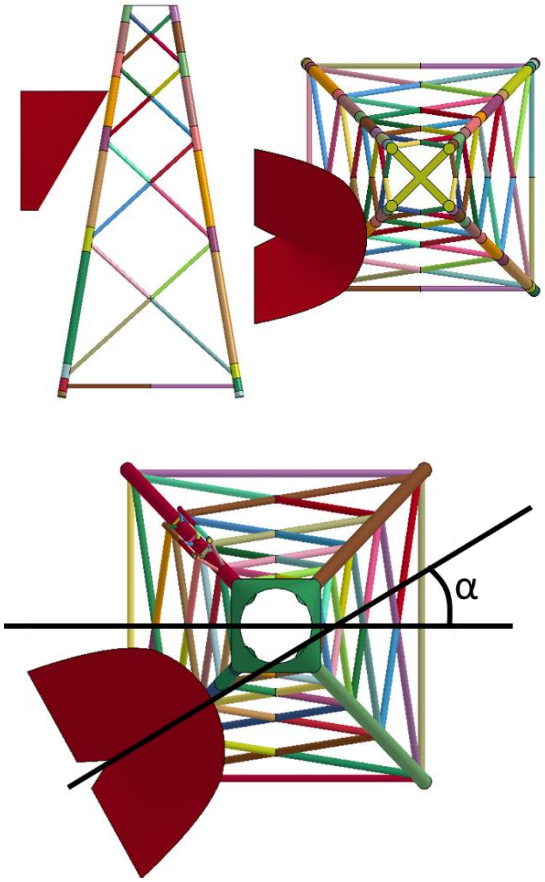
Mesh size

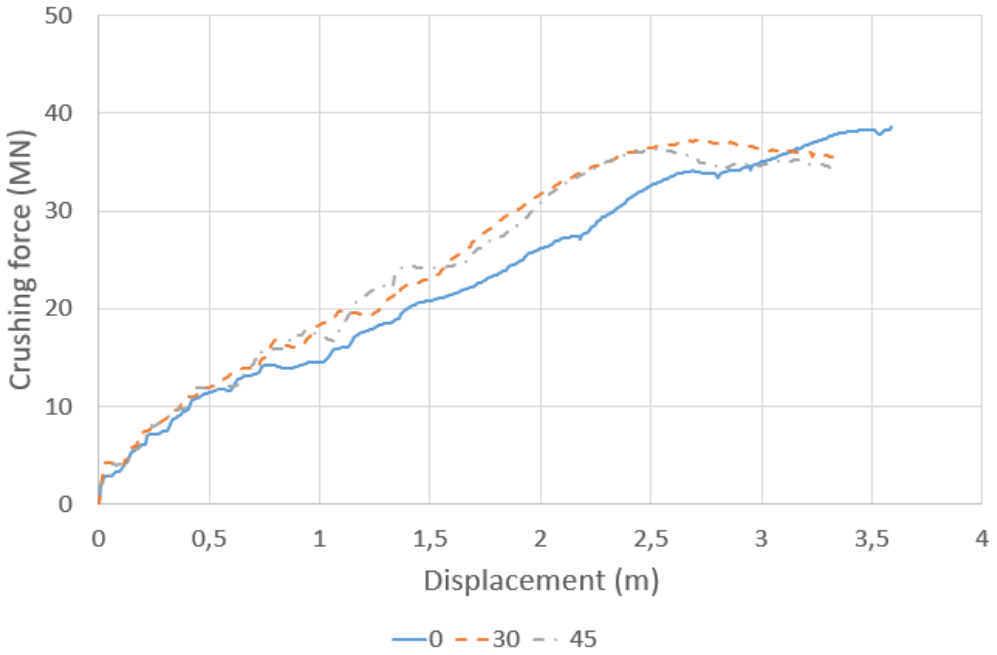




No significant variation for a mesh size < 10cm

Results


α


Crushing force (MN)
50
40
30
20
10
0
0
0,5
1
1,5
2
2,5
3
3,5
4
Displacement (m)
0
30
45

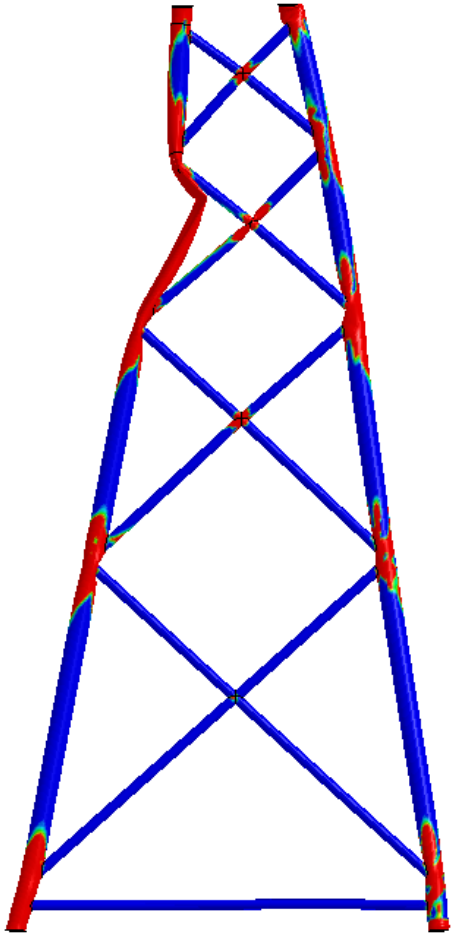
Rupture

- Lehmann & Peschmann (2002)

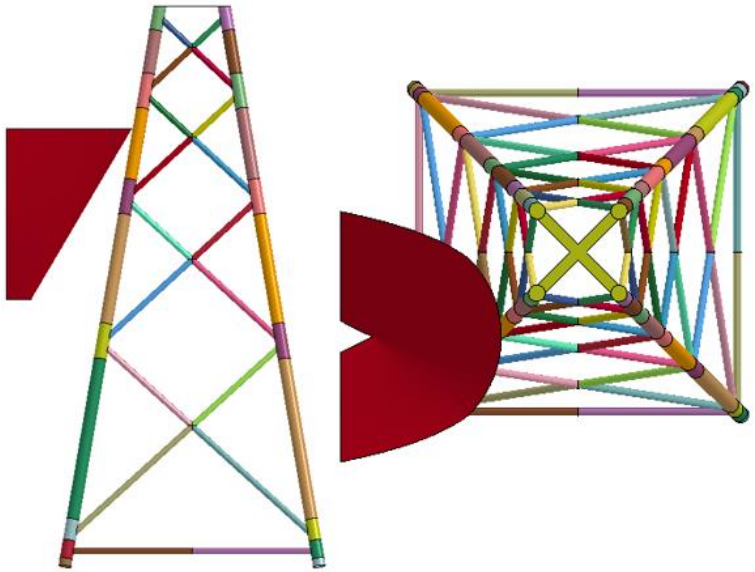
$$\varepsilon_f = \varepsilon_g + \varepsilon_e \frac{t}{l_e}$$

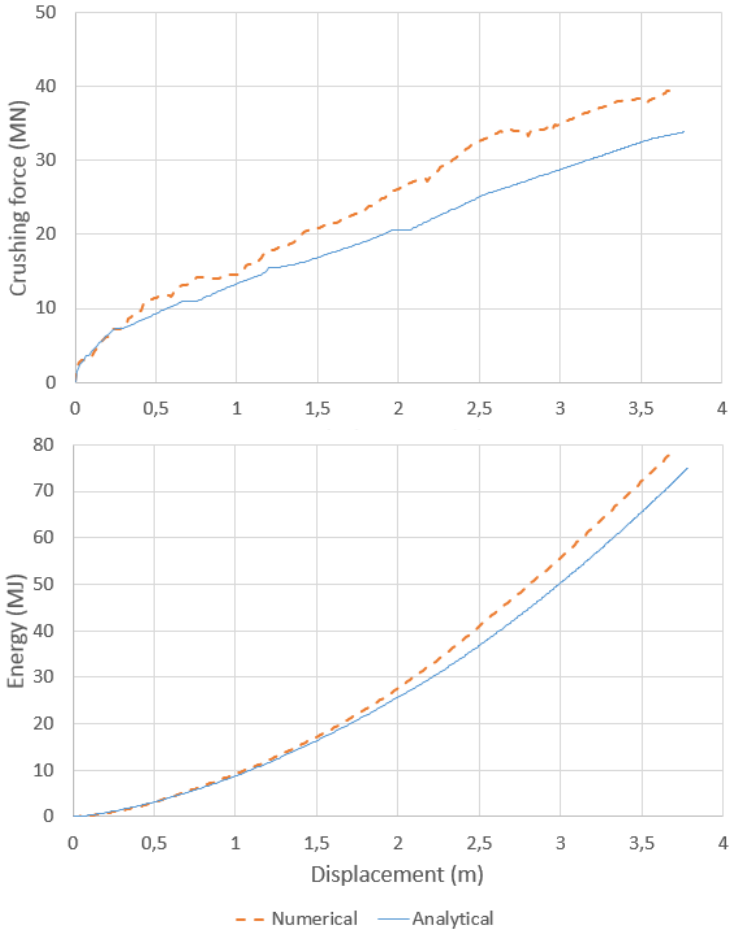
- Applicable on zones in tension

- No rupture for $E_k < 75$ MJ

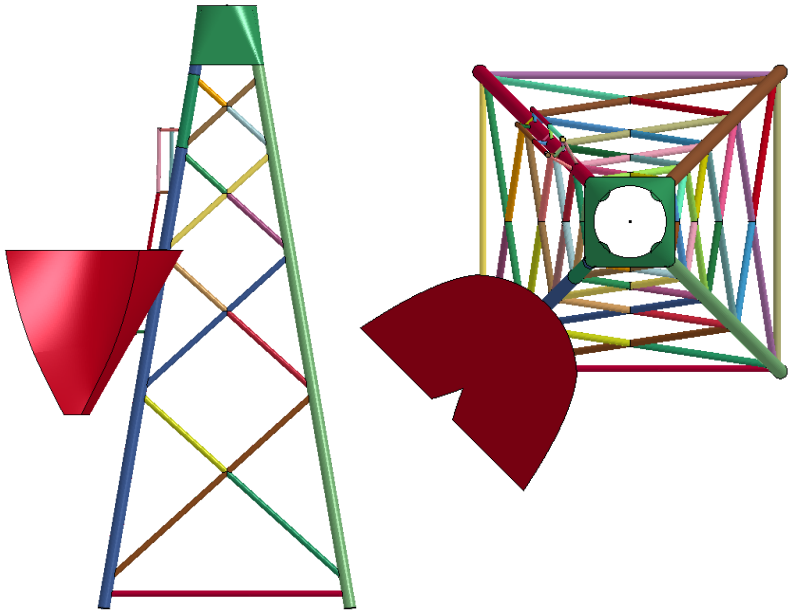


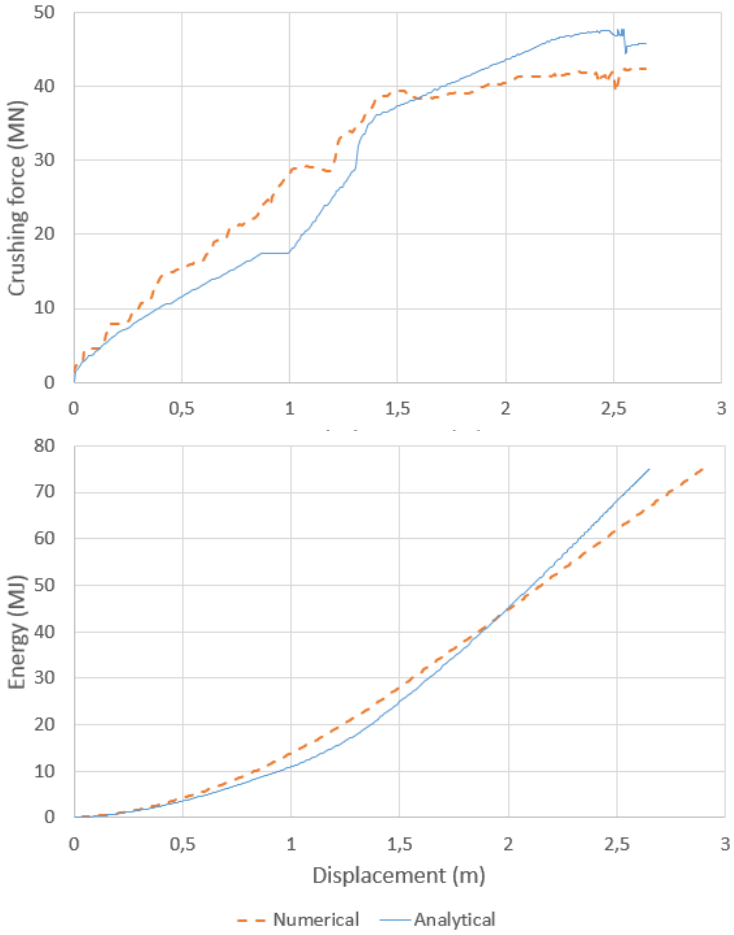
Validation



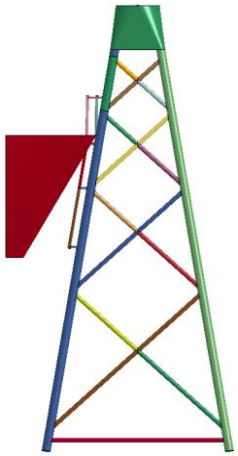

Crushing force (MN)
0
10
20
30
40
50
0
0,5
1
1,5
2
2,5
3
3,5
4
Energy (MJ)
0
10
20
30
40
50
60
70
80
Displacement (m)
Numerical
Analytical

Validation

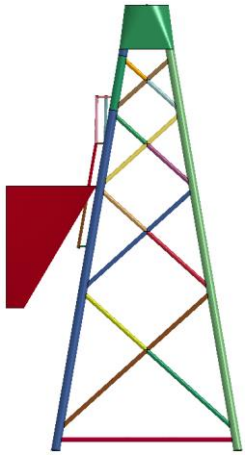



Crushing force (MN)
50
40
30
20
10
0
0
0,5
1
1,5
2
2,5
3
Energy (MJ)
80
70
60
50
40
30
20
10
0
Displacement (m)
Numerical
Analytical

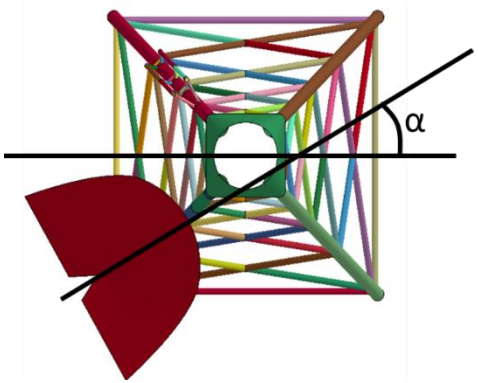
Validation



Case A



Case B



Simul.	Max ship disp. (anal)	Max ship disp. (num)	Disc (%)
A0	3m78	3m59	5
A30	3m55	3m32	7
A45	3m53	3m33	6
B0	3m52	3m36	5
B30	2m72	2m98	9
B45	2m65	2m90	9

Conclusions & Perspectives

- Analytical and numerical simulations are described
- Validations show a discrepancy < 10%

- Future work
  - More investigations for rupture
  - Several contact points
  - Deformability of the striking ship
  - Ship colliding sideways

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