

Presentation of a simplified method for the crashworthiness of offshore wind turbine jackets

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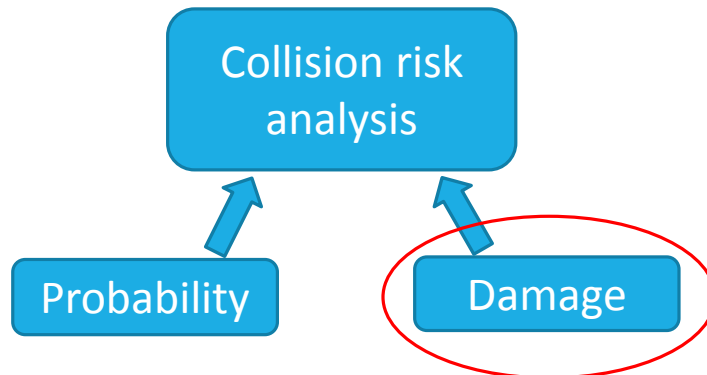
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Philippe Rigo (ULg)



Context

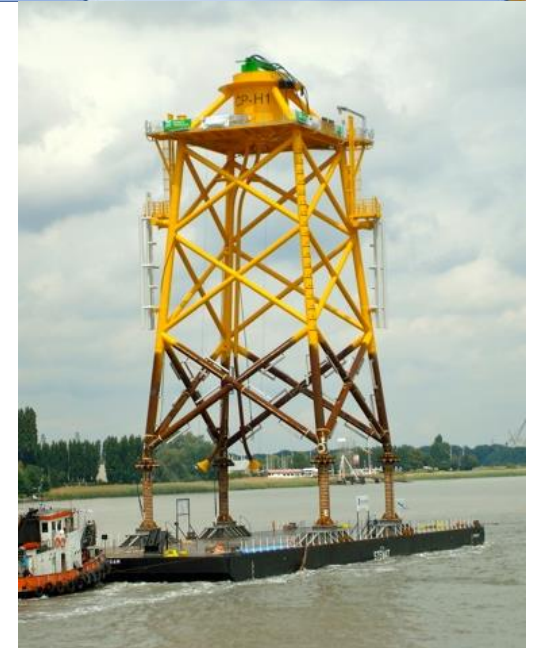
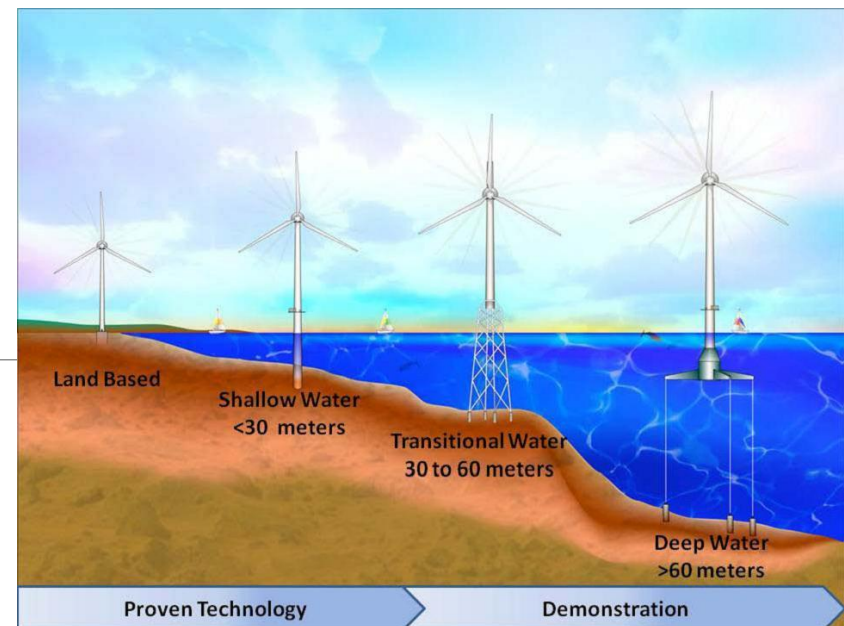
- More and larger wind farms
- Closer to traffic lanes (passengers and commercials)
- Need of maintenance



[offshoreenergytoday.com]
[northnorfolknews.co.uk]
[maritimejobs.org]

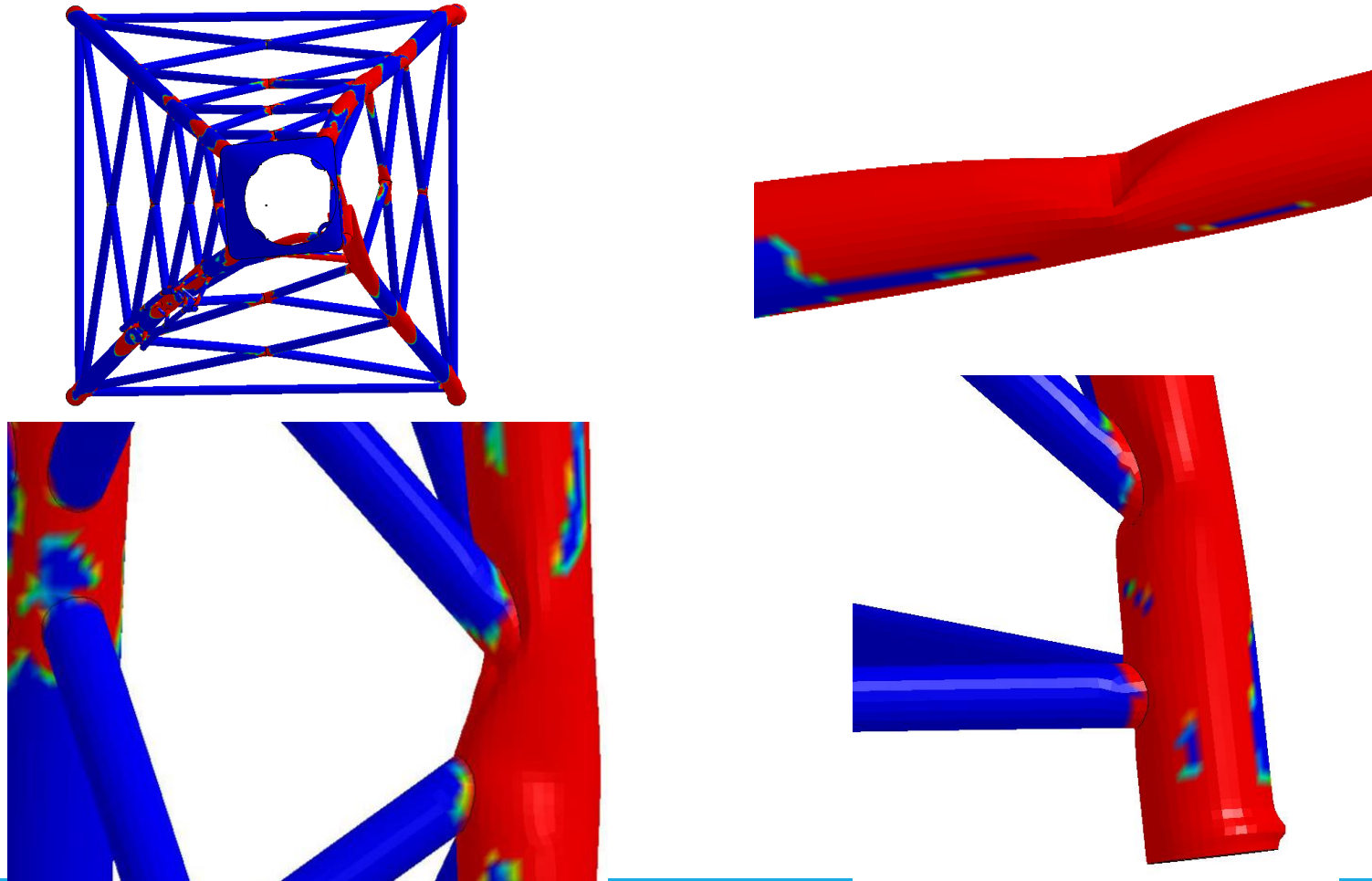
Context

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



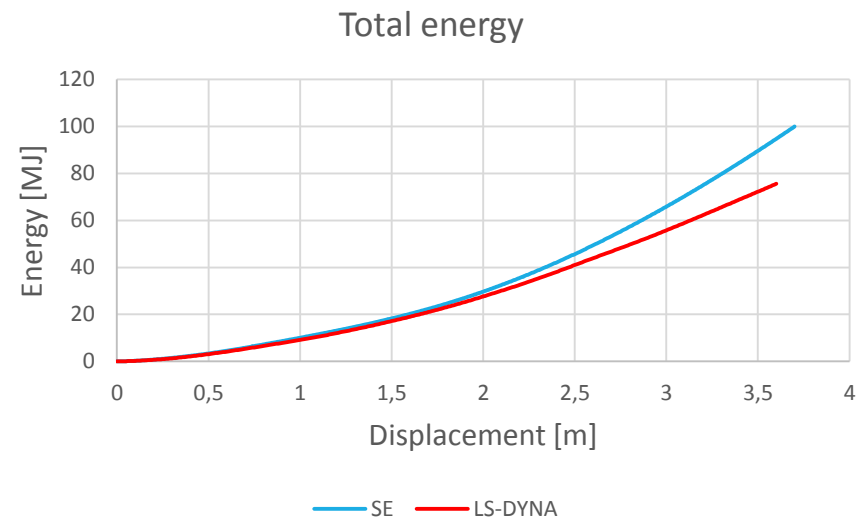
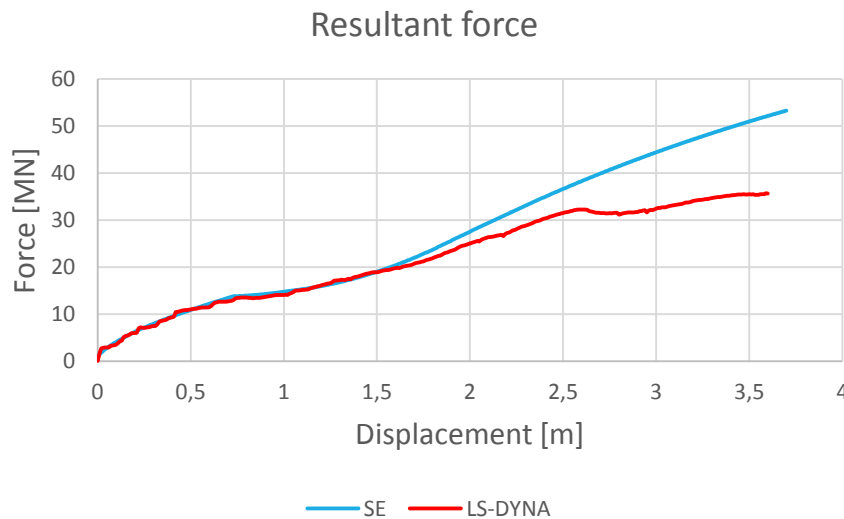
[boem.gov], [smulders-hoboken.com]

Deformation modes



State of art

- Only local crushing taken into account
- Good results for low energy impacts

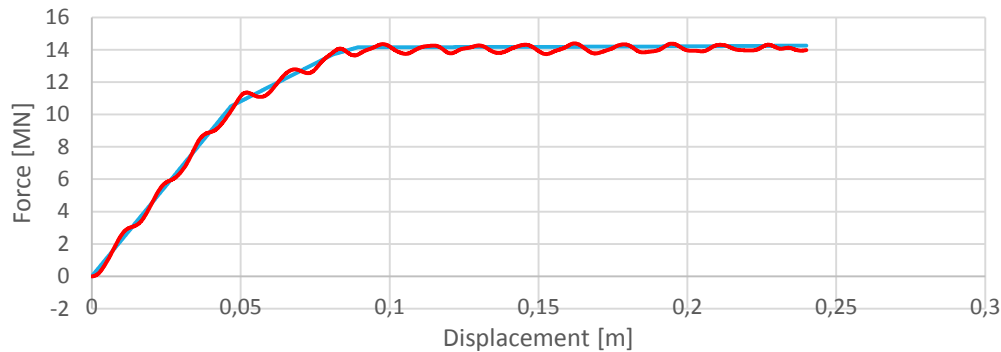


- Model too rigid in case of large energy impacts
- Other deformation modes have to be added

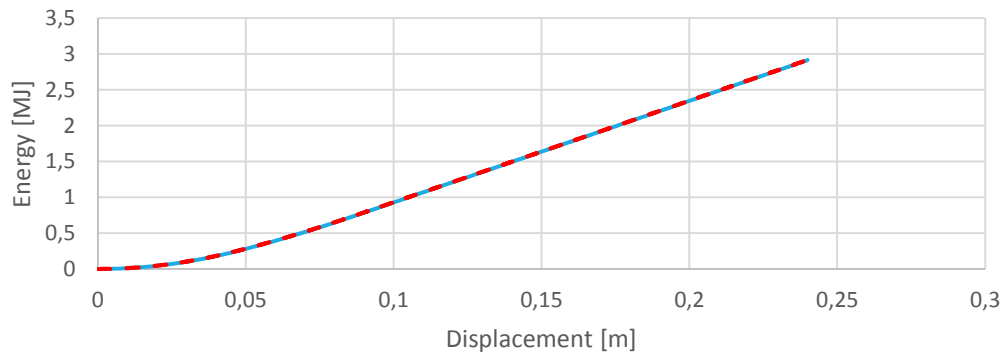
[BULDGEN L., LE SOURNE H., PIRE T., *Extension of the Super-Elements Method to the Analysis of a Jacket Impacted by a ship*, Marine Structures, 2014, vol. 38, pp. 44 – 71]

Global deformation

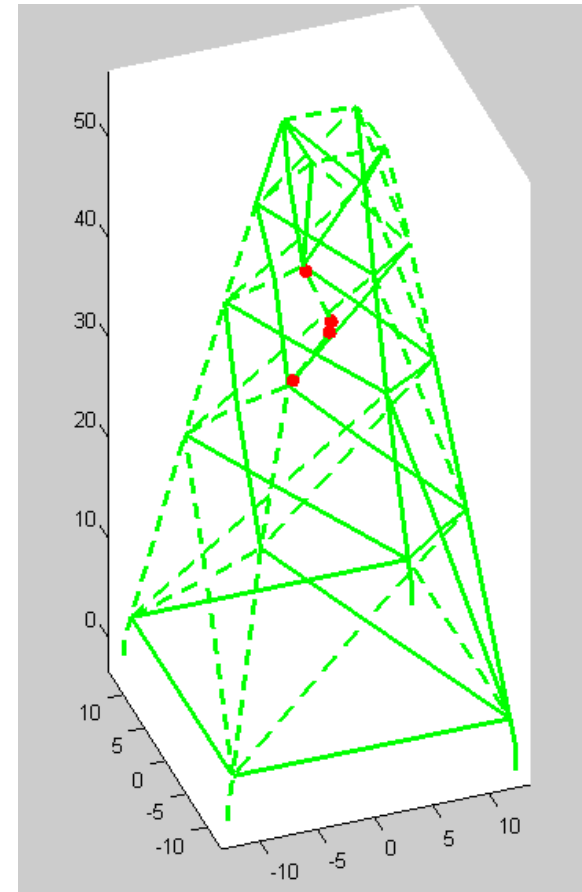
Resultant force



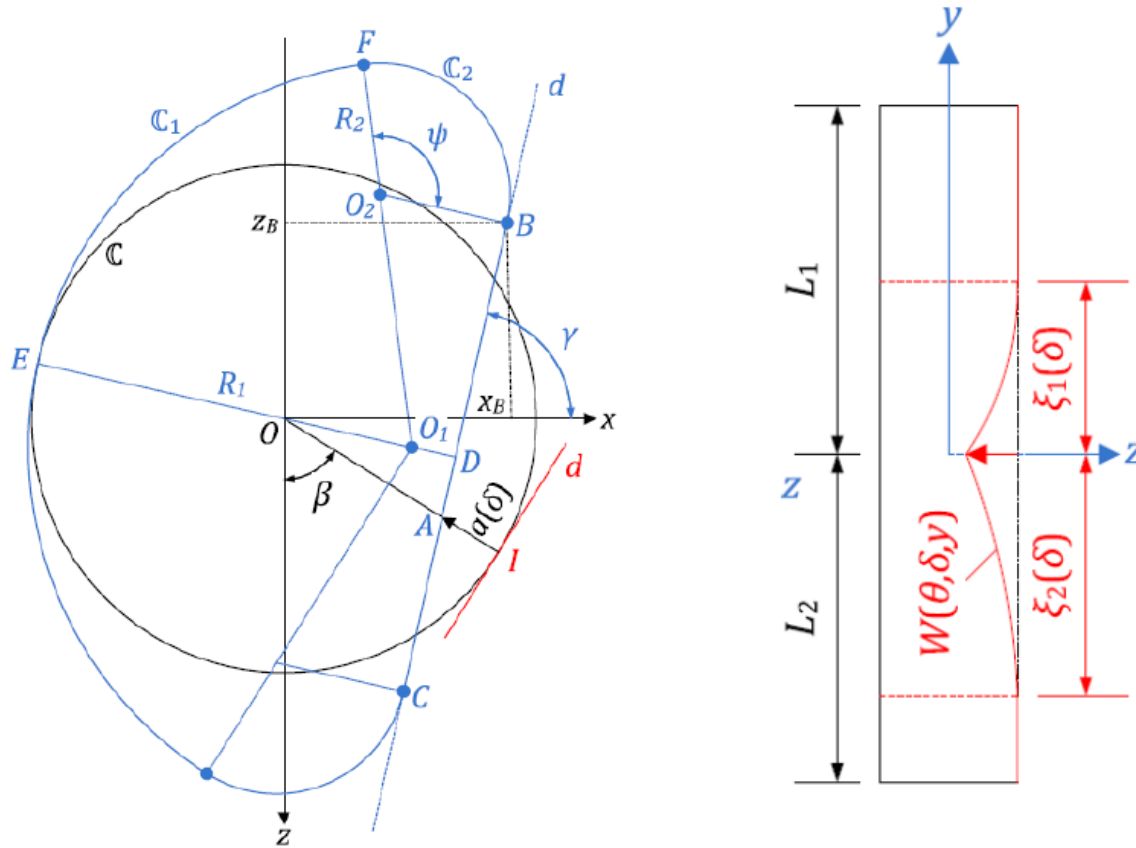
Total energy



— SE - - - LS-DYNA



Local crushing : model



[BULDGEN L., LE SOURNE H., PIRE T., *Extension of the Super-Elements Method to the Analysis of a Jacket Impacted by a ship*, Marine Structures, 2014, vol. 38, pp. 44 – 71]

Local crushing : developments

- Local crushing

- Rings

$$\dot{E}_b = 2m_0 \left(\frac{V_B}{R_2} + \left(\frac{1}{R_2} - \frac{1}{R_1} \right) V_F + \int_F^E \dot{\chi}_1 dl + \int_D^F \dot{\chi}_2 dl \right)$$

- Generators

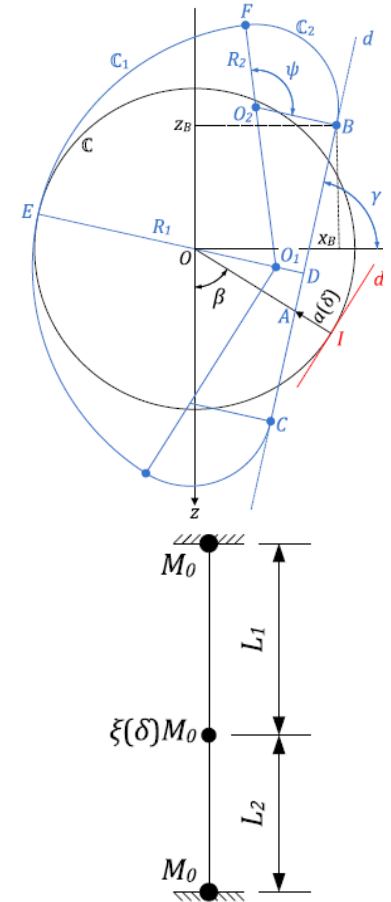
$$\dot{E}_m(\theta, \delta) = n_0 \int_{-\xi_2}^{\xi_1} \dot{\epsilon}_m(\theta, \delta, y) dy = n_0 \dot{\delta} \left(\frac{1}{\xi_1} + \frac{1}{\xi_2} \right) w(\theta, \delta) \frac{\partial w}{\partial \delta}$$

- Total

$$P_l(\delta) \dot{a}(\delta) = \sum_i \dot{E}_i$$

- Three-hinges mechanism

$$P_g(\delta) = \frac{L_1 + L_2}{L_1 L_2} \left((1 + \xi_t) M_0 \left(1 - \frac{N(\delta)^2}{N_0^2} \right) + N(\delta) (\delta - \delta_t) \cos \gamma_t \right)$$



Local crushing : results

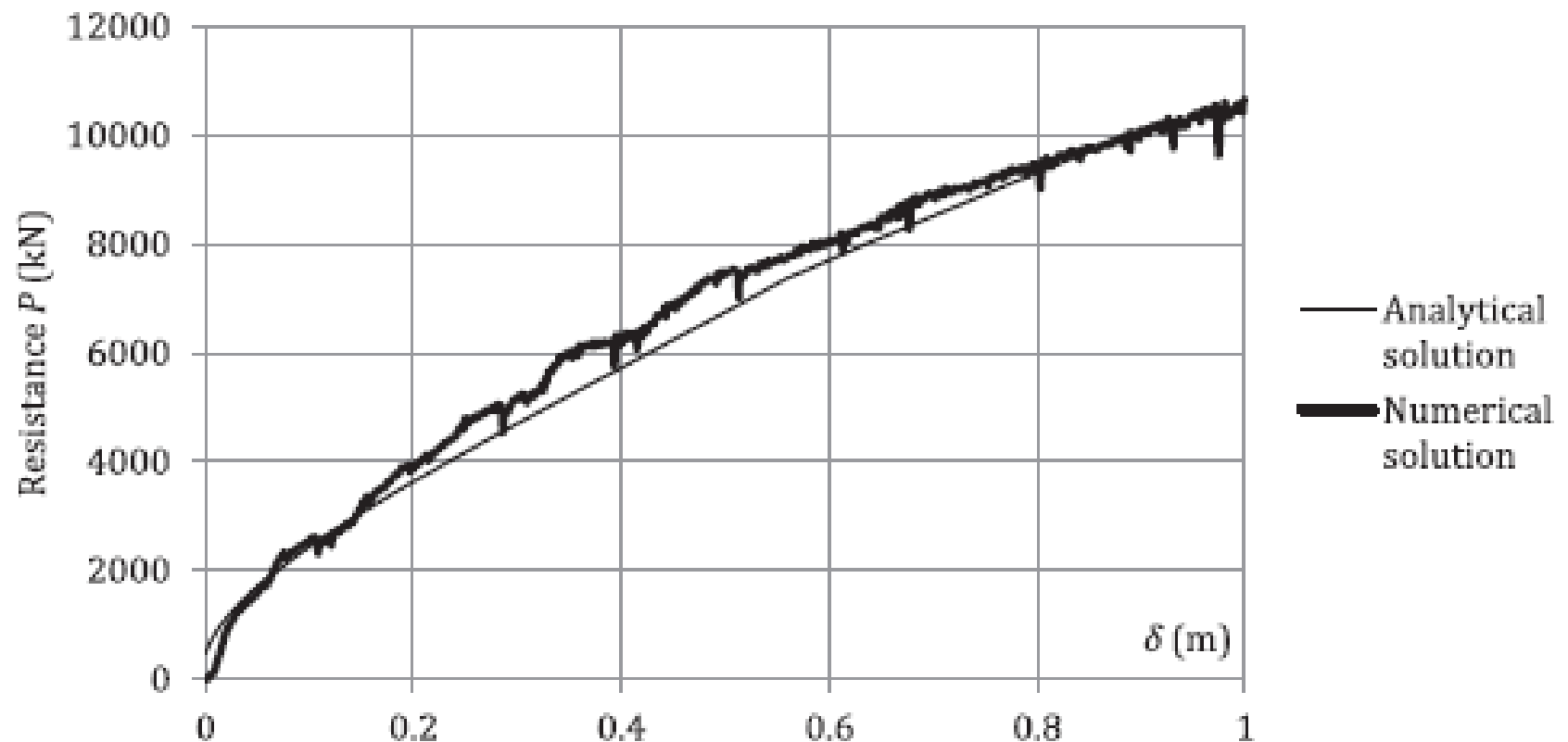
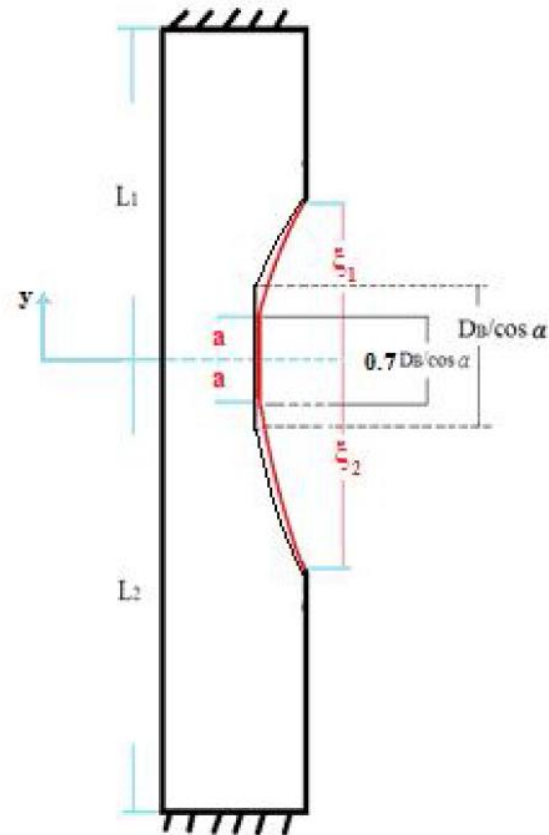
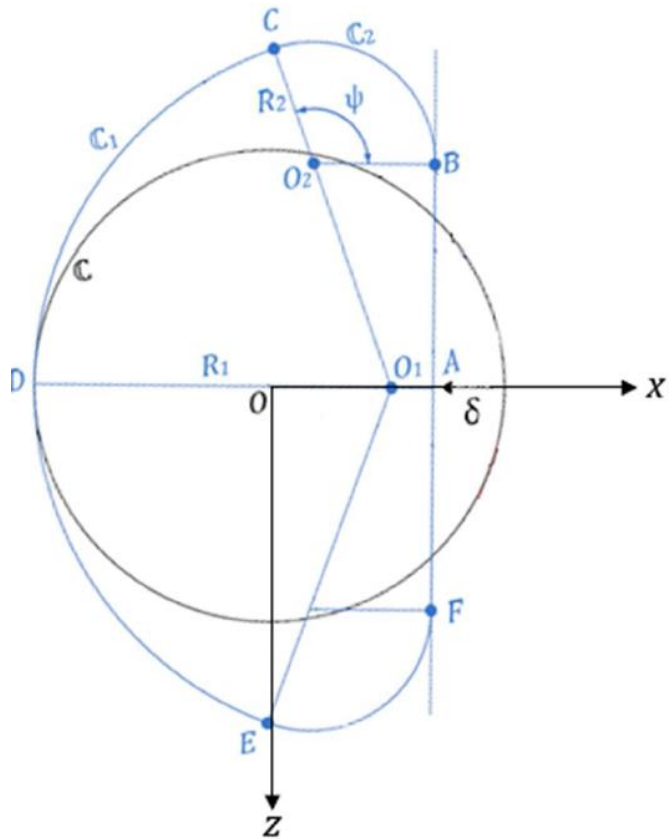


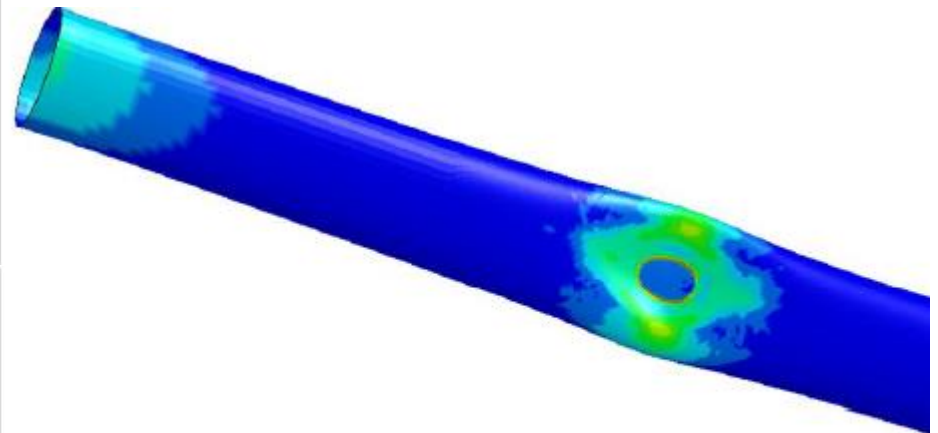
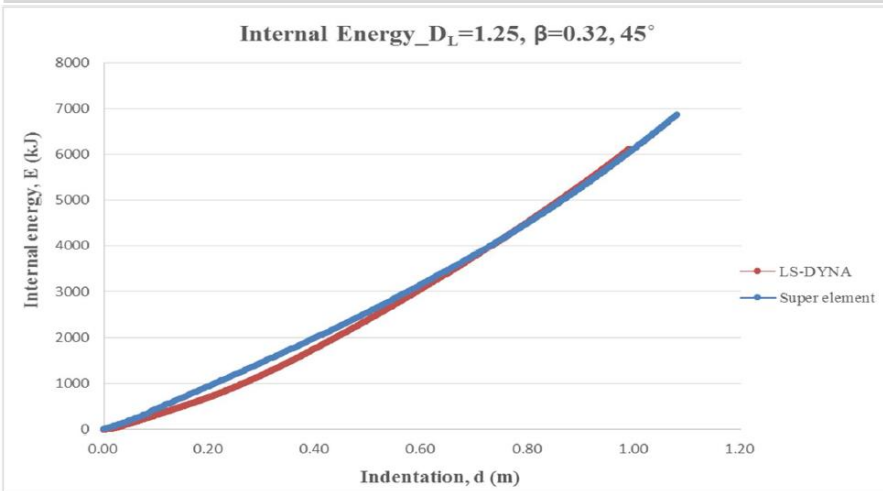
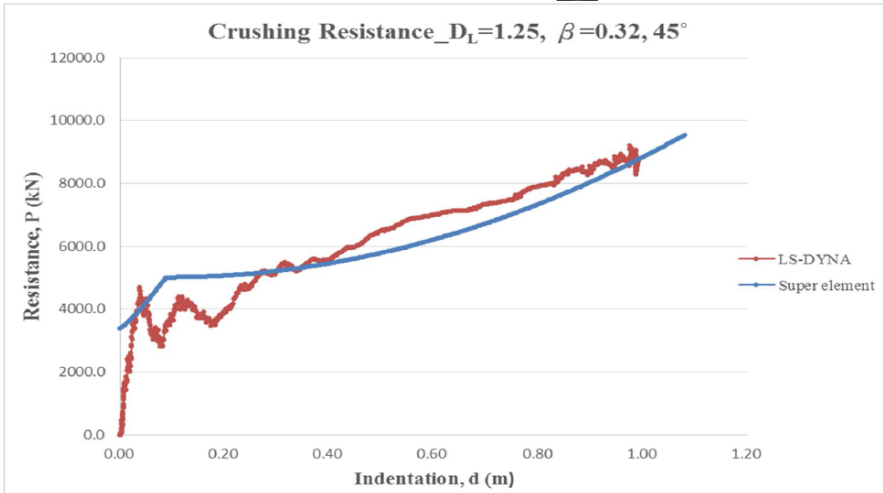
Fig. 20. Comparison of the analytical leg resistance to the numerical one for scenario 1.2.

Punching : model

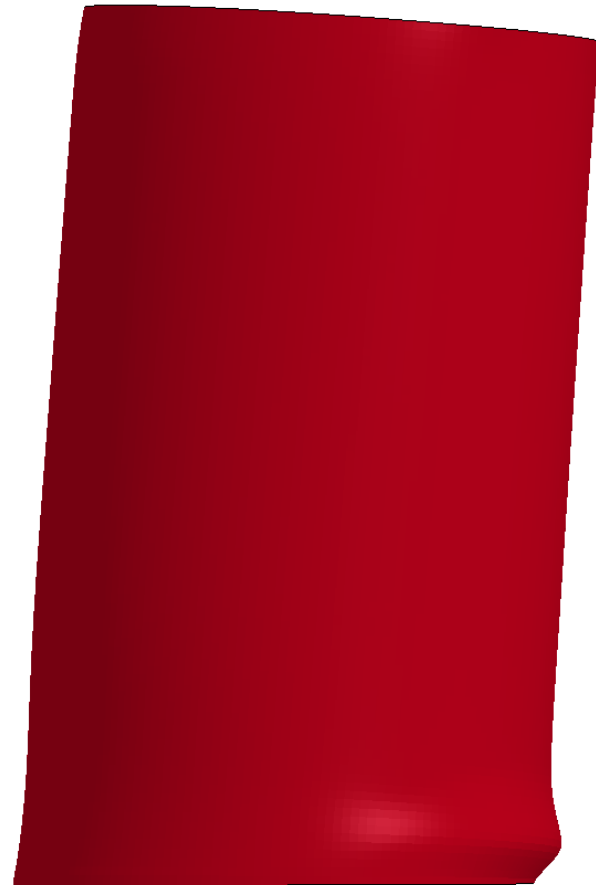
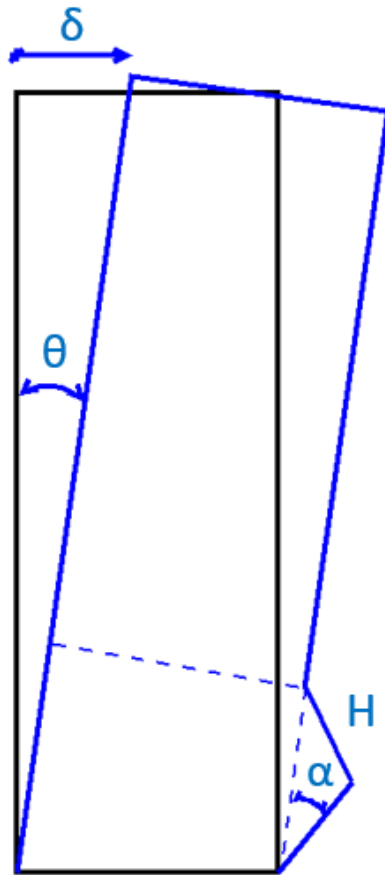


[HSIEH J.-R., *Analytical formulations for ship-offshore wind turbine collisions*, Master thesis, Nantes : ICAM (EMSHIP Erasmus Mundus Master Course), 2015, 104 p.]

Punching : results



Buckling : model



Buckling : developments

- Hinges 1-3

$$\dot{E}_{H,1-3} = 2m_0 \int_0^{\pi/2} \frac{\partial \alpha}{\partial \theta} R d\theta \dot{\theta}$$

- Hinge 2

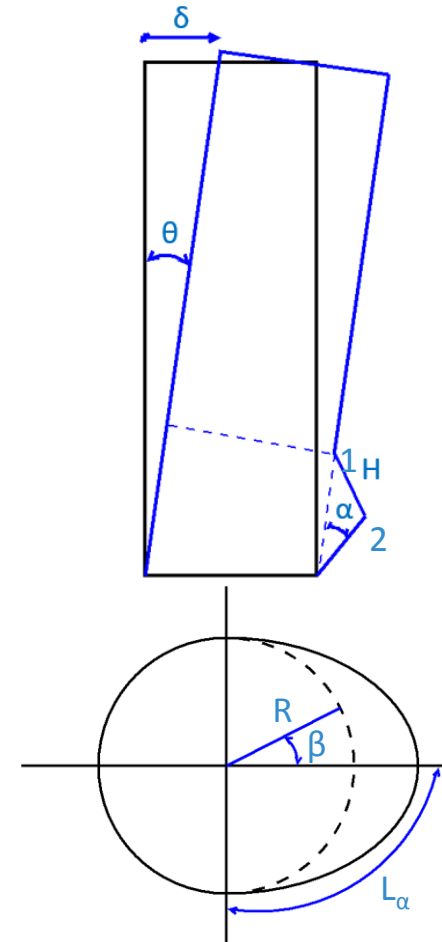
$$\dot{E}_{H,2} = 4m_0 \int_0^{\pi/2} \frac{\partial \alpha}{\partial \theta} \bar{ds} d\theta \dot{\theta}$$

- Membrane effect

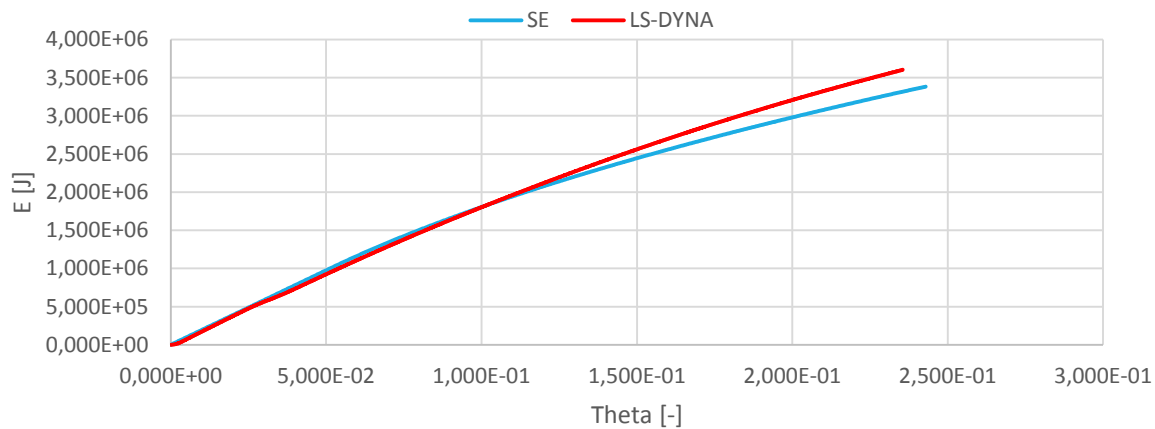
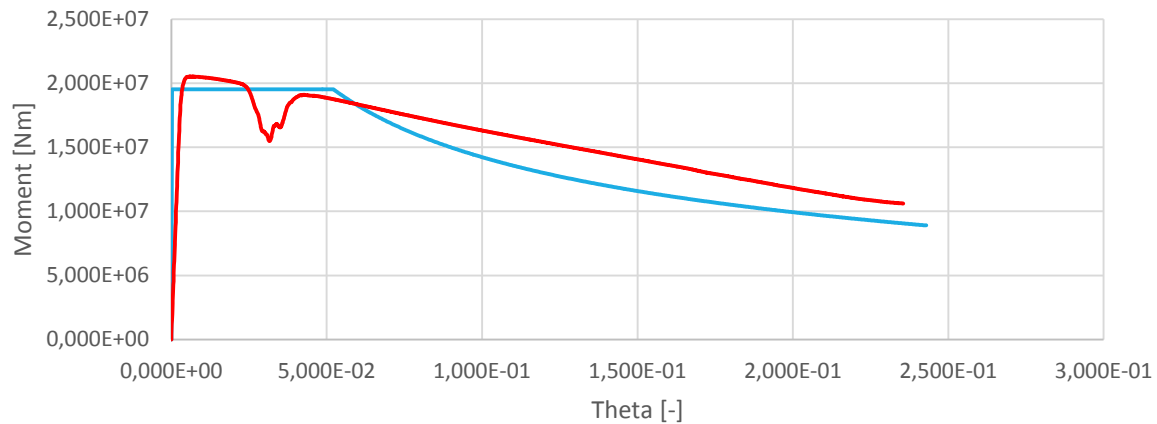
$$\begin{aligned} \dot{E}_M &= 4n_0 \int_0^H \int_0^{\pi/2} \dot{\epsilon} \bar{ds} d\beta dz \\ &= 4n_0 \frac{\dot{\theta}}{\pi R} \int_0^H L_\alpha^2 dz \end{aligned}$$

- Total

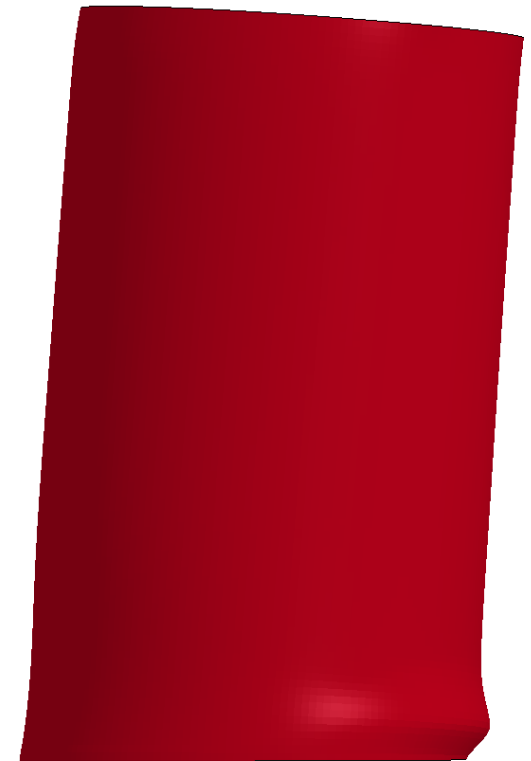
$$M\dot{\theta} = \sum_i \dot{E}_i$$



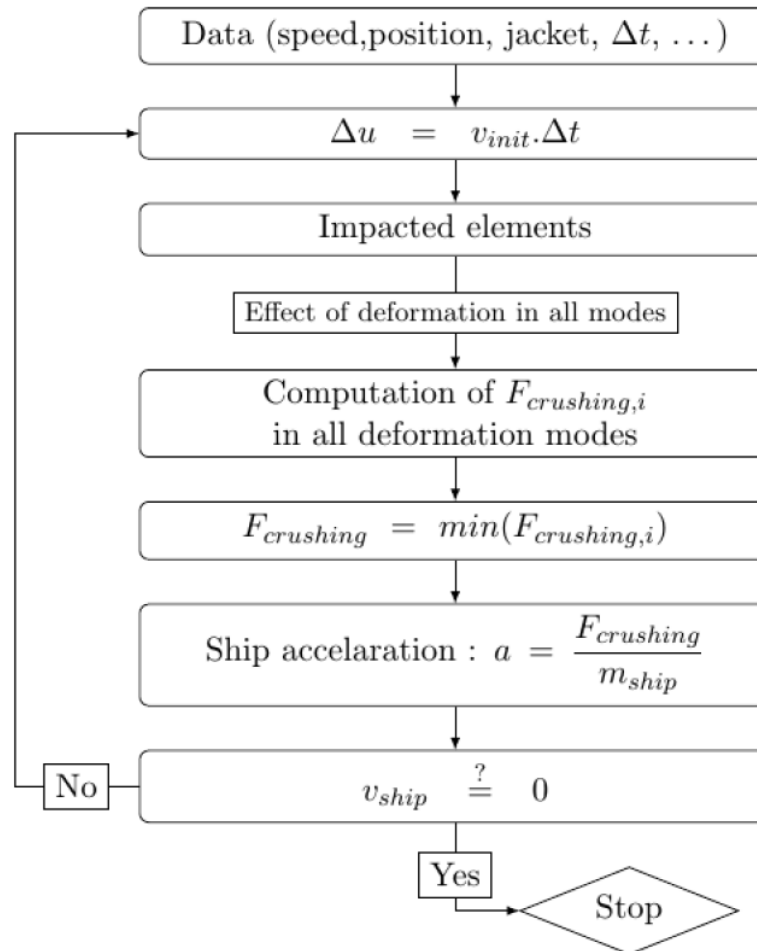
Buckling : results



— SE — LS-DYNA

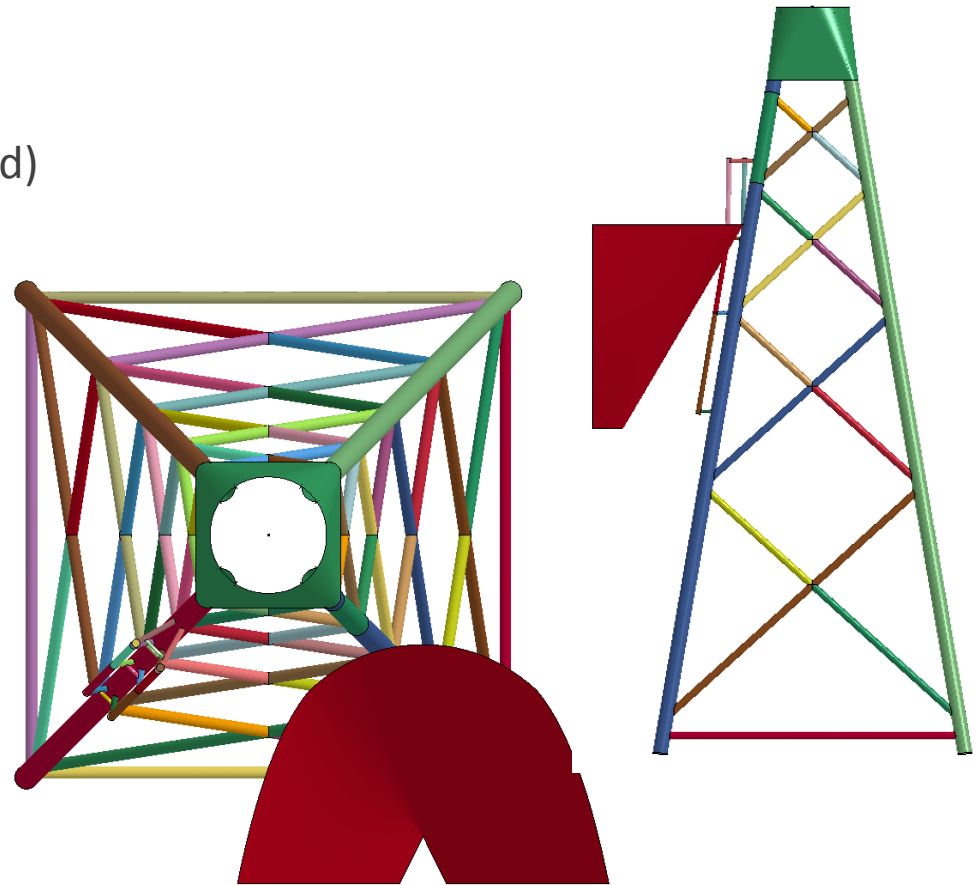


Complete algorithm



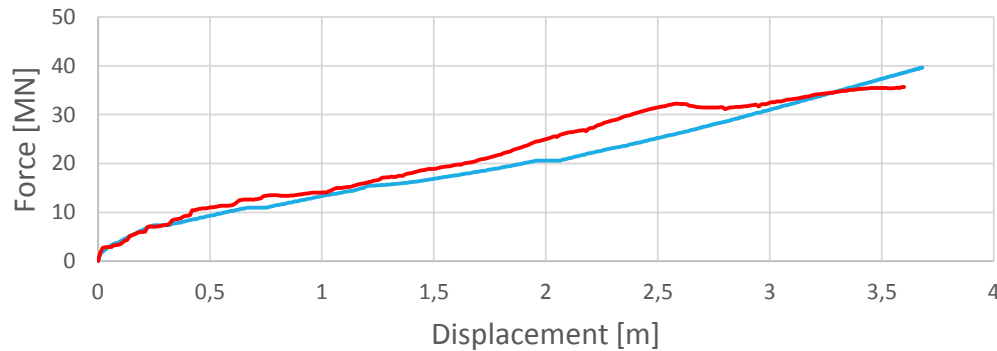
Complete model : scenario

- Colliding ship :
 - Non-bulbous OSV
 - 6000 tons (added mass included)
 - 5m/s initial speed
 - 75 MJ kinetic energy
- Impact point
 - On a leg, between two nodes
 - Perpendicular to one plan

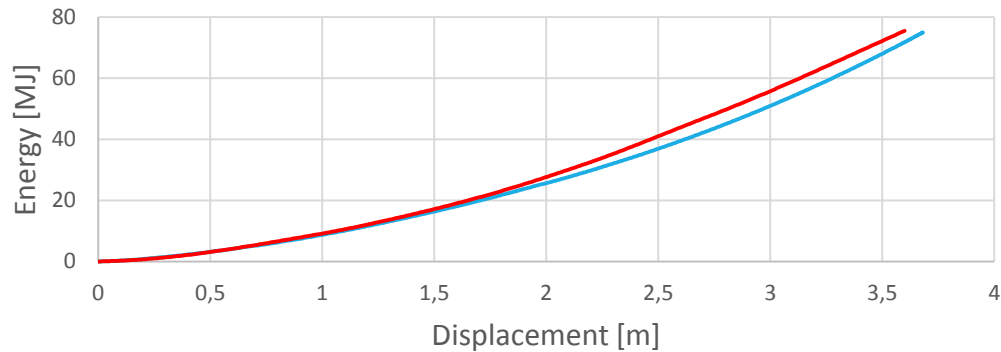


Complete model : results

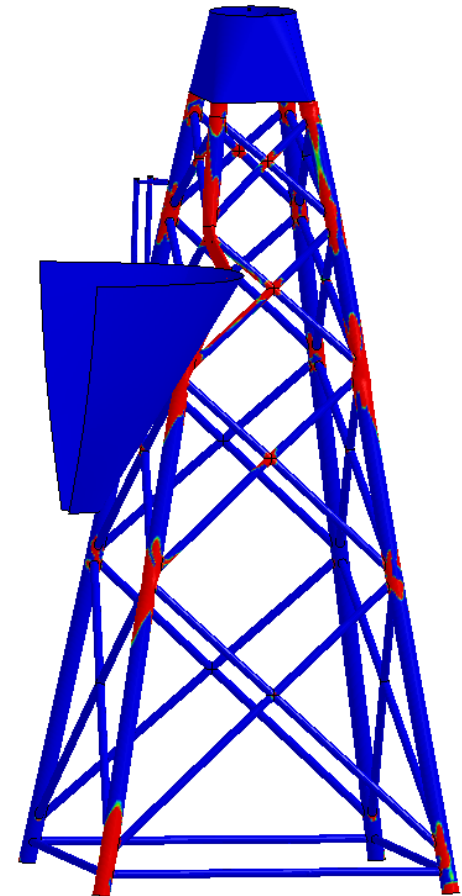
Resultant force



SE LS-Dyna
Total energy

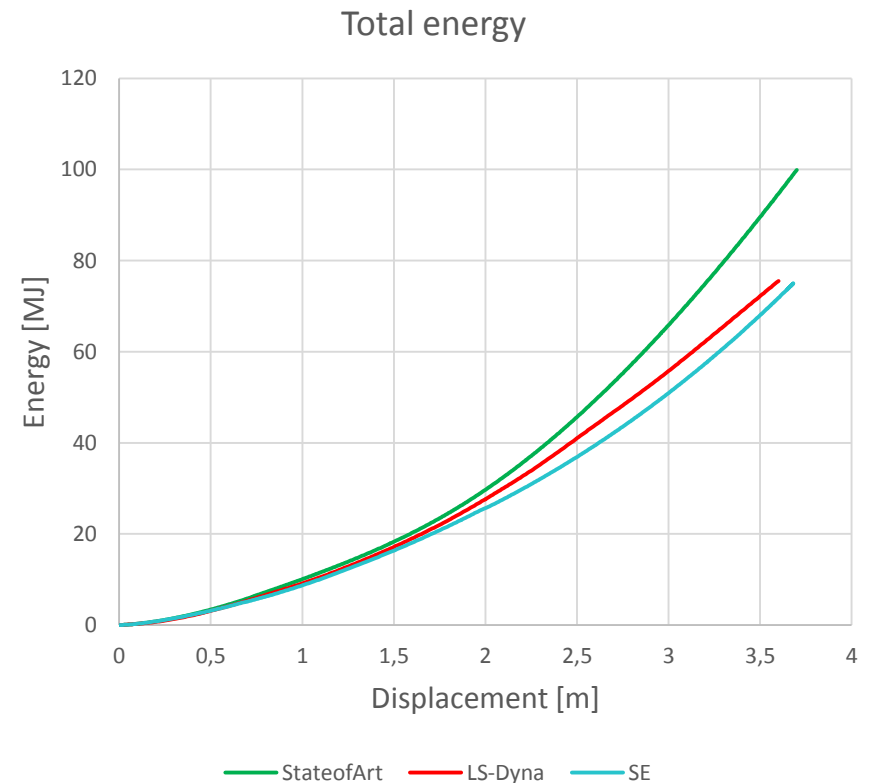
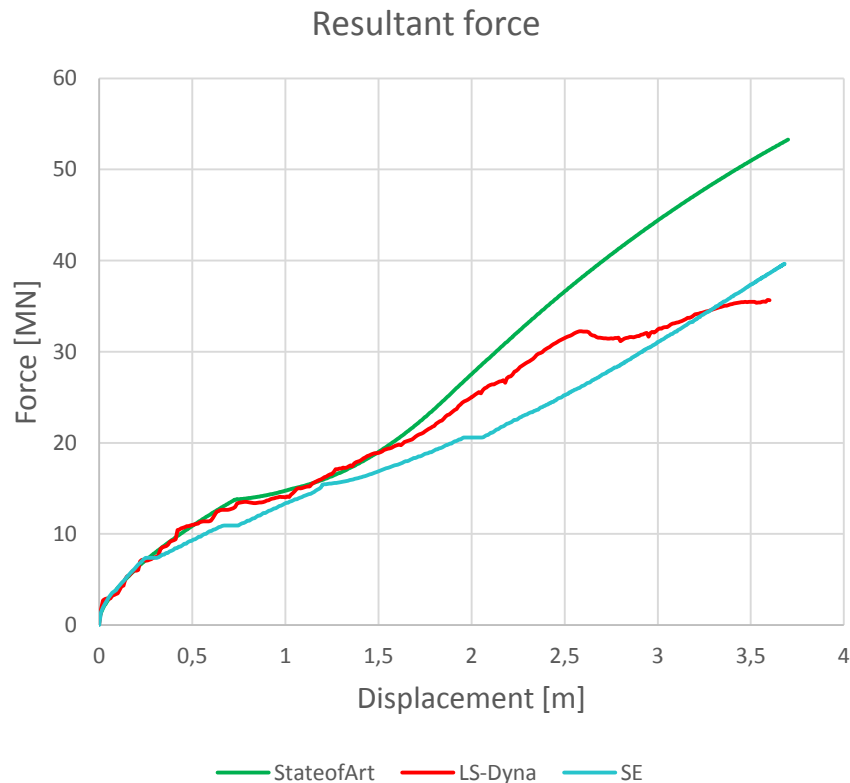


SE LS-Dyna



Complete model : comparison

- Better accuracy for large energy impact



Conclusions

- Short computation time : ≈ 5 minutes (instead of ≈ 10 h for FE)
- Good accuracy in results : difference of max. 10% in terms of energy
- Still needs more validation tests

Good tool for pre-design stage

Acknowledgements



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MSC Software Corporation

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Thank you
