COLLISION TROUBLES : towards a new and powerful analysis for an accurate design with less important risks

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INTRODUCTION

With the growth of offshore wind energy sector and associated size of wind farms, installation, exploitation and marine traffic becomes important around and inside the dedicated maritime areas.

As a consequence, collision risk between vessels but also from a vessel into a structure is rising. Already seen as a major concern to guarantee the safety and operational durability of offshore structures in the oil & gas sector, risk is nowadays multiplied and object of dedicated studies.

For this reason, continuous research is being carried out in this field to characterize collision and failure procedure of offshore structures and the impacting vessels.

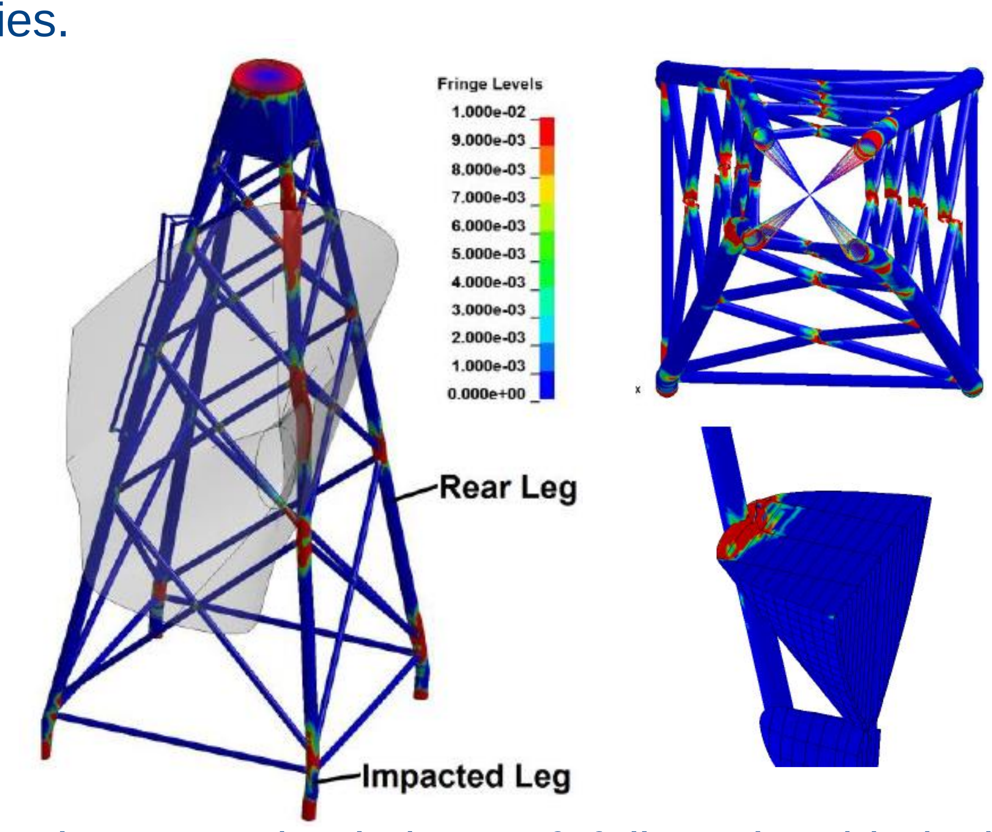
In the framework of the research project called CHARGEOL, ICAM, Bureau Veritas and STX France Solutions are validating an industrial procedure and numerical software using a new approach methodology.

Based on super-elements, this tool gives the opportunity to reduce CPU time by over than 1000 times compares to typical finite element calculations and increase the number of collision cases and impact on structure design possibilities.

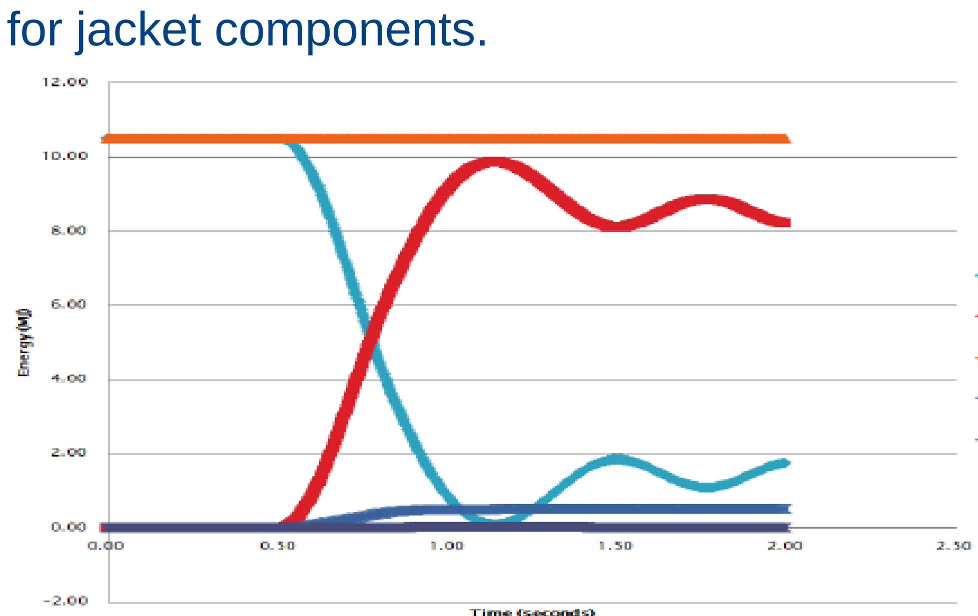
LS – DYNA SIMULATIONS

As a starting point, numerous LS-DYNA simulations have been carried out in order to better understand the crushing behavior of a jacket subject to ship collision.

LS-DYNA simulations have underlined the energy dissipation in the jacket for different ship impact velocities.



Finite elements simulations of full scale ship-jacket collisions have shown that at the beginning of the impact, the crushing resistance of a leg or a brace is essentially coming from the local mode on the impacted jacket components. As the ship is still moving forwards, the global mode is progressively activated. Consequently, there is a switch of behavior for jacket components.



Lots of parameters have been taken into account for such simulations:

- Structure model
- WTG
- Soil
- Stiffness of structure
- Type of Vessel (rigidity, speed)
- Collision scenario

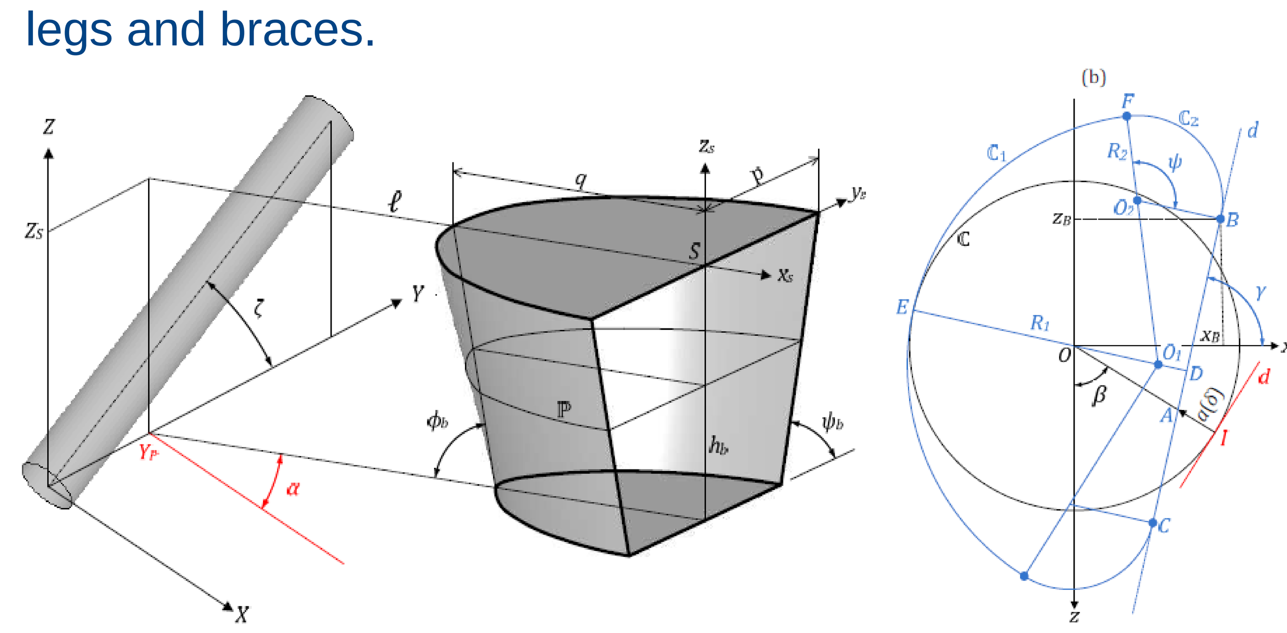
SUPER ELEMENT METHODOLOGY

Several 'tube' super-elements have been developed based on analytical derivation of the crushing resistance of horizontal and vertical clamped cylinders. The basic idea then consists in idealizing the jacket as a set of individual tubes with particular connections at their extremities.

In order to obtained analytical closed-form solutions, the impacted cylinder is supposed to be as a set of generators supported by independent rings that are free to slide on each other without shearing.

In addition, tube crushing behaviour is supposed to be a superposition of local section crushing and global beam bending deformation.

Based on the so-called 'upper-bound theorem', a plastic analysis is carried out in order to derive analytically the internal energy and the crushing resistance of impacted legs and braces.



Some formula

Impact on a vertical cylinder - crushing resistance formula

For global behaviour:

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

With $N(\delta) = \min\left(\frac{N^2{}_0(\delta-\delta_t)\cos\gamma_t}{2(1+\xi_t)M_0}; N_0\right)$

Impact on an horizontal cylinder – Crushing resistance formula

For global behaviour:

$$P_{hg}(\delta) = \frac{\mathrm{L}\sin\beta}{l_1(\delta) l_2(\delta)}((1+\varepsilon_t)M_0\left(1 - \frac{N(\delta)^2}{N_0{}^2}\right) + N(\delta)(\delta - \delta_t)\cos\alpha\sin\beta)$$

With $N(\delta) = \min\left(\frac{N^2{}_0(\delta-\delta_t)\cos\gamma_t}{2(1+\xi_t)M_0}; N_0\right)$

Impact on an oblique cylinder- crushing resistance formula

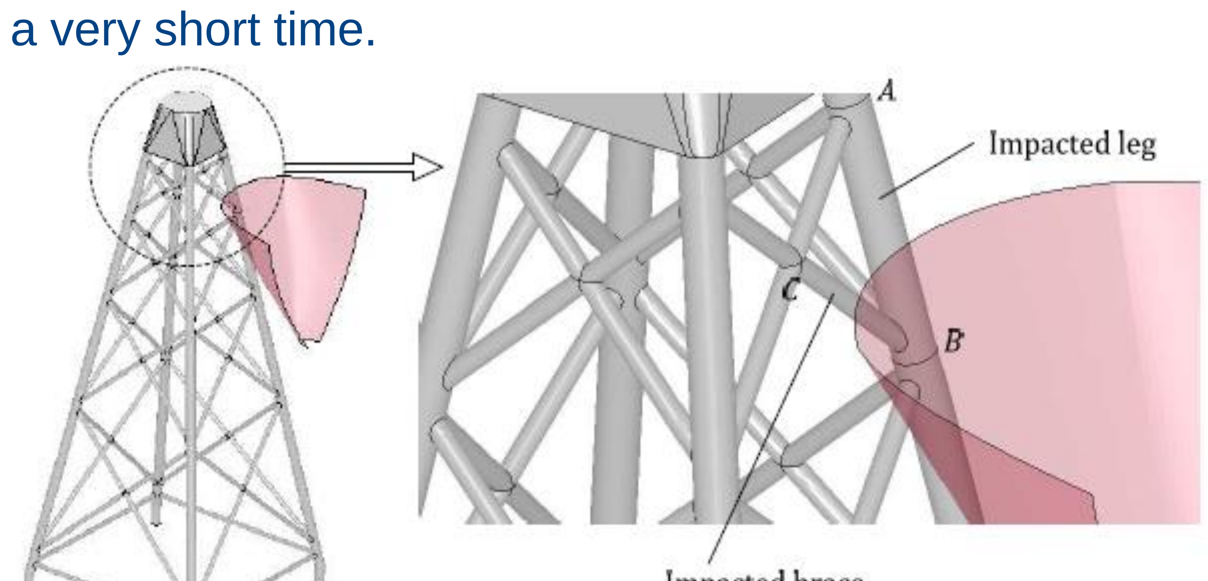
$$P(\delta) = \left(1 - \frac{2\xi}{\pi}\right)P_h(\delta) + \frac{2\xi}{\pi}P_v(\delta)$$

With P_h and P_h respectively extracted from horizontal and vertical formula

SUPER ELEMENT METHODOLOGY

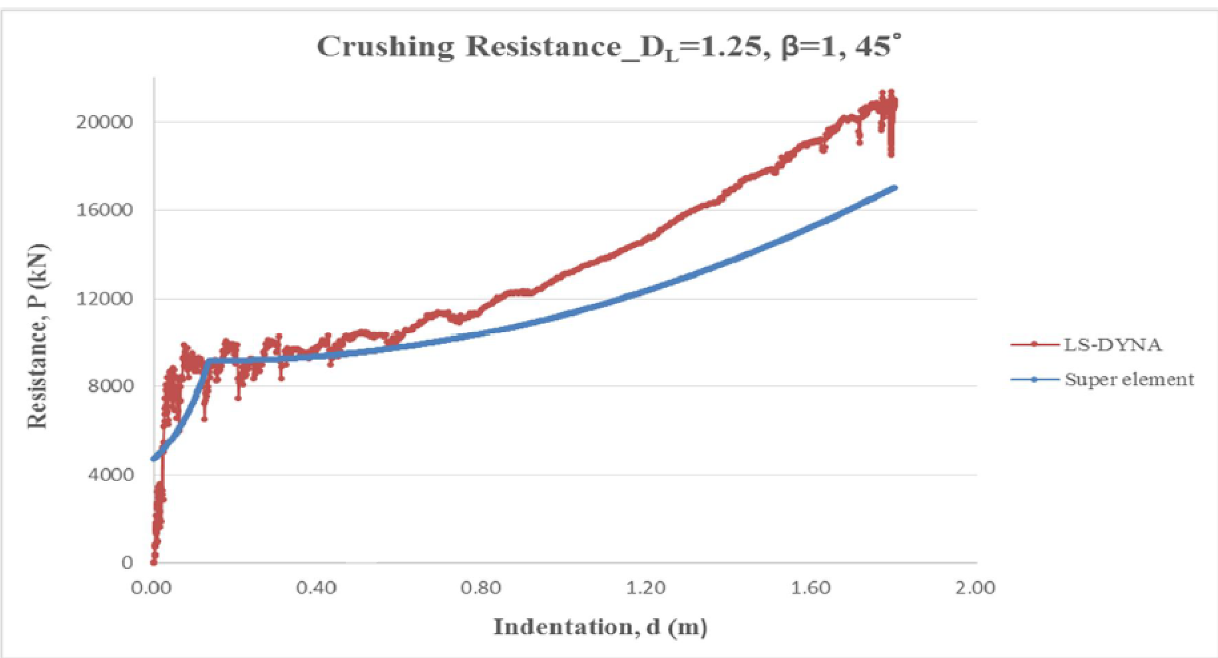
Once such analytical developments have been validated by comparison with numerical results, the entire jacket is modelled as an assembly of super-elements and simulations can be carried out for the overall structure.

Thanks to very limited time of calculation (about 30s per case), numerous scenario can then be studied in a very short time.

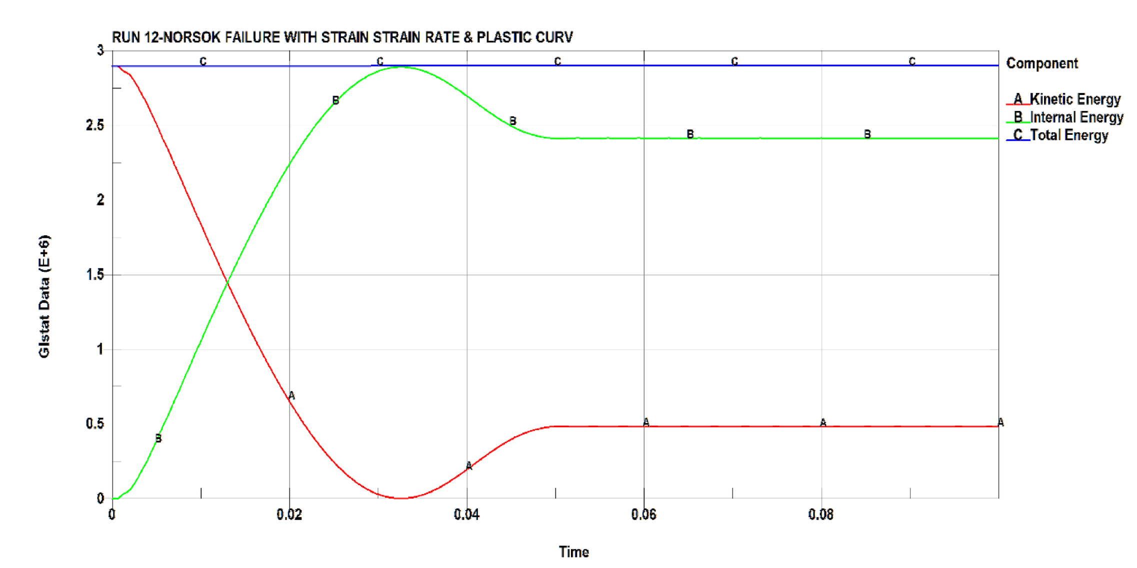


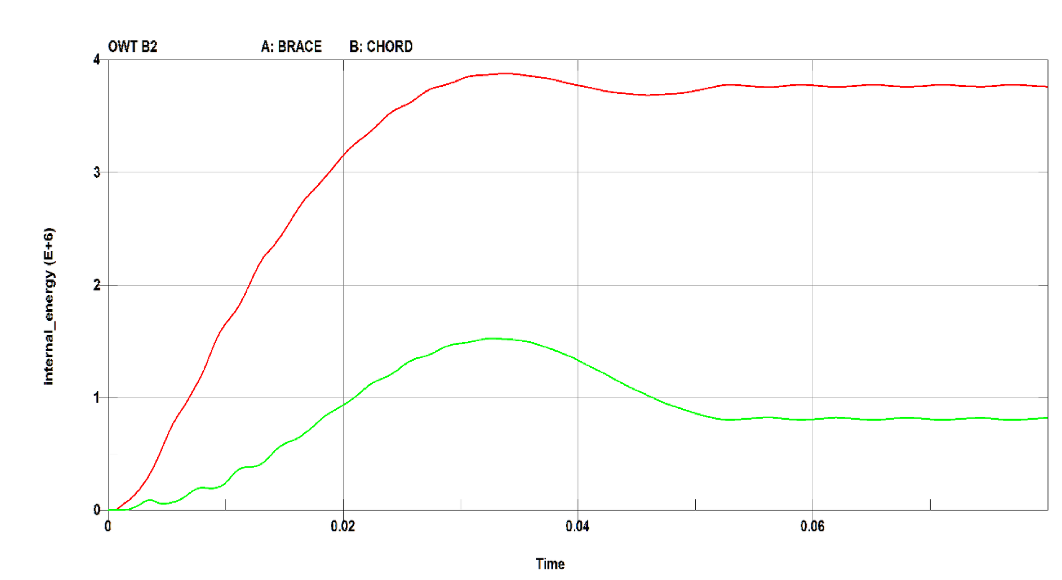
RESULTS

Super elements for different type of cylinder and phenomena are compared with results obtained using LS-DYNA simulations. Figure below gives an example of validation on one tubular component.



Energy exchange and dissipation is also main part of the verification process. Global energy dissipation from vessel to jacket but also its distribution on the jacket is verified.





Conclusions

Currently validating this innovative and industrial tool in order to use it in nearly design studies, , ICAM, Bureau Veritas and STX France Solutions have found some way to reduce design risk around collision analysis.

Requested at a very early stage, this software gives accurate results on the behaviour of the jacket and requires very limited time of calculation when jacket design is still moving at this stage.

Improving capability of design and associated knowledge and giving obviously more guarantee regarding safety and operational durability of the structures, this software is a good answer to growing requirements in offshore industry and especially in Germany where collision analysis is part of the first BSH step.

References

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