Structural impact on offshore structures

We show how the non-linear finite element (FE) method is used in order to verify the capacity of impacted offshore structures. We focus on the potential of the FE method for offshore structural impact and pinpoint the limitations and pitfalls of engineering use, which are today’s focus of research.

Dropped objects have to be considered in the design of offshore structures. The impacting objects may range from long drill collars to containers and the objective of design is to verify the capacity of the relevant deck section. Simple design guidelines exist for hand calculations to assess whether an impacting body will cause penetration. This method is a quick way of assessing the capacity of the relevant structure and is widely used in the initial design phase. However, the hand calculations are restricted to certain geometries of the deck and the impacting bodies. If the structure during its lifetime has to be upgraded to meet new requirements, such as a higher mass or increased drop height of the impacting body, then simple hand calculations may come to short and prove too conservative. The effort of carrying out a non-linear finite element (FE) structural analysis will then earn its merit.

The other part is related to local deformations involving large plastic strains around the impacted region.

When we use the FE method coupled with shell elements, we can represent the geometry of the structure highly accurately and the global energy absorption is very well predicted also. Figure 1 shows an example from the Oseberg platform where a Dropped Object Protection (DOP) is suspended beneath a loading ramp. The DOP protects a central control room from accidentally dropped containers. The verification of the capacity of the DOP was done using the explicit finite-element code LS-DYNA. The energy absorption was mainly by global deformation involving low plastic strains. The computational time limits the number and the minimum size of the shell elements that can be applied in the FE simulation. For the DOP case in Figure 1, the plastic strains are low and we can get a good solution by using rather large shell elements.

The design philosophy is simple; absorb all the initial kinetic energy of the dropped object as elastic and plastic work in the impacted deck without causing structural failure, such as penetration. For an impacted offshore structure the absorbed energy can usually be divided in two parts. One part is related to the global activation of the structure where the energy absorption is mainly elastic.

Figure 1. DOP on Oseberg platform subjected to free-falling container

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However, for a pipeline hitting a deck section vertically, Figure 2, we need very small elements in order to predict the plastic straining and material failure locally. This will lead to an unacceptable computational time for the complete structure. The solution is to divide the computation into two stages. First we do a global analysis with coarse elements. Then we map the velocity of the boundaries of a small central region from the first simulation and prepare a second simulation with a finer mesh of the central region, see insert of Figure 2.

As computer power increases, reliability of FE simulations to accurately predict structural behaviour and failure increases. However, continued research is still needed in order to make this approach engineering practice. The failure initiation and propagation is dependent on several complicating factors, such as mesh size and proper identification of failure criteria, anisotropy, plastic flow, adiabatic heating and strain-rate sensitivity to be used with the material models.

For upgrade of offshore installations, detailed structural FE simulations may be cost efficient compared to doing structural testing. Figure 3 shows the helicopter anchor system at the helideck of the Heimdal platform. Owing to an operational change to a new and heavier helicopter type, the ultimate capacity of the aluminium-based anchor system needed verification. A detailed FE model was made of the anchor system including material failure. The capacity of the anchor system was checked for several loading angles, Figure 4.