Development of a water filled fender system for off-shore installations

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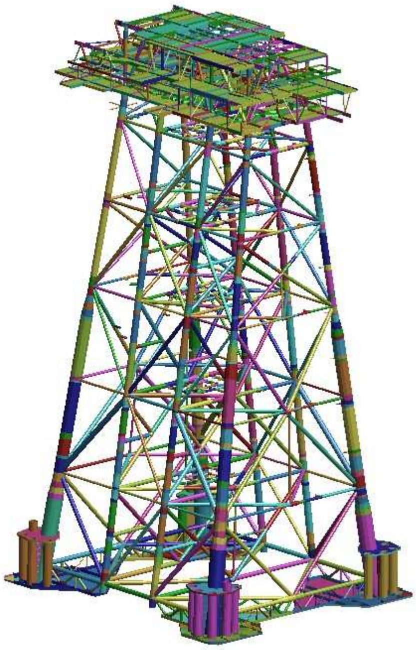
Introduction

In order to extend the life and productivity of an off-shore oil and gas platform an new installation has been proposed to provide a compression unit. The existing platform is already extensively occupied, having been in existence for over 25 years, and a new approach was required to facilitate the compression unit. This additional facility is an addition outside the existing envelope of the platform and in line with requirements it must withstand a direct ship impact of given mass and velocity. It has been proposed that a fender system be designed that will absorb the energy from the ship impact allowing time to facilitate repair of the platform extension without the need to stop production from the platform.

LS-DYNA has been used to model the platform, the proposed extension and the fender system to determine the effects of the ship impact. As with all projects the requirements have changed during the investigation and this paper only represents some of the investigation in to suitability and design of a proposed fender system

Analysis approach

An existing SESAM model of the platform has been translated to create an LS-DYNA model, shown below, to provide full information on the effects of the ship impact to the structure. To this the additional installation will then be added. This report only deals with the effects of the fender and does not present any results of the platform

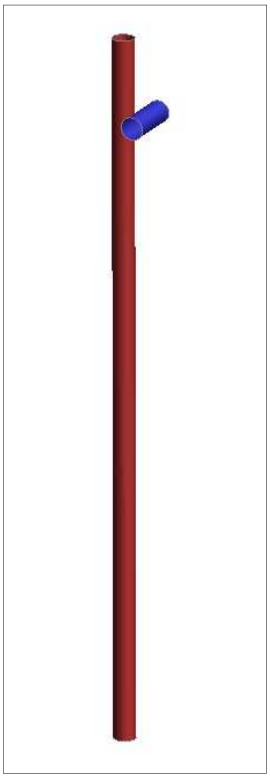


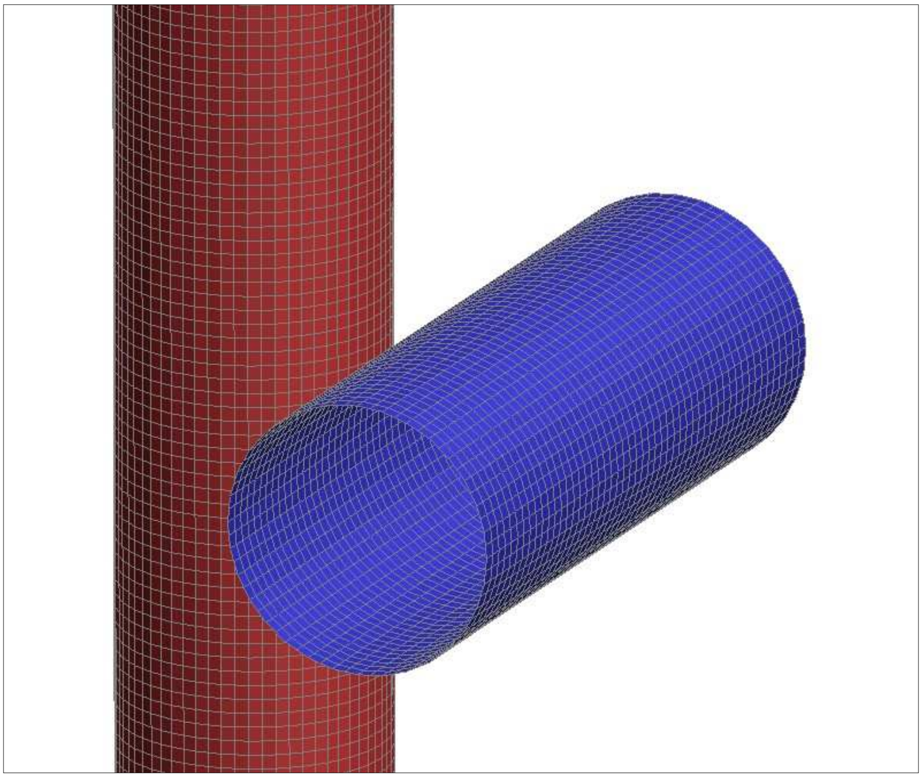
The proposed installation consists of a single support leg of 4.5m diameter which connects directly to the piles and to the topside of the existing platform. A fender system is to be provided over a length of at least 23m which is the potential strike zone of the ship. Initial requirements were for a 8000Te vessel, with added mass due to the entrained water, travelling at 2m/s. This gives an initial kinetic energy of 21.4MJ which is well above the normal platform ship impact energy requirement of 14MJ. The ship is represented by a rigid cylinder of 4.5m diameter.

A series of analyses, only a few of which are presented here, were used to develop a fender system that would absorb the required energy without imposing large forces elsewhere in the installation.

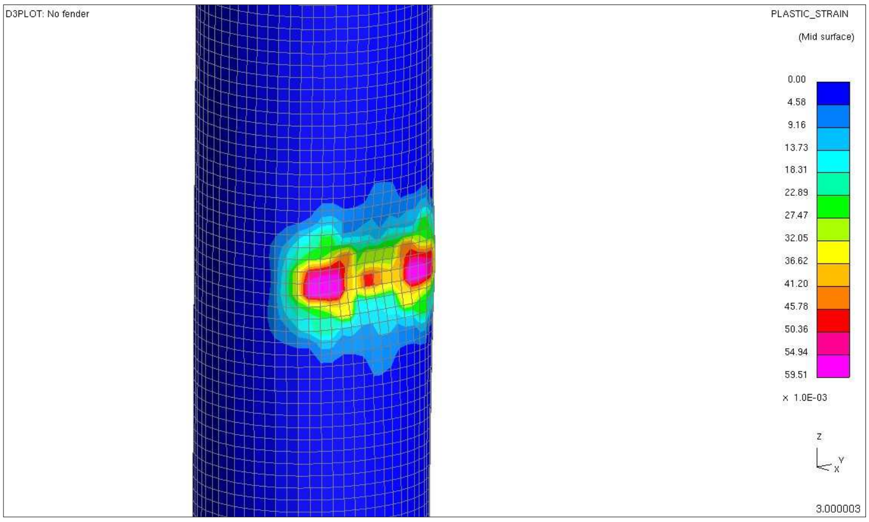
Initial analysis results

A series of 8 analyses are presented here which show the increased complexity and improvement of the design. The first analysis considers the impact on the platform leg without any fender system to provide a comparison. The initial configuration is shown in the figures below.



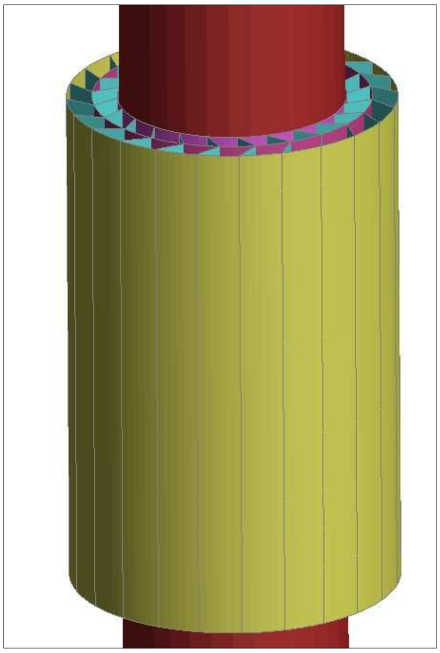


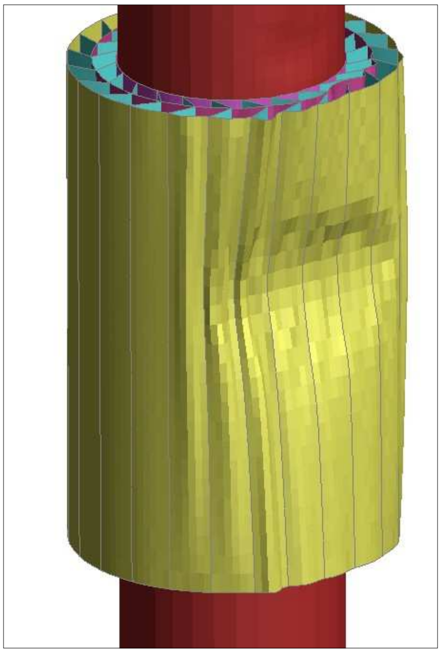
The platform leg is approximately 136m long, 4.5m diameter and 76mm thick. High order thin shell element have been used for all analyses. The ship strikes the platform leg and all energy is transferred from the ship to the platform leg. The final deformed shape and associated plastic strain is shown in the figure below.

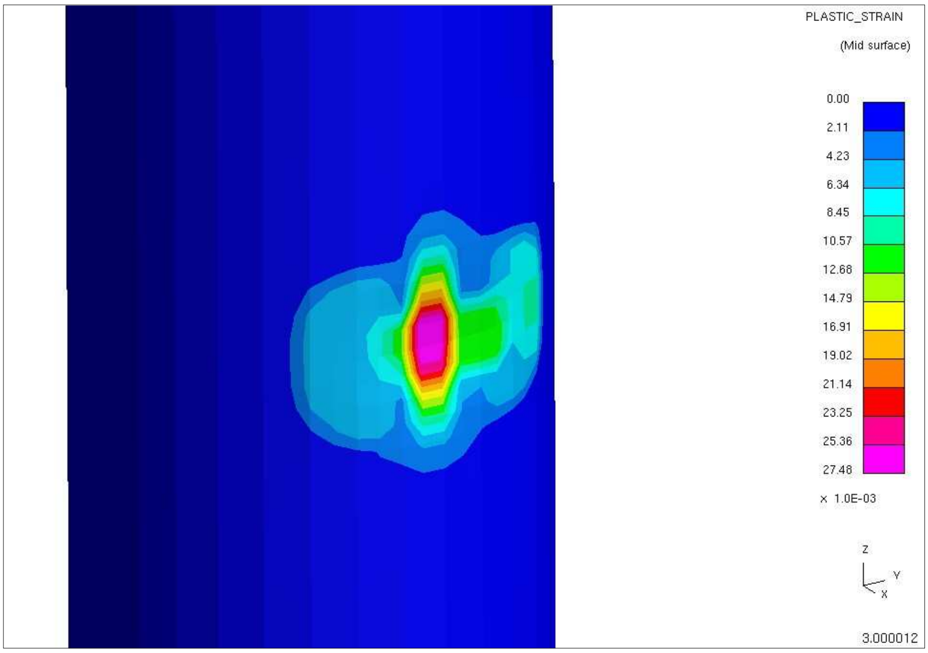


This amount of deformation and the high strains associated would be sufficient to cause collapse of the structure and as such a fender system is required to absorb the energy.

The design remit was that the main platform leg must remain elastic or undergo minimal surface plastic strains that would not cause collapse of the structure. It must also not transfer high forces to the rest of the structure. An initial design was used to demonstrate that this could be possible. Although impracticable to manufacture, the initial design showed the improvement that could potentially be achieved. The figures below show the design detail, which consists of two sets of angled “fins” between three concentric shells, the final deformed shape and the predicted strains in the platform leg.

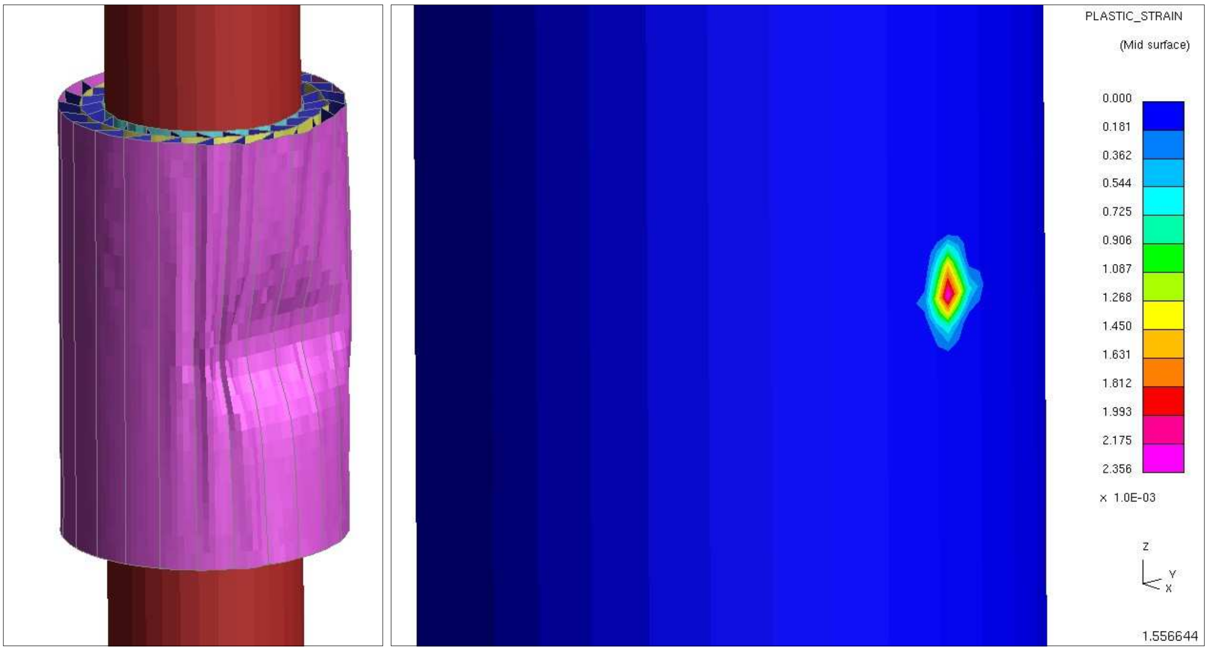






This shows that the strain in the platform leg has been reduced from 6% over a large area to 2.7% over a much smaller area. To further reduce the strains in the platform leg and to reduce the reaction forces at the top and bottom of the platform leg the effects of water within the fender were included.

It is clear that the effects of water will generally reduce movement of the platform leg, but the mass damping effect has been excluded from the analyses as the wave effect will have a significant effect on the movement of the leg. These wave loading effects are assessed separately outside this report.
The figures below show the final deformed shape and the predicted strains in platform leg when water is included in the analysis.

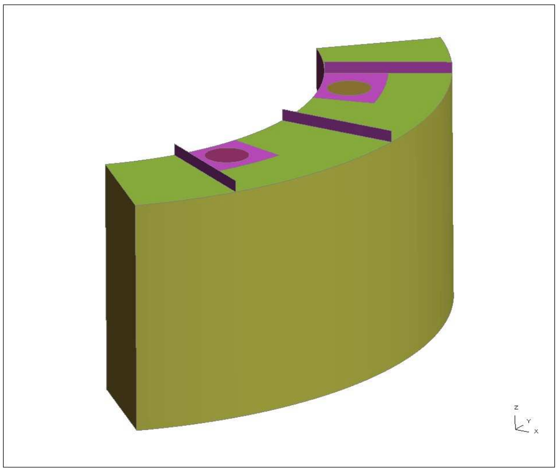


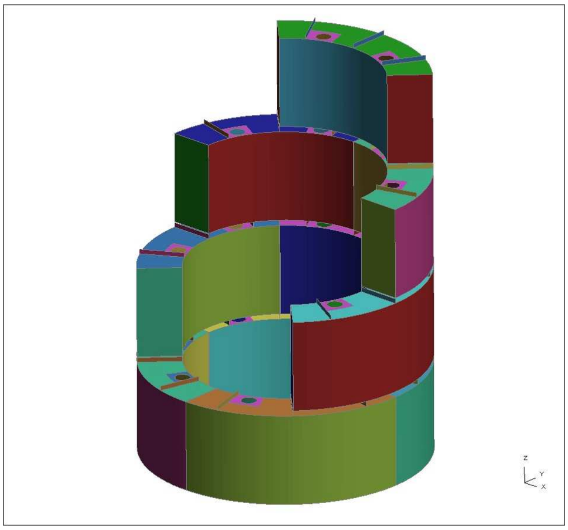
The plastic strain in the platform leg is now a localised surface strain of 0.2% which will not cause collapse in the leg. In addition the reaction forces observed at the top and base of the platform leg are reduced by the introduction of the water in the analysis as energy is dissipated in moving the water.

These simplified analyses were sufficient to provide confidence to the customer that the development of a water filled fender system could significantly reduce the deformation in the platform leg and decrease the forces applied to the platform.

Water filled fender analyses

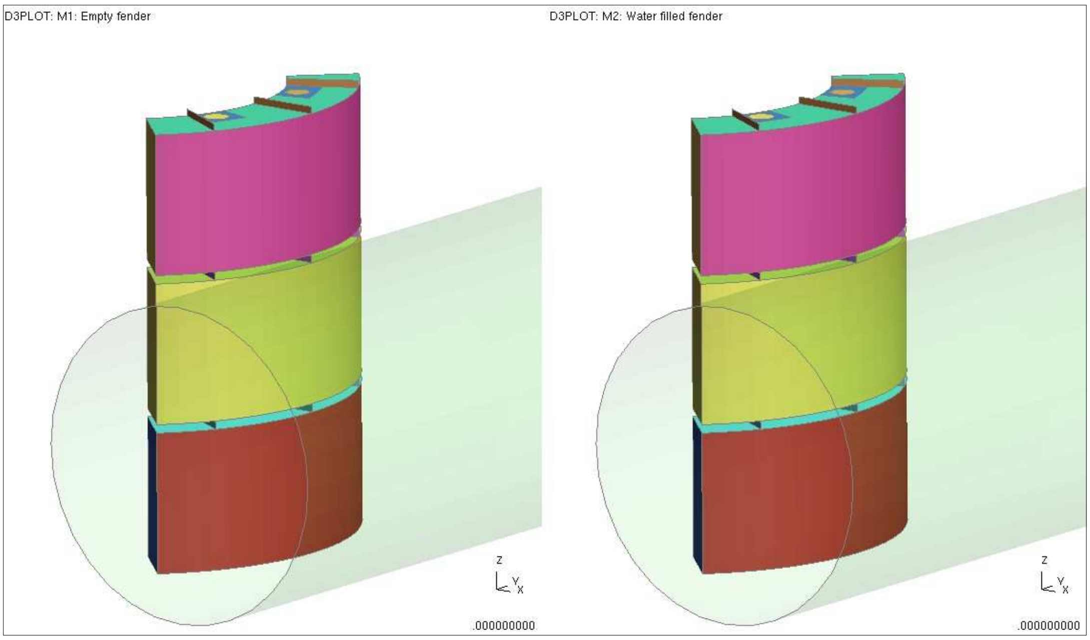
The initial concept was for a repairable or replaceable compartmentalised design. This would enable replacement of smaller sections of the fender system if they were to become damaged. The design is shown in the figure below.



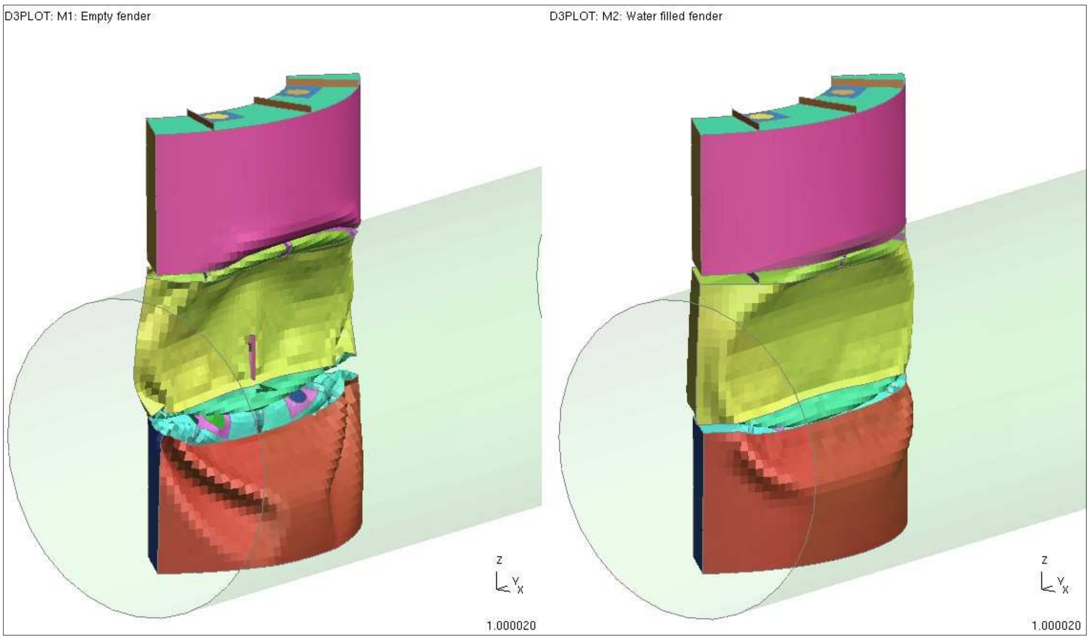


The fender system is formed from these hollow quadrants which are 1m thick and 2m high. They are constructed from 12mm thick steel with two holes in the top surface which are designed such that the amount of water that can flow through them is such that it will decelerate the ship at a constant rate. These quadrants are welded around the platform leg and separated vertically by supports on the top face to allow the water to flow out between them.

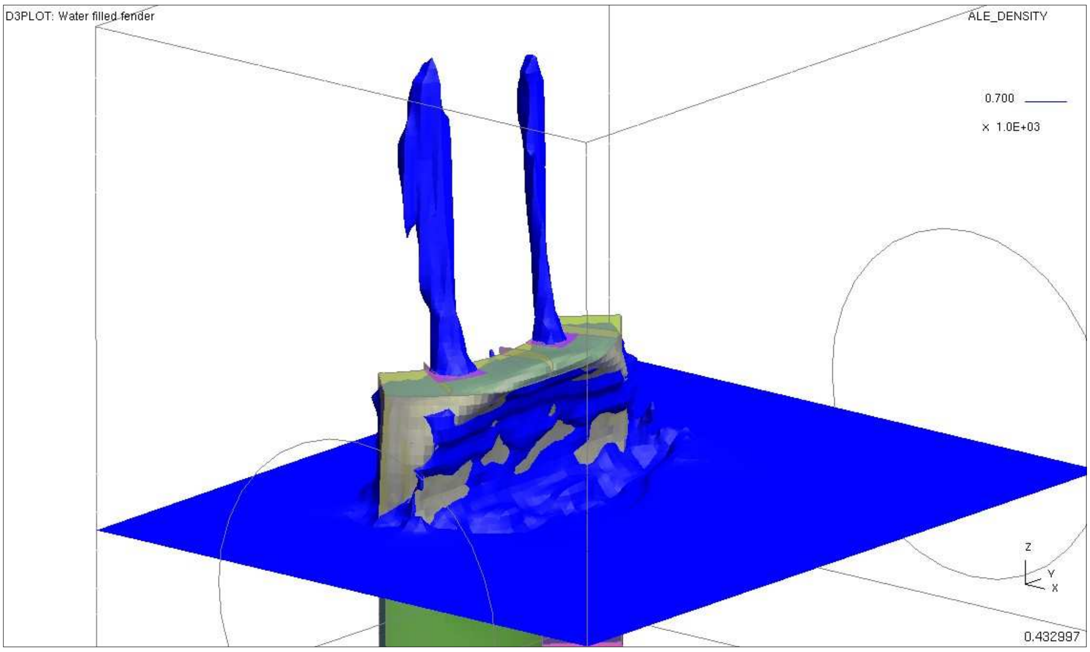
An analysis was completed to show how this design would perform when dry and wet and to ensure that the analysis details were correct before a full model was created. The initial model consists of three quadrants placed on top of each other and restrained accordingly. The empty and water filled analyses are shown below.



The final deformed shape for the two analyses are shown below.

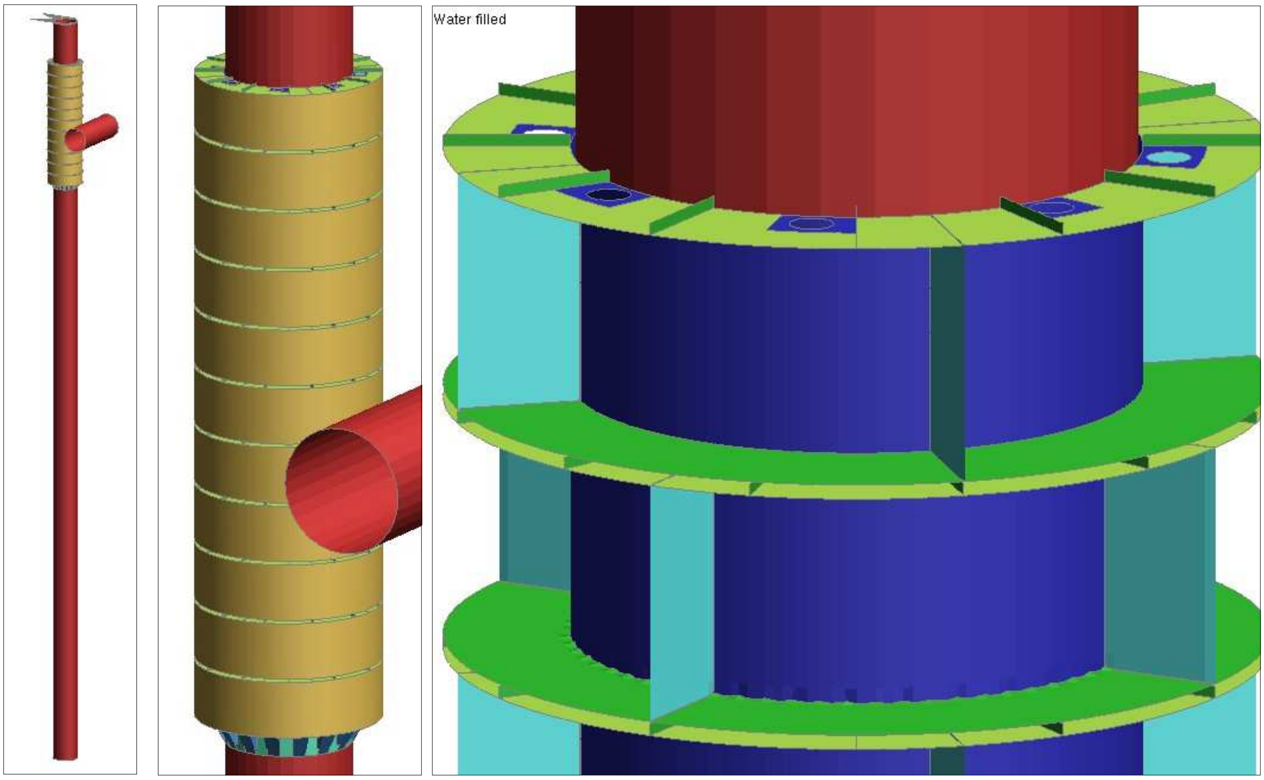


It can be seen that the deformation is significantly reduced when the effects of the water are included. Animations of the water filled analysis show the water being forced out of the holes during the impact. An analysis with only two quadrants, where the water is ejected upwards, shows this even more clearly.


D3PLOT: Water filled fender
ALE_DENSITY
0.700
× 1.0E+03
Z
Y
X
0.432997

Complete fender analysis

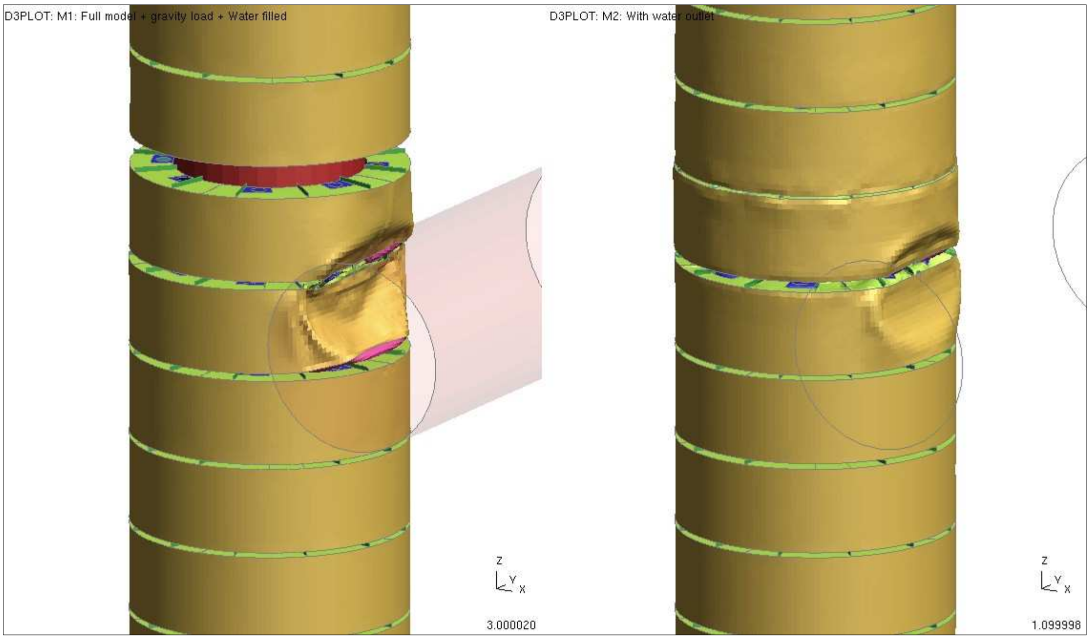
The results from the initial water filled fender analysis provided sufficient confidence to tend the model to the complete length required of 23m. The finite element model is shown below.



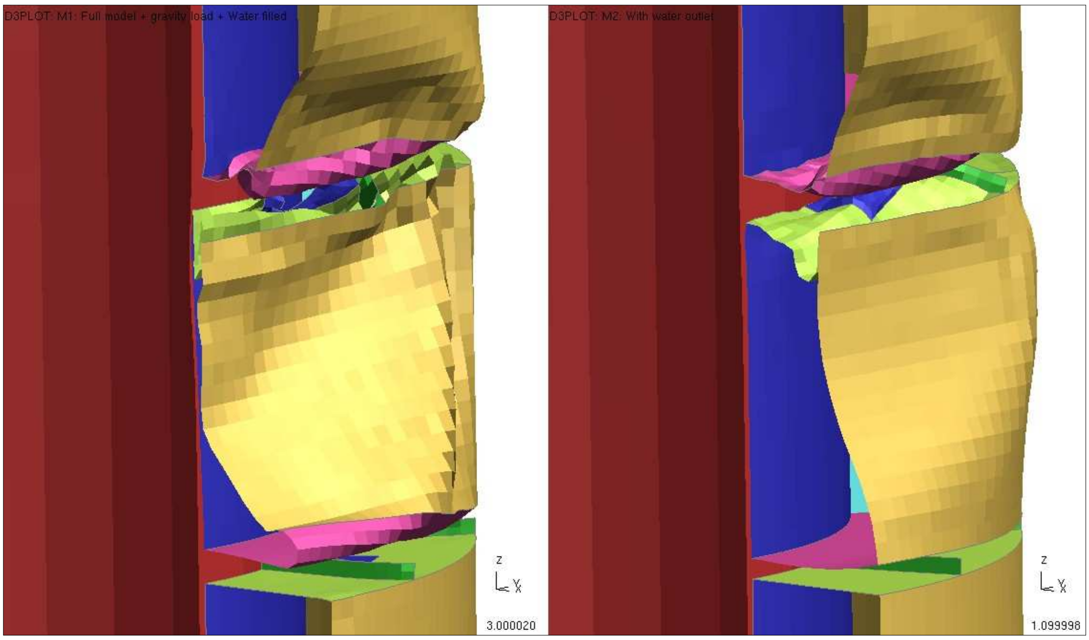
The image on the left shows the full model with rigid ties to two points at the top and centrally at the base.
The central image shows a close up of the fender system and the 11 sets of four quadrants. Each set of four quadrants are welded together along the front and back faces.
The third image shows the internal structure of the fender as the outer face has been removed. Creating the separate quadrants means that the water is contained and any failure of a quadrant would not result in complete loss of the water in the fender system.

The intention is that each quadrant would be filled at the time of installation and fitted with a bursting disk to minimise marine growth. If necessary water level monitoring could also be installed but the system is intended to be as corrosion resistant as possible. Minor damage to the fender should not result in loss of the water. Subsequent analyses, which are not reported here, consider the possibility of a self filling system to minimise the amount of monitoring required.

The figure below shows the results from a dry fender assembly and the water filled fender assembly.

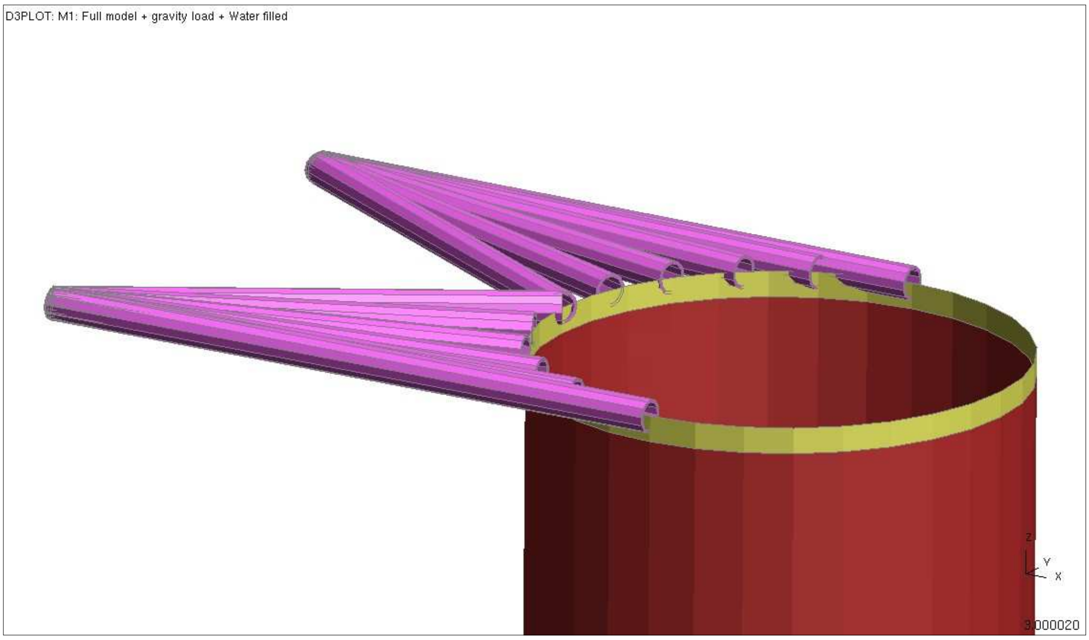


As would be expected, the deformation of the water filled fender, shown on the right, is substantially less than those of the dry fender, shown on the left.

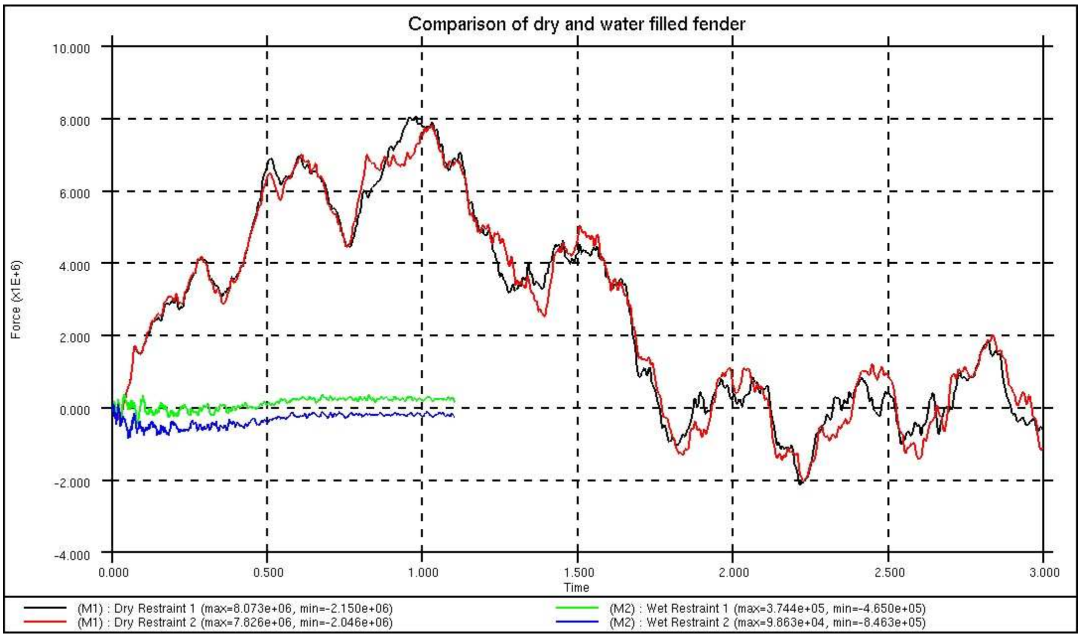


A cross section at the point of impact shows that the dry fender has completely compressed and damage is observed in the main platform leg, however, in the water filled fender system the platform leg remains undeformed.

The forces applied to the main platform are also important. The truss system that connects the top of the platform leg to the main platform are represented by rigid ties from the top of the leg to two points which are the free ends of the truss. These can be seen in the figure below.



The forces are monitored at these points and the comparison between the dry and water filled fender systems is shown below.



The impact duration for the dry fender (1.1 seconds) is much longer than for the water filled fender (0.5 seconds). The reaction forces at the restraints are significantly reduced by the inclusion of the water in the fender. The dry fender peak reaction force is 8.1MN compared to the water filled fender peak reaction force of -0.8MN.

Conclusions

This investigation is part of a major project to design and analyse an off-shore installation on an existing platform. The full details cannot be given at present as the project is still on going.

The analysis work to date clearly shows the benefits of utilising the effects of water in an off-shore impact scenario and how LS-DYNA can be a valuable tool in modelling water flow.