Key research into LNG behaviour in shallow water

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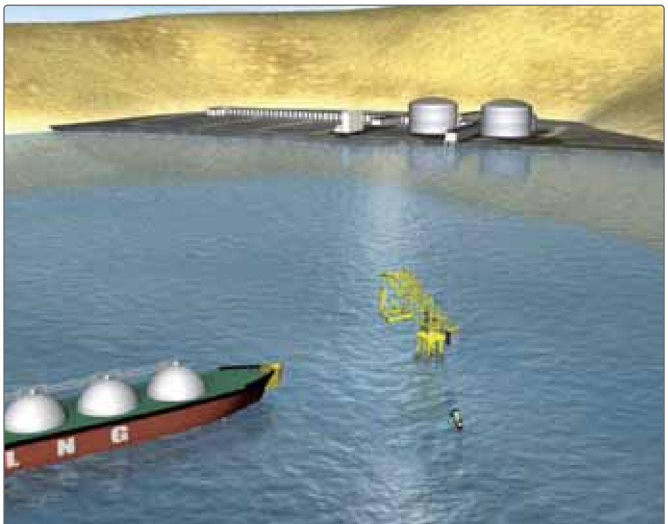
Long waves and moored vessels

Long waves, although hardly visible, can cause large problems for moored ships. Over the last decade hydrodynamic research has focused on deep and ultra-deep water developments. However, recent experience with the development of offshore liquefied natural gas (LNG) terminals has shown that the issues related to shallow water hydrodynamics are at least of similar complexity. For example, low frequency wave effects such as set down (or infragravity waves) can result in significant excitation, while streamlined LNG carrier hulls have a very low damping effect against low frequency motions such as surge. The combination of excitation and low damping can result in significant resonant motions and related mooring loads. While more and more LNG terminals were built in shallow water, with water depths of approximately 15 – 40 metres, a better understanding of these shallow water hydrodynamics was desired.

The HAWAI project

In 2006 a joint industry project (JIP) was started that aimed to explore shallow water wave dynamics in order to provide reliable wave information leading to optimal offshore LNG facility designs. In this JIP, a number of organisations contributed to the research project, with all participants benefitting from the developed knowledge. Deltares was one of the partners that contributed to this project of 24 participants. The project was led by MARIN and other partners involved were, amongst others, Bureau Veritas and Single Buoy Moorings as well as the Delft University of Technology. The project, which was called HAWAI - short for shallow water initiative – ran from 2006 to 2007.

HAWAI recognised that the development of reliable offshore LNG terminals in shallow water locations requires an improved insight into the hydrodynamic effect of sea conditions in such areas. HAWAI investigated not only wave and current conditions at a number of representative mooring locations, but also ship motions and mooring structure loads that could be expected in such environments. Variables such as water depths, ship draughts, seabed contours and wave frequencies were also be accommodated and, in addition, the project investigated the applicability of model testing techniques for shallow water operational scenarios.



Artist's impression of a near shore LNG terminal

By using the combined expertise of offshore hydrodynamics and coastal engineering, the project resulted in an improvement of knowledge of shallow water physics that are important for the design of offshore LNG terminals. The results provided the participants with a better understanding of ship motions and mooring prediction methods in sea conditions common to such areas.

The second phase

Although the first HAWAI project already provided much insight in the complexity of the wave conditions in shallow water areas, a practical methodology on how to apply this knowledge in the design of a terminal was still missing. From a designer's point of view, there was a need for practical and generic guidelines. Therefore, in 2009 a follow up of the HAWAI project was started, named HAWAII. The aim of this second project was to develop a practical design methodology for near shore shallow water LNG terminals, making use of the insights gained in the first HAWAI JIP. The majority of the 24 original participants also joined together for this follow-up project.

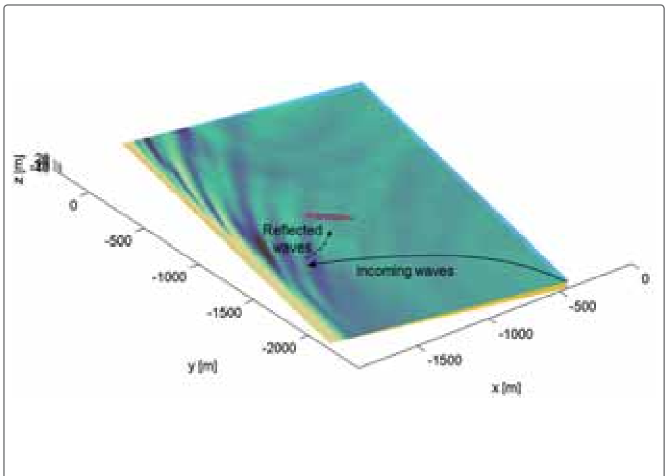
In the HAWAII JIP, a practical design methodology was proposed. This methodology was illustrated with a case study involving the design of a LNG terminal for a fictitious but realistic shallow water mooring location. In this case study, each step of the developed design methodology is performed, starting with obtaining the offshore wave climate and concluding with a final estimate of the expected downtime at the near shore mooring location. This case study showed how the design methodology can be applied in a practical, realistic situation. The HAWAII JIP resulted in a concise design methodology, providing practical guidelines for a step-by-step design approach. In each step the relevant physical processes are identified and guidelines are provided on how to account for it.

Developing tools

Next to this step-wise design methodology, several tools have been developed within this research project and delivered to the participants. These tools consist of methods to:

- Estimate low-frequency wave conditions at a near shore mooring location;
- Compute hydrodynamic loads related to the low-frequency waves that are present at the mooring location;
- Estimate line forces and vessel motions.

The application of the design methodology in the case study showed the relevance of correctly predicting the near shore



Example of low-frequency waves reflecting off a coast, showing the relevance of a correct prediction of low-frequency wave directions at a near shore mooring location

shallow water wave conditions. It was shown that low-frequency waves can have a significant effect on expected downtime and a correct prediction of the low frequency wave spectra at the mooring location is required for a correct downtime prediction. Near shore low-frequency wave conditions are largely influenced by the local bathymetry and coastline orientation. Estimation of low-frequency wave reflections off the coast, with correct wave height, period and direction is not trivial. For this, dedicated models that are mainly developed and used in the field of coastal engineering may provide a valuable addition to the tools that generally used for offshore vessel motion prediction.

Scale model testing

The main part of the developed design methodology is based on results of numerical simulations. The applied numerical models are often carefully validated for situations for which they are developed, ie. for coastal applications, mainly with very shallow water depths of less than ten metres. When applying these models in a realistic case study, a reality check can be of great value. One way to verify the numerical results obtained in the design methodology is to perform scale model tests. Such tests are often performed in a final stage of a design process, due to the high costs involved of setting up a physical scale model. When set up carefully, scale model tests can provide a complete representation of the most important shallow water physics at a near shore terminal.

Presently, an initiative has been proposed to the HAWAII JIP participants to finalise the research project by performing scale model tests. These tests will illustrate the use of physical scale model tests in the practical case study and aim to provide validation for the developed models in a realistic mooring situation. The model tests are planned to be performed in 2013 in the Delta Basin of Deltares, which is one of the largest shallow water wave basins in the world, measuring approximately 50 metres by 50 metres.

Example of scale model tests performed at Marin in the first JIP HAWAI

Safer designs

The HAWAI and HAWAII JIPs showed that for the correct prediction of moored vessel motions and mooring line forces in a shallow water wave environment, a combination of model tools that are presently used in both maritime and coastal engineering fields is required. Combining the knowledge of those fields will result in safer designs of near shore terminals.

ABOUT THE AUTHOR

Mr Van der Hout has a MSc degree in marine technology and is a staff member of the harbour and offshore technology section at Deltares. He works on hydrodynamic topics related to nautical activities in and around harbours, including ship manoeuvring and moored-ship studies. He is involved in research and development projects regarding low-frequency waves, passing ships and in the development and testing of several hydraulic mathematical models.

ABOUT THE COMPANY

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