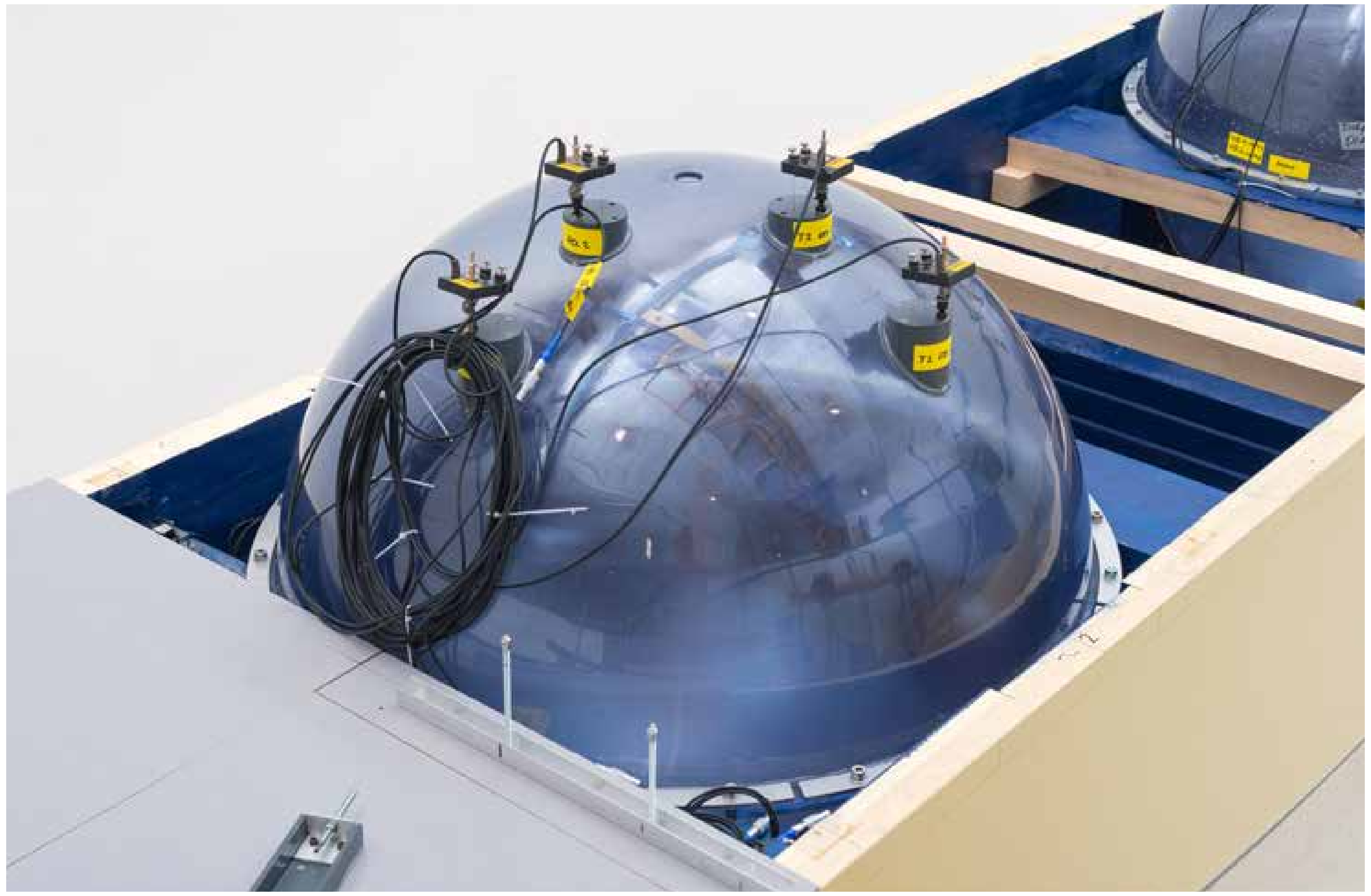
Influence of LNG sloshing on offloading operations

Petronas recently commissioned MARIN to perform side-by-side model tests on Petronas FLNG 1 and a MOSS LNGC. During this project, MARIN assessed the influence of LNG sloshing in the partially filled tanks on the LNGC's motions.



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FLNGs are being developed for gas production and processing in remote offshore locations. The floating production unit is turret moored at the gas field location and ensures the gas production, storage and offloading. The offloading usually takes place in a side-by-side configuration and a loading arm permits the transfer of liquefied gas from the FLNG to the LNGC through an articulated pipe system.

The most critical issues during this operation are the loads in the side-by-side mooring lines between the two vessels, the loads in the floating fenders and the relative motions at the loading arm location. These issues are mainly determined by the environmental loads on the two vessels, which are in close proximity, and by the strong hydrodynamic interaction between the vessels. But in addition to external loads, there are also internal loads such as the sloshing of the liquefied gas in the LNGC tanks. Taking the sloshing loads into consideration while designing the side-by-side mooring and the loading arm will lead to a more accurate prediction of the terminal's workability.

Reliable measurements Usually, the workability of an LNG terminal is assessed by running time-domain simulations in such a way that the non-linearities of the side-by-side mooring are taken into account.

The objective of MARIN's model tests, which included the modelling of sloshing in the tanks, was to provide reliable measurements that can be used for the validation of the numerical model of the Petronas FLNG.

In the Seakeeping and Manoeuvring Basin model tests took place on the LNGC alone, and on the LNGC moored side-by-side to the FLNG. For practical and safety reasons, LNG cannot be used during model testing. But as LNG is about twice as light as water, two equivalent tanks filled with water were modelled to represent the four tanks filled with LNG. In this way the ratio between the mass of the fluid in the tanks and the total displacement of the shuttle tanker was respected.

Several filling rates of the tanks were investigated. The spherical tanks were custom-made for the project using transparent PVC and coloured water so the motions inside the tanks could easily be visualised and the sloshing modes occurring in the tanks identified. Four resistive wave probes were mounted in each tank to measure the wave elevations. To relate these measured wave elevations to sloshing modes, a video camera recorded the fluid motions inside the tanks. The combination of measurement data and the visual aids led to a better understanding of the different sloshing modes.

Soft-spring mooring Firstly, tests on the LNGC were carried out when it was alone. In these tests, the shuttle was fixed in a soft-spring mooring. This mooring kept the model in place without interfering with the wave frequency motions. The vessel motions and the wave elevations were measured at four positions in each tank. By comparing the motions measured in the tanks, for which several filling rates were tested, conclusions could be drawn about the influence of the sloshing on the vessel motions.

After completion of the LNGC tests, similar ones were conducted with the FLNG fixed in the soft-spring mooring and the LNGC moored side-by-side to the FLNG. The side-by-side arrangement was represented by four fenders and eight mooring lines with bilinear characteristics. In addition to the vessel motions and wave elevations in the LNGC tanks, the fender and side-by-side line loads were also measured. These tests are more representative of the offloading operation and showed the influence of the sloshing on the relative motion between the two vessels, as well as on the side-by-side line and fender loads.

This challenging project was successfully completed and confirmed that the combination of detailed modelling, accurate measurements and flow observation using a video camera is a great way of helping clients validate their numerical tools. Additionally, the lessons learnt during the project are a significant step forward in helping to maximise the LNG terminal's availability.