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Measuring wave impacts under extreme conditions

How advanced pressure sensors from Kistler help researchers to understand sloshing

MARIN

THE ATMOSPHERE

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LNG (liquefied natural gas) tankers carry the liquefied natural gas around the world in special containers.

To gain insights into the complex physics inside cargo containment systems (CCS) partially filled with liquefied natural gas (LNG), the Dutch research institute MARIN has developed a new facility named The Atmosphere (ATM). 100 pressure sensors from Kistler inside the ATM deliver accurate feedback on sloshing wave impacts – a major contribution to improving CCS designs not only for LNG but also, potentially, for hydrogen in the near future.

Natural gas is a cornerstone of cleaner and more sustainable energy provision at global level. Pipelines and shipping are both used to transport this fuel from its natural origins to its destination of use, but shipping is the more economical method – especially over longer distances. Liquid gas is carried at temperatures of around –162°C by special-purpose ships known as LNG tankers, sometimes recognizable because of their partly visible spherical tanks. More than 600 of these vessels are already in service throughout the world, and the market is expected to continue growing in the coming years. In terms of design, there is still plenty of scope for optimizing the tank geometry of these ships, but this requires groundbreaking research into the fundamental physical mechanisms behind the processes involved. One phenomenon that is not yet fully understood is sloshing – the motion of a liquid (LNG in this case) inside a container due to external forces (such as the ship's movements): and this is where MARIN plays a key role.

The Maritime Research Institute Netherlands (MARIN) in Wageningen is one of the world's leading marine research centers. Since 1932, MARIN has built up a vast stock of expertise based on a combination of numerical simulations and experiments performed in large-scale facilities comprising various basins for ship model tests, together with on-board measurement and testing. With the backing of a public-private partnership including Dutch universities, industry partners and federal funding, a new globally unique facility was commissioned in 2016. The Atmosphere (ATM) is a giant research facility capable of creating different atmospheric conditions by varying the pressure (0.02–10 bar), temperature (15–200°C) type of gas (He, N2, SF6 and water vapor), relative humidity (0–100%) and other parameters that influence the sloshing dynamics in a real LNG tanker. The ATM consists of an autoclave with an outer diameter of 2.5 m and a length of 15 m – people can actually enter it, but events inside are usually observed through one of the 17 inspection windows.

Precise results under varying environmental conditions

Rodrigo Ezeta, a researcher at MARIN who holds a PhD in Fluid Mechanics, explains the approach as follows: "The Atmosphere offers full environmental control of temperature and pressure: this is relevant for LNG cargo containment systems, which normally operate close to the boundary between liquid and vapor. This gives us a better understanding of the sloshing phenomena that occur in a real container inside a ship." Inside the autoclave lies a flume where waves can be created artificially. As soon as these waves hit the impact wall, pressure sensors from Kistler record the impact loads with a very high degree of accuracy. 100 of these sensors are installed in a T-shaped array. Ezeta again: "During the commissioning phase of the facility, we found that this is the best layout to obtain precise impact loads. The upper part of the T-shaped array allows detailed capture of the loads generated by the wave crest, while the lower part of the T registers the effects of the gas pocket that can be 'trapped' in between the wave and the wall." According to Ezeta, research has already shown that these gas pockets – in addition to the loads generated by the wave crests – can have a non-negligible effect, so they could also exert a detrimental influence on the container.

Synchronized signals from a hundred sensors

Due to their high natural frequency and short rise time, the pressure sensors from Kistler can capture the highly dynamic sloshing events inside the flume. They also feature an optimized membrane to minimize the thermal shock that occurs when sensor exposure changes suddenly from gas to liquid. To prevent noise and bias effects, the Kistler engineers developed a special cable solution that transmits the signals from the test chamber through

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Rodrigo Ezeta, Research & Development at MARIN
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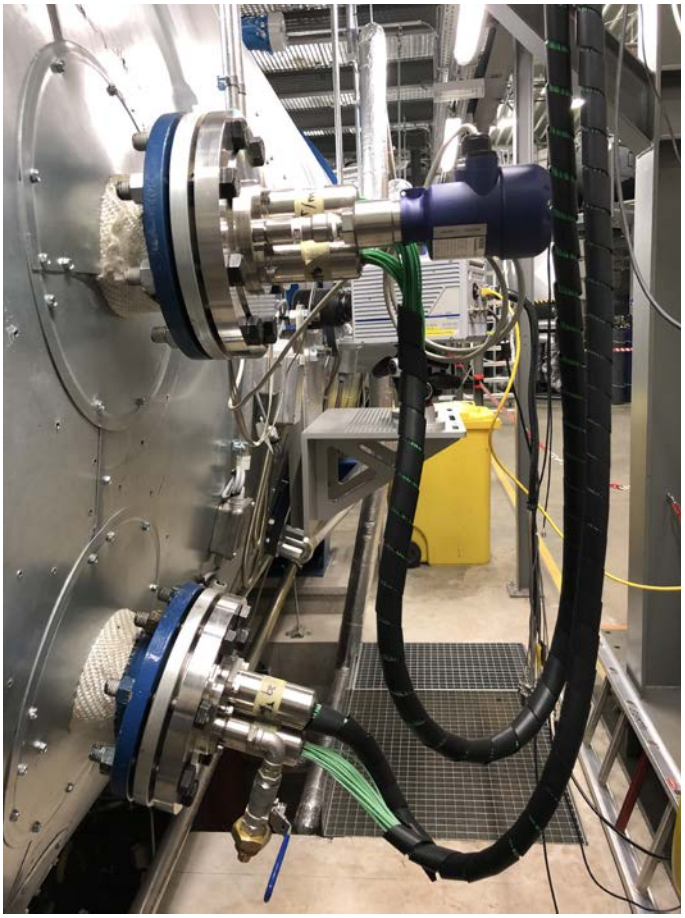
a vacuum tube to the outside of the autoclave. Signal processing and data acquisition are then handled by 25 automatically synchronized LabAmp 5165A charge amplifiers, which directly digitize the signals of all 100 pressure sensors at a rate of 100 kSps. "We're very happy with the solution from Kistler. It's reliable and robust, and it works flawlessly," Ezeta reports.

What are the main goals of research at MARIN's The Atmosphere, and what results can be expected? "The installation only became fully operational in early 2020, so we're still at the beginning of our research. One major goal is to improve the scaling models that the industry has used until now," Ezeta explains. At present, sloshing tests are typically conducted with a small tank on a moving hexapod so as to simulate sloshing. But when the sloshing dynamics are upscaled to real-size dimensions, biases arise in the tests due to the complexity of the underlying physical mechanisms at play. Ezeta continues: "One of our main objectives is to reduce the uncertainty caused by this scaling. One key question is: why do the pressures vary so much?" This turns out to be a key factor for sloshing events, so it also plays an important part in the design of tanks within ships.

Results also expected to benefit hydrogen tanker design

"Research so far has already shown that it is important to take all physical parameters and effects into account," Ezeta notes. "Our results will give businesses a better understanding of what is happening inside their tanks, and this will help them to keep on improving their testing methodologies. And, last but not least, our research is an enabler for a new type of tanker that will carry hydrogen rather than natural gas." In theory, hydrogen is even more sustainable than natural gas because its combustion does not produce any greenhouse gases; however, it has a very low liquefaction temperature of 33 Kelvin (corresponding to –253°C under atmospheric conditions). The world's first liquefied hydrogen tankers are expected to become operational in 2021. Rodrigo Ezeta sums up his experience with the measurement technology: "We're very satisfied with our collaboration with Kistler, and we're looking forward to many successful tests thanks to sensors that are renowned for their long-term durability and stability. We are also constantly looking for new collaborations within academia and different industries, where the ATM with it unique features can provide accurate measurements. Our Atmosphere is open to everyone!"



Custom cable solution from Kistler for pressure sensors inside the autoclave (left) of The Atmosphere sloshing test facility at the MARIN research institute in Wageningen (Netherlands)

Accurate pressure measurement in demanding environments

- Short rise time, high sensitivity and natural frequency
- Optimized membrane to reduce thermal shock
- Very wide operating temperature range (–196°C to +350°C)
- Pressure range up to 250 bar (3,626 psi)
- Variants with charge (PE) or voltage (IEPE) output available

These extremely compact sensors – with a diameter of only 5 mm – can be mounted with different housings, adapters and cables to best fit the application scenario.

Precisely synchronized fast-sampled charge signals

The LabAmp 5165A from Kistler is a dynamic dual-mode laboratory charge amplifier and data acquisition device for piezoelectric sensors. Key features include:

- Low noise
- 24-bit A/D conversion
- High sampling rates (up to 200 kSps per channel)
- Universal inputs (charge, IEPE, voltage)
- Wide frequency and charge range
- Fully flexible analog output scaling
- Scalable to high channel counts thanks to PTP device synchronization

A high sampling rate combined with scalability and excellent signal quality make the 5165A the perfect choice for this challenging 100-channel application.

Find out more about our applications:
www.kistler.com/applications

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