GTT Expert in LNG

GTT Inside

The GTT newsletter - July 2020 - n° 17

Message from Eric Dehouck, Deputy CEO, GTT

Have you ever been surprised and fascinated by discovering the technical depth, the level of detail, the mastery necessary to achieve something which appears simple at first sight?

«Simplicity is the ultimate sophistication,» Leonardo da Vinci said.

The same holds true for that specific dish that you know how to prepare to perfection: the dosage is precise, nothing too much, the gesture is safe, a thousand times repeated and carefully transmitted from generation to generation. The list of ingredients is supposedly well known but this dish remains unique and yours.

When I joined GTT three months ago, I first discovered a technology that seemed quite simple to me. However, each day working with passionate engineers and technicians, I have discovered a level of technical mastery that I did not imagine. There is an obsession here, more than 55 years-old, to master all aspects of the technology we offer to our customers. It is a matter of trust that the Shipyards, Charterers, Ship-owners, and Class, place in us and which is embarked on nearly 400 LNG tankers around the world, every day.

In this issue of GTT Inside, we have chosen to share with you two examples of very advanced studies that we are conducting to better master our technologies. These are the digital image correlation at cryogenic temperatures and the corrosion simulations on the INVAR™ M93. This work has made it possible to better master the operations and design of our systems in extreme conditions. With GTT inside this month, we are also launching a creative and new concept: the LNG Block™, aimed at supporting shipyards develop the LNG as a fuel market and therefore, contributing to the reduction of CO_2 emission.

To earn the trust of those who invest in, operate and construct the ships, GTT will continue to invest heavily in the mastery and development of our technologies. We are therefore honoured to share with you that we have just been rewarded for being the N°1 mid-size company for filling patents in France with a total of 58 patents filed in 2019.

I wish you a good read.

Eric DEHOUCK

TECHNOLOGIES

Make LNG as a fuel easy: the LNG Block™ solution

LNG as fuel is now the solution of choice for the future of green shipping. Hence, new yards are interested in addressing the upcoming increase in LNG fuel demand. Meanwhile, the highest concern for the owners is to minimize risk and reach a reliable and cost effective solution.

For that purpose, GTT is developing a new solution in order to meet these challenges, called “LNG Block™”. No revolution here as GTT gathers the existing practices of the shipping industry and the standard methods of cryogenic tank construction of skilled GTT licensees.

The LNG Block™ solution consists in building the ship section incorporating the LNG fuel tank in a specialised yard, which is then delivered to the client yard responsible for building the vessel.

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The client yard subcontracts to a GTT licensee the construction of the entire block housing the LNG tank. The scantling of the block including the LNG tank structure is designed by the client yard with the assistance of GTT experts, considering the specific requirements of the membrane containment system. The block is constructed and the containment system is outfitted under the supervision of the licensee in a dedicated yard. GTT teams supervise the membrane outfitting as well as the block integration in the client yard. The block can be also outfitted with the Fuel Gas Handling System, electrical networks, ventilation and piping networks, at the choice of the client yard.

With this solution, many shipyards, whatever their location and LNG background, can offer LNG fuel solutions with reduced construction risk and optimized delivery schedule.

In order to develop this construction model, GTT works with several industrial partners to offer this solution to the market in 2020.

The first development project is undertaken with Dongsung Finetec, a long-term Korean partner delivering the main components of GTT containment system for over twenty years for LNG Carriers and LNG fuelled ships.

Dongsung Finetec has built up its own capabilities of constructing LNG Cargo containment systems as well as the outfitting of LNG pipe and equipment insulation.

After launching the *LNG Brick®* exoskeleton tank into the market with GTT in 2018, Dongsung Finetec has secured the competences of manufacturing LNG Tank structures and outfitting the Mark III technology. With the LNG Block™ solution, Dongsung Finetec will contribute to the significant shortening of shipbuilding schedule for the benefit of shipyards and ship-owners.

With its own skilled engineers and a solid track record from collaboration with Korean shipyards, Dongsung Finetec can successfully manufacture the outfitted blocks with their industrial partners (block fabricators).

With this LNG Block™ approach, LNG projects, wherever their location, can be carried out relying on experienced partners.

INNOVATION

Expert assessment of corrosion behaviour of GTT LNG tanks

For pre-docking and post-docking operations, inert gas produced by on-board generators, resulting from MGO or MDO combustion, is used as a temporary medium in the tanks.

Inert gas is mainly composed of N_2 and CO_2, thus avoiding the explosive mix of oxygen and methane. This standard operating procedure has always been respected. However, cargo tanks should not be kept under inert gas for more than three days.

In 2019, during an LNG Owners' Forum meeting, GTT received a number of questions about the possibility of extending the duration of inert gas use.

We know that inert gas contains several components potentially detrimental to membranes, such as SO_X and NO_X.

This issue has led GTT's Materials Department and APERAM's Imphy Research Centre to cooperate on a study with the aim to find appropriate solutions.

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Historical Cooperation

A strong partnership between **GTT** and **APERAM** in Imphy has existed for 60 years. Imphy is part of APERAM's Alloys & Specialties segment. APERAM's Alloys & Specialties segment is the fourth largest producer of specialty alloys in the world, and is specialised in the design, production and transformation of various specialty alloys and certain specific stainless steels.

APERAM supplies shipyards with INVAR™ M93 for the membrane which is used in **GTT's NO96 technology.**

GTT and APERAM regularly join forces to answer questions from shipyards and ship-owners in order to help them find solutions.

For instance, between 2012 and 2015, a first phase of corrosion tests conducted by GTT in partnership with APERAM, concluded that it is possible to use dry air as a preservation atmosphere for INVAR™ M93 and for stainless steel 304L (used for GTT's Mark III system) without any time limit.

This study allowed the ship-owner to use dry air in place of nitrogen and thus reduce OPEX. The cargo tank preservation conditions are detailed in GTT's external document n°3344 rev 02, entitled *"Cargo tanks and insulation spaces preservation"*. This document can be obtained upon request.

To evaluate the effect of inert gas, we decided to continue the collaboration and to once again use the corrosion simulator.

Corrosion simulator and approach

The corrosion simulator was designed by APERAM and set up in its Research Centre *(figure 1)*.

The simulator consists of five climatic chambers, which are equipped with valves, gas cylinders and flowmeters.

Fig.1: Corrosion simulator - Climatic chambers with their equipment

The technology chosen by APERAM in order to obtain a relative humidity of 10% at +5°C in the simulator is based on gas mixture. This choice was supported by a long experience in heat treatment conducted under controlled dew points and the wish to restrict any intervention on the controlled humidifying system during the test.

A controlled dew/frost point (here, Td <0°C) could be obtained using two different approaches:

- The saturation in water vapour, in humid air, when passing near a cooled wall at the targeted frost Td temperature (air drying and ice formation at the cooler wall).
- The appropriate mixture of dry gas and humidified gas at a chosen dew temperature in order to obtain a mixture with a partial water vapour pressure corresponding to the targeted frost temperature Td.

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Since the simulator has to operate for several months, the first solution presents the major disadvantage of producing a large quantity of ice, which needs to be regularly evacuated. On the other hand, the solution with gas mixture permits testing without any intervention on the humidifying system, if the following conditions are respected:

- The temperature of the humidifying cell should be lower than room temperature in order to avoid condensation phenomena in gas pipes.
- A sufficient water quantity in order to humidify the dry gas during the total period of the test.

Relative humidity generators used for the hygrometer calibration (ex: Gruter & Marchand models) are manufactured according to a technology with a gas mixture. This supports the method chosen.

Four corrosive atmospheres with different quantities of corrosive agents were defined *(table 1)*.

The content limits of 100 ppm NO_2 and 10 ppm SO_2 are the limits given by the inert gas generator supplier. Even though these extreme amounts have never been measured, it was essential to check their effects.

Inert Gas	N_2	O_2	CO_2	NO_2	SO_2	Dew point
High NO	Bal	1%	14%	100 ppm	0 ppm	-20°C
High SO	Bal	1%	14%	0 ppm	10 ppm	-20°C
Low NO	Bal	1%	14%	20 ppm	0 ppm	-20°C
Low SO	Bal	1%	14%	0 ppm	5 ppm	-20°C

Table 1: Inert gas compositions

The influence of the corrosive agents NO_2 and SO_2 are studied separately.

Samples will be exposed to these atmospheres for periods ranging from several days to several weeks (60 days).

After exposure to those corrosive atmospheres, samples will be exposed to high temperature (55°C) and high relative humidity (95%) over several different periods in order to simulate the re-introduction of humidity (ageing) in the tank after opening during a dry dock.

Chemical and mechanical characterisation

Following exposures to inert gas and ageing, chemical (Glow Discharge Optical Emission Spectroscopy) and microstructural examination (Scanning Electron Microscope) will be performed in APERAM's Research Centre, on exposed samples, in order to assess the evolution over time of the corroded surface fraction, the depth of the corroded cortical layer, and the kind of corrosion mechanism.

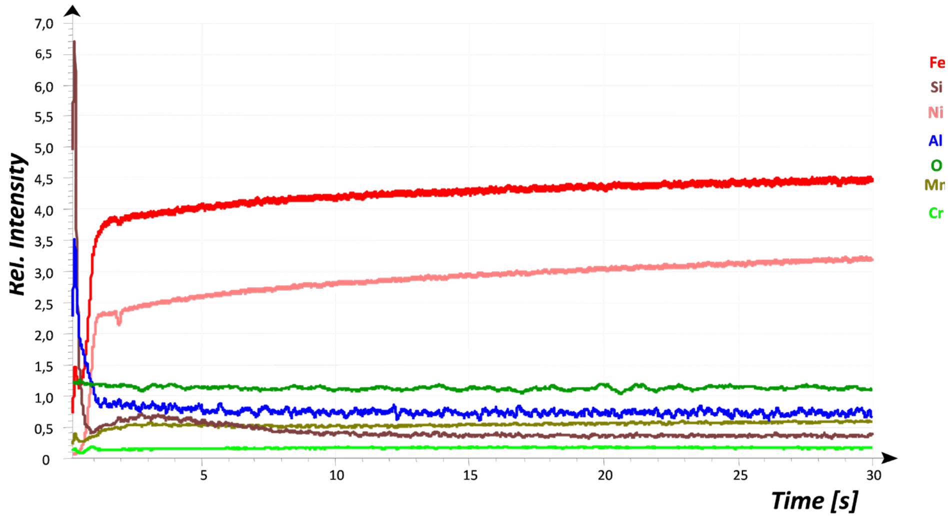

Fig.2: Surface chemistry of INVAR™ - M93, measured by GDOES

In addition, in order to assess the impact of a potential corrosion of the specimen on the mechanical behaviour, fatigue tests will be performed.

Our experimental approach was to define a maximal stress to reach 300,000 fatigue cycles for a reference sample (sample not exposed to corrosive atmosphere and ageing) and compare the fatigue behaviour of corroded samples at this stress level.

The results of these mechanical tests will enable us to decide the authorised duration for the use of inert gas.

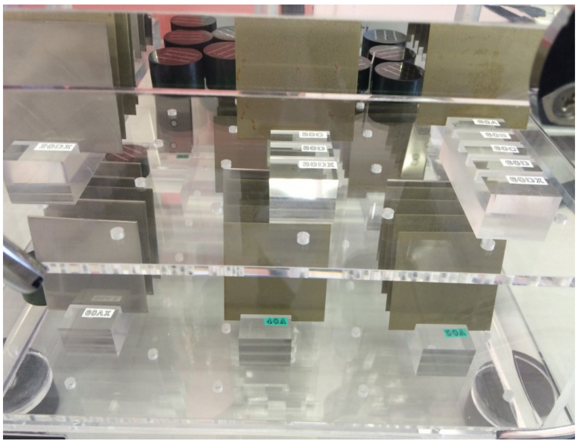

Fig.3: Samples after different exposure times - on hold before chemical analysis

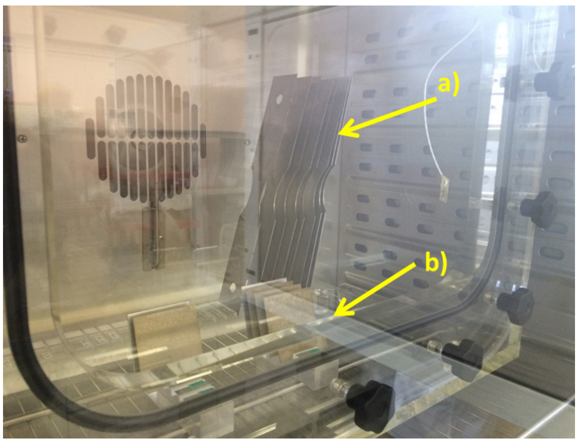

Fig.4: Corrosion chamber
a) Fatigue samples
b) Samples for chemical and micrographic analysis

Next steps

We expect the results of the studies to demonstrate the flexibility brought by the NO96 INVAR™ membrane and by the Mark III stainless steel membrane during ship maintenance operations. Depending on what we will observe, such a test campaign might afford the industry new perspectives to optimize ship maintenance operations, to increase the safety of the tanks, or to develop enhanced features of inert gas generator.

The first results of the study about the behaviour of INVAR™ M93 and 304L stainless steel in inert gas containing 100 ppm of NO_2 are expected for September 2020. Studying the ageing effects of INVAR™ M93 by such test campaigns with dedicated facilities, conditions and methodology is a long-term process. The study of the behaviour of both membrane types in a 10 ppm SO_2 atmosphere will start before the end of this year. Knowing the importance of the results, we will regularly keep the LNG Industry updated with the development of these tests.

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INNOVATION

3D Digital Image Correlation at cryogenic temperature

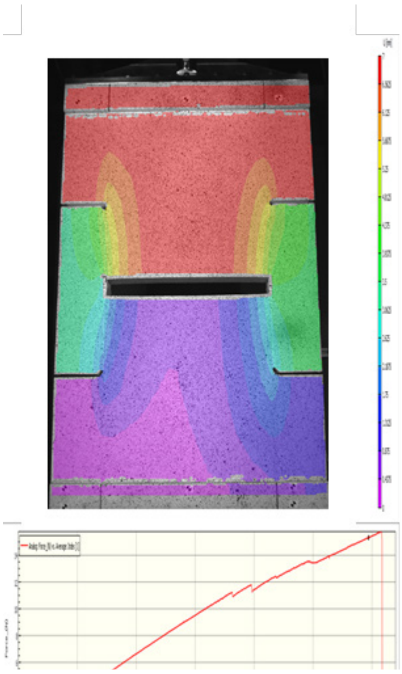

Fig.1: Visualisation of the displacement field as a function of the applied force

GTT is constantly looking at ways to increase its systems' performance and efficiency by improving its testing and validation methods.

As part of its approach for the validation of new CCS technologies, the GTT Prefabrication laboratory recently acquired a new measurement system called 3D Digital Image Correlation in order to improve the design of its new technologies. 3D Digital Image Correlation is a contactless optical measurement method that achieves high precision over relatively large studied areas. The analysis and interpretation of this global data in the form of displacement fields and strain fields make it possible to improve the correlation between Thermomechanical Tests and Numerical Models. It also improves the identification of mechanical stresses of CCS components under in-service loads.

To date, although some laboratories are familiar with Digital Image Correlation, there has been very little experience in using this method during mechanical tests at cryogenic temperatures. It was therefore a challenge for GTT to be able to adapt this measurement method to our cryogenic testing facilities.

After acquiring this measurement system, the engineers and technicians in the Prefabrication laboratory of GTT used their expertise and know-how in Instrumentation and Thermomechanical Tests to develop a "defrost" system synchronised with the associated photographic equipment and test machine data. A system for mounting the cameras and specific lighting allows for the observation of the behaviour of the sample with high precision behind the window of the cryogenic chamber.

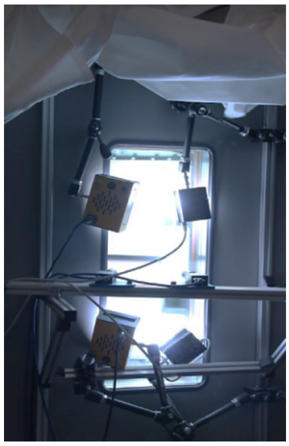

Fig.2: Lightning set-up

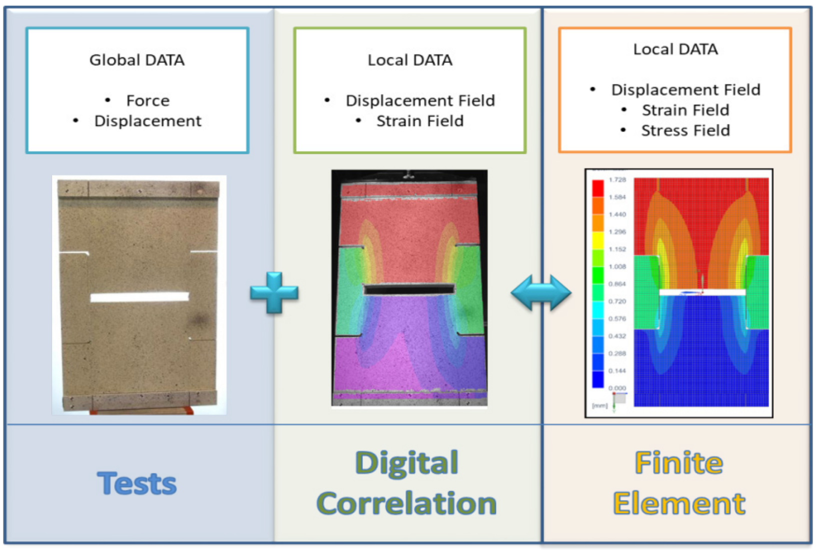

Fig.3: Correlation Tests / Calculations

Tests were successfully carried out on samples of Mark III technology sub-assemblies made up of various materials (Reinforced Polyurethane Foam and Plywood), representing several study plans at different cryogenic temperatures (down to -163°C: the operating temperature of the primary membrane on a LNG carrier).

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These first tests were conclusive and made it possible to refine and improve existing numerical models. It also allowed GTT to understand better the behaviour of the systems with regard to in-service stresses. The analysis and interpretation of this global data in the form of displacement fields and deformation fields enhance the correlation between Thermomechanical Tests and Numerical Models and the knowledge about the cryogenic behaviour of the systems as well.

One of the major challenges in developing membrane containment systems is the ability to properly model and understand the mechanical behaviour of its complex structure. Made of thin metallic or composite materials subject to cryogenic temperatures, static and dynamic loads, the containment systems require some design analyses going far beyond what we could find in the literature or in any classic design approach.

These new capabilities of the GTT laboratory offer a wide range of new possibilities in all the innovation activities. The better measurement of the behaviour of the technologies during in-service conditions will allow the design teams to strengthen their understanding of all the accumulated return of experience of the systems. Such a breakthrough, pushing back the current state-of-the-art allows the engineers to refine their assessment of the system design margins which could result in further optimization when developing new technologies. This new testing method provides more accurate measures of all the local effects and behaviours of the structure. All the finite element models with their modelling assumptions can now be recalibrated according to those more accurate measures. By doing so, the innovation processes will be improved and may result in shorter lead-times for new technology development and large scale tests.

This new in-house-testing facility fully supports the innovation teams in their continuous efforts to provide the industry with higher performance systems relying on enhanced design features.

