12 m free-sailing model with 70 pressure gauges

# Oasis of the Seas

## The next generation in cruising matched by its equivalent in model testing

Oasis of the Seas, the largest cruise liner ever in the world, will set sail in December. As this magnificent ship prepares for its maiden voyage, Report takes the opportunity to focus on the measurement techniques used in this interesting and challenging project.

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MARIN partnered with the shipyard, STX Europe in Finland, the owner RCCL, and engineering team to meet the stringent performance requirements set for this 360 metre plus vessel to ensure efficiency, comfort and safety. In fact, STX Europe already started to work with MARIN on the development and design of this next-generation cruise liner back in 2005. This cooperation was based on a long-standing relationship between the shipyard and MARIN, which is also highlighted in this issue.

**Flexural response in seaway** One challenging task was to quantify the slamming-induced flexural response of the ship at an early stage of development and to compare this with the response of an existing ship. The first step was to measure the wave-induced impact pressures. Over 70 pressure gauges were mounted on large-scale models (12 metres) of the reference ship and these were tested in a free-sailing model in the Seakeeping & Manoeuvring Basin. Associating each pressure with an area and an orientation, yielded input for dynamic finite element calculations on the structural vibrations of each ship.
Hull girder vibrations were validated in two ways. First of all STX Europe, which performed the finite element calculations, compared the calculated values with the shipyard's continuous measurements at sea and the comparison showed excellent agreement. Secondly, results were compared with direct measurements with a segmented 7-metre, free-sailing model. In this model the vertical and horizontal two- and three-node bending modes were modelled with a simple flexible backbone. A new development here was the modelling of the first torsion mode. The prediction of slamming-induced, passenger discomfort required careful measurements on the vibration accelerations in each of the six segments. In addition, the horizontal and vertical bending and torsion moments were recorded by means of strain gauges.

**Manoeuvrability** With frequent calls to harbours, confined bays and passages through fairways and channels, the low speed manoeuvring capability of this enormous vessel had to meet stringent requirements and was given the highest priority. MARIN's Shallow Water Basin and Full Mission Simulator were used to evaluate this. Measurements determined the forces and interactions on the vessel due to the 60MW

6-segmented model mounted on a flexible backbone.


Model tested in severe weather conditions. Lifeboats mounted on force transducers.

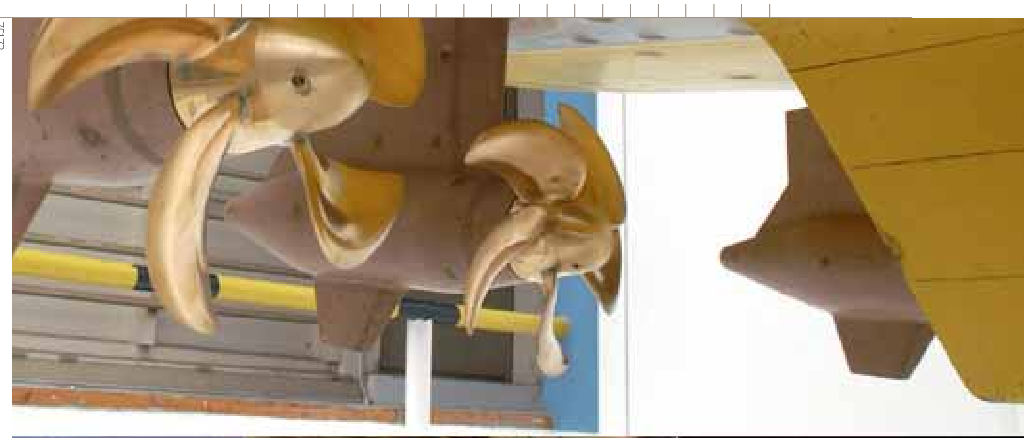
Sailing in channel based on real life operation area.

Stiff cardan joint and 6 component balance.

of main propulsion power and the 22MW of bow thruster power and the relevant ship motions. A large model was used to examine the thruster efficiencies accurately by having large, 14cm, model-scale bow thrusters on which thrust, torque and revolution could be measured. The model was mounted to the carriage by means of strain gauges and two low-friction sliding poles to realise realistic trim and sinkage effects. The poles were connected by means of a stiff double and single cardan joint and two six-component balances.
This meant that longitudinal, transverse, yaw and roll forces could be measured. By measuring these overall forces and the main propeller and bow thruster thrusts, the relating interaction forces could be derived. Relevant operating conditions and a suitable environment was used to test the ship model in several water depths and a realistic mock-up of the entrance channel of Miami was set up. A mathematical prediction model was built up and this was used in MARIN's Full Mission Simulator to verify the vessel's performance in several ports.
In the Seakeeping & Manoeuvring Basin free-sailing model tests were performed to determine the manoeuvring characteristics at cruising speeds. These proved to be excellent, largely due to the triple-pulling, pod propulsion concept. The engine power and torque limits were modelled using MARIN's modular BSS control system. It is especially important to model these engine limits when assessing manoeuvring characteristics for vessels with podded-propulsion.

**Extreme events** A special task in this project was to quantify the risk of lifeboat wetting and the associated loads. A thorough investigation was made to evaluate the vertical forces acting on the lifeboats in steep waves. Experiments with a free-drifting model in extreme seas were conducted to demonstrate compliance with the IMO Weather Criterion.

**Speed performance** To accurately predict speed-power performance the following test set-up was developed. For the pod units MARIN's standard thruster units were used. The geometry of the pod housings was accurately milled at model-scale and fitted around the shape of the thruster transducers. During the self-propulsion tests, the propeller torque and thrust were measured inside the hub of the propeller. Additionally, the thrust produced



Full and model scale pods (model scale image is mirrored)

by the whole podded propulsor was measured. Subtracting this value from the propeller thrust resulted in the so-called drag of the pod unit.
Scale-effect correction has to be applied on the housing/strut drag of the pods. Nowadays, the advanced scale-effect correction method, PODU, has been developed from an extensive number of model experiments on pods and importantly, from full-scale measurements made available to MARIN by clients.

**Vibration** For large cruise vessels comfort is an important issue. A problem can arise from propeller-induced pressure pulses. To investigate this, cavitation observations and pressure measurements were conducted in MARIN's Depressurised Towing Tank.
To determine the cavitation pattern, video cameras are installed forward of the propeller in or outside the model, so the back of the propeller can be observed. One camera is also installed behind the model to observe the face of the propeller. A stroboscopic light source, located above the model behind a Perspex window or outside the model, provides illumination. Hull pressure measurements are conducted with the use of strain gauge pressure transducers. In addition, acceleration transducers are fitted in the afterbody of the model to measure the vibrations to check whether the parasitic vibration-induced pressure fluctuations are sufficiently low. The results follow from the analysis of pressure pulses at different locations and an integration of the total force at various blade frequencies. Special criteria were developed to check if the propeller-induced force on the hull was acceptable or not.

To verify the stringent requirements of the Oasis, full-scale measurements were carried out. The results show very good correlation with respect to powering performance, manoeuvring characteristics and seakeeping behaviour. The Oasis of the Seas is ready for its maiden voyage. The Oasis project team of MARIN congratulates STX Europe and Royal Caribbean Cruise Lines on the successful completion of this challenging project.