The Boldrewood Towing Tank

Bertrand Malas gives an insight into the history and design of the University of Southampton's new towing tank, located at its Boldrewood Innovation Campus

Fig. 1 Construction (February 2014)

Built in 1975, the first Boldrewood Campus was dedicated to Medical and Biological sciences. In April 2006, the university announced plans to develop a 'professional campus' on the Boldrewood site, to house the marine services division of Lloyd's Register. In October 2010, the Boldrewood Campus was fully closed for redevelopment. From 2014 onwards, five buildings have been built and now host various engineering departments.

Discussions about the build of a towing tank started when the redevelopment of the campus was announced. In 2012, after the development had started, a crash in construction prices allowed the university to add the towing tank building in the existing construction budget, so it was quickly decided to go ahead. The main characteristics were agreed later that year and construction started in 2013 (see Figure 1).

The fit-up process for the Boldrewood towing tank has been a complicated journey with several delays, especially in the procurement of the carriage drive system. At the time this article is being written, the tank is scheduled to be fully operational in Spring 2020.

Design features

The Boldrewood towing tank is 138m long, 6m wide and 3.5m deep, which corresponds to just under 3,000m^3 of freshwater. Despite appearances, the bottom of the tank is flat [1]. The target maximum carriage speed was fixed to 12m/s, which is high for a facility of this size but gives the ability to run a wide range of experiments.

These dimensions were selected based on the experience of university staff, past recommendations [2] and the site's physical limitations. The length is the maximum achievable on site, due to the presence of a gas supply at the east end and a protected tree at the west end. These particulars form a good compromise for a facility designed to accommodate education, research, but also commercial experiments.

A review of existing and past towing tanks (see Figure. 3) shows that the Boldrewood tank is a relatively small facility, but it is by far the largest university towing tank in the United Kingdom, and within the top five in Europe. It is the first towing tank to be built in the UK since the late 1960s. The facility can accommodate models up to 6m in length, which is sufficient enough to obtain accurate results for most ship types.

The tank room has been designed without any windows to avoid direct sunlight on the water. This has been known to cause issues in some tanks due to re-circulating currents, thermocline or algae growth that can affect the quality and repeatability of the results.

The carriage design was developed through collaboration between the university staff and subcontractors. After considering several options, it was decided to go ahead with an aluminium monocoque carriage driven by two winches and two synthetic Dyneema cables. Although cable driven carriages have been operated in the past, it is believed that the Boldrewood carriage is the first dual cable system. It is expected that once the control system is fully tuned, this will allow a better control of the carriage motions, especially at low speeds where vibrations can be problematic.

The carriage was designed to be a flexible working platform. Equipment can be fitted under the floor with ease through lifting panels. The moonpool is large and allows good visibility for the users, and a lifting platform allows access to the model. The carriage is fitted with Rexroth panels to aid easy attachment of equipment.

The operation of the carriage was based on staff experience and past research about the effects of acceleration or deceleration on people in transport [3] [4] [5]. Table 1 details the expected different modes of operations for the Boldrewood carriage.

Towing tanks all over the world use different systems to damp the waves created by the model or the wavemaker between runs. These systems are very important as they increase the productivity of the facilities by reducing the waiting time between runs. It is usually achieved by the presence of an end beach, at the opposite end to the wavemaker, and in some cases by an additional system on one or both side walls. Over the last few decades, the university staff have extensively used the GKN tank on the Isle of Wight. It was decided to replicate the concept of an automatic side beach system on one wall, as was used there, as it is deemed to be the most effective one, although complex mechanically. The Boldrewood tank is fitted with 12 batches of five beaches each, controlled from the walkway or the carriage (see Figure 4).

A 12 paddle HR Wallingford wavemaker is installed at the west end of the tank. It is capable of generating regular and irregular waves with a maximum height of 0.70m and a significant wave height of 0.37m respectively. It can also generate oblique waves, which is not a conventional feature for a towing tank wavemaker, but it allows static experiments to be performed at varying wave angles using the underwater platform.

The rail alignment in a towing tank is a very important process and must be carefully thought through. Misaligned rails can lead to a bumpy ride and noisy measurements. The Boldrewood towing tank is fitted with 440 refurbished soleplates that were salvaged from the GKN tank on the Isle of Wight when it was closed in 2008. These soleplates allow for horizontal, vertical and roll adjustment of the rails. The rails were delivered in sections and welded in situ in January 2015 (see Figure 6).

A review of existing literature [2] [6] showed the following:

- The concrete should be allowed to settle in once the tank is filled with water. The Australian Maritime College (AMC) tank staff measured deflections of up to 1.2mm in the rail alignment within 12 months of filling the tank;
- A laser or telescope cannot be used due to the temperature gradient in the air;
- The rails must be aligned vertically to follow the curvature of the earth horizontally and in roll (in Southampton, the sagitta for an east to west orientated tank of 138m is about 0.6mm);
- The top faces of the rails must be level to within ±0.1mm over their length.

The tank was filled in June 2015. The rail alignment process was started in January 2016, as it was assumed this allowed enough time for the concrete to settle. The following methods were used, as recommended by the literature review and refined in house:

- A master spirit level with a precision of 0.02mm/m was used for roll adjustment;
- A 0.3mm Dyneema fishing line was attached to one bespoke winch at each rail end. This line has a breaking point of about 25kg and very little stretching, which allowed it to be pulled very tight and reduce the catenary effectively. A microscope was mounted on the rail to look down at the line and perform the adjustment with high precision (see A and B on Figure 8);
- The tank walls are fitted with a small trough in the concrete. This trough was filled with water (a surprising 600litres). Two steel pins were precisely machined. A datum bracket was installed at one end of the tank to adjust the length of the pins so that their pointy end just broke the surface tension of the water (see C and D on Figure 7). Another bracket was moved along the tank to the desired alignment location. Each pin was checked and readjusted to the datum on a regular basis due to the water level changing in the trough with evaporation.

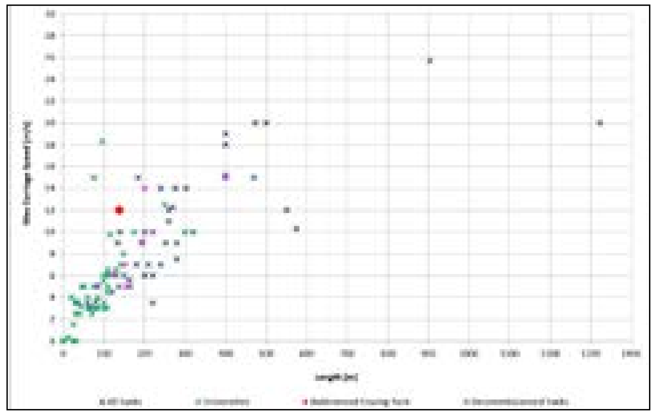

Fig. 2 Review of towing tanks dimensions

Mode of operation	I	II	III
Max. acceleration/deceleration	0 to 0.1g	0.1g to 0.2g	0.2g to 0.25g
Movement restrictions	None	People seated (not necessarily in a seat)	People seated and belted
Max. no. of people	10	10	6

Table 1 – Carriage operation modes

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These methods rely on the human vision, the rail alignment had to be performed by one single person. It took the towing tank technician David Turner about three weeks per rail to finish the alignment process. The Boldrewood towing tank only has a walkway on its south side, so the north rail alignment had to be performed from a floating pontoon, which made it more complicated.

The vertical alignment of the south rail was checked in 20 spots along the tank length in June 2016. This showed that the concrete did not move during that period.

Fig. 3 View of the carriage

Other equipment

The Boldrewood towing tank is fitted with a water treatment system in order to maintain the water quality. This consists in two large sand filters, an ultraviolet lamp and a chlorine injection pump. The system is operated between 18.00 and 04.00 every night, so no recirculation currents are present in the tank during tests. The chlorine levels are monitored on a weekly basis and can be adjusted if necessary when humans are required to be in the tank, for example for swimming experiments.

The limited availability of large ocean basins for research and education has led the University of Southampton to purchase two Qualisys motion capture systems for the towing tank: one for above water measurements and one for under water measurements. The two systems can also be coupled for hybrid measurements. Using reflective markers, the measurements can cover single point trajectories in space or six degrees of freedom for rigid bodies. This technology is versatile and has allowed the university to develop new experimental methods used for various education, research and commercial projects [7].

The towing dynamometer was designed in house by the Wolfson Unit. This is a multiple tow posts design that can accommodate a large range of drag and sides forces, but can also measure heave, pitch, roll, roll moment and yaw moment. The dynamometer is suitable for all types of experiments and can accommodate small and large models.

A 6x2m underwater platform is installed in the tank, about 10m from the wavemaker, where the quality of the waves is best. This can be used as a lifting platform for large underwater vehicles or more often for mooring tests with ship models, wind generator buoys, wave energy devices or offshore platforms.

An underwater Particle Imagery Velocimetry (PIV) system was purchased by the university for the Boldrewood towing tank. This system consists of two cameras housed in a torpedo and a laser sheet. The tank is seeded with small particles and the PIV system measures 3D flow within the laser sheet.

Fig. 4 View of the side beaches

Fig. 5 View of the wavemaker after installation

Fig. 6 Rail welding

Why would anyone build a towing tank today?

Amongst the 9,000+ visitors that have seen the tank since 2015, lots of people ask why the university has decided to build a tank in an age where computational fluids dynamics (CFD) is seen by many as good and mature enough to replace towing tanks. The question is widely discussed in various conferences and magazines in the marine industry. There have been several CFD workshops in the last few years [8] [9] [10] [11] where participants performed CFD calculations on a given hull geometry and benchmark their results against the model tests and/or sea trials results. Looking at the most recent workshops results for calm water resistance, they show large scatter in the results (between 10% and 15% for the Lloyd's Register workshop [10] and ±10% for the Sailing Yacht Research Association workshop [11]). A study performed by the International Towing Tank Conference in 2014 [12] shows that when performed according to the ITTC guidelines, the uncertainty of resistance model tests should be 2% or less. Although CFD is a great tool in the early design stage of ships, especially when it comes to hull form optimisation, these results show that scale model experiments still have and will continue to have a major role to play in the marine industry. CFD results for more complex problems like propulsion, manoeuvring or seakeeping should be treated with even more care, but these are areas where well established experimental procedures have been in place for many years.

The Boldrewood towing tank has been designed with flexibility in mind, so that a wide range of experiments in various domains can be performed in addition to conventional towing experiments, in particular for education and research. To date, the facility has been used for experiments in domains such as sailing (see Figure 9), wave energy, offshore wind, sports engineering, shipping, autonomy and biomechanics. This facility is a great asset to allow students across the whole Faculty of Engineering and Physical Sciences to have exposure to physical experiments and their associated procedures (preparation, calibration, scaling, analysis, etc). At a time when engineers spend most of their time working on computers, it is very important for students to acquire practical knowledge and to understand the importance of validation data for any numerical simulations they may undertake.

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Fig. 7 Rail alignment techniques

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Fig. 8 Motion capture experiments on a free-running sailing yacht (13)