Catching the whale, controlling large ships in ports

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On 16 December 2012 the CMA CMG Marco Polo made her first call at the Port of Rotterdam. This box ship with a capacity of over 16,000 twenty-foot equivalent units (TEU) and the coming sister ships are presently the largest container vessels in the world, but in a couple of months the first of the Maersk Triple E vessels will take the lead with a capacity of 18,000 TEU. This increase in the size of container vessels and similar developments in other shipping segments (bulk carriers: Valemax, cruise ships: Oasis of the Seas, liquefied natural gas (LNG) carriers: Qmax vessels) puts pressure on the existing port and terminal infrastructure in their ports of call. In this article we take a closer look at the impact of these 'whales' on port operations by considering the latest container ships.

Characteristics of large container vessels

The vessels of the Emma Maersk class (launched in 2006) and the MSC Beatrice class (2009) have called at the large container ports for several years now. The main dimensions of the new Marco Polo class and the Triple E class are not very different from those of the Emma Maersk as the first lines of the table below show. It is interesting to note that the Marco Polo is less wide, but can carry more containers. This is due to the more forward position of the deckhouse, a concept first used for the MSC Beatrice and also applied to the Triple E. Going further down the table below a few interesting differences appear. The displacement of the Triple E is significantly larger while the engine power is 20 per cent less.

This is further demonstrated by showing the ratio between installed engine power and displacement: Maersk Triple E has 30 per cent less power per tonne displacement than the other three vessels. This is mainly because the Triple E will be sailing at a lower speed. Because of the lower speed the Triple E has a more full body; hence the larger capacity and displacement. The wind area is also significantly larger, but the ratio bow thrusters/lateral area is almost equal for the Maersk vessels and better than for the other two ships. On the basis of these characteristics one can conclude that the stopping and turning capabilities of these vessels reduces, whereas the capability to control the bow will remain intact.

Together with the larger wind areas (22.5 per cent increase of lateral area), this has consequences for the role of the tugs when manoeuvring in ports.

Manoeuvring strategy

In many ports the common practice is that the tugs await the ships just inside the protection of the breakwaters. Once the stern tug is attached, the assisted vessel can be kept under control much easier, but as it takes several minutes to transfer and fix the towline, the tugs are only able to assist the vessel when it is already well within the port. But as the large container vessels are responding slower to the engine, the strategies need to be adapted: tugs must catch the 'whale' earlier. For some ports this will mean outside the existing harbour entrance, exposed to waves. Extending breakwaters is a solution for this problem, but preparing tugs, tug crew and pilots to assist in waves may be a more cost-effective alternative. Pilots, tug masters and captains are facing the following issues when receiving these big vessels:

- The tug has to connect and assist in waves;
- Pilots and tug masters have to cope with the slower response of the vessel;
- The big vessels are sensitive to wind.

So they'd better be prepared!

Training

It is important that the pilots and the tug masters are well prepared when the large ships call at the port, especially if such a

TABLE 1: DIMENSIONS COMPARED

Parameter	Unit	MSC Beatrice class	Emma Maersk class	Marco Polo class	Maersk Triple E class
Capacity	TEU	13,798	15,500	16,020	18,000
Length oa	m	366.1	397.7	396	399
Beam	m	51.2	56.4	53.6	59
Depth	m	29.9	30.2	29.9	30.2
Displacement	tons	170,520	213,000	205,700	249,000
Engine power	kW	72,240	80,080	80,080	2x32,000
Bow thruster	kW	2x1700	2x2200	2x1800	2x2500
Stern thruster	kW	-	2x2200	-	-
Frontal wind area	m2	2320	2738	2438	2898
Lateral wind area	m2	13435	13366	15667	16373
Power/Displacement	[kw/tons]	0.42	0.38	0.39	0.26
Bow thruster/lateral area	[kw/m2]	0.25	0.33	0.23	0.31

Figure 1: Pictures from a combined training for pilots and tug masters (for LNG carriers)

Figure 2: Simulating an escort tug in the Desdemona simulator

new strategy for the manoeuvre is required. This can be trained in combined simulations involving both the pilot on the container vessel and the master(s) of the tug(s), each of them sailing his ship from a separate simulator. In this way both technical aspects (eg. the time for the tug to respond to the order of the pilot) and the human aspects of the pilot and tug master cooperation (communication) are fully captured. Figure 1 shows some pictures from a recent training where the pilot was commanding an LNG carrier on MARIN's Full Mission Bridge 1, while two experienced tug masters were sailing the bow and stern tugs on two new Compact Manoeuvring Simulators in a dedicated tug configuration with ASD and winch controls.

When carrying out such simulations, the virtual world must be a good representation of the real world. Though feedback from our clients indicates that – based on some 30 years of experience – we usually get quite close, modelling techniques are continuously further improved making use of the ever-increasing computational power.

Tug effectiveness in waves and tug safety

Connecting and assisting with tugs in waves puts different demands upon the tug and the crew. The tug should be designed and have the necessary equipment for assisting in waves. Detailed research regarding this subject was undertaken by MARIN in the SAFETUG joint industry project.

One of the most critical elements when operating in waves are the loads in the towing line: snap loads might result in line breakage. This can be prevented by installing an active or passive towing winch that smoothens out the line forces. At lower wave conditions using a nylon tail in the towing line is also effective for reducing the snap loads. Another measure that can be taken is minimizing the motions of the tug. The latter also has the advantage that it contributes to crew safety and comfort.

Apart from technical measures to improve performance in waves, the effect of ship motions on human performance was studied in SAFETUG. This was done by executing escort simulations on a fixed-base simulator at MARIN and on the Desdemona simulator. The TNO Desdemona simulator is a cabin with a basic bridge mock-up which can only accommodate one subject (tug master) at a time. Inside the cabin a 210 degree scenery is projected. This cabin is mounted in an advanced motion platform (see Figure 2). The tug master had to execute escort manoeuvres in high sea states, while the cabin moved in the same way the tug master's chair would do on the real tug. To measure his workload the master also had to respond to a secondary task: he had to press a foot switch as soon as the red LED on a special headset turned red.

One of the outcomes of this experiment was that tug captains with more experience performed better when handling a tug in waves. They performed their tasks better at a lower work load. So gaining more experience through training has a positive effect on the overall tug performance.

SAFETUG's results were also used to improve our simulator models. Wave response is tuned towards the outcome of the seakeeping tests and MARIN has the capabilities to model complex winch response in the simulation models. Tug operators can play with the winch settings and experience the effect on line loads when assisting in waves.

Presently MARIN is working on a follow up project which will focus on tug safety and response scenarios in emergency situations.

Wind loads

Another important aspect is the modelling of the wind loads. The wind forces on the ship are usually calculated from the wind speed at 10 metre height of the position of the centre of gravity of the ship and wind coefficients describing the forces (frontal, lateral and turning moment) in relation to the wind speed. These wind coefficients are usually based on wind tunnel measurements for a typical open sea wind profile. While this may give acceptable wind loads for fairly open sea areas, using the same approach is not suitable in port areas. The wind field in the port area is highly complex due to the shielding effects of tank farms, high buildings and other ships, and the wind working on the vessel is not uniform over the length and height of the vessel. The variations of the wind speed over the length of the vessel can significantly affect the manoeuvre. Standard wind tunnel measurements give no clue on such effects and the way it can be taken into account in the simulations.

The effect on the vessel can be both ways: overestimation and underestimation of the wind loads. By applying a uniform wind field equal to the wind on open sea, the effects of surface roughness and shielding by obstacles on the wind field is not taken into account. Recent studies by the Technical University Eindhoven for the Port of Rotterdam show that the effects on the wind speed at lower heights can be significant (see Figure 3). This is of relevance for container terminals where the containers stored on the terminal can have a large effect on the wind profile in the port basin right next to it.

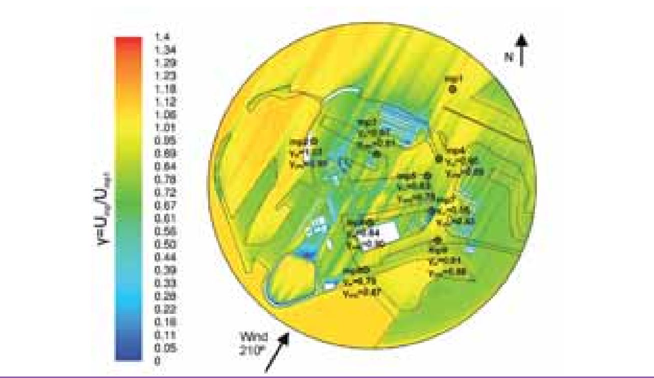

Figure 3: Result of CFD simulations for Port of Rotterdam: contours of normalised mean wind speed in horizontal plane at 15 metres above mean sea level (normalisation is performed using the wind speed at mp1)

From Janssen, Blocken, Van Wijhe, 2012

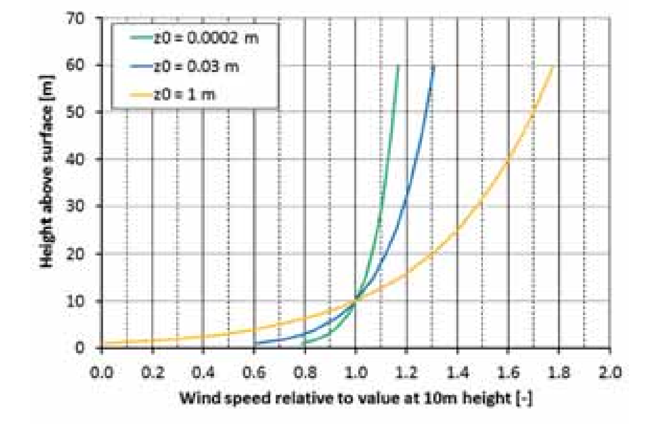

Figure 4: Logarithmic vertical wind profile for different surface roughness.

Figure 5: The Marco Polo virtually entering the Port of Rotterdam during recent simulations

Applying results of such calculated wind fields in combination with regular wind coefficients may on the other hand underestimate the actual wind load as the vertical wind speed profile in the port basin differs significantly from the profile on open sea or in the wind tunnel. This is illustrated in Figure 4, which shows the often applied logarithmic wind profile for different values of the surface roughness: open sea (0.0002 metres), grass land (0.03 metres) and villages (1.0 metres). It can be seen that the profiles are very different. This affects the wind load calculation, especially for the large container vessels for which the height to which containers are stacked on deck increases up to about 45 metres above the water level.

Accurately modelling the wind loads on the big 'whales' in manoeuvring simulations for port areas therefore still has some challenges.

- The spatial variation of the wind speed in the port area, for example, must be captured correctly. CFD calculations are a powerful tool as Figure 3 shows, but there are still questions regarding the most suitable way of modelling. Objects and buildings can be explicitly included in the 3D grid or the effect can be taken into account by just modifying the surface roughness.
- The variation of the vertical profile over the port area must also be taken into account when modelling the port. Both spatial and vertical variation depends on the wind direction.
- And the effect of both horizontal variations (bow in shelter, stern not) and vertical variations of the wind speed (wind profile) must be taken into account in the mathematical model of the ship.

These challenges are subject of the wind load joint industry project (JIP) initiative that has recently been launched by MARIN and a number of partners. With the results of this project, the participants will be able to determine the wind loads more accurately, so that the operating limits of the large container vessels can be determined more precisely. In this way the pressure which the growing ship size puts on the existing port and terminal infrastructure – where wind is often the predominant load factor on ships – will be predicted more accurately, thus taking away uncertainties on port operations by developing an optimised admission policy. With the improved modelling of wind and tug capabilities in waves the pilots and tug masters can also better train and optimise their strategy for catching the whales and bring them safely to shore.

The wind load JIP is open for participants. When interested contact Jos van Doorn

ABOUT THE AUTHOR

Jos T.M. van Doorn graduated in 1982 from Delft University of Technology in Naval Architecture (ship hydrodynamics). Following his graduation he worked for ten years as specialist in ship hydrodynamics at Delft Hydraulics on port and fairway design studies. In 1992 he started working at MSCN. He executed various ship manoeuvring studies for new ports, fairways, bridges and offshore facilities. Since 2005 he is manager of MSCN, the nautical centre of MARIN.

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ABOUT THE COMPANY

MARIN is an independent and innovative service provider, providing hydrodynamic and nautical research for the maritime industry. MARIN's nautical centre MSCN is specialized in nautical and safety studies, ship manoeuvring training and VTS training. Studies are executed for new port and fairway developments (sea going and inland waterways), entrance policies, design of new vessels and for offshore operations. Furthermore traffic and safety studies are executed for developments on the North Sea and for ports and terminals.

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