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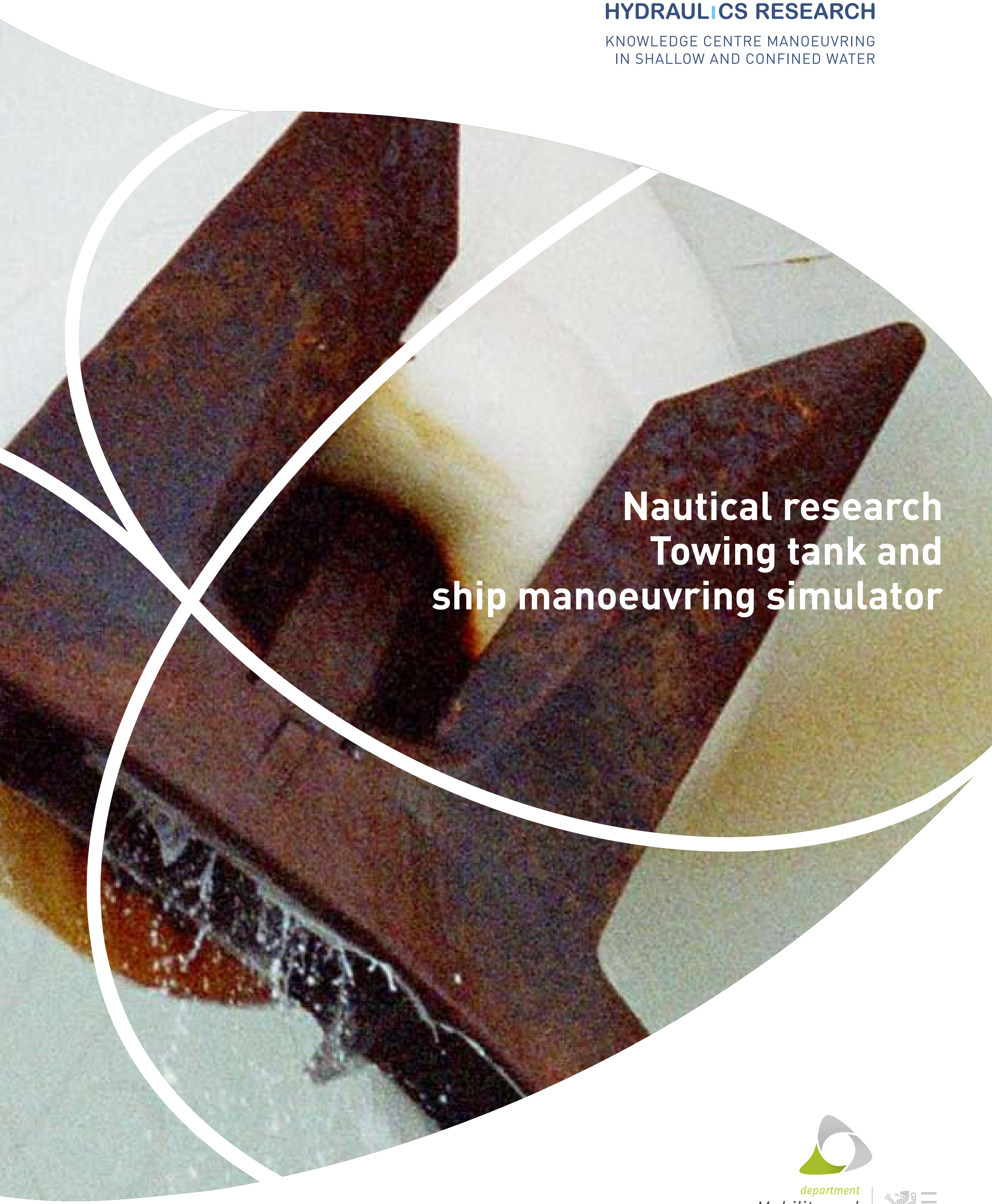
HYDRAULICS RESEARCH

KNOWLEDGE CENTRE MANOEUVRING
IN SHALLOW AND CONFINED WATER



Nautical research
Towing tank and ship manoeuvring simulator

www.watlab.be

department
Mobility and Public Works

1. Knowledge Centre - "Manoeuvring in Shallow and Confined Water"

Ports are important for economic prosperity; this applies especially to the Flemish ports with their supraregional importance; they handle a considerable part of European import and export. Ensuring the accessibility to these ports is thus of crucial importance to maintain economic prosperity.

Shipowners want to transport as much as possible as cheaply as possible. This can be achieved by an increase in scale. Larger vessels can, with a same crew complement and an almost equivalent remaining fixed cost, transport more freight and therefore generate a higher profit. The fact that vessels are becoming larger, with no corresponding immediate increase of the vertical and horizontal dimensions of the navigable waterways is a drawback however. The larger vessels thus must reach the ports via relatively small waterways. This affects their manoeuvrability considerably.

- The limited water depth will change the pressure distribution around the vessel and lead to an increase in hydrodynamic forces. The manoeuvrability decreases which, amongst other things, manifests itself in a substantial increase in the turning circle of the vessel or the required bend radius, e.g. on a river.
- The squat (a combination of a mean bodily sinkage plus a trimming effect) increases by a decreasing keel clearance which makes touching bottom more probable. An analogous remark can be made for entrance channels subject to the influence of waves, such as the

mud accumulates on the fairway bottom. This mud layer requires maintenance dredging to ensure the harbour access. The upper layer however usually consists of highly liquid mud, which is difficult to dredge. Increasing draught of vessels causes keels to make contact with the mud. The manoeuvrability of the vessel is significantly affected even with a small under keel clearance above the mud layer.

Scheur [fairway]. Through the waves the vessel will pitch, heave and roll. With larger vessels, this pitching and heaving response may be less, dependent on the wave spectrum, but the probability of touching bottom nevertheless increases on account of the decreased keel clearance and the greater effect of the rolling motion (due to waves, wind, bends) by vessels with a larger beam.

- There is much shipping traffic to a busy port such as Antwerp. Vessels meet and overtake each other, by which the hydrodynamic pressure fields of both vessels influence each other and forces between both vessels interact. This ship-to-ship interaction can cause the vessels to drift toward each other, resulting in a collision. The increasing size of vessels elevates the probability of such interactions as well.
- Interactions do not only occur between the vessels themselves, but also between the vessel and the river or sea bank. If the vessel is sailing eccentrically in a channel, the hydrodynamic pressure field differs between starboard and port. As a result of this, a lateral force and a bow out moment act on the vessel, usually sucking it to the nearest bank. Smaller under keel clearances still reinforce this phenomenon. At different ports throughout the world (amongst others, Zeebrugge, and to a lesser extent, Antwerp)

In May 2008, the Knowledge Centre "Manoeuvring in Shallow and Confined Water" was established. It has as objective to collect and record the scientific and experience-based knowledge concerning the behaviour of vessels in shallow or confined waterways, to expand this and to keep this knowledge available, in support of the admittance policy and the development of the waterways for vessels bound for Flemish ports and inland shipping. The organization of the Knowledge Centre is that of a co-operation between Flanders Hydraulics Research and the Maritime Technology Division of Ghent University.

2. Towing tank

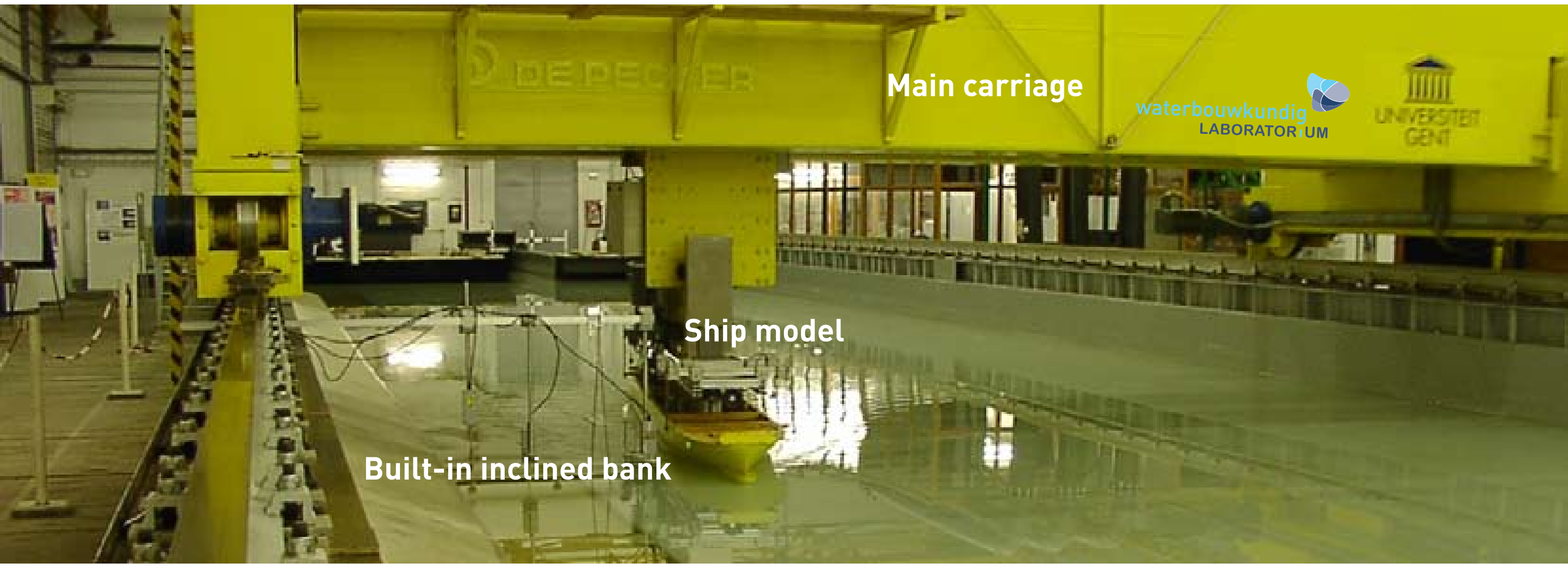
As research into the behaviour of vessels in confined water often requires model testing, a shallow water towing tank was constructed during the years 1992-1993. The "Towing Tank for Manoeuvres in Shallow water (co-operation Flanders Hydraulics Research – Ghent University)" has been a member of the ITTC (International Towing Tank Conference) since 1993. It is equipped with a "Planar Motion Mechanism", a wave generator and an auxiliary carriage or a second beam connected to the towing carriage for the testing and measuring of ship hydrodynamic forces and moments. The automatic control allows the carriage to operate unmanned, so that tests can be automatically carried out and this on a 24/24, 7/7 basis.

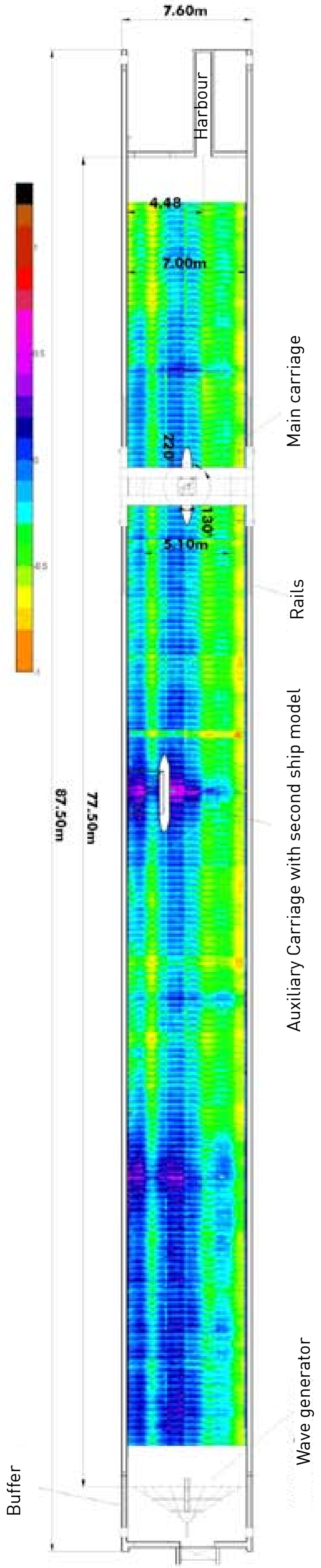
Main dimensions – towing tank

Total length	87.5 m
Effective length	68.0 m
Width	7.0 m
Maximum water depth	0.5 m
Length of ship models	3.5 to4.5 m

The towing tank has a total length of 87.5 m, approximately 68 m of which can be used for tests, and a width of 7 m. The water depth has been intentionally limited to 0.5 m, as Flanders Hydraulics Research only investigates the behaviour of vessels in shallow water, such as typical at ports, entrance channels and canals.

In order to assure the quality of the test results, the rails on which the towing carriage moves have been meticulously aligned: the height difference between the two rails and the transverse deviation of

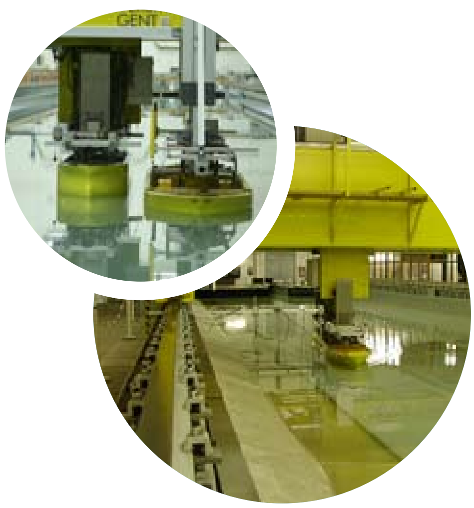


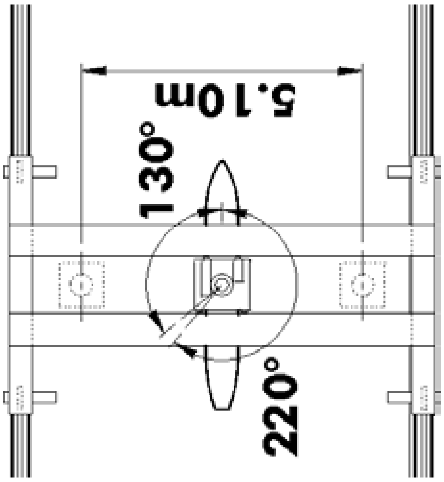


the guide rail is less than 0.5 mm. The height difference over the entire length of the rails is less than 1 mm.

In order to improve the test results for experiments with a very small under keel clearance, extensive maintenance was carried out on the bottom of the towing tank in 2008. The bottom of the towing tank was completely milled level so that the height difference between the lowest and the highest point of the bottom did not amount to more than 2 mm over the entire length of the tank.

The towing carriage is equipped with a "Planar Motion Mechanism". With this, captive manoeuvring tests can be carried out. These are performed via a ship model, equipped with propellers and rudders, which follows a predetermined trajectory imposed by the towing carriage. During this trajectory, the forces acting on the vessel (hull, propeller(s) and rudder(s)) are measured. In this way, a trajectory in the horizontal plane can be imposed to the ship model. The model can move freely along the vertical plane. The measurement results are used to derive mathematical formulas expressing the forces acting on the vessel. This set of formulas is used to predict the manoeuvring behaviour of a vessel during simulations on the manoeuvring simulator.

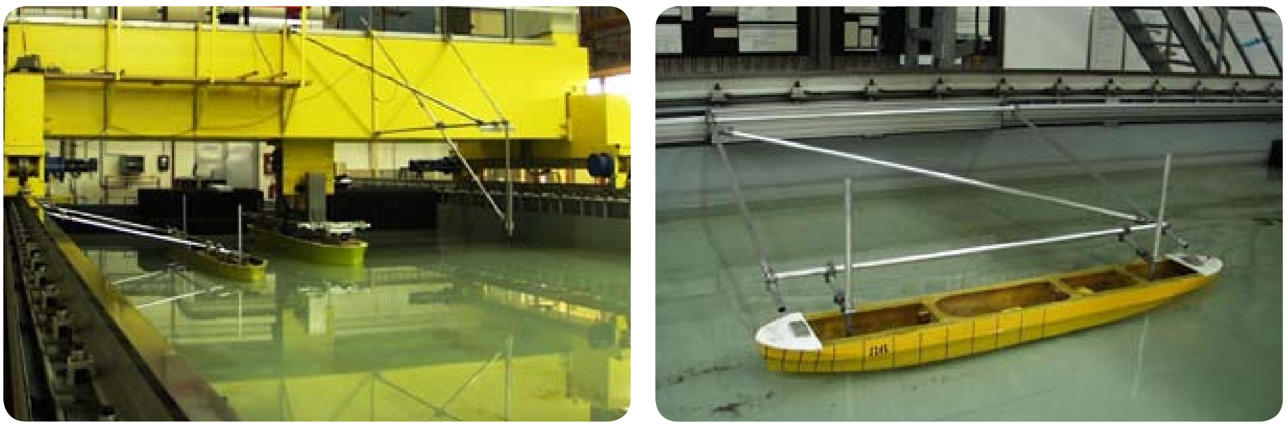




		Main carriage	Lateral carriage	Yawing table
Position	Min	0.00 m	-2.55 m	-130.0 °
	Max	68.0 m	+2.55 m	+220.0 °
Velocity	Min	0.05 m/s	0.00 m/s	0.00 °/s
	Max	2.00 m/s	1.30 m/s	16.0 °/s
Acceleration	Max	0.40 m/s²	0.70 m/s²	8.0 °/s²
Power output		4 x 7.2 kW	4.3 kW	1.0 kW

The towing tank is also equipped with a wave generator enabling the study of wave induced vertical motions made by a vessel induced by waves. A wave generator can generate both regular as well as irregular waves. This wave generator allows captive sea keeping tests to be carried out, with which the track of the ship model is imposed by the towing carriage in the horizontal plane. The vertical response under influence of the generated wave pattern is not impeded and can therefore be measured experimentally. The wave generator is driven by an electro-hydraulic unit with as kinematic properties: impact length 0.3 m, velocity 0.6 m/s, acceleration 4.4 m/s².

In order to enable ship interaction tests, the towing tank is equipped with an auxiliary carriage. This auxiliary carriage can propel a second ship model along a straight course at a maximum velocity of 1.2 m/s, so that tests can be carried out with two encountering or overtaking vessels.



Auxiliary carriage for ship interaction tests

An alternative for the execution of ship-ship interaction tests is a second beam, which is mounted on a fixed frame that can be attached to the carriage.

Ship interaction tests: tugboat and Container ship.

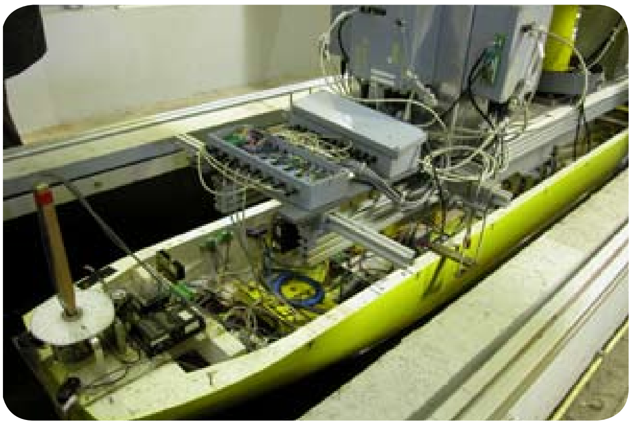
Ship-ship interaction tests: Aframax and VLCC

During spring 2009 the towing carriage was adapted so that free running manoeuvring tests with a high level of automation can be carried out as well.

The towing tank application software comprises both the control of the three horizontal degrees of freedom, rudder, propulsion and other auxiliary equipment, such as the communication between the PC and the DIOCs (Direct Input-Output Control). The communication between the DIOCs and the PC can run through a serial port or an Ethernet connection.

The DIOCs provide for:

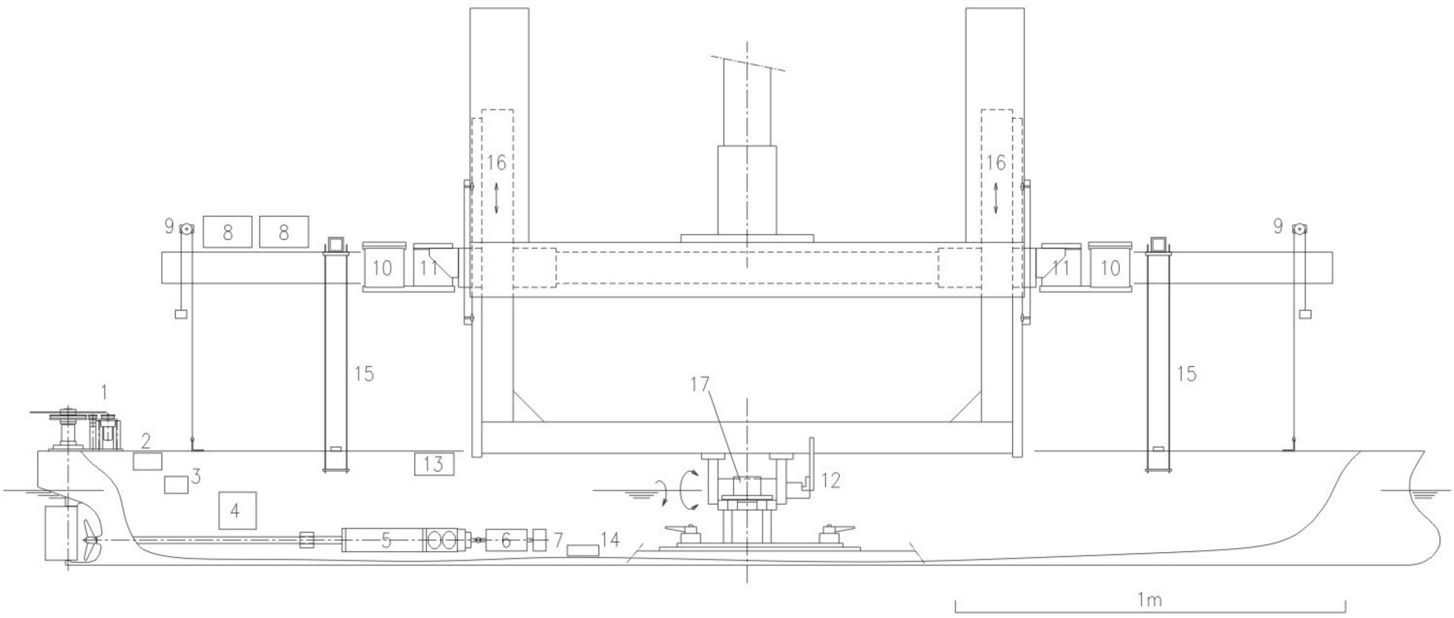
- The control of the input ports;
- The logging of the input ports;
- The control of the output ports;
- The on and off switching of the logging accordant to a predetermined track.



DIOCs for communication with the computer

The control and measurement are fully integrated. A mechanical safety device was installed to prevent the ship model from touching bottom, which could cause damage to the hull, rudder(s), propeller(s) and/ or force gauges.

1. Rudder mechanism	7. Propeller revolutions counter	13. Propeller control
2. Electronic rudder	8. Sensor amplifier	14. Bilge water safety device
3. Bilge pump (bilge water pump)	9. Sinking meter (4x)	15. Vertical motion limiter (4x)
4.Battery	10. Longitudinal force gauge (2x)	16.Vertical guide rails
5.Propelling force and shaft coupling torque gauge	11. Transversal force gauge (2x)	17. Universal joint (pitching and rolling motions)
6. Propeller driving motor	12. Roll moment meter	



SOME RECENT PROJECTS

Nautical bottom

The nautical bottom is defined by PIANC (International Navigation Association) as the level where the physical characteristics reach a critical limit beyond which contact with a ship's keel causes either damage or unacceptable effects on controllability and manoeuvrability.

The concept of the nautical bottom is often applied with mud covered beds. For reasons of survey technology, the density of the mud is used to determine the critical limit. For the Port of Zeebrugge, e.g., the nautical bottom has a density level of 1200 kg/m³. This level is based on experimental research carried out at Flanders Hydraulics Research since 2001.

The results of simulator research should however be checked against reality. This requires, amongst other things, the monitoring of arriving and departing deep-draughted vessels and a follow-up of the evolution of the mud layer characteristics. Enabling the passage of deep-draughted vessels - this also applies to larger container ships with a capacity of up to 14000 TEU - over the mud layers requires an adequate training of the pilots involved. More research proved to be required for this.

In 2008, a new consolidated mathematical model was implemented in the simulators enabling the simulation of a vessel's behaviour above and in contact with any realistic mud layer. The year was concluded with the implementation of experimental research aimed at the behaviour of bow thrusters in muddy navigation areas.

Bank effects

The asymmetrical flow around a vessel, such as induced through the proximity of banks, leads to pressure variations between the starboard and port sides. Consequently, the vessel will be attracted to the nearest bank, while the bow is pushed towards the fairway. The effect is, of course, largely dependent on the distance between the vessel and the bank, but also on the vessel's speed and under keel clearance. Control of the vessel will become impossible with too strong bank effects. A reliable estimate for these bank effects is of importance in order to be aware of the limit conditions for safe traffic.

A website was built for this specific research: http://www.bankeffects.ugent.be.

The research contributes toward determining the limits of safe shipping traffic to the Flemish ports.

The ship passes along the built-in banks to measure the ship-bank interaction forces.

Ship-ship interaction

Applications of ship-to-ship interaction for the transfer of liquid cargoes such as oil and LNG* will greatly increase in the future. It is expected that these complex operations will increasingly take place under adverse weather conditions. In order to better understand the hydrodynamic effects, which are of great importance to these manoeuvres, a research project entitled 'Investigating hydrodynamic aspects and control strategies for ship-to-ship operations' was set up, co-ordinated by MARINTEK (Trondheim, Norway) and financially supported by the Research Council of Norway.

The principal objective of this research project is that of improving the current ship-to-ship interaction training on ship manoeuvring simulators by enhancing the knowledge of the complex flows arising between vessels that sail closely to each other. The project comprises four work packages: 1 CFD* calculations, 2 PIV* measurements, 3 mathematical modelling for simulators, 4 nautical safety and control aspects.

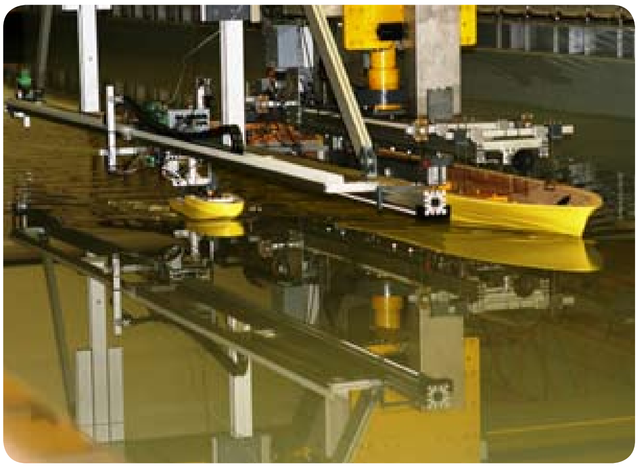
Within the scope of the third work package, model tests have been carried out in the Towing Tank for Manoeuvres in Shallow Water. A model of an Aframax tanker was attached to the PMC* of the towing tank, whilst a VLCC* model was directly connected to the towing carriage. Forces, moments and displacements were accurately measured on both ship models. The water surface was monitored by three wave gauges.

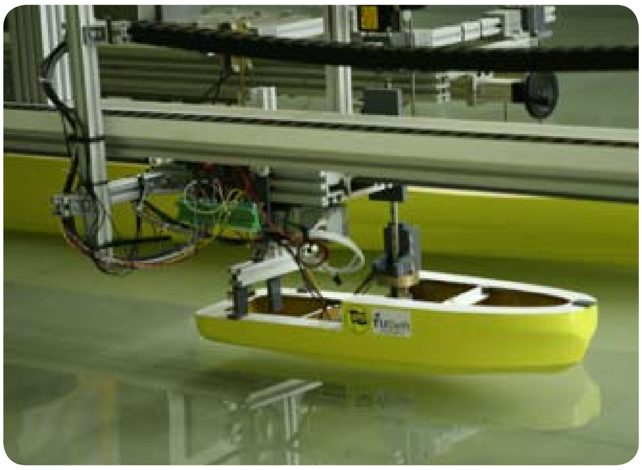
Website: http://www.sintef.no/Projectweb/STSOps

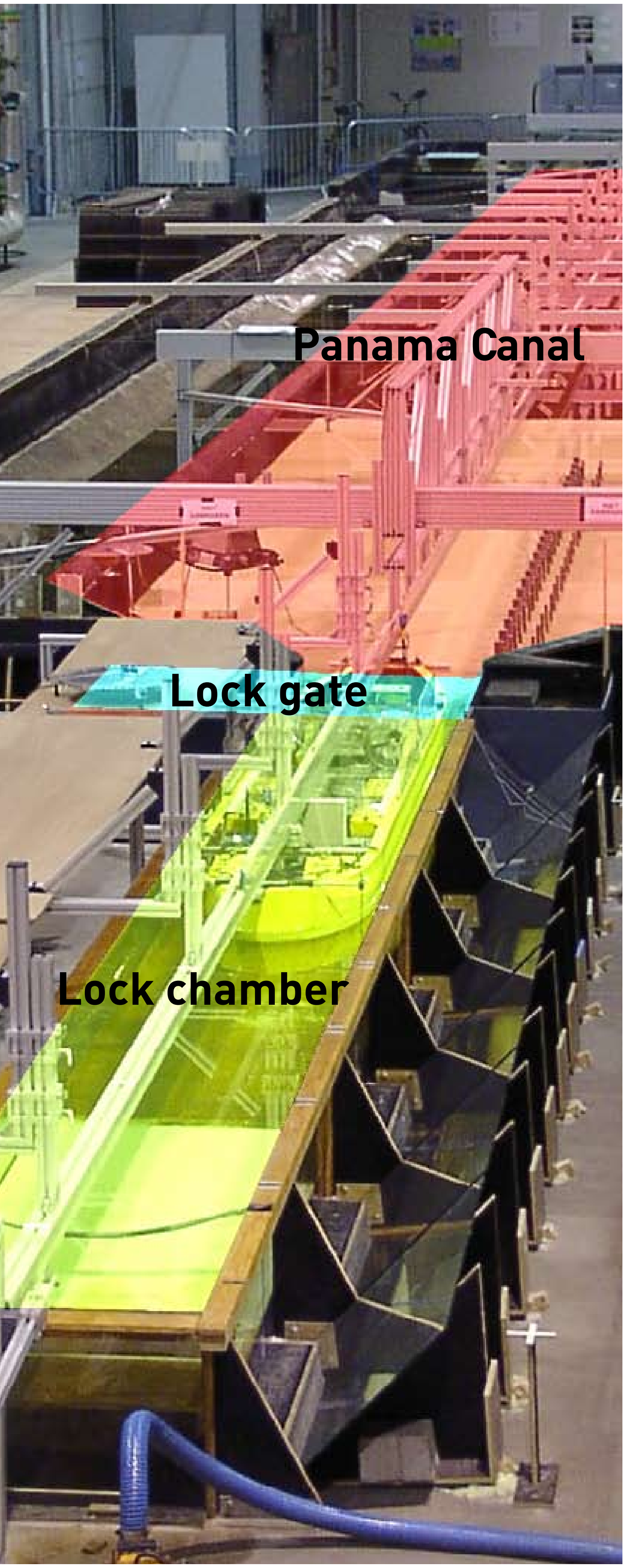
*LNG: liquefied natural gas, CFD: computational fluid dynamics, PIV: particle image velocimetry, PMC: planar motion carriage, VLCC: very large crude oil carrier.

Tugboat bow wave interaction

When a tugboat is close to the bow of a container ship, its dynamic behaviour and controllability will substantially change. Tests were carried out with models in the Towing Tank for Manoeuvres in Shallow Water in order to determine these effect and their interdependencies. For a clear understanding of the physical phenomena arising in the proximity of a container ship and a tugboat, the flow around the container ship and tugboat has been registered. Based on the measurements from the towing tank, a numerical model will be validated in order to improve the prediction of motion behaviour. This research is carried out on behalf of the towing and salvage company URS by a student from the Delft University of Technology within the scope of his Master's thesis for a Master of Science degree.







Panama (Research outside the towing tank)

The Consorcio Post-Panamax commissioned Flanders Hydraulics to carry out a scale model study for the navigation in the new designed locks (Third Lane) for the Panama Canal. The design vessel is a 12000 TEU container ship. The layout comprises a lock without an approach wall, with a permeable approach wall or with a closed approach wall against which the vessel can align or be moored before entering the lock, such as is presently the case in the Panama Canal locks. Different situations for this 3-stage lock were required to be examined, both the entering as well as the exiting at the ocean side, as well as the lake side and the sailing from chamber to chamber.

The tests took the density variations between the ocean and the lock into account. Tugboat assistance, entry method and choice of approach wall were deduced from these measurements.

Support for the probabilistic admittance policy to the Flemish ports:
Start-up of the ProToel programme for Zeebrugge Port

For the entry to the Port of Zeebrugge there is a deterministic admittance policy which requires a minimum under keel clearance over the entire itinerary. Moreover, the transverse current velocity at the port moles may not exceed a maximum value.

A tidal window can be determined on the base of predictions of current and tide. A specific vessel shall use it to sail, problem-free, an entire itinerary (for example, from Kwintebank to Albert II dock in the Port of Zeebrugge). However, a probabilistic analysis, which takes the waves, the resulting vessel motions and bottom touching probability into account, allows a better determination of the tidal windows.

Within the scope of this project, a programme to determine a probabilistic tidal window was implemented. The databank of vessel motion characteristics has, with the aid of model tests and numerical calculations with Seaway and Aqua+, been expanded to vessels with a length of 400 m (E- type of Maersk Sealand). Local information is available for currents, the astronomical tides and standard wave spectra for the years 2008 and 2009. Furthermore, it is possible to retrieve up-to-date predictions of current, tides and wave spectra from the HYDRA server and to use these during the calculations.

The user can select a vessel, as well as the draught and the itinerary and indicate the date and time. The results of the calculations are automatically saved in an XML format and can be directly viewed as a table in ProToel (Figure 1). This table can be exported to a PDF.

ProToel Results

Scheepsromp	W100	Traject	KWB_-_Z-All_K120_(S1)
Maximum Diepgang [m]	15.5	Datum van reis	01/08/2008 CET
GM [m]	0.0	Golf	true

Ligging		Grenswaarde	13:45 CET	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15	16:30	16:45	17:00
Kwintebank	Tijdstip [CET]		13:54	14:09	14:24	14:39	14:54	15:09	15:24	15:39	15:54	16:09	16:24	16:39	16:54	17:09
	Getij Zeebrugge [m LAT]		4.63	4.69	4.71	4.67	4.58	4.52	4.36	4.26	4.04	3.92	3.68	3.55	3.30	3.18
PvhZ-SZ	Tijdstip [CET]		15:10	15:25	15:40	15:55	16:10	16:25	16:40	16:55	17:10	17:25	17:40	17:55	18:10	18:25
	Getij Bol van Heist [m LAT]		4.51	4.39	4.24	4.08	3.91	3.74	3.56	3.37	3.18	2.96	2.71	2.44	2.17	1.91
PvhZ-Strekdammen	Tijdstip [CET]		15:25	15:40	15:55	16:10	16:25	16:40	16:55	17:10	17:25	17:40	17:55	18:10	18:25	18:40
	Getij Zeebrugge [m LAT]		4.36	4.21	4.04	3.86	3.68	3.49	3.30	3.09	2.88	2.63	2.35	2.08	1.82	1.58
Zeebrugge A2 K120	Tijdstip [CET]		15:42	15:57	16:12	16:27	16:42	16:57	17:12	17:27	17:42	17:57	18:12	18:27	18:42	18:57
	Getij Zeebrugge [m LAT]		4.16	4.04	3.80	3.68	3.43	3.30	3.02	2.87	2.54	2.35	1.99	1.81	1.50	1.35
Kwintebank-Scheur	Min BrutoUKC tov NautBodem [%]	15.00	35.00	34.62	33.63	33.02	31.63	30.89	29.35	28.55	26.90	26.04	24.22	23.22	21.01	19.85
	Min BrutoUKC tov NautBodem [m]	2.32	5.42	5.37	5.21	5.12	4.90	4.79	4.55	4.42	4.17	4.04	3.75	3.60	3.26	3.08
	TrajectPunt		206	205	206	204	206	205	206	204	206	204	206	204	206	204
Scheur_West	Min BrutoUKC tov NautBodem [%]	15.00	34.62	33.63	33.02	31.63	30.89	29.35	28.55	26.90	26.04	24.22	23.22	21.01	19.85	17.63
	Min BrutoUKC tov NautBodem [m]	2.32	5.37	5.21	5.12	4.90	4.79	4.55	4.42	4.17	4.04	3.75	3.60	3.26	3.08	2.73
	TrajectPunt		113	114	114	114	113	114	113	114	113	114	113	114	113	114
Pas_van_het_Zand	Min BrutoUKC tov NautBodem [%]	12.50	34.12	33.48	32.04	31.28	29.74	28.94	27.26	26.40	24.55	23.51	21.19	19.98	17.71	16.67
	Min BrutoUKC tov NautBodem [m]	1.94	5.29	5.19	4.97	4.85	4.61	4.48	4.23	4.09	3.80	3.64	3.28	3.10	2.75	2.58
	TrajectPunt		1	2	1	2	1	2	1	2	1	2	1	2	1	2
	Min BrutoUKC tov TopSlib [%]	-7.00	34.12	33.48	32.04	31.28	29.74	28.94	27.26	26.40	24.55	23.51	21.19	19.98	17.71	16.67
	Min BrutoUKC tov TopSlib [m]	-1.08	5.29	5.19	4.97	4.85	4.61	4.48	4.23	4.09	3.80	3.64	3.28	3.10	2.75	2.58
	TrajectPunt		1	2	1	2	1	2	1	2	1	2	1	2	1	2
Zeebrugge_Ingang	Min BrutoUKC tov NautBodem [%]	12.50	34.12	33.14	32.04	30.90	29.74	28.53	27.28	25.98	24.55	22.98	21.19	19.39	17.71	16.17
	Min BrutoUKC tov NautBodem [m]	1.94	5.29	5.14	4.97	4.79	4.61	4.42	4.23	4.02	3.81	3.56	3.28	3.00	2.75	2.51
	TrajectPunt		0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Min BrutoUKC tov TopSlib [%]	-7.00	34.12	33.14	32.04	30.90	29.74	28.53	27.28	25.96	24.55	22.98	21.19	19.39	17.71	16.17
	Min BrutoUKC tov TopSlib [m]	-1.08	5.29	5.14	4.97	4.79	4.61	4.42	4.23	4.02	3.81	3.56	3.28	3.00	2.75	2.51
	TrajectPunt		0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Max stroming [knts]	2.00	2.03	1.86	1.70	1.52	1.31	1.07	0.82	0.60	0.58	0.70	0.83	0.97	1.12	1.28
	TrajectPunt		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zeebrugge	Min BrutoUKC tov NautBodem [%]	10.00	28.26	27.52	26.00	25.22	23.59	22.75	20.99	20.03	17.86	16.67	14.30	13.19	11.17	10.22
	Min BrutoUKC tov NautBodem [m]	1.55	4.36	4.27	4.03	3.91	3.66	3.53	3.25	3.10	2.77	2.58	2.22	2.05	1.73	1.58
	TrajectPunt		611	601	611	610	611	601	611	611	611	611	611	601	611	601
	Min BrutoUKC tov TopSlib [%]	-7.00	10.20	9.45	7.93	7.15	5.53	4.68	2.92	1.97	-0.20	-1.39	-3.76	-4.87	-6.90	-7.85
	Min BrutoUKC tov TopSlib [m]	-1.08	1.58	1.47	1.23	1.11	0.86	0.73	0.45	0.30	-0.03	-0.22	-0.58	-0.75	-1.07	-1.22
	TrajectPunt		611	601	611	610	611	601	611	611	611	611	611	601	611	601
Zeebrugge_Kaai	Min BrutoUKC tov NautBodem [%]	10.00	28.26	27.52	26.00	25.22	23.59	22.75	20.99	20.03	17.86	16.67	14.30	13.19	11.17	10.22
	Min BrutoUKC tov NautBodem [m]	1.55	4.38	4.27	4.03	3.91	3.66	3.53	3.25	3.10	2.77	2.58	2.22	2.04	1.73	1.58
	TrajectPunt		615	615	615	615	615	615	615	615	615	615	615	615	615	615
	Min BrutoUKC tov TopSlib [%]	-7.00	10.20	9.45	7.93	7.16	5.53	4.68	2.92	1.97	-0.20	-1.39	-3.76	-4.87	-6.90	-7.85
	Min BrutoUKC tov TopSlib [m]	-1.08	1.58	1.47	1.23	1.11	0.86	0.73	0.45	0.30	-0.03	-0.22	-0.58	-0.76	-1.07	-1.22
	TrajectPunt		615	615	615	615	615	615	615	615	615	615	615	615	615	615
Kans op bodemraking		1.00E-2	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0

Save

Results of ProToel calculations

3. Simulator

The ship manoeuvring simulator comprises various components. There is firstly the mathematical model. This is the calculating core behind vessel motions. Different forces act upon a sailing vessel: forces generated by the movement of the vessel through the displaced water, by wind, current, waves and other passing vessels.

Secondly, the simulator has a navigation bridge. From the instruments, the radar and the exterior view through the windows of the simulated bridge, the captain or pilot can see how the vessel behaves. With adaptive commands (rudder(s), telegraph, tugboat assistance) he/she steers the vessel. Dependent on these commands, the interaction of forces on the vessel can be calculated. From this, the speed and the new position of the vessel is calculated and displayed on instruments and radar. In this manner, manoeuvring is simulated as realistically as possible.

Mathematical model

The most important component of the simulator is the mathematical model. On the one hand, it predicts the effect of external forces acting upon the vessel and on the other hand, the hydrodynamic forces acting on the vessel's hull, rudder and propeller.

The mass and all forces acting upon the vessel are calculated five times per second. The new position, speed and course of the vessel are derived from this. At this new position, all the forces are calculated anew for a next time-step. From these calculations again the position, speed and course of the vessel can be derived allowing the vessel to continue to sail up to the end of the manoeuvre.

Ship's bridge

The ship's bridge is equipped with the necessary instruments and control devices for the steering of the various types of vessels (e.g. container ship, cruise ship, tugboat etc.).

Instructor area

The exercise conditions (ships, place, current, wind etc.) can be set up in the instructor area. It is also possible to set the atmospheric conditions of the exterior view. These can range from a very calm sea with a haze up to rough storm conditions.

The instructor controls the movement of other vessels and can thus stimulate the navigator on the bridge to anticipate this. The instructor also operates tugboat assistance requested for, bridges, lock chambers and ship traffic lights.

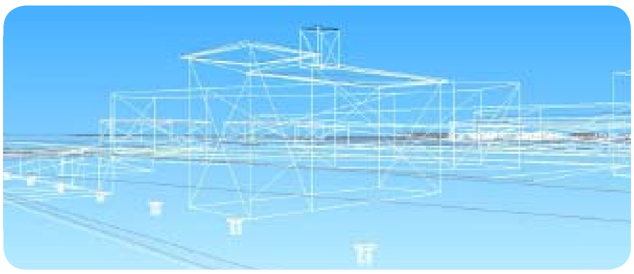
Exterior view

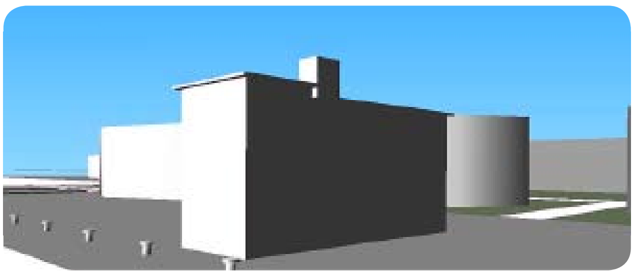
The exterior view is a display of the surroundings visible from the ship's bridge up to a distance of some 10 kilometres on both sides of the waterway. The time for creating an exterior view can be estimated to be approx. 30 to 40 working days, but it strongly depends on the extend and the detailing of the surroundings to be displayed.

The first task when creating an exterior view is to explore and to photograph the environment; the objective of this will be clarified later.

After the on site work, the design phase follows. One starts with making a wire frame model. Angles, lines and surfaces are added at the correct height in order to obtain a three-dimensional representation of the surroundings. The wire frame model must still be "clad". This can be accomplished through colouring the different surfaces. Finally, parts of the photos of the area are draped as a layer over the wire-frame model. The buildings are finished similar to as they are in reality.

Later, "other" vessels are also inserted which will meet the "own vessel" controlled on the bridge during the simulation.





Finally animations such as smoke, undulating water, weather conditions, indicating lights, ambient sound etc. are added to the exterior view.

Research

Simulation techniques can be applied for testing specific proposals for new designs of ports, approach/ entrance channels by qualified pilots. These persons can assess whether a new design does not hinder navigation so that the limits for safe traffic, the maximum dimensions of the vessels calling at a port, the maximum allowed wind or current on entry, what action to take by poor visibility etc. can be defined.

It is also possible to examine if new nautical procedures and auxiliary resources improve safety, e.g. use of tugboats, moving of buoys etc.

RECENT PROJECTS

Arrival and departure regulation for 8000 and more TEU container ships with a maximum draught of 145 dm.

Location

'Notice to Mariners 02-2005' mentions that from September 2005 on the arrival and departure for container ships with a length from 340 m up to a maximum of 360 m is regulated. Container ships having the mentioned length can only have the respective draughts of 140 dm and 130 dm. Shipping companies were however, on their request, granted exceptional exemptions on the base of which some large container ships departed with a draught of 135dm.

To have examine the influence of the new generation of container ships – with lengths exceeding 360 m – on shipping traffic on the Western Scheldt, the Shipping and Assistance Services requested research to scientifically validate a new arrival and departure regulation.

Research

The dimensions of the examined container ships were selected in accordance with the maximum size of existing or planned container ships. The dimensions of these vessels are given in the table below.

	MAERSK	CMA-CGM	MSC	MAERSK
TEU	8400	11400	13230	14000
LOA (m)	352.0	365.5	381.0	397.6
LPP (m)	331.8	349.5	362.4	376.0
B (m)	42.8	48.4	51	56.4
T1 (m)	12.2	12.8	13.1	13.1
T2 (m)	14.6	15.4	16.0	16.6

The Western Scheldt is a winding river characterized by a limited water depth and a limited width. Predicting the behaviour of the container ships on the river required the setup of an extensive mathematical modelling which takes the phenomena given below into account:

- Manoeuvring behaviour in open water with an under keel clearance varying from 10% to 100% of the vessel's draught;

- The influence of banks on the manoeuvring behaviour;
- The influence of the interaction with other vessels on the manoeuvring behaviour.
- Apart from the influence of the restricted sailing environment on the manoeuvring characteristics, squat also plays a significant role in the accessibility for large container ships. Squat is the sinking and trimming of the vessel under the influence of the disturbance caused by its sailing speed in surrounding water. If a vessel sails in very shallow water, then this extra sinking may be responsible for bottom touching or serious vibrations may occur.

Within the scope of the study 689_04, extensive research of squat was performed focussing on the effect of the below-mentioned parameters:

- Forward speed through the water;
- Propeller action;
- Transverse speed through the water;
- Yaw rate;
- Other shipping traffic;
- Banks.

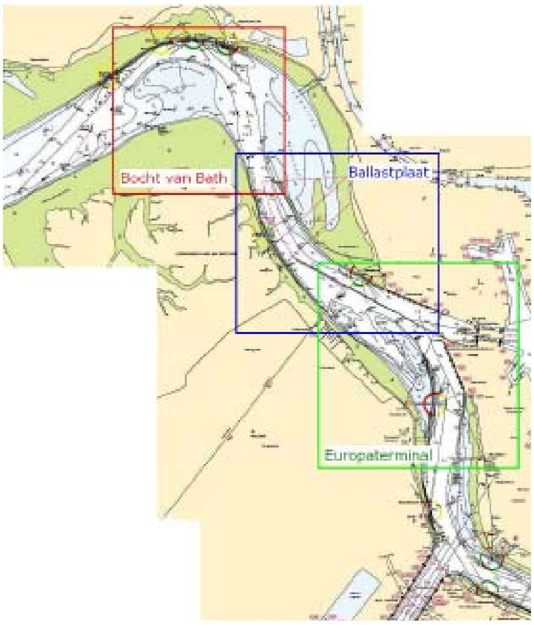
The models for squat and manoeuvring behaviour in confined waters were implemented into the mathematical model of the ship manoeuvring simulators.

Evaluation

The accessibility for the examined container ships was evaluated on the basis of real-time simulations carried out on both ship manoeuvring simulators, SIM360+ and SIM225. During these simulations, the most difficult scenarios were simulated as prescribed by the Steering Committee. It concerned head on encounters between two large container ships at three unfavourable locations on the Scheldt (see figure) by a maximum ebb current and maximum flood current. Both the approaching as well as the departing container ship, were steered by pilots on a separate simulator bridge for which a coupling of both simulators was necessary.

This required ten simulation days, with 112 encounters carried out in six different situations (3 locations by 2 current situations). For each of these situations, the encounters could be evaluated on the basis of the lateral distance kept during the encounters and the distance kept by both vessels up to the line of buoys.

As an example, the evaluation of encounters is visualized in the bend of Bath by a flood current. The different encounter locations are depicted in a colour which indicates the reserves with which the encounters were carried out. Low evaluation figures (see legend) correspond to favourable



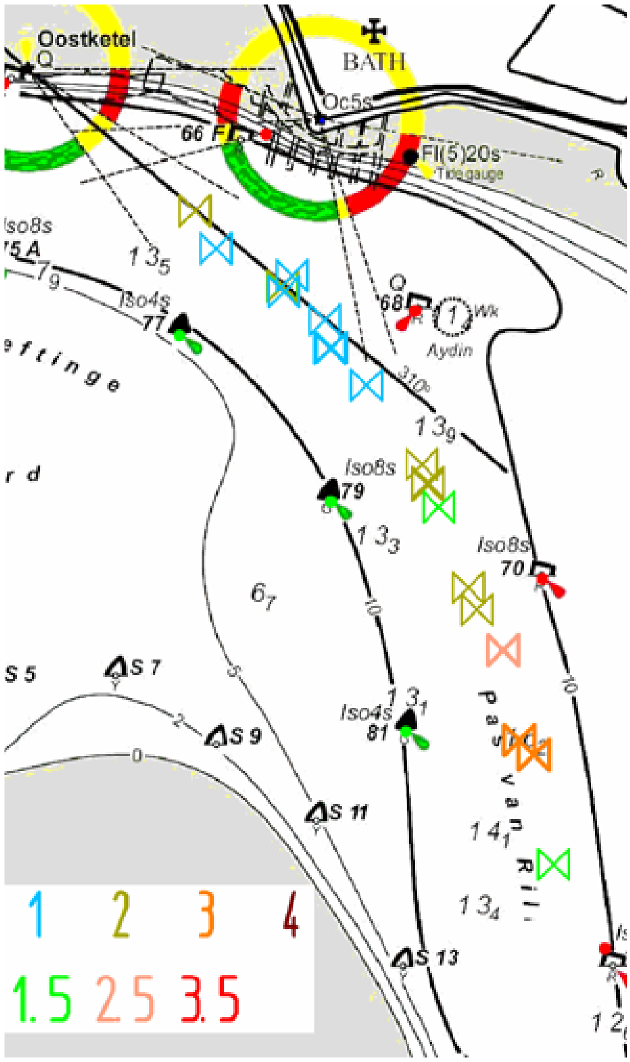
encounters.

Encounters near to buoy 68 were carried out with a generally favourable outcome. Encounters more to the south were subject to greater difficulties.

Results

From the research that was carried out, preconditions could be formulated connected to the arrival of larger container ships to the port of Antwerp.

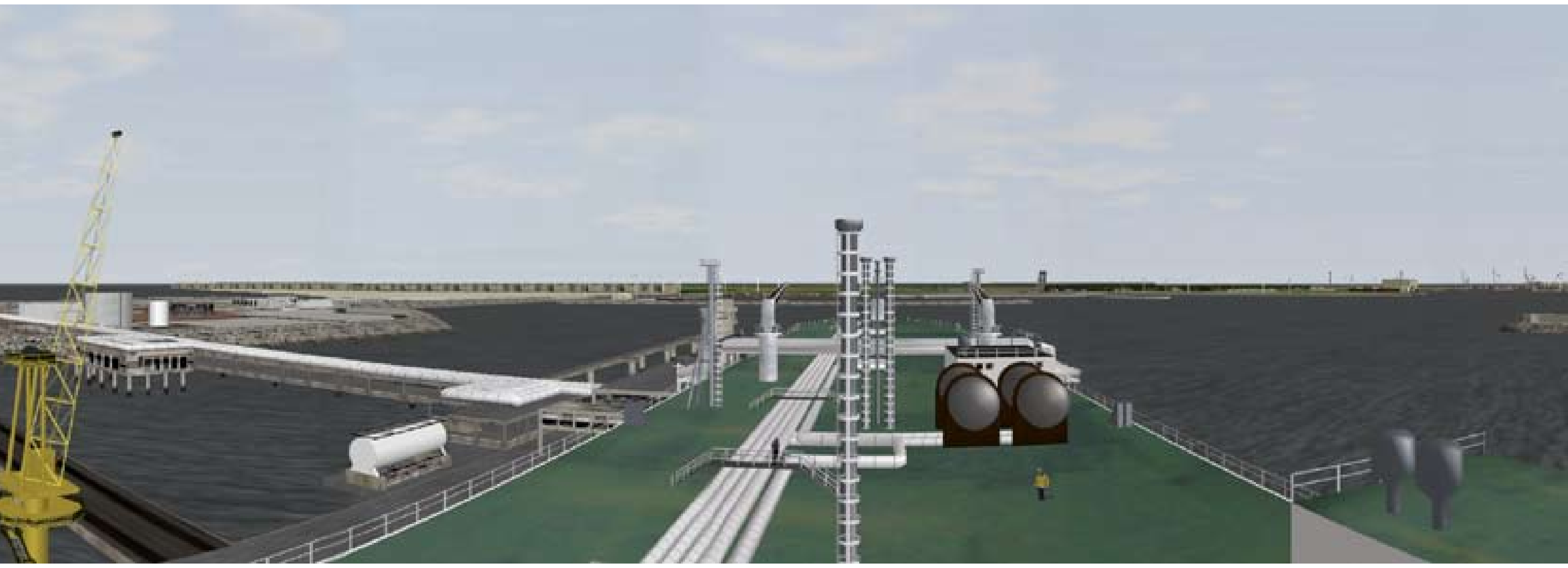
Accordingly, encounters with large vessels at some locations turned out to be unrecommendable and valuable data were obtained regarding the squat with large container ships. Moreover, it appeared that the approach or departure with relevant container ships should be carried out in an expedient manner and that also the other shipping traffic is required to be attuned to these container ships. More extensive research (amongst other things, by low water conditions) is required to supplement the research in study 689_04.



aasland Port, accessibility for a 400 m container ship

In this study the accessibility of a second lock, which gives access to the Waasland Port (Antwerp harbour), was examined for a container ship with a length of 400 m. Currently, the Kallo Lock is the only access way to this part of the port's left bank. The vessel has a beam of 56.4 m whilst the lock has a width of 68 m and a length between the outermost gates of 500 m. In previous studies, the accessibility was examined for a bulk carrier, and a 350 and 366 m container ship. The entrance layout of the 2nd lock on the Waasland canal, as amended in the design phase in 2007, was again used in this study. Additionally, wheel fenders with their depression properties were installed at all corners of the lock as indicated by the Municipal Port Authority.

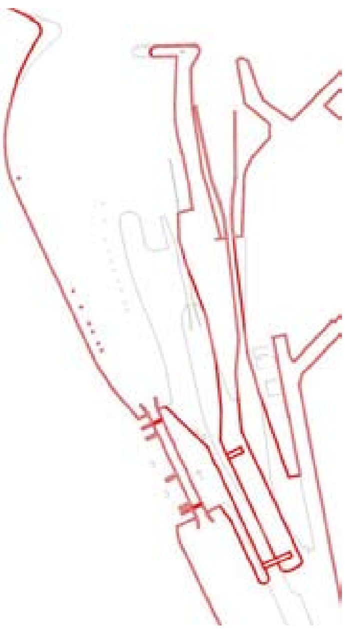
These real-time simulations were carried out by the river pilots at the Deurganck Dock and by the pilots of CVBA Brabo on the Waasland canal while assistance was provided by the tugboat captains of URS and the port authority towage service. The objective of the simulations was to evaluate the conditions to be met in order to safely pilot this 400 m container ship in and out the lock. Wind conditions with different wind directions and wind speeds corresponding to 5 and 6 Bf were applied. Tugboat configurations were assessed as optimal when the pilots could safely execute manoeuvres with a minimum contact with the wheel fenders in the lock.



Manoeuvre simulations - largest sea lock within Terneuzen complex

The project's largest sea lock within the Terneuzen complex (see figure) is accessible for vessels with a length of up to 366m and a beam up to 49m. During this study, the behaviour of both a bulk carrier as well as a container ship having the maximal dimensions was studied in the outer port configuration by means of a two-dimensional real-time simulation. It encompassed an entry and departure simulation carried out by the river and canal pilots on the basis of a two-dimensional plan view, or bird's eye view, of the vessel and the surroundings.

The study yielded information on the required stopping distance for the studied vessels; the optimal position of the sea lock within the complex; the optimal configuration of the port entrance and the necessary tug assistance depending on the wind condition.



Flexible tugboat alternative for the protecting pontoons at the West Lock, Terneuzen

During 2008, the bascule bridges of the West Lock at Terneuzen were replaced with new bridges built at a larger distance from the lock chamber. As a consequence the probability of car carriers hitting the sensitive superstructure of the bridges was reduced. Simulation research examined which tug assistance was required to protect the new lock configuration instead of protecting pontoons (the buffer pontoons AK3 and AK4 and the Europa barge).

Further, the influence of the flexible deployment of towing vessels was examined. Recommendations were formulated with respect to the most favourable tugboat configuration dependent on wind conditions.

A view of the AK4 pontoon during the entry of a car carrier. This pontoon could be replaced by the flexible use of a tugboat.

The position, velocity components and forces acting upon the vessel during simulation runs are saved and can thereafter be used for further analysis.

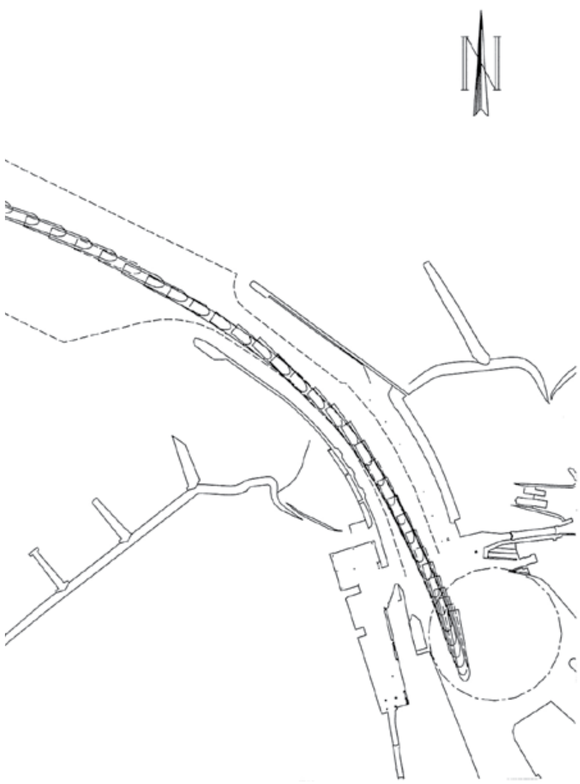
Carrying out real-time simulations on simulator SIM225.

Training

The simulator has a certificate from the Maritime Inspectorate and can be used for the training of ship's officers.

What do these navigators do on the simulator? They sail and manoeuvre with small and large vessels in the most difficult situations conceivable:

- They sail into locks and to quays on a river and carry out anchoring manoeuvres;
- They approach the various jetties and terminals and moor to these;
- They learn to work with tugboats in an efficient and safe manner;
- They are trained to follow correct procedures and acquire a number of necessary routines;
- Etc.



Sailing course plot: vessel entering the port of Ostend

Maritime Technology
Ghent University
Technologiepark 904
9052 Ghent
Belgium

Tel: +32 9 264 55 59
Fax: +32 9 264 58 43

Websites
www.maritiem.ugent.be
www.bankeffects.ugent.be

Flanders Hydraulics Research
Berchemlei 115
2140 Antwerp
Belgium

Tel: +32 3 224 60 35
Fax: +32 3 224 60 36

Websites
www. watlab.be
www.shallowwater.be

Composition

Flanders Hydraulics Research

Responsible editor

dr. Frank Mostaert
Head of division
Berchemlei 115
2140 Antwerp
Belgium

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