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The Effect of Shipping Traffic on Moored Ships

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ABSTRACT

The Antwerp Port Authority is particularly interested in the investigation of specific cases of interaction between passing and moored vessels that take account of the specific situation in the harbour of Antwerp. To cope with different questions a captive manoeuvring test program has been carried out at the towing tank for manoeuvres in shallow water, for different under keel clearances and dock widths. The present paper will give an overview of the tests that have been carried out and will specifically discuss the effect of swinging versus passing and the effect of meeting vessels on the moored ships.

KEY WORDS: Ship-ship interaction; Towing tank; mooring; swinging; meeting

INTRODUCTION

Research on Passing Effects of Ships

ROPES (Research On Passing Effects of Ships) is a joint industry project aiming at increasing insight in the physical factors influencing the forces induced by a passing vessel on moored vessels. This will result in recommendations on best practices concerning choice of methodologies and tools for predicting motions and mooring loads of moored ships based on the passing vessel forces. Both Flanders Hydraulics Research (FHR) and Ghent University (GU) joined the project and are committed to the Antwerp Port Authority being an industrial participant in the project. The Antwerp Port Authority is particularly interested in the investigation of specific cases of interaction between passing and moored vessels that take account of the specific situation in the harbour of Antwerp:

- The traffic in the Deurganck and the (yet to be built) Saeftinge dock where large sailing and manoeuvring container carriers interact with equally large moored container carriers;
- The setup of jetties on the river banks and in the docks to moor tankers that also will be affected by the passing ships;
- The interaction with smaller (inland) vessels.

To cope with these questions a captive manoeuvring test program has been carried out at the Towing Tank for Manoeuvres in Shallow Water at FHR, for different under keel clearances and dock widths in the following set-ups:

- Tests within the regular ROPES program:
  - Interaction between a passing container vessel and two moored container vessels;
  - Interaction between a passing container vessel and a moored tanker and inland vessel;
- Extra tests on behalf of the Antwerp Port Authority:
  - Interaction between a swinging container vessel and one or two moored container vessels;
  - Two container vessels meeting each other near a selection of moored ships.

This paper gives an overview of the extra tests, namely swinging and meeting tests. The discussion will focus on the qualitative differences between swinging and passing on different types of moored vessels and whether superposition is acceptable in case of multiple passing.

State of the Art

Although swinging and meeting of ships in harbour areas where ships are moored are daily practice, little to no attention has been given to the subject in literature. Most authorsfocus on the effect a single ship has on moored vessels. Worthwhile to mention are the investigations reportedin [1]-[7], that can be resumed in Fig. 1 showing the typical forces and moments that act in the horizontal plane of a moored ship while being passed. The amplitude of forces and moments decrease with increasing under keel clearance.

Multiple ships passing was under numerical investigation in [8]. A major question with multiple ships is whether superposition of forces and moments, i.e. the sum of the effects of each passing ship separately, is possible. In [8] such superposition did not seem valid for all cases.

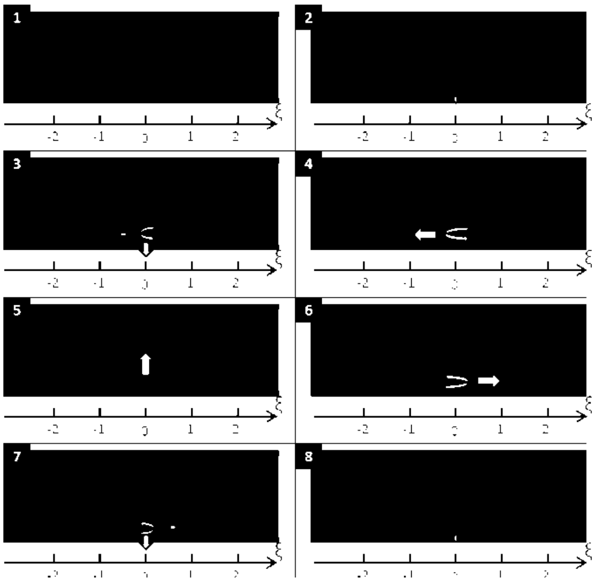

Fig. 1 Forces acting in the horizontal plane of a moored ship while subjected to a passing ship.

Finally, the authors did not succeed to find any relevant literature on the effect caused by a swinging ship. Mostly it is believed that passing leads to more severe effects than swinging.

EXPERIMENTAL SETUP

Towing Tank for Manoeuvres in Shallow Water

All tests described in this article have been carried out at the Towing Tank for Manoeuvres in Shallow Water (co-operation FHR-GU) between October 2011 and April 2012. This shallow water towing tank (88 m * 7 m * 0.5 m) is equipped with a planar motion carriage, a wave generator and an auxiliary carriage for ship-ship interaction tests. Thanks to computerized control and data-acquisition, the facilities are operated in a fully automated manner. The carriage runs 24/7 without the need for permanent surveillance.

Fig. 2 Overview of an example test-setup.

Selection of Ships and Scale

The tests have been carried out for three different dock widths, namely 595 m (*Saeftinge dock wide variant*), 500 m (*Saeftinge dock narrow variant*) and 425 m (*Deurganck dock*), the first width being 85 times the towing tank width. For this reason the program has been executed on scale 1/85 with the ship models shown in Table 1.

Table 1. Used ship models (scale 1/85)

Code	Type	Length [m]	Beam [m]	Draft [m]	Use
C0D	Container	328.1	45.9	13.1	Meeting
C0P	Container	369.75	51.85	15.2	Moored
C0U	Container	348.5	45.05	13.1	Moored
C0W	Container	356.15	53.55	15.2	Own ship
T0Y	Tanker	260.95	47.6	15.2	Moored
B02	Inland	108.0	11.45	3.65	Moored

The smaller dock widths were obtained by building a quay wall all over the length of the tank. The values of draft were selected either on maximal draft (3.65 m), post-panamax draft (15.2 m) or a value of 13.1 m. The latter draft allows a tide independent call towards the Antwerp harbour area. Taking into account the tidal range of the river Scheldt,the under keel clearance was variedbetween 10% and 40% of the maximal draft 15.2 m.

Mooring Layout

Test Naming Conventions. Tests are grouped in series per combination of mooring layout and under keel clearance. The name of such a series starts with C0W01S, 'C0W' being a code for the sailing ship model, '01' for the loading condition, and 'S' indicating the presence of other ship models in the tank. This combination is followed by a code 'X' for the combination of test type and dock width, and 'd' a digit indicating the under keel clearance of the sailing ship, see Table 2.

Table 2. Relationship between test parameters and test series code

Meaning	**Code**
40% ukc	d = 1 or 7
10% ukc	d = 3 or 9
Meeting ships in *Saeftinge dock wide variant*	X = I
Meeting ships in *Deurganck dock*	X = K
Swinging ships in *Saeftinge dock wide variant*	X = S
Swinging ships in *Saeftinge dock narrow variant*	X = T

Meeting. During meeting tests ship C0W meets ship C0D while one or two other ship models are moored in different configurations, see Table 3 and also the appendix. The main parameters that were varied per under keel clearance and dock configuration are:

- Relative speed of the encountering vessels:
  - C0W: 2, 3, 5 and 7 knots
  - C0D: 2 and 5 knots
- Passing distances between the sailing vessels:
  - 1 ship width between C0W and C0D
  - 1 ship width between C0W and C0U or T0Y
  - A position in between (only for largest dock width)
- Encounter positions (bow to bow): positions 1, 3, 5, 7 and 9 in Table 4.

Table 3. Mooring layout.

		Meeting ship	Moored ship(s)			
Series	**ukc**	**C0D**	**C0P**	**C0U**	**T0Y**	**B02**
C0W01S(I,K)1	40%	x		x		x
C0W01S(I,K)3	10%					
C0W01S(I,K)7	40%	x	x		x	
C0W01S(I,K)9	10%					
C0W01S(S)1	40%		x			
C0W01S(S)3	10%					
C0W01S(S,T)7	40%		x	x		
C0W01S(S,T)9	10%					

Swinging. Ship C0W swings in between the available lateral space at different longitudinal positions (2, 3, 5, 7 and 8 in Table 4). Other parameters that were varied were:

- Yaw velocities (±12.5 or ±25 °/min);
- Sway velocities 0 kn and ±0.2 kn or ±0.5 kn.

Table 4. Encounter positions.

Meaning	Code
One ship length before the bow of the moored ship	1
One half ship length before the bow of the moored ship	2
At the bow of the moored ship	3
At the midship of the moored ship	5
At the stern of the moored ship	7
One half ship length behind the stern of the moored ship	8
One ship length behind the stern of the moored ship	9

Measurements

All results are given in a right handed ship bound coordinate system, with origin amidships on the water plane, the longitudinal axis x pointing positively towards the bow, the transversal axis y pointing to starboard side and the vertical axis z pointing positively downwards.

On the sailing ship C0W and on the moored ships the following data has been measured in function of time:

- Longitudinal force fore and aft;
- Lateral force fore and aft;
- Sinkage fore and aft.

On the sailing ship C0W the following additional data was measured:

- Longitudinal position;
- Lateral position;
- Course angle;
- Propeller rate;
- Propeller thrust;
- Propeller torque;
- Longitudinal and lateral rudder force.

Additionally the water level has been measured on the locations, marked by WG in the appendix.

MEETING

Conventions

As different ships are involved some conventions are introduced. The longitudinal distance between a moored ship 'M' and the passing ship C0W 'P' is expressed as:

$$x_{MP} = \xi_{MP}\frac{L_M+L_P}{2} \quad (1)$$

Whereas the longitudinal distance between C0W and the encountering ship C0D 'E' is:

$$x_{PE} = \xi_{PE}\frac{L_P+L_E}{2} \quad (2)$$

and between C0D and the moored ship:

$$\xi_{ME} = \frac{x_{ME}}{\frac{L_P+L_E}{2}} \quad (3)$$

The dimensional coordinate x is always the distance between the midships sections. Figures are presented with the distance ξ_{MP} in the abscissa, while other different coloured lines have the following meaning:

- Three vertical yellow lines represent, from left to right, the positions corresponding to $\xi_{ME} = -1$ (bows meeting); $\xi_{ME} = 0$(midships meeting) and $\xi_{ME} = 1$ (sterns meeting);
- A vertical red line represents the position $\xi_{PE} = 0$;
- The black curve represents the force measured during the test;
- The magenta curve represents the force measured during a (extrapolation of a) test with only the ship C0W passing by;
- The light blue curve represents the force measured during a (extrapolation of a) test with only the ship C0D passing by;
- The green curve represents the sum of the magenta and light blue curve.

Comparing the black and the green curves indicates whether superposition is acceptable or not. Lateral distances PE, MP and ME are expressed as number of widths of ship C0W.

Superposition

Fig. 3 – 5 show some cases where superposition is certainly acceptable. However, as mentioned in [8], this is not always the case.Fig. 6 shows for instance how superposition over-predicts the extreme values of the longitudinal force acting on the moored vessel.

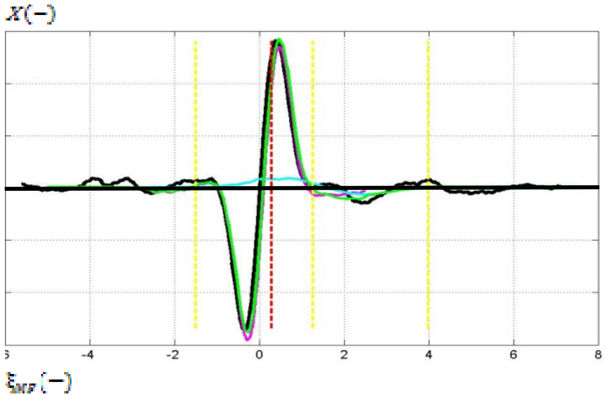

Fig. 3 Longitudinal force acting on the moored ship C0P due to passing of C0W (40% ukc, 5 kn) and C0D (2 kn). PE = 1.5B, MP = 1.0B and ME = 3.5B. Deurganck dock.

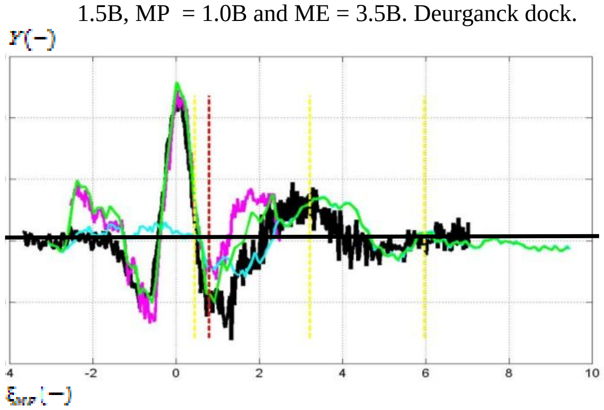

Fig. 4 Lateral force acting on the moored ship C0P due to passing of C0W (40% ukc, 5 kn) and C0D (2 kn). PE = 1B, MP = 3.6B and ME = 1.8B. Wide Saeftinge dock.

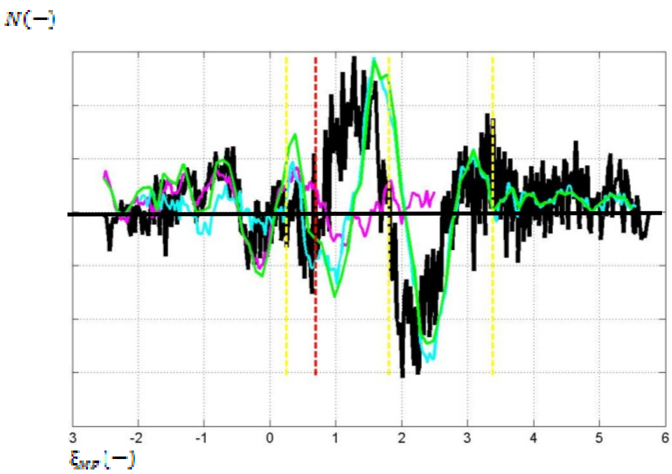

Fig. 5 Yawing moment acting on the moored ship C0P due to passing of C0W (40% ukc, 3 kn) and C0D (2 kn). PE = 4.5B, MP = 7.1B and ME = 1.8B. Wide Saeftinge dock.

Deviations are not always overestimations, but can also be underestimations, or be the result of phase shifts, especially for the yawing moment. As a general rule of thumb superposition results into less reliable approximations with decreasing under keel clearance and when both sailing ships meet closer to the moored ships. The dock width is only of little influence.

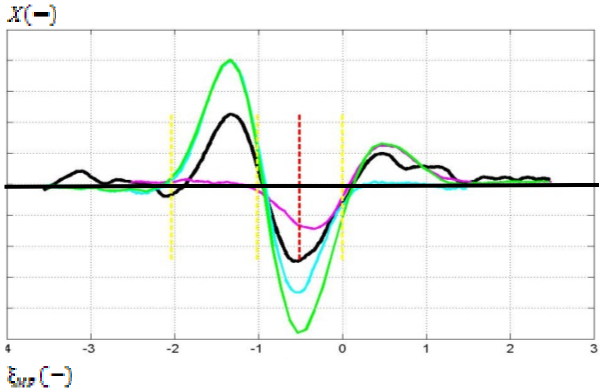

Fig. 6 Longitudinal force acting on the moored ship C0P due to passing of C0W (10% ukc, 5 kn) and C0D (5 kn). PE = 2.8B, MP = 5.4B and ME = 1.8B. Wide Saeftinge dock.

SWINGING

Swinging acceleration

The forces acting on a moored ship during a swinging manoeuvre can be split up into the forces and moments during acceleration of the swinging ship and during the stationary phase. The continuous acceleration function was chosen in such way that the full scale ship could be swung by two tugs of 30 ton bollard pull. The acceleration has sometimes a dominant effect as can be seen on Fig. 7, where the stationary moments during swinging are of the same amplitude as the moments after completion of the manoeuvre.

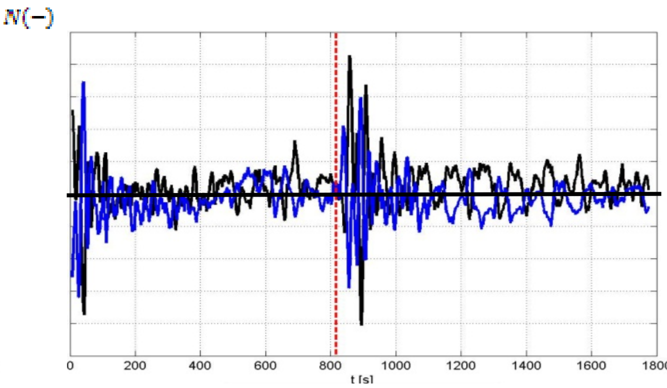

Fig. 7 Yawing moment acting on the single moored ship C0P due to swinging of C0W (10% ukc, 0.2kn sway) at a

half ship length astern of C0P. Wide Saeftinge dock. Black line: -12.5°/min, blue line: 12.5°/min. Red vertical line indicates the start of the deceleration.

Stationary swinging

Longitudinal position. The forces and moments during the stationary phase depend much on whether the swinging is combined with sway or not. If the ship swings without sway next to the moored ship a returning trend is observed for the average forces and moments as shown on Fig. 8.This could be called an ideal case, because a difference in longitudinal position or sway velocity influences both the maximal value as the course angle where this value occurs. In general the longitudinal force and yawing moment decrease once the ship swings further away, while the lateral force turns maximal if the ship is swinging near bow or stern of the moored vessel.

Sway velocity.A lateral velocity causes the swinging ship to move towards the moored ship during swinging (or the other way round). A sway movement, be it towards the moored ship or not, will always cause larger forces and moments on the moored ship, see Fig. 9.

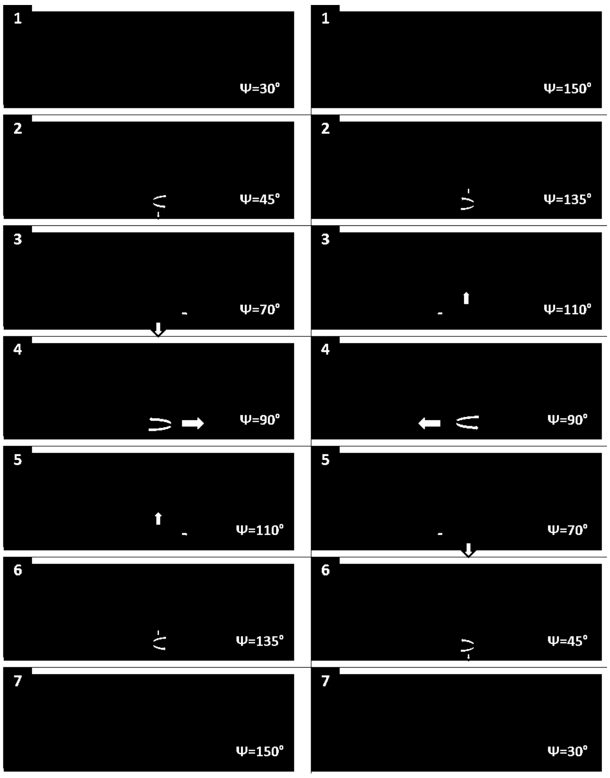

Fig. 8 Forces acting in the horizontal plane of a moored ship while subjected to a purely swinging ship at the same longitudinal position (stationary phase only).

Swinging vs. Single Ship Passing.As for the passing tests the dock width is of little influence. For the same reason the fact that another ship is moored on the opposite side of the dock has little effect on the mooring forces and moments.

The maximal forces and moments that occur during the manoeuvre are mostly larger during passing. However, the under keel clearance has a more significant effect on the forces and moments during swinging. For 10% under keel clearance larger sway forces and yawing moments can be obtained during swinging, of course dependant on the actual position of the ship and sailing speed.

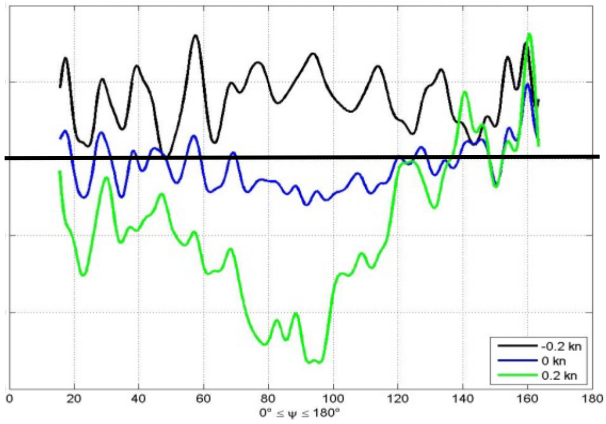

Fig. 9 Longitudinal force acting on the moored ship C0U due to swinging of C0W (10% ukc -12.5°/min).Wide Saeftinge dock. Influence of sway speed (positive is towards C0U).

CONCLUSIONS

This paper presented the results of new tests that were carried out to assess the behaviour of moored vessels subjected by shipping traffic. As literature mostly focusses on a single passing ship the test program also included swinging ships and multiple passing ships.

For most cases it can be concluded that the forces and moments that act on a moored ship due to multiple passing ships can be superposed. However one should pay attention that this method will have less accuracy with decreasing under keel clearance and when the two sailing ships meet close to the moored ship.

The tests with the swinging ship revealed some new insights. Not only the acceleration phase can be very important, but also at lower under keel clearances the forces and moments acting on the moored ship can be significant and even yield larger maximal forces and moments compared to realistic passing manoeuvres.

An additional concern that could use more investigation is that a swinging manoeuvre usually takes more time than a passing manoeuvre, which can have adverse effects on the mooring equipment. Future research will therefore focus on the effects swinging or multiple passing has on the mooring setup itself by using the measured forces as an input for a mooring configuration program.

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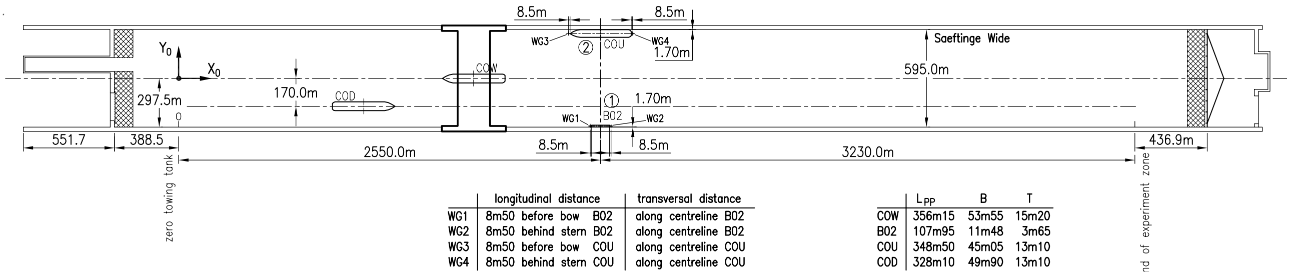
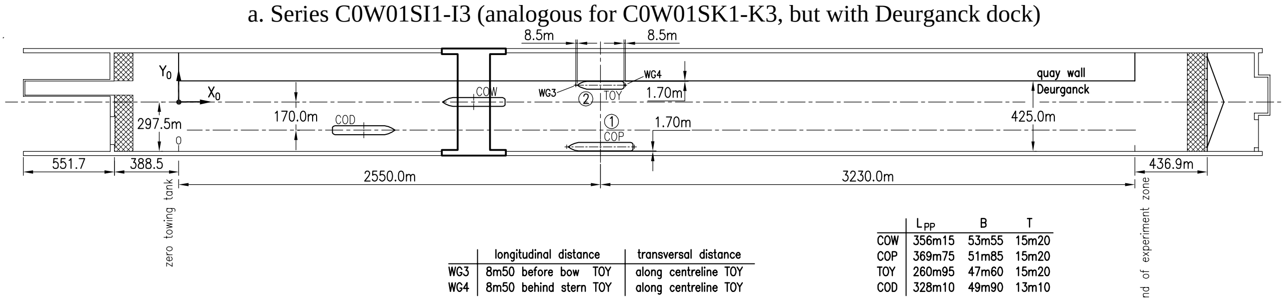
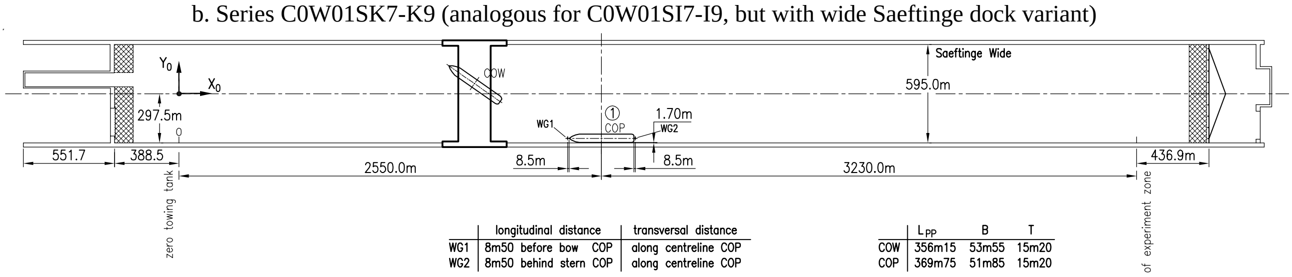
APPENDIX: EXPERIMENTAL LAYOUT



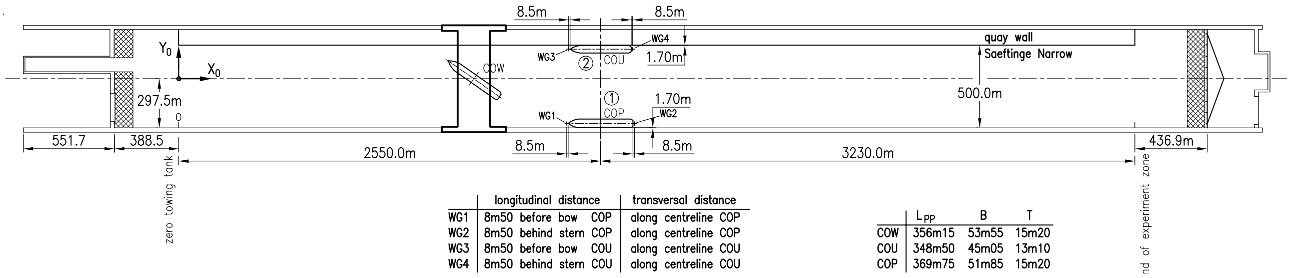
a. Series C0W01SI1-I3 (analogous for C0W01SK1-K3, but with Deurganck dock)



b. Series C0W01SK7-K9 (analogous for C0W01SI7-I9, but with wide Saeftinge dock variant)



c. Series C0W01SS1-SS3



d. Series C0W01ST7-T9 (analogous for C0W01SS7-S9, but with wide Saeftinge dock variant)

Fig. 11 Overview of experimental layout (full scale values).