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Verfügbar unter/Available at: https://hdl.handle.net/20.500.11970/99857

Vorgeschlagene Zitierweise/Suggested citation:
Denehy, S. P.; Duffy, Jonathan; Ranmuthugala, D.; Renilson, M. R. (2016): Squat in Berthed Ship - Passing Ship Interaction for Restricted Water Cases. In: Uliczka, Klemens; Böttner, Carl-Uwe; Kastens, Marko; Eloot, Katrien; Delefortrie, Guillaume; Vantorre, Marc; Candries, Maxim; Lataire, Evert (Hg.): 4th MASHCON - International Conference on Ship Manoeuvring in Shallow and Confined Water with Special Focus on Ship Bottom Interaction. Karlsruhe: Bundesanstalt für Wasserbau. S. 107-114.
https://dx.doi.org/10.18451/978-3-939230-38-0_14.

4th MASHCON, Hamburg - Uliczka et al. (eds) - © 2016 Bundesanstalt für Wasserbau ISBN 978-3-939230-38-0 (Online)
DOI: 10.18451/978-3-939230-38-0_14

SQUAT IN BERTHED SHIP – PASSING SHIP INTERACTION FOR RESTRICTED WATER CASES

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SUMMARY

This paper presents a study on berthed ship – passing ship interaction for two different channel widths using physical model scale physical experiments and Computational Fluid Dynamics (CFD). The interaction forces and moment and the sinkage of the berthed ship were measured for the two different channel widths. In order to determine the effect that the additional blockage caused by the berthed ship had on the squat of the passing ship, the squat was also measured under the same conditions as in the ship interaction scenarios, but without the presence of berthed ship. The two restricted water cases were replicated in model scale using 3D inviscid double body CFD simulations and validated against experimental results. The CFD models were run with the passing ship fixed in the static level trim condition as well as with the passing ship fixed at the running sinkage and trim condition measured from the physical model scale experiments to determine whether the latter would improve correlation with the experimental results.

NOMENCLATURE

AMC	Australian Maritime College
B	Beam (m)
BD_N	Near bank offset distance (m)
BD_F	Far bank offset distance (m)
Fr_h	Froude depth number $\left(Fr_h = U/\sqrt{gh}\right)$
g	Gravitational constant (9.81 m/s^2)
h	Water depth (m)
L_B	Berthed ship length between perpendiculars (m)
L_C	Characteristic length ($L_C = \frac{L_P+L_B}{2}$) (m)
LCG	Longitudinal centre of gravity
L_P	Passing ship length between perpendiculars (m)
MTB	Model Test Basin
N	Yaw moment (N)
N'	Non-dimensional yaw moment (-)
PD	Passing ship position $\left(\mathrm{PD} = \frac{\mathrm{x}}{\mathrm{L_C}}\right)$
S	Lateral separation, centreline to centreline (m)
T	Draft (m)
U	Passing ship speed (m/s)
UKC	Under keel clearance
x	Longitudinal coordinate of passing ship's centre of gravity from berthed hip's centre of gravity (m)
X	Surge force (N)
X'	Non-dimensional surge force (-)
Y	Sway force (N)
Y'	Non-dimensional sway force (-)
ρ	Water density (kg/m3)
∇_B	Berthed ship displacement (m3)
∇_C	Characteristic ship displacement $\nabla_C = \frac{\nabla_P+\nabla_B}{2}$) (m3)
∇_P	Passing ship displacement (m3)
θ	Trim angle (degrees)

1 INTRODUCTION

Berthed ship motions induced by the interaction effects of a passing ship can cause excessive mooring forces and interrupt loading/unloading procedures. Extreme cases of berthed ship - passing ship interaction have resulted in damage to vessels and mooring infrastructure, injury and even death to personnel. To ensure safe and efficient port operation, it is essential to understand the interaction between berthed and passing ships.

In order to accurately predict the berthed ship motions and mooring loads due to the passing ship, the interaction forces and moments must first be accurately predicted. There are a number of empirical methods [1, 2] that can be used to predict the berthed ship - passing ship interaction forces and moments. These methods are mostly based on results from laterally unrestricted cases, where the effect of the banks is negligible. Past work, including some conducted by the current authors [3-6], has shown that the increase in blockage due to banks has a significant effect on the magnitude and form of the interaction forces and moments and should be accounted for when predicting the interaction effects.

This study presents results from physical scale model experiments of berthed ship - passing ship interaction of bulk carriers conducted at the Australian Maritime College's (AMC) Model Test Basin (MTB) facility. The interaction forces and moments imparted on the berthed ship were measured for two restricted water bathymetries. The model tests were conducted with a berthed bulk carrier being passed by an identical bulk carrier on a parallel heading. Two near bank arrangements were tested; a wide channel, where the bank effects are negligible [7], as well as for the case where a bank was placed close to the berthed ship, resulting in significant bank effects. The tests were conducted at four passing ship speeds from Fr_h 0.15 to 0.25. In addition to the surge force, sway force and yaw moment, the sinkage at the LCG and the trim angle experienced by the berthed ship during the interaction scenario were also measured. The sinkage at the LCG and the running trim angle of the passing ship were measured during the interaction scenarios as well as under the same conditions but without the berthed ship in order to quantify the effects of the additional blockage from the berthed ship on the squat of the passing ship.

Results from the physical scale model experiments were used to quantify the interaction forces and moments and sinkage and trim angle and also used to validate CFD simulations using an inviscid double body model. Past authors [8-10] have shown that this method can accurately predict the interaction forces and moments for certain cases. The bathymetry for the two cases tested in the physical scale model experiments was replicated in the CFD models. The CFD models were run with the passing ship fixed in the static trim condition as well as with the passing ship fixed with the running sinkage and trim angle measured in the physical scale model experiments to determine whether this would improve the correlation between the CFD predictions and the experimental results.

The work presented in this paper is part of a larger study to develop a technique to rapidly predict the interaction forces and moments on a berthed ship due to a passing ship in restricted waterways. The aim of this study is to use a validated CFD model to predict the interaction forces and moments for a wide range of cases to form a matrix of data to develop the new simplified technique.

2 PHYSICAL SCALE MODEL EXPERIMENTS

A series of physical scale model experiments were conducted at the AMC's MTB facility to measure the interaction forces and moments experienced by a berthed ship due to a passing ship for two bathymetry arrangements. The sinkage at the LCG and the running trim angle (squat) experienced by the passing ship and the sinkage at the LCG and the trim angle of the berthed ship were measured in the region in which interaction effects can be felt by the berthed ship (two ship lengths forward and aft of the berthed ship [11]). The passing ship squat measurements from the interaction scenarios were then compared to squat measurements, in the same bathymetry arrangement, with the berthed ship removed to quantify the effect the additional blockage of the berthed ship has on the squat of the passing ship.

The test program used in the physical scale model experiments is given in Table 1. The bathymetry arrangement and sign convention used in the experiments and CFD simulations are shown in Figure 1. The forces and moments were measured about the berthed ship's longitudinal centre of gravity (LCG). The LCG was located $0.475L_B$ aft of the forward perpendicular.

The tests were conducted at low passing ship speeds typical of real life scenarios. For such cases the free surface effects can be considered negligible [11]. The water depth to draft ratio was 1.20 for all conditions.

The passing ship's path was parallel to the berthed ship's centreline, with a $2.50B$ lateral separation between the berthed and passing ship's centrelines (S). The vertical surface piercing banks were positioned parallel to the passing and berthed ship's centerlines. The near bank (portside of berthed ship) and far bank (starboard side of the passing ship) for Conditions 1 and 3 were equally spaced $8.25B$ from the passing ship's path (see Figure 1). For Conditions 2 and 4, the near bank was $3.04B$ to the portside and the far bank was $8.25B$ to the starboard side from the passing ship's path.

Table 1. Test program for physical scale model experiments test program

Condition	Passing ship speed	Lateral separation	Near bank offset	Far bank offset
	Fr_h	S	BD_N	BD_F
1	0.17 – 0.23	$2.50B$	$8.25B$	$8.25B$
2	0.17 – 0.23	$2.50B$	$3.04B$	$8.25B$
3	0.17 – 0.23	-*	$8.25B$	$8.25B$
4	0.15 – 0.23	-*	$3.04B$	$8.25B$

Note * - No berthed ship

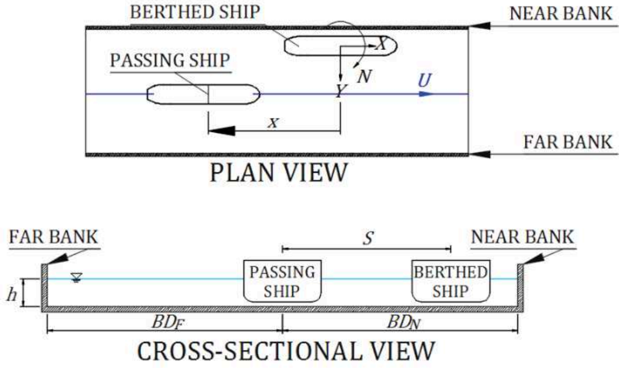

Figure 1. Schematic view of bathymetry arrangement and sign convention

The physical scale model experiments were conducted using 4m MarAd F series bulk carriers [12]. This would represent a 1:71 scale to represent a 300m cape class vessel. The passing ship was fitted with a turbulence stimulation wire fitted at 5% L_P [13]. The berthed and passing ship models were ballasted to a static even keel draft of 0.22m. The pitch radius of gyration for the berthed and passing ship models were $0.24L_B$ and $0.24L_P$ respectively. A body plan view of the ship models used in the experiments and CFD simulations are shown in Figure 2. To reduce modelling and meshing requirements, a bulk carrier hull form with a simplified skeg arrangement was used in the CFD predictions (shown in red in Figure 2). Huang and Chen [14] has shown that the form and magnitude of the interaction forces and moments are not greatly influenced by the hull form, however, the effect that the simplified hull geometry has on the interaction forces and moments has not be quantified in this study.

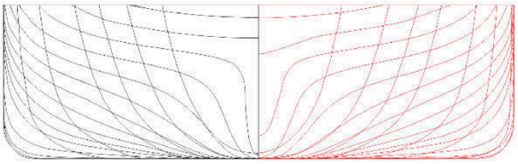

Figure 2. Left (black): body plan of MarAd F Series [12] used in the physical scale model experiments. Right (red): hull form used in the inviscid double body numeric simulation.

2.1 TEST PROCEDURE

The passing ship was accelerated from rest to a predetermined constant speed before reaching the region that affects the berthed ship (two ship lengths fore and aft of the berthed ship's LCG) [11]. The passing ship speed was kept constant until the effects on the berthed ship were negligible. For the passing ship the following were measured passing ship speed, sinkage at the LCG and running trim angle. For the berthed ship the following were measured: interaction surge force, sway force, yaw moment, sinkage at the LCG and trim angle. All measurements were sampled at 200Hz. An uncertainty analysis was conducted for each instrument used within the experiments, employing a similar method to that presented by Duffy [15].

2.2 EXPERIMENTAL RESULTS AND DISCUSSION

The results from the experiments were filtered using a 4th order low pass Butterworth filter with a 0.12Hz cut off frequency. The interaction forces and moments were non-dimensionalised by the formulae:

$$X' = \frac{X}{\rho g \nabla_C {Fr_h}^2} \tag{1}$$

$$Y' = \frac{Y}{\rho g \nabla_C {Fr_h}^2} \tag{2}$$

$$N' = \frac{N}{\rho g \nabla_C L_C {Fr_h}^2} \tag{3}$$

The time domain results are presented against the non-dimensional passing ship position (PD) where,

$$PD = \frac{x}{L_C} \tag{4}$$

and x is the coordinate of the passing ship's LCG relative to the berthed ship's LCG. Hence, when the passing ship is adjacent the berthed ship at $x = 0$ and $PD = 0$.

The peak to peak interaction surge force, sway force and yaw moment experienced by the berthed ship due to the passing ship are shown in Figure 3. Due to the size of the data point markers required, the uncertainty bars presented are somewhat obscured. The increase in the surge force, and the reduction in the sway force and yaw moment due to the smaller near bank offset is consistent with past findings [3-6].

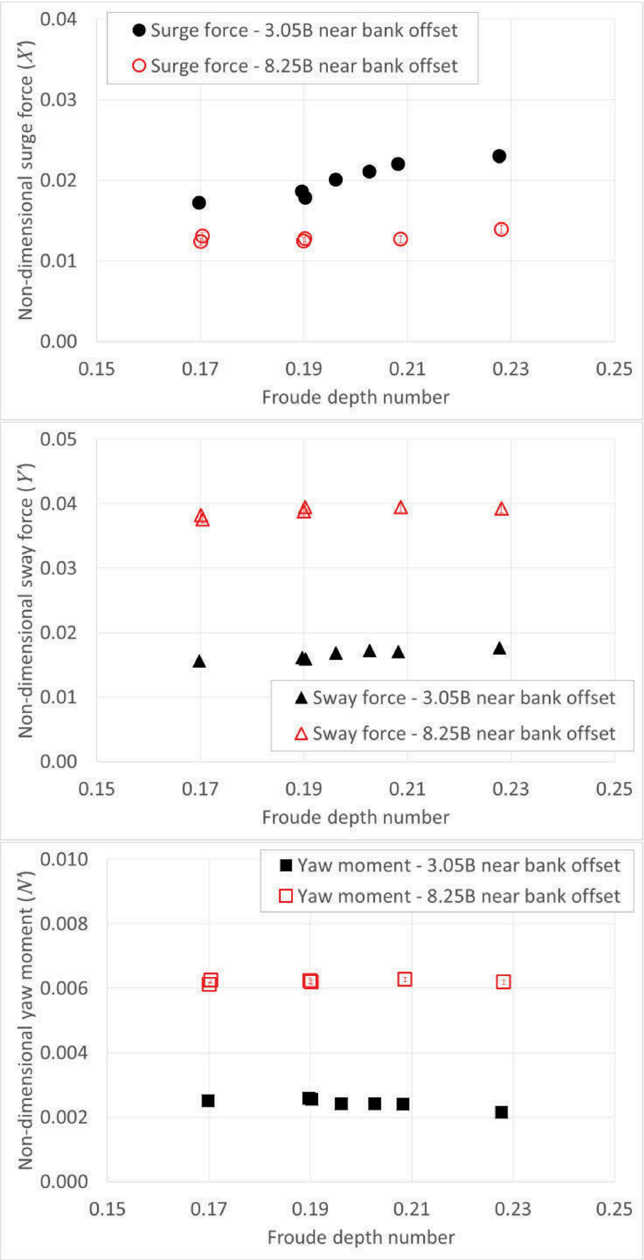

Figure 3. Peak to peak surge force (top), sway force (middle) and yaw moment (bottom) for Conditions 1 and 2 showing the effect of near bank offset distance.

Figure 4 shows the sinkage and trim angle experienced by the berthed ship due to the passing manoeuvre as a function of the passing ship position at the passing ship speed of $Fr_h = 0.23$. The uncertainty in the sinkage at LCG and trim angle measurement is shown in grey and light red/pink in Figure 4.

The maximum berthed ship sinkage at the LCG occurred when the berthed and passing ships were approximately adjacent. The maximum berthed ship trim angle occurred when the passing ship was half a ship length aft and forward of the berthed ship ($-0.5PD$ and $+0.5PD$).

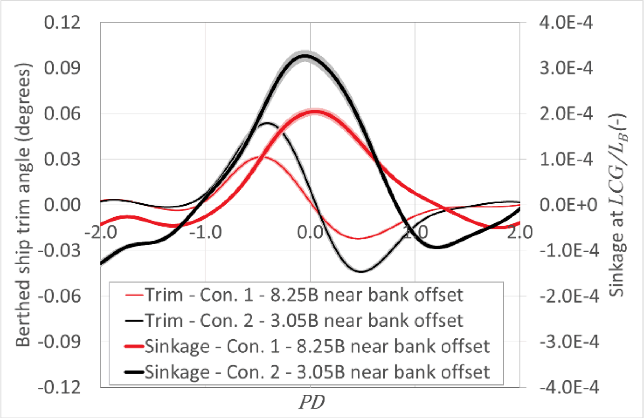

Figure 4. Berthed ship sinkage at LCG and trim angle measured in Conditions 1 and 2 as a function of passing ship position (PD).

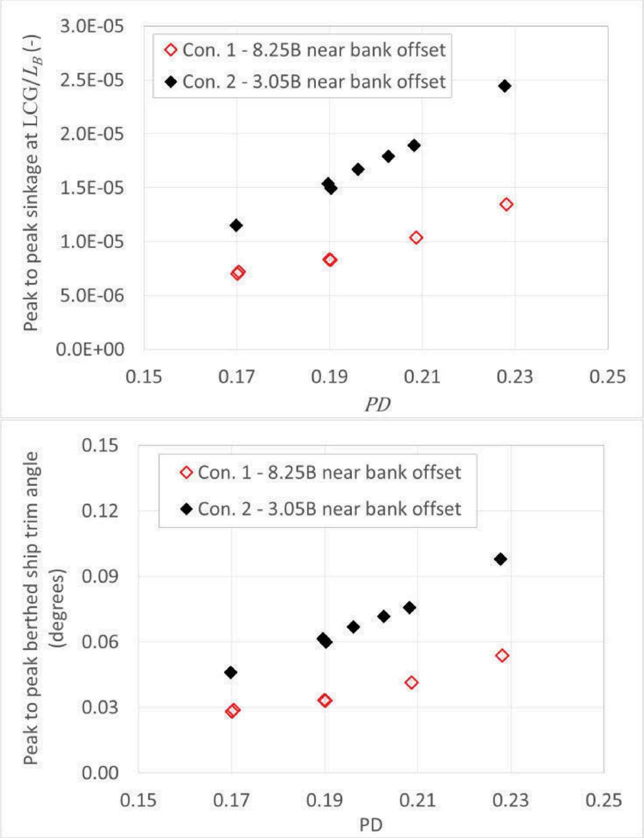

Figure 5. Peak to peak berthed ship sinkage at LCG (top) and trim angle (bottom) easured in Conditions 1 and 2 as a function of passing ship speed.

The peak to peak berthed ship sinkage at the LCG and the trim angle for Conditions 1 and 2 are shown in Figure 5. The measured sinkage at the LCG and the trim angle for the berthed ship increased as passing ship speed increased. The reduction of the near bank offset distance increased both the sinkage at the LCG and the trim angle of the berthed ship. It should be noted, however, that the sinkage at the LCG and the trim angle experienced by the berthed ship due to the passing ship was small. The maximum heave experienced by the berthed ship was 0.6% of the berthed ship's draft and the maximum peak to peak trim angle of the berthed ship was only 0.098 degrees.

No unsteady effects were observed in the passing ship sinkage at the LCG and the running trim angle due to the presence of the berthed ship in either bathymetry arrangement. It should be noted that the experimental results presented here are for the water depth to draft ratio of 1.20. The additional blockage due to the berthed ship would have been greater in shallower cases and should be investigated further in order to determine if it has any dynamic effects on the passing ship.

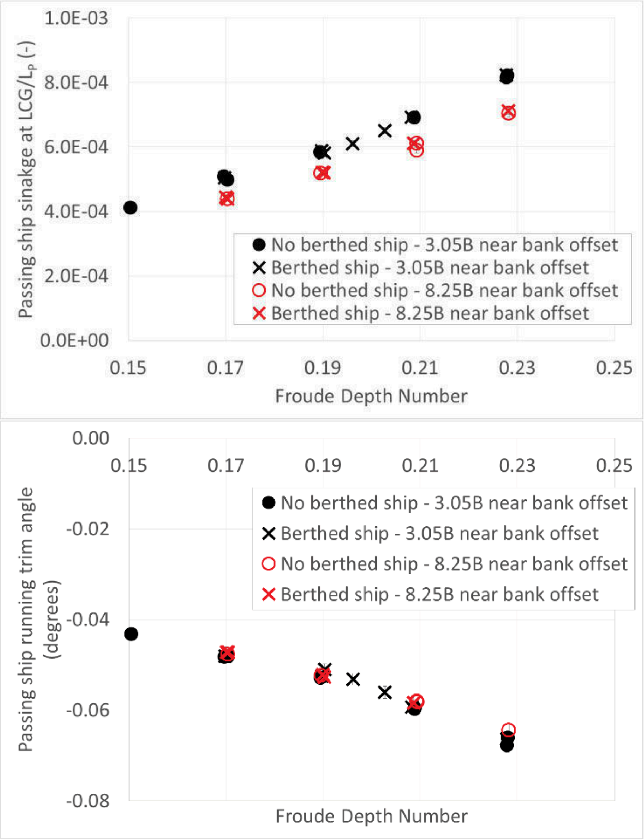

Figure 6. Passing ship average sinkage at the LCG (top) and trim angle (bottom) measured in Conditions 1 - 4 as a function of passing ship speed.

Figure 6 shows the average heave and running trim angle of the passing ship for Conditions 1 – 4 as a function of the passing ship speed. Again, due to the data point size, the uncertainty bars are hard to see in Figure 5. The additional blockage of the berthed ship did not increase the passing ship's sinkage at the LCG or the trim angle in either bathymetry case. The reduction of the near bank offset increased the heave of the passing ship but had little effect on the measured trim angle. It should be noted that the measured trim angle of the passing ship was very low, below 0.1 of a degree.

3 CFD SIMULATIONS

The interaction forces and moments on the berthed ship were predicted for four cases using an inviscid double body CFD simulation model developed within the software Star CCM+© [16]. The CFD predictions were conducted at model scale. Remery [11] observed that at the low passing ship speeds (commonly seen in berthed ship – passing ship interaction), due to the lack of Kelvin type wave pattern the free surface and viscous effects could be ignored, while still accurately predicting the interaction forces and moments imparted on the berthed ship. This method has been successfully implemented by others [8-10] with good correlation achieved against compatible experimental data.

The CFD predictions in this study were conducted using a six degree of freedom implicit unsteady solver. The berthed and passing ship models were constrained in six degrees of freedom. To achieve the double body method the dimensions of the physical scale model experiments were replicated in the CFD model and mirrored about the free surface. The domain was discretized using a hexahedral mesh. An overset mesh was used to model the passing ship. The longitudinal ends of the domain boundaries were modelled as a velocity inlet and a pressure outlet. In order to verify the CFD model, a time step and mesh convergence study was conducted. The mesh used in the CFD model had a base size of 0.08m. The mesh in Case 1 & 3 ($8.25B$ near bank) and Case 2 & 4 ($3.04B$ near bank) consisted of approximately 2.3 and 2.1 million cells, respectively. The time step used in the CFD model was 0.125 seconds. Details of the CFD model can be found in Denehy et al. [17, 18].

The test program for the CFD simulations is shown in Table 2. Cases 1 and 2 were conducted with the passing ship fixed in the static draft condition (i.e. at an even keel draft of 0.220m) for the bathymetry in Conditions 1 and 2 [17, 18]. Cases 3 and 4 were conducted with the passing ship fixed in the running sinkage and trim position measured in the physical scale model experiments. The CFD predictions were conducted at the passing ship speed of $Fr_h = 0.23$.

As with the experiments, the water depth to draft ratio for all CFD cases was 1.20.

Table 2. Test program for CFD simulations

Case	Near bank offset	Far bank offset	Passing ship		
			Speed	Draft at LCG	Trim angle
	BD_N (-)	BD_F (-)	Fr_h (-)	T (mm)	θ (deg)
1	$8.25B$	$8.25B$	0.23	$0.303B$	0.00
2	$3.05B$	$8.25B$	0.23	$0.303B$	0.00
3	$8.25B$	$8.25B$	0.23	$0.306B$	-0.06
4	$3.05B$	$8.25B$	0.23	$0.307B$	-0.06

3.1 CFD RESULTS AND DISCUSSION

The interaction forces and moments were filtered using a 4th order 0.12Hz cut off frequency Butterworth filter. The interaction surge force, sway force and yaw moment were non-dimensionalised using equations (1), (2) and (3), respectively, while the passing ship position was non-dimensionalised using equation (4). The non-dimensional interaction forces and moments from the CFD predictions from Cases 1 – 4 are compared to the measured non-dimensional interaction forces and moments from the experimental Conditions 1 and 2 in Figure 7 for the passing ship speed of $Fr_h = 0.23$. The uncertainty in the interaction force and moment measurements is shown in grey and light red/pink in Figure 7.

The percentage difference between the peak positive and peak negative interaction forces and moments between the experiments and CFD predictions can be seen in Table 3.

Surge force prediction

For the near bank offset of $8.25B$, the peak negative surge force, occurring around $-0.5PD$, was predicted fairly accurately in both Case 1 & 3 by the CFD models (within 8%). The positive peak surge force, occurring around $0.5PD$, was over predicted by the CFD models (Case 1 & 3). For the $3.04B$ near bank offset, Cases 2 & 4, the peak surge force values were over predicted by the CFD models. The over prediction was greater for the case with the passing ship fixed in the running sinkage and trim angle condition.

From the non-dimensional surge force (X') in Figure 7a, it can be seen that the experimental surge force was increased by approximately 65% by the reduction in the near bank offset. The increase in the predicted surge force from the CFD was 82% and 80% for the fixed static draft level trim condition (Case 1 & 2) and the fixed running sinkage and trim angle (Case 3 & 4), respectively.

Sway force prediction

For the $8.25B$ near bank offset, the even keel CFD model predicted the experimental sway force very well, agreeing within 6% of the experimental measurement. The peak positive sway force, occurring around $0.0PD$, was over predicted by the CFD model with the passing ship fixed in the running sinkage and trim angle by 24.6%. The level keel CFD model tested correlated very well with the sway force in the 3.04*B* case, within 5% of the experiments.

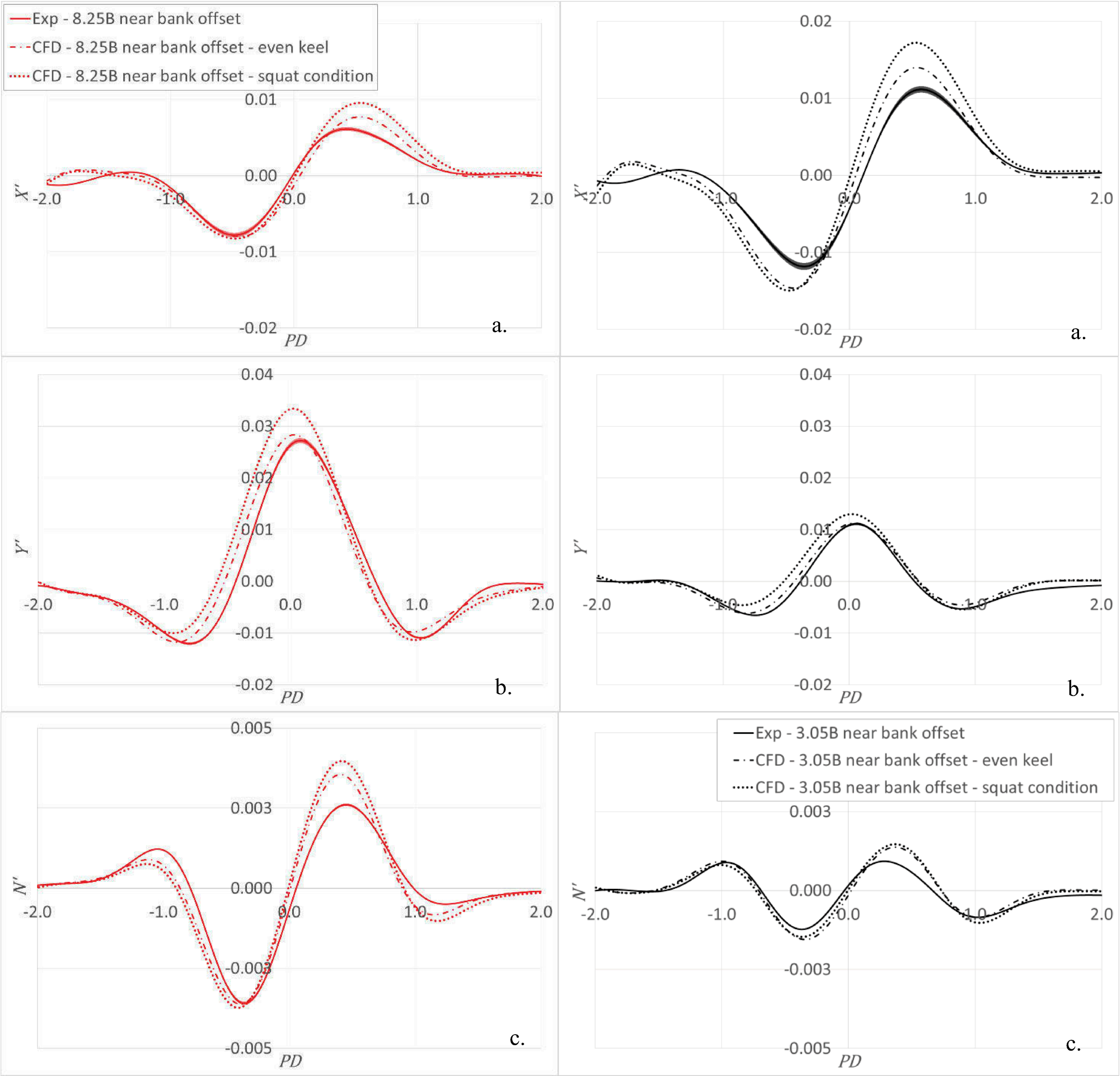

Figure 7. Comparison of the non-dimensional interaction surge force (X'), sway force (Y') and yaw moment (N') from physical scale model experiments and the inviscid double body CFD simulations.

Table 3. Percentage difference of the peak positive and peak negative interaction forces and moments of CFD prediction from the experimental results (+percentage indicates an over estimation, - percentage indicates under estimation)

		X'		Y'		N'	
		Peak - %	Peak + %	Peak - %	Peak + %	Peak - %	Peak + %
Case 1	8.25*B* - Level static draft	4.3	27.7	-0.8	5.9	2.4	38.6
Case 2	3.04*B* - Level static draft	26.0	27.9	-4.7	3.4	28.4	51.5
Case 3	8.25*B* - Using measured sinkage and trim angle	7.7	58.6	-4.1	24.6	5.6	55.1
Case 4	3.04*B* - Using measured sinkage and trim angle	28.9	57.5	-15.7	19.7	21.6	61.0

From Figure 7b the reduction in the near bank offset reduced the sway force (Y') by 55% in the experimental measurements and 57% and 58% for the CFD predictions with the passing ship fixed with static level trim and fixed in the running sinkage and trim angle configuration respectively for the passing ship at a speed of $Fr_h = 0.23$.

Yaw moment prediction

For the $8.25B$ near bank offset case, the initial peak positive yaw moment was under predicted by CFD model in Case 1 & 3. The CFD predicted peak negative yaw moment, occurring around -$0.4PD$, correlated well with the experimental results, within 6%. The peak positive yaw moment, occurring around $0.4PD$, and the second peak negative yaw moment, occurring around $1.2PD$, was over predicted by the CFD model. For the $3.04B$ near bank offset case the CFD model correlated poorly with the experimental results using both the fixed and measured sinkage and trim cases as seen in Figure 7.

The yaw moment (N') was reduced by 65% in the experimental case by the reduction in the near bank offset for the passing ship speed of $Fr_h = 0.23$, as seen in Figure 7c. The CFD models predicted a reduction of 59% and 62% due to the reduction in near bank offset for the passing ship fixed in the level static trim case and fixed at the running sinkage and trim angle case, respectively.

In general, the predictions from the CFD model with the passing ship fixed in the even keel condition correlated very well with the experimental sway force. More work is required to better model the surge force and yaw moment. Modelling the passing ship fixed at the running sinkage and trim angle based on the experiment results in general reduced the agreement with the experimental results. Hence, further investigation into the CFD prediction technique is required to determine why this is the case.

4 CONCLUDING REMARKS

A series of physical scale model experiments were conducted at AMC'S MTB facility to measure the interaction forces, moments, sinkage and trim on a berthed ship and the sinkage and trim on a passing ship for two different channel widths at a water depth to draft ratio of 1.20.

The reduction in the near bank offset significantly increased the surge force and reduced the sway force and yaw moment. The passing ship was shown to cause a very small change in sinkage and trim on the berthed ship. The berthed ship sinkage at the LCG and trim angle was increased as passing ship speed increased. The additional blockage caused by the presence of the berthed ship did not affect the squat of the passing ship for the cases tested.

Simulations using the CFD model generally agreed reasonably well with the experimentally measured sway forces, however the agreement with the experimentally measured surge force and the yaw moment was poor. Modelling the passing ship fixed at the sinkage and running trim based on the experimental results reduced the agreement with the experimentally measured forces and moment.

5 REFERENCES

1. Flory, J. (2002). The Effect of Passing Ships on Moored Ships. *Prevention First 2002 Symposium*, California State Lands Commission.

2. Kriebel, D.; Seelig, W.; Eskijian, M. (2005). Mooring loads due to parallel passing ships. *Naval Facilities Engineering Service Center*, Port Hueneme, California, USA,

3. Denehy, S.P.; Duffy, J.T.; Ranmuthugala, D.; Renilson, M.R. (2014). Influence of restricted water on the time domain interaction forces and moment on a berthed ship due to a passing ship. *Australian Journal of Civil Engineering, ,* Vol 12, No. 1, pp. 53 – 66.

4. Duffy, J.T.; Webb, G. (2003). Berthed Ship - Passing Ship Interaction: A Case Study for the Port of Newcastle. *Coasts & Ports Australasian Conference 2003*, Auckland, New Zealand.

5. Flory, J.; Fenical, S. (2010). Quay Wall Influence on Passing-Ship Induced Mooring Loads. *Ports: 2010: Buiding on the Past*, *Respecting the Future*, ASCE.

6. van der Molen, W.; Moes, J.; Swiegers, P.B.; Vantorre, M. (2011). Calculations of Forces on Moored Ships due to Passing Ships. *2nd International Conference on Ship Manoeuvring in Shallow and Confined Water: Ship to Ship Interaction*, Trondheim, Norway

7. Lataire, E.; Vantorre, M.; Vandenbroucke, J.; Eloot, K. (2011). Ship to Ship Interaction Forces During Lightering Operations. *2nd International Conference on Ship Manoeuvring in Shallow and Confined Water: Ship to Ship Interaction*, Trondheim, Norway.

8. Pinkster, J.A.; Pinkster, H.J.M.; (2014). A fast, user friendly, 3-D potential flow program for the prediction of passing vessel forces. *2014 PIANC World Congress*, San Francisco, USA.

9. Bunnik, T.; Toxopeus, S. (2011). Viscous Flow Effects of Passing Ships in Ports. *Proceedings of the ASME 2011 30th International Conference on Ocean, Offshore and Artic Engineering*, Rotterdam, The Netherlands.

10. van der Hout, A.J.; de Jong, M.P.C. (2014). Passing Ship Effects in Complex Geometries and Currents. *PIANC World Congress*, San Francisco, USA.

11. Remery, G.F.M. (1974). Mooring Forces Induced by Passing Ships. *Proceedings of the 6th annual Offshore Technology Conference*, Dallas, Texas, USA.

12. Roseman, D.P. (ed.) (1987). The MarAd systematic series of full form ship models. *Society of Naval Architects and Marine Engineers Publications*.

13. International Towing Tank Conference (ITTC), (2002). *Recommended Procedures and Guidelines: Model Manufacture Ship Models, 7.5-01-01-01.*

14. Huang, E.T.; Chen, H.C. (2006). Passing Ship Effects on Moored Vessels at Piers. *Proceedings Prevention First 2006 Symposium*, Long Beach, California, USA.

15. Duffy, J.T. (2008). *Modelling of Ship-Bank Interaction and Ship Squat for Ship-Handling Simulator*. Thesis for Doctorate of Philosophy, University of Tasmania, Launceston, Australia.

16. Star CCM+ User Manual, www.cd-adapco.com/products/star-ccm%C2%AE, first accessed 01/01/2014.

17. Denehy, S.P.; Duffy, J.T.; Renilson, M.R.; Ranmuthugala, D. (2015). Channel width effects on berthed ship - passing ship interaction from experiments and CFD predictions. *2015 MARSIM Conference*, Newcastle, UK.

18. Denehy, S.P.; Duffy, J.T.; Renilson, M.R.; Ranmuthugala, D.; (2015). Restricted water effects on berthed ship – passing ship interaction. *2015 Coast and Ports Conference*, Auckland, New Zealand.

6 AUTHORS' BIOGRAPHIES

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