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Hydrodynamic Interaction of Two Bodies in Waves

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Introduction

When multiple vessels or floating bodies are in a close proximity, the large resonant elevations of free surface occur in the gap. Most of the linear seakeeping programs currently used by the industry, for example, those solving the body interaction problem in the frequency domain, over-predict free surface elevations between vessels and hence the low-frequency loadings on the hull. This can cause problems in the design of the fenders, hawsers and loading arms and lead to unsafe operations.

Many researchers have made contributions to overcome this problem. Huijsmans et al. (2001) developed a lid technique to suppress the unrealistic values of low-frequency forces and wave elevations. In their work, the free surface in the gap is replaced by a flexible plate. A generalized mode technique was used by Newman (2003) to model the free surface. Chen (2005) proposed a linear dissipation term to modify the free-surface equation.

These methods however require to input the artificial damping factors. Efforts have made to determine the damping factors. For example, Pauw et al. (2007) compared the experimental data and numerical results for two side-by-side LNG carriers in head seas. The numerical results were based on a panel method code using a flexible damping lid in the gap region. Various gap widths were used in an attempt to obtain rationale for predicting suitable damping factors. No unique value for the damping factor was found to cover all the measured cases. Molin et al. (2009) used a set of massless plates in the gap between two fixed barges and a quadratic damping force was applied to the plates. The numerical results were compared to the model tests of two rectangular barges in irregular waves. A drag coefficient of 0.5 for determining the quadratic damping force led to good agreement with experimental data.

Since these potential-flow based methods are inadequate to give reasonable predictions without providing the experimental data beforehand, it is desirable to determine the damping contribution due to viscous flow based on CFD methods.

This paper presents the preliminary numerical and experimental studies of wave elevations between two bodies in close proximity with an objective to quantify the contribution of viscosity. Model tests were carried out to two identical box-like bodies with round corner in waves. Motions of the bodies and wave elevations in the gap between the two bodies were measured. CFD methods solving RANS equations, based on OpenFoam and Star-CCM+, were applied to simulate the hydrodynamic interaction of the two bodies in head seas. A panel-free method based seakeeping program, MAPS0, was also used for the prediction of motions and wave elevations. The computed motions and wave elevations by CFD and MAPS0 were compared with experimental data and the solutions by the potential-flow code, WAMIT.

Numerical Methods

A frequency-domain program, MAPS0, a sub-suite of Motion Analysis Program Suite (MAPS), was used to compute the motions and wave elevations in the gap between the two bodies. MAPS is based on the panel-free method (Qiu et al., 2006) and includes programs for both frequency-domain and time-domain analysis based on the potential-flow theory. The CFD computations are based on OpenFoam and Star-CCM+.

Experimental Tests

Model tests were carried out at the towing tank of the Ocean Engineering Research Center (OERC) at Memorial University to measure the motions of two bodies and the wave elevations for a variety of wave headings and frequencies. The tank is 60 m long, 4.5 m wide and 3 m deep.

Two identical 1:60 box-like simplified FPSO models, as shown in Fig. 1, were used, which have round bilges. Each model was restrained in the tank by two soft mooring lines which allow for body motions in six degrees of freedom but prevent excessive drift motions. The body motions were measured by a Qualisys system and wave elevations at three locations in the gap were measured by wave probes. Note that model tests were also carried out for a single body.

Figure 1: Two bodies in head seas

The particulars of the model-scale ships are listed in Table 1. In this phase, model tests were conducted in regular waves. The frequencies of waves are from 3.92 rad/s to 7.16 rad/s, which is corresponding to 0.51 rad/s to 0.92 rad/s in full scale. The wave steepness was 1/30.

Table 1: Model Particulars

	Model 1	Model 2
Length(m)	1.997	1.998
Breadth(m)	0.397	0.397
Depth(m)	0.301	0.300
Draught(m)	0.103	0.104
$\Delta(kg)$	76.6	76.6
KG(m)	0.131	0.124
$R_{xx}(m)$	0.135	0.125
$R_{yy}(m)$	0.535	0.502
$GM_T(m)$	0.054	0.053

Table 2: Gaps and Locations of Wave Probes

	Unit	Model Scale
Wave Heading	*degree*	180
Gap Width 1	m	0.40
Gap Width 2	m	0.45
Gap Width 3	m	0.55
Wave Probe 1	m	(0,0,0)
Wave Probe 2	m	(0.5,0,0)
Wave Probe 3	m	(-0.5,0,0)

Numerical Results

To quantify the viscous effect on the free surface elevation in the gap between two bodies, computations were performed for head seas using Star-CCM+, OpenFoam, MAPS0 and the low-order frequency-domain program WAMIT. The numerical results were then compared with the experimental data. Three gaps, 0.4m, 0.45m and 0.55m in model scale, were investigated. The full-scale results are presented below.

Figures 2 to 4 present the comparison of predicted wave elevations with experimental data at wave probe 1 for the three gaps, respectively. The predictions by MAPS0 and WAMIT, which are both based on the potential-flow theory, agree very well and are in good agreement with the experimental results at low frequency band. It is also observed that there are less oscillations in the predicted elevations by MAPS0 than those by WAMIT. At the resonant frequencies, both MAPS0 and WAMIT over-predicted the wave elevations.

The predicted heave and pitch motions by MAPS0 and WAMIT for body 1 are presented in Figs. 5 to 8 for the two gaps (0.40m and 0.45m). They are in good agreement with the experimental data. The predicted heaves by MAPS0 are slight better than those by WAMIT.

Figure 9 presents the effect of gap width on the predicted wave elevations. It can be seen that the resonant wave elevation decreases with the gap width increases.

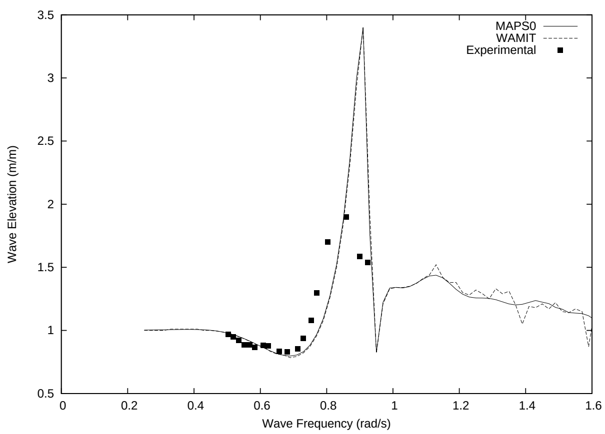

Figure 2: Wave elevation at location 1, gap=0.40m

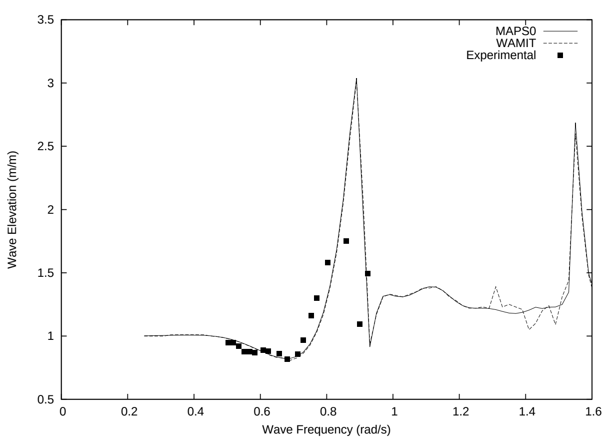

Figure 3: Wave elevation at location 1, gap=0.45m

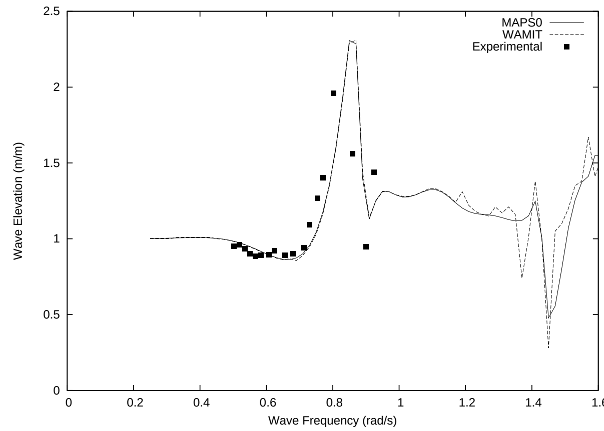

Figure 4: Wave elevation at location 1, gap=0.55m

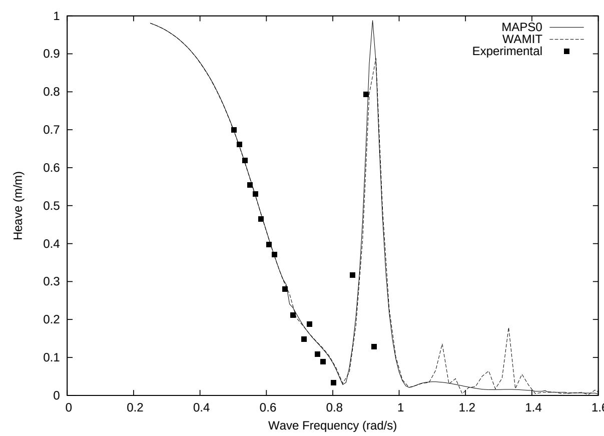

Figure 5: Heave of body 1, gap=0.40m

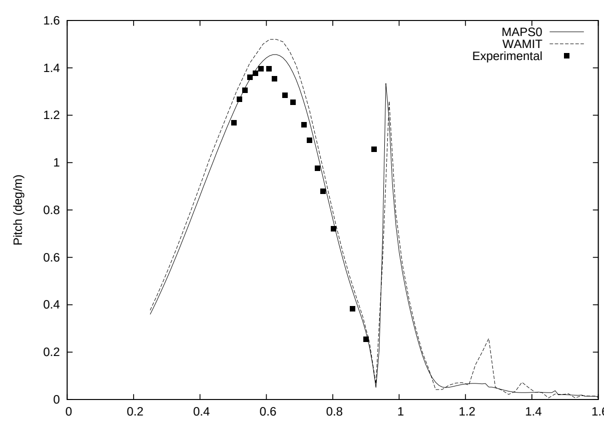

Figure 6: Pitch of body 1, gap=0.40m

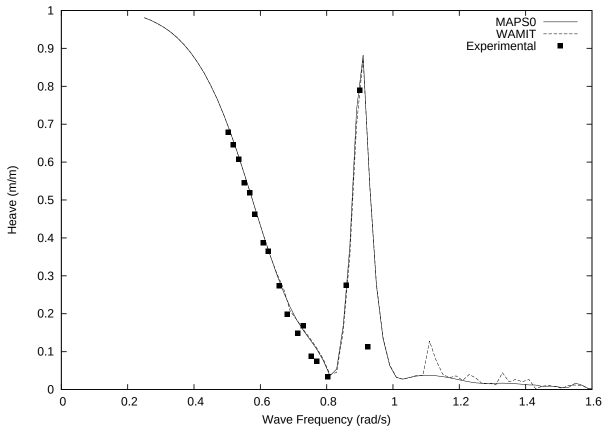

Figure 7: Heave of body 1, gap=0.45m

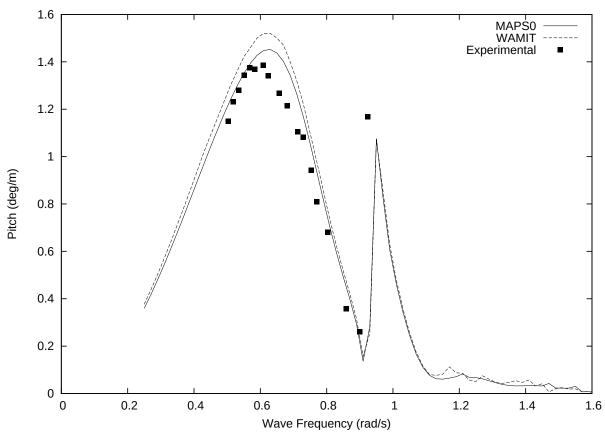

Figure 8: Pitch of body 1, gap=0.45m

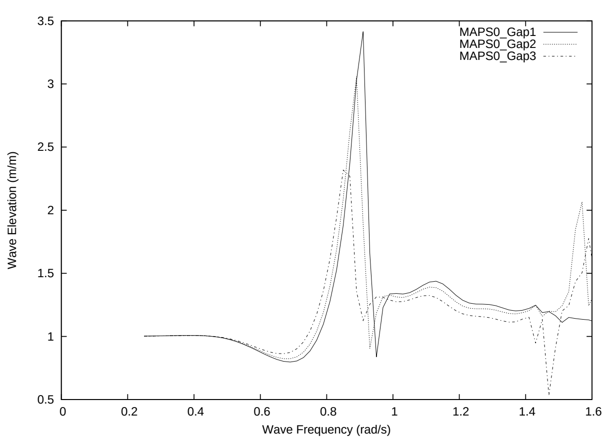

Figure 9: Wave elevations at location 1 for three gaps

Concluding Remarks

Experimental and numerical studies were carried out to investigate the hydrodynamic interaction of two side-by-side bodies in waves. Potential-flow programs based on the the panel-free method and the panel method and the CFD methods were used to compute motions of bodies and wave elevations in the gap between two bodies. The computational results were compared with experimental data. It is anticipated that the CFD results will be presented and the viscous effect will be discussed at the Workshop.

Acknowledgement

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