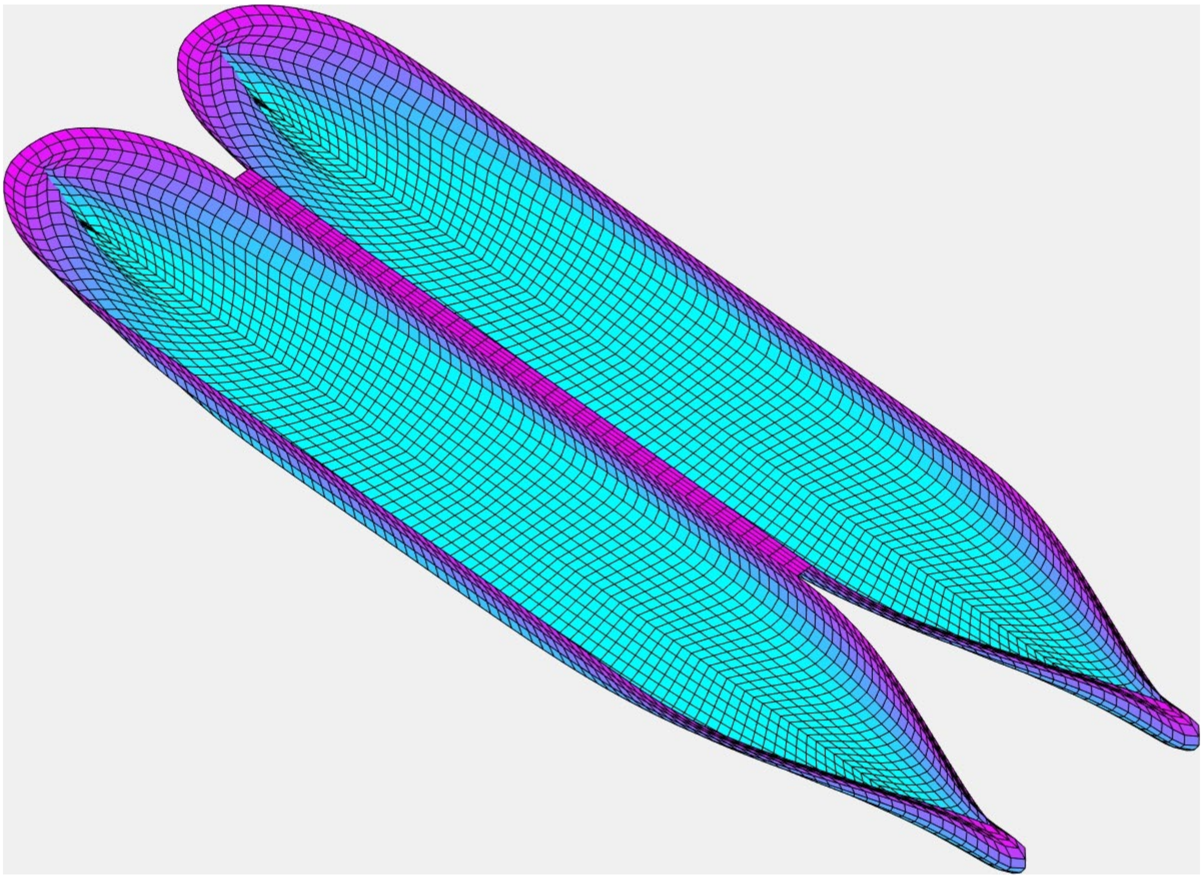
Level 29, 221 St Georges Tce
Perth, WA 6000

Contact: Dr Tim Gourlay
+61 416 328883
tim@perthhydro.com

Calculation of Second-Order Wave Loads for Side-by-Side LNG Carriers

Tim Gourlay

Perth Hydro Research Report R2020-03



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SUMMARY

This report follows on from Perth Hydro report R2019-08, which calculated first-order wave loads and wave-induced motions for a Marin model test case of side-by-side LNG carriers. Second-order wave loads are now calculated for the same test case.

WAMIT v7.3 software is used for the calculations in this report. Results are compared with DIFFRAC calculations presented in Pauw et al. (2007).

CONTENTS

1. Test case

The test case is described in Pauw et al. (2007) and Bunnik et al. (2009). It consists of a 1:50-scale LNG carrier close to a basin wall on its port side, representative of two identical side-by-side LNG carriers.

Particulars of the LNG carrier(s) and test setup are shown in Table 1.

Length between perpendiculars	274.0 m
Beam	44.2 m
Depth	25.0 m
Draught	11.0 m
Displacement	97759 tonnes
Block coefficient	0.716
Vertical Centre of Gravity	16.1 m above keel
Longitudinal Centre of Gravity	-1.1 m forward of Station 10
Transverse Metacentric Height (GM)	5.0 m
Roll Radius of Gyration	16.3 m
Pitch Radius of Gyration	70.1 m
Yaw Radius of Gyration	70.0 m
Water Depth	37.5 m
Gap to Basin Wall	2.0 m
Gap to Image LNGC	4.0 m

Table 1: Particulars of the LNG carrier test setup. All dimensions given at full scale.

Surface meshes for the LNG carrier up to the waterline, at various refinements, were provided by Marin for the study. The surface mesh used in this report is shown in Figure 1.

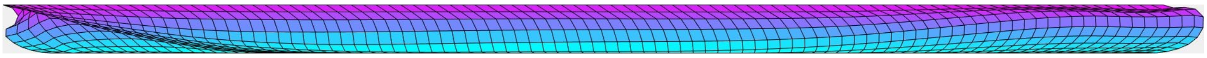

Figure 1: 2376-panel LNG carrier surface mesh (with no hull lid) used for this study

For the side-by-side case, both vessels need to be meshed, together with an optional gap lid in between them.

2. Second-order wave loads

The second-order wave loads given here are also known as “drift forces”. These are calculated as the steady component of the second-order wave force in regular waves, as developed in Newman (1967) and output in WAMIT v7.3. They are proportional to wave amplitude squared and vary with wave frequency.

The regular-wave second-order loads may be used to calculate slowly-varying, difference-frequency loads on moored vessels in irregular seas, as described in Newman (1974). The regular-wave second-order loads correspond to the diagonal elements of the Quadratic Transfer Function matrix (Newman 1974, Pinkster 1981). Off-diagonal elements of the QTF matrix may be estimated using geometric or arithmetic averages of the corresponding diagonal elements (Newman 1974, Orcina 2012).

Settings used for calculating second-order wave loads are shown in Table 2. WAMIT options are described in WAMIT (2019).

Method	Details
‘WAMIT, control surface’	IOPTN(7)=1, open-top cuboidal control mesh
‘WAMIT, momentum balance’	IOPTN(8)=1
‘WAMIT, gap lid with pressure integration’	IOPTN(9)=1, IDAMPER=1, gap lid mesh
‘DIFFRAC’	Digitized from Pauw et al. (2007, Fig.11) with no gap lid

Table 2: Settings used for calculating second-order wave loads

Calculated second-order wave loads are shown in Figure 2.

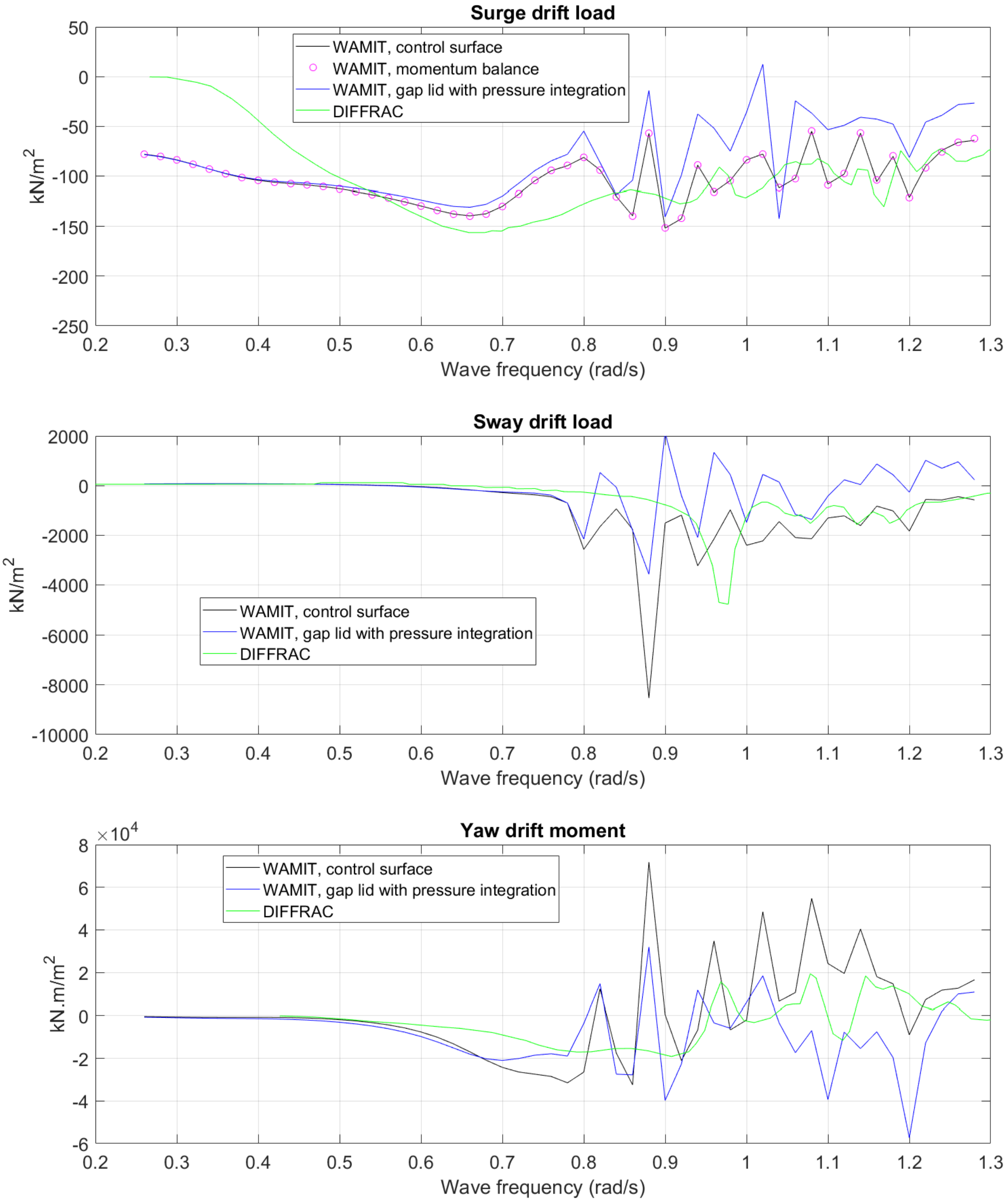

Figure 2: Calculated second-order wave loads from WAMIT and DIFFRAC

3. Conclusions

Conclusions from the study were:

- Sway drift load on the starboard LNG carrier in head seas was generally negative over the frequency range, meaning that the ships are pushed apart.
- Yaw drift moment on the starboard LNG carrier in head seas was generally negative, except at high frequencies, meaning that the bows are pushed apart.
- In WAMIT, surrounding each ship with a “control surface” to calculate drift loads was found to match the drift loads on the two-body system from a far-field momentum balance in head seas.
- The WAMIT “control surface” and “pressure integration” methods gave similar results at wave frequencies up to 0.7 rad/s (wave periods of 9.0 seconds and above).
- At wave frequencies of 0.8 rad/s and above, drift loads become erratic due to gap resonance effects (see Gourlay 2019).
- Reasonable agreement was found between WAMIT and DIFFRAC second-order loads, given the difficult nature of these calculations for side-by-side vessels in shallow water.

4. Acknowledgements

Information on the model tests was kindly provided by Willemijn Pauw and Tim Bunnik, of Marin. Surface meshes for the model-tested LNG carrier were kindly provided by Frédérick Jaouën, of Marin.

5. References

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