On the modeling of passing ship effects

Tim Bunnik
MARIN
Haagsteeg 2, Wageningen, The Netherlands
t.bunnik@marin.nl

Serge Toxopeus
MARIN\TU Delft
Haagsteeg 2, Wageningen, The Netherlands
S.L.Toxopeus@marin.nl

Abstract

This paper presents a method to compute the effect of passing ships on moored ships. The method is in principle based on the method originally developed by Pinkster [3]. He developed a method to quantify these effects based on linear potential flow. The disturbance of the passing vessel on the port geometry and moored ship is analyzed using a double-body flow. The reflection of this disturbance on the geometry of port and moored ship is analyzed using a linear diffraction method. This method has shown to give good results for ships sailing straight ahead, but is expected to be less accurate for passing ships sailing under a drift angle, in which case the viscous wake related to the lift force on the vessel becomes more dominant.

Therefore, the method by Pinkster is extended with viscous effects. The disturbance caused by the passing ship on the moored ship and port geometry is computed by a RANS method instead of a potential flow method. The diffraction effects due to the presence of the moored ship and port geometry is accounted for in the same way as Pinkster did by means of a linear diffraction analysis. A comparison is made with model tests for a ship passing a moored ship along a quay at various drift angles. Results are shown for the traditional method (potential flow disturbance) and for the considerably improved method (RANS disturbance).

Introduction

Vessels moored in ports experience hydrodynamic forces due to water motions set up by passing vessels. For large vessels travelling at low speeds these effects are mainly associated with long-period return current and drawdown generated by the passing vessel sailing in a restricted waterway. These currents and drawdown lead to so-called suction effects on moored vessels.

Research into the effect of passing ships on moored ships has been going on for many years. Remery [1] carried out an extensive experimental investigation where the passing ship size, distance, and speed were varied. Measured captive forces were used to determine motions and loads in mooring lines. Huang and Chen [2] applied an unsteady RANS solver to determine the forces on a moored ship perpendicular to the passing ship path. However, neither verification nor validation of their method was done. Pinkster [3] presents a method in which he computes the disturbance caused by the passing ship by a potential method, which he then applies as incident flow to a linear diffraction method for the moored ship. This gives reasonable results for ships moored at a quay.

In none of these cases, ships passing under a drift angle were studied. The objective of this paper is to present and validate a method for the effect of ships passing a moored ship under a drift angle. The approach is similar to the one developed by Pinkster [3], except that the disturbance model is replaced by a RANS model to taken into account effects of viscosity properly. Verification of the method is carried out by means of grid refinement studies. Validation is carried out by means of scale experiments which are presented in the next section.

Experiments

Passing ship experiments were carried out in MARIN's shallow water basin. This basin has a length of 220 m and an effective width of 15.7 m. Force measurements were carried out on a captive ship model which was positioned 0.0366 m from the vertical basin wall. The passing ship model was pulled by the basin carriage at constant speed through the basin at various speeds, drift angles and passing distances. The water depth was 0.514 m. Two lasers registered when the passing ship sailed past specific well defined points before and aft of the moored ship. This enabled accurate time synchronization with the simulations. The setup for the experiments is shown in Figure 1. The passing ship has a length of 9.581 m, beam of 1.492 m and a draft of 0.445 m. The moored ship has a length of 7.277 m, beam of 0.843 m and a draft of 0.330 m.

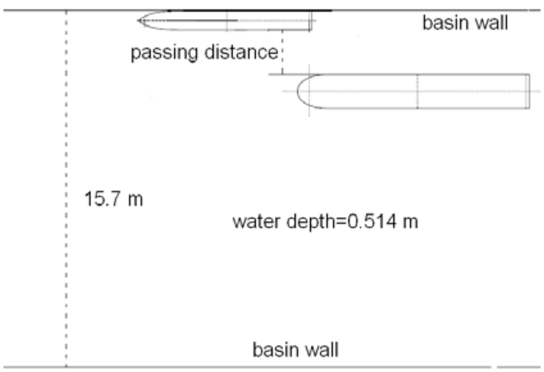

Figure 1: Setup of experiments

Two experiments were used for validation of the numerical model. In both cases, the passing speed was 0.458 m/s and the passing distance 2.618 m. The drift angles varied between 0.0 and 7.5 degrees. In this work, all simulations and experimental results are shown on model scale. The passing distance is defined as the minimum distance between portside of the moored vessel and starboard side of the passing vessel. A positive drift angle means that the bow of the passing vessel turns away from the moored ship. The rotation axis is the intersection of station 10 and centre plane of the passing ship.

Calculation method for passing ship forces on moored ships

The calculation method presented in this paper consists of two distinct steps. First, it is assumed that the passing vessel creates a disturbance on its surroundings (the moored vessel geometry). This can be thought of in a similar way as the disturbance which is caused by for example incoming ocean waves. This means that the actual geometry of the moored ship is not present in the computation of the disturbance. The disturbed water velocities and the pressures on the position of the moored vessel are computed, without that vessel actually being there. Since the displaced water in reality cannot go through the geometry of the moored vessel (no-flux condition), a reflected or diffracted wave is generated. This is the second step of the computational procedure. It is assumed that this reflected wave has no interaction back to the passing ship. It can be imagined that this assumption becomes less valid as the passing distance decreases or the passing speed decreases.

There are several ways to compute the disturbance flow created by the passing ship. The two methods used in this paper are a double-body potential flow method and a double-body RANS method (steady computations). In both cases, free-surface effects are neglected. The implementation of the double-body potential flow method is based on the work by Grue and Biberg [6]. The details of the RANS method are described in the work of Vaz [4]. The diffracted waves from the moored ship are computed using a linear diffraction program, see Bunnik [7]. Since this method is implemented in the frequency domain, prior to the linear diffraction analysis the disturbance velocity time traces are transformed from the time domain into the frequency domain by means of the Fast Fourier Transform (FFT). After solving for each frequency component of the diffracted pressure, the diffracted pressure time traces are found by means of the inverse fast Fourier Transform (iFFT). The total pressure follows from adding the diffracted pressure to the disturbance pressure. Integration of the total pressure over the wetted ship surface yields the forces and moments on the moored ship due to the passing ship.

Results

In the present work, the SST turbulence model without stream-wise vorticity correction [5] has been used in the RANS model. Detailed grid refinement studies were carried out for both the RANS computations and the linear diffraction analysis. Only the converged results on the finest meshes are shown here.

Figure 2 shows the pressure and velocity field obtained by the RANS method for drift angle β=7.5°. On the right, the velocity and pressure time trace is shown on a point on the moored ship (this point travels with constant speed through the passing-ship-fixed RANS or potential flow domain). Clear differences can be observed between the RANS and potential flow model for the longitudinal velocity and water pressure. The differences in the transverse velocity are much smaller. It should be noted that the differences for zero drift angle (not shown here) are much smaller.

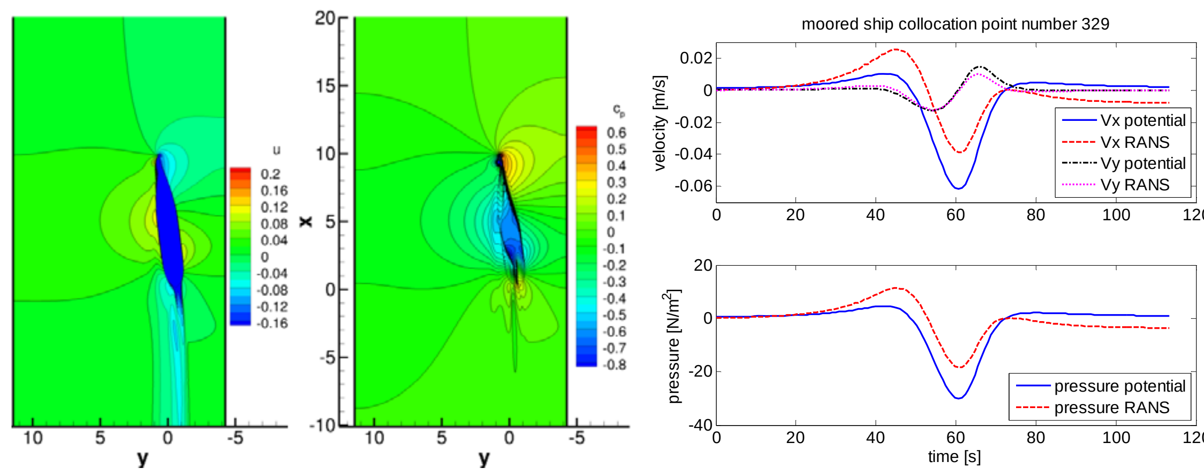

Figure 2: RANS velocity (left) and RANS pressure (middle) fields, β=7.5°. Time traces of velocity and pressure on location of moored ship (right).

Figure 3 shows the computed and measured forces and moments on the moored ship for drift angles of β=0° and β =7.5°. Both the results using a RANS disturbance and a potential-flow disturbance are shown. The upper subplot shows the longitudinal distance between stations 10 of the passing and moored ship. The following can be noticed:

- At β =0°, the potential flow and RANS disturbance methods result in very similar forces on the moored ship. The agreement with the experiments is good. Some deviations can be seen in the yaw moment.
- At β =7.5°, the potential flow disturbance method gives inaccurate results for the surge force, and to a lesser extent for sway and yaw. The RANS disturbance method gives a much better prediction for surge and sway, and slightly better for yaw.

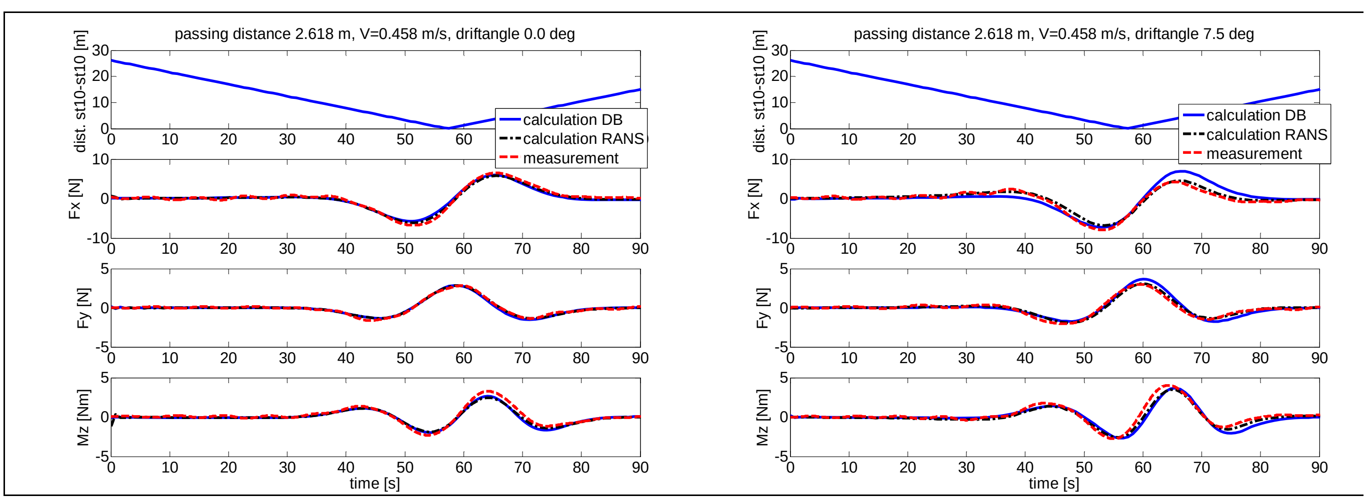

Figure 3: Forces on moored ship, β=0° (left) and β=7.5° (right).

The fact that the RANS disturbance method gives much better results is a clear indication of the importance of viscous effects and/or rotation in the flow around the passing ship sailing under a drift angle.

Conclusions

A one-way coupling between

1. either a double-body potential flow disturbance or a double-body RANS disturbance and
2. a linear diffraction model

was successfully implemented to investigate the forces induced by passing vessels on moored vessels. Validation was done by means of model tests in which a sailing vessel passes a moored vessel along a quay at various drift angles. The simulations show that:

- A very good agreement is found between experiments and simulations (using both RANS and potential flow disturbance) for zero drift angle.
- At a drift angle of 7.5 degrees, considerable differences start to appear between the simulation using potential flow disturbance and the experiments. The simulation using RANS disturbance however, gives much better results.

Based on the findings in this paper, the following recommendation for future work are made:

- The simulations and experiments were done at model scale, at which viscous effects were found to be important. To investigate scaling effects, simulations should also be done at full-scale, preferably validated against full-scale trials.
- For small passing distances, a one-way coupling is no longer sufficient. For those cases, either:
  a) a two-way coupling between RANS and linear diffraction should be implemented, or
  b) a complete CFD solution should be obtained using for example a sliding interface between the passing ship and moored ship.

References

[1] Remery, G.F.M., 1974. "Mooring Forces Induced by passing Ships", In *Offshore Technology Conference*, OTC 2066, Houston, Texas, May 6–8.

[2] Huang, E.T. and Chen, H.-C., 2007. "Influences of Site Specifics on Passing Ship Effects", *Proceedings of the Sixteenth (2007) International Offshore and Polar Engineering Conference*, Lisbon, Portugal, July 1–6.

[3] Pinkster, J.A., 2009. "Suction, Seiche and Wash Effects of Passing Ships in Ports", *SNAME Annual Meeting and Expo*, paper 024, Providence, RI, October.

[4] Vaz, G., Jaouen, F.A.P. and Hoekstra, M., 2009. "Free-surface viscous flow computations. Validation of URANS code FRESCO". In *28th International Conference on Ocean, Offshore and Arctic Engineering (OMAE)*, OMAE2009-79398, Honolulu, Hawaii, May 31–June 5.

[5] Menter, F.R., 1994. "Two-equation eddy-viscosity turbulence models for engineering applications". *AIAA Journal*, Vol. 32(8):1598–1605, August.

[6] Grue, J. and Biberg, D., 1993. "Wave forces on marine structures with small speed in water of restricted depth", *Applied Ocean Research*, Vol. 15(3):121–135.

[7] Bunnik, T., Pauw, W. and Voogt, A., 2009. "Hydrodynamic Analysis for Side-by-Side Offloading", *Proceedings of the Nineteenth (2009) International Offshore and Polar Engineering Conference*, Osaka, Japan, June 21-26, pp 648–653.