Predicting the effect of passing ships

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Introduction

Passing ships create disturbances in the water which result in forces on other ships and floating structures. Such hydrodynamic forces can result in high mooring forces and unacceptable motions of the moored vessels. Passing ship effects have in the past concentrated on suction effects associated with the primary or "double-body" flow around the passing vessel. See ref(1). By definition, this means that real free-surface effects, i.e. surface wave propagation effects, are not accounted for. The reason for basing the effects of passing ships on double-body flow models is that generally such ships are moving at low Froude number values , even when viewed in relation to the waterdepth. However, depending on harbour geometry, even in the case of large, slow ships , the disturbance created by the ship may set up seiches in the harbour which will also have their effect on moored vessels.

Nowadays, with the advent of more fast vessels, also in restricted waterways, not only the effects of the primary disturbance but also the secondary waves , also known as wash, need to be taken into account when analysing the effects of passing ships.

In this contribution attention is focussed on models to predict the effects of passing ships taking into account free-surface effects for both the slow and fast passing ship.

In the case of large, slow ships, the free-surface effects are due to the surrounding harbour geometry being excited by instationary water motions arising from the , essentially double body flow pattern moving with the passing ship.

In the case of fast moving ships, the free surface effects are due to the wash waves generated by the passing ship which propagate into the harbour thus creating a more or less complicated incoming wave system for the moored ship. In this contribution a computational method for predicting such effects is introduced. Results of computations will be compared with results of model tests.

Computational method

The computational method is based on the assumption that the flow induced by the passing ship relative to the passing ship frame of reference is either time-independent in flow pattern with velocities which are linearly dependent on the ship's speed (double-body flow model) or time-independent but depending on the speed of the vessel (wash waves). In both cases the flow induced by the passing ship is instationary relative to the earth-fixed frame of reference of the harbour and of the moored ship.

A second assumption is that the flow around the passing ship is not affected by any reflections of its own flow by the surrounding harbour geometry or by the moored ship. This assumption implies that the flow about the passing ship can be determined without the presence of the harbour geometry (except for the waterdepth if it is appropriate to assume a constant waterdepth equal to that of the fairway along which the ship is moving). This assumption need not always be made but is one which reduces the amount of computations considerably.

Based on the above assumptions the developed computational procedure reduces to the following :

- Determine the flow around the passing ship under the assumption of restricted waterdepth only
- Determine the flow induced by the passing ship at the location of the harbour geometry and the moored ship
- Determine the diffraction effects of the harbour and the diffraction and radiation effects of the moored ship and the resultant hydrodynamic forces and motions

Flow around the passing ship

In the case of large , slow ships whose main disturbance is related to suction-type effects on moored ships and/or seiches induced in harbours, the double-body flow model based on 3-d diffraction is adequate. See ref(1). We have developed the code DELPASS based on this approach. Shallow water effects have been included using the method given in ref (2). The solution of the 3- d flow results in the distibution of the (constant) source strengths on the boundary elements (zero-order panels) describing the vessel shape. Due to the assumption of double-body flow the flow pattern is speed independent and the induced fluid velocities are a linear function of the ship's speed.

For the case of vessels moving at higher Froude numbers and for which the main disturbance is associated with wash wave, we make use of the 3-d panel model RAPID , developed by Raven (ref (3)) for the prediction of wave patterns around ships moving at constant speed and at restricted waterdepths. The wave pattern and the associated fluid velocities and pressures are known within the domain covered by the free surface boundary elements. Due to the presence of the free surface, the induced fluid velocities need to be recalculated each speed of the vessel.

Disturbance at the location of the harbour geometry and moored vessel

In both previous cases the flow is constant with respect to the ship system of co-ordinates. For a ship passing through a harbour geometry, the disturbances are time-dependent relative to the harbour and moored ship. For subsequent computations of the harbour and moored ship responses use is made of the linear 3-d potential method. The harbour geometry and the moored vessel are described in the usual way by a distribution of boundary elements (panels) over the mean wetted surfaces.

The disturbance created by the passing ship is transformed into time-dependent normal velocities and pressures at the collocation points of the boundary elements describing harbour and moored ship.

For the case of large, slow moving ships for which the disturbance is determined based on double-body flow, the velocities and pressures can be obtained directly from the sources strengths on the passing ship taking into account the relative positions of the elements on the ship as it passes through the harbour and the elements on the harbour geometry and the moored ship.

In the case of wash waves which are computed based on 3-d codes such as RAPID, the harbour geometry and the moored ship may be situated beyond the domain covered by the boundary elements used. In such cases, two procedures have been developed to extend the wave pattern outside of the RAPID area. The first procedure takes the form of a row of numerical wavemakers (3-d boundary elements, wave making sources) which are on a line parallel to the direction of travel of the passing vessel within the area covered by the free surface panelling. The wave maker source strengths can be derived from the normal velocities induced by the passing ship. Based on these source strengths, the wave propagation outside the RAPID domain can be computed in the normal way.

The second procedure makes use of a longitudinal wave cut along a line parallel to the direction of travel of the passing ship , within the RAPID domain. Both methods are applied in the frequency domain after FFT of time domain data as explained in the next section.

Determination of diffraction effects of the harbour and the moored vessel, forces on the vessel and vessel motions.

From the second step, time domain records of the disturbance velocities and pressures of the passing ship at the collocation points of the harbour and moored ship are known. By means of the Fast Fourier Transform method time domain records of velocities and pressures are decomposed into their frequency components retaining both amplitude and phase information. Subsequently, using the multi-body frequency domain 3-d diffraction code DELFRAC (ref (4)) the diffraction and, for the moored vessel, the radiation potentials are solved for all frequencies. Inverse FFT of results give the time domain behaviour of the harbour/moored ship combination with respect to such quantities as wave elevations, hydrodynamic forces on the moored vessel and total fluid velocities and pressures. This procedure is applied for both the input based on double-body flow and wash waves. For the case of input based on wash waves resultant time domain data on pressures and fluid velocities are used to compute time domain records of second order wave drift forces on the moored vessel.

Examples

In figure 1 through figure 3 examples are given of the forces and motions of an 80 m long moored inland waterway barge being passed at a distance of 65 m by a 30 m long fast passenger ferry travelling at 26 knots in open water at a waterdepth of 8 m. In the presentation details of the method and results will be given of a number of applications using both the double-body flow input and the wash wave input for the case of vessels moored in open water and in harbours. These will include the following:

- Solitary waves created by an accelating barge in a canal
- Solitary waves created by a barge entering a canal at constant speed
- Seiches generated by a ferry entering and stopping in a harbour
- Behaviour of a vessel in a dock next to the fairway due to a passing fast ferry

Results will include animations showing resultant vessel motions and wave elevations due to passing ships. For some cases computed results will be compared with results of experiments.

References

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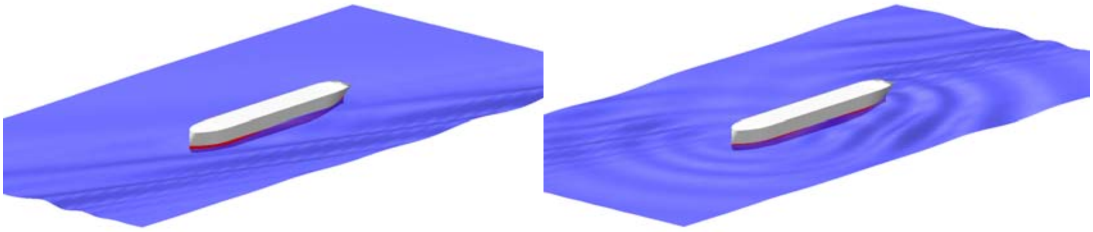

Figure 1 : Inland Barge passed by a Fast Ferry. Time lapse between shots 22 s

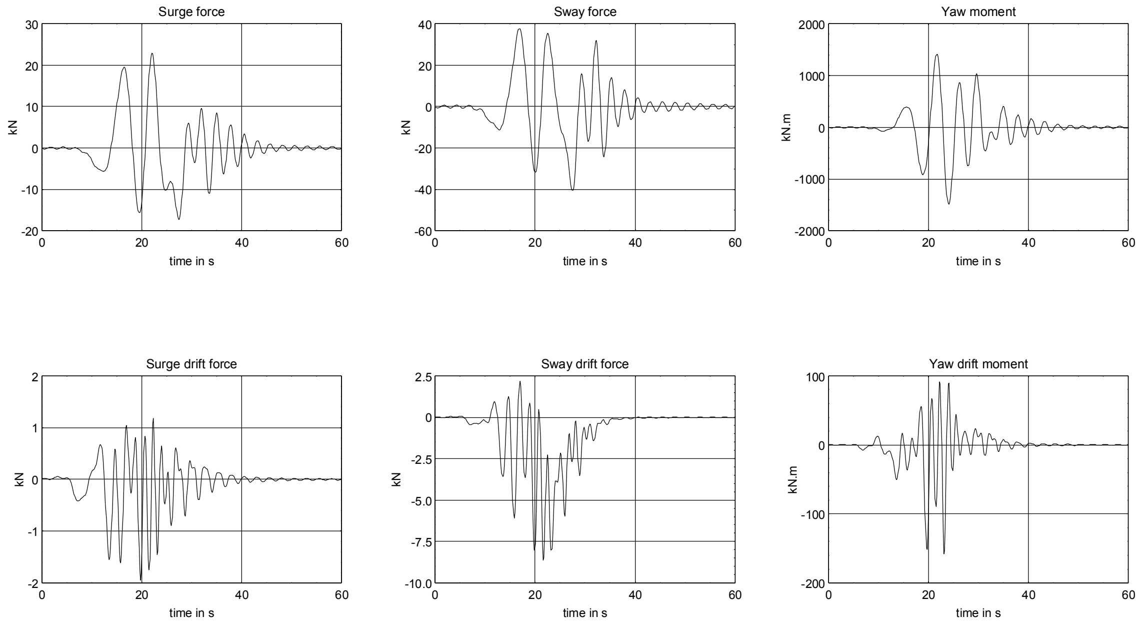

Figure 2 : First and Second Order Forces on Inland Barge passed by Fast Ferry

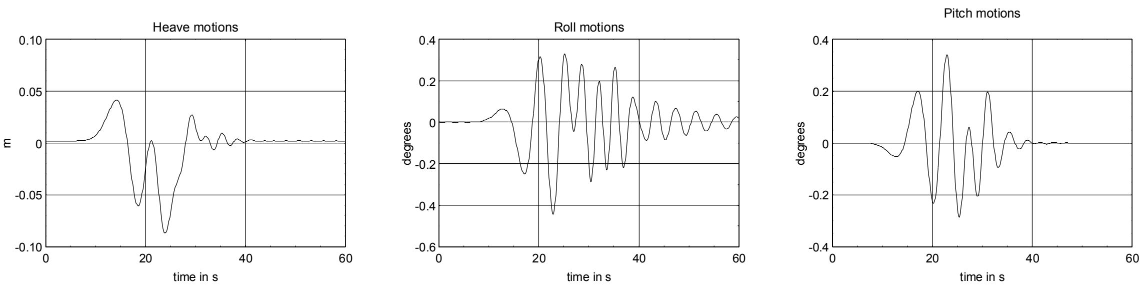

Figure 3 : Wave Frequency Motions of Inland Barge due to passing Fast Ferry