Passing Ship Induced Long Waves In Confined Water

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Introduction

Ships moored in harbours are subjected to hydrodynamic forces due to other ships passing nearby. These hydrodynamic forces induce motions of the moored ship which may hinder loading/discharging operations or cause damage to the mooring system.
The forces originate from different wave systems generated by the passing ship, each having its own characteristics: low frequency forces, sometimes known as suction forces, are associated with the primary pressure system around the sailing ship. The secondary wave system, or 'wash waves', causes a relatively high frequency force. Finally, instationarities in sailing behaviour or in the waterway geometry that the ship is sailing through may cause another kind of waves: a soliton-like wave can occur under certain circumstances. This is a wave existing of one single crest that, after it has been generated, propagates ahead of the ship through the confined waterway. It's the latter kind of wave that's being focussed on in the present study. This paper addresses a method to predict these waves. Also results of validation experiments involving a barge passing a canal constriction will be presented.

The first reason to investigate solitary waves originates from a study carried out by the Ministry of Transport and Waterways in the Netherlands in 1979, based on full scale measurements. It showed that large inland barge combinations (10000 t) entering a long canal from relatively open water are capable of generating solitary waves which propagate through the canal system ahead of the vessel, causing unexpected rises of the free-surface resulting in damage to moored vessels. In this particular case, the barge combination causing the damage was still several miles away from the affected moored vessels.
Earlier experiments carried out at DUT showed that unsteady sailing behaviour causes similar effects: a model of a barge, accelerating in shallow water generates a solitary wave that propagates through the towing tank ahead of the towed barge. A fairly good agreement was found between the measured and predicted wave height at locations ahead of the vessel.
As a follow-up to these experiments, additional tests were carried out in 2005. This time a canal constriction was built through which a barge model was towed. The water level was measured at several locations in the canal. As expected a solitary wave was generated the moment the model passed the constriction. Calculations using a slightly modified improved prediction method again show a fairly good agreement.

Computational method

The computational method used for the prediction of the wave height anywhere in the confined waterway the ship is sailing in, is based on 3D linear potential theory. A numerical panel method is used for the calculation: both ship and waterway are represented by a 3D panel distribution. The method can be presented by 4 steps:

1. determination of the flow around the passing ship. Here, a so-called double body flow around the ship is calculated: the free surface boundary condition implies zero normal velocity at the free surface. Contrary to previously published work (see ref [1]), restrictions in both vertical and horizontal direction of the waterway / harbour are taken into account.
2. Time traces of the disturbance by the passing ship's double body flow at each of the panels of the waterway (ignoring the presence of the passing ship itself) are Fourier- transformed into frequency components.
3. The diffraction effects of the waterway are determined: the velocity potential is solved, this time taking into account the linearised free surface boundary condition enabling the generation of diffraction waves.
4. The obtained frequency domain solution of the velocity potential is inverse-transformed into the time domain. Pressures, velocities and wave heights at any desired location can be determined now from the known velocity potential.

Experiments

In order to validate calculated results, model tests were carried out at scale of 1:70 in tank #2 of the Ship Hydromechanics Laboratory. This facility measured 80 m x 2.78 m which corresponds to 5600 m x 195 m full scale . Tests were carried out for waterdepths amounted to 5.6 m and 4.2 m full scale values. Additional walls were placed in the towing tank to model a canal constriction. Two kinds of experiments were carried out: See Figure 3 which shows a schematic plan view of the test set-up. The hatched outer-most boundaries represent the existing towing tank walls with a full scale width of 189 m. Additional walls were placed over a full scale length of 3160 m to model the walls of the narrow part of the canal with a full scale width of 90 m, represented by the normal lines in Figure 3. A first set of runs was carried out in the 'canal configuration' during which the free surface elevation was measured at the locations marked by the dots. Additional tests were done with the 'harbour configuration': an opening was created in one of the canal walls enabling waves to enter the thus obtained protected harbour-like area. Free surface elevation was measured in this area while again the model was sailing through the canal. Speed and sailing direction of the vessel and water depth were varied for both configurations. The vessel dimensions : Length 91 m , Breadth 22 m , Draught 2.625 m.

Results

For both the canal and harbour configuration, typical results are shown in Figure 1 and Figure 2 respectively. Time traces of the measured and calculated surface elevation are shown at measurement locations 1, 2 , 3 and 4 (indicated in Figure 3). The position of the passing vessel with respect to the concerning measurement location is also indicated. For the canal configuration the occurrence of a solitary wave preceding the vessel is obvious and predicted fairly well. The somewhat more complicated wave pattern within the harbour (Figure 2) generated by the vessel passing the harbour entrance also shows a fairly good agreement with the prediction.

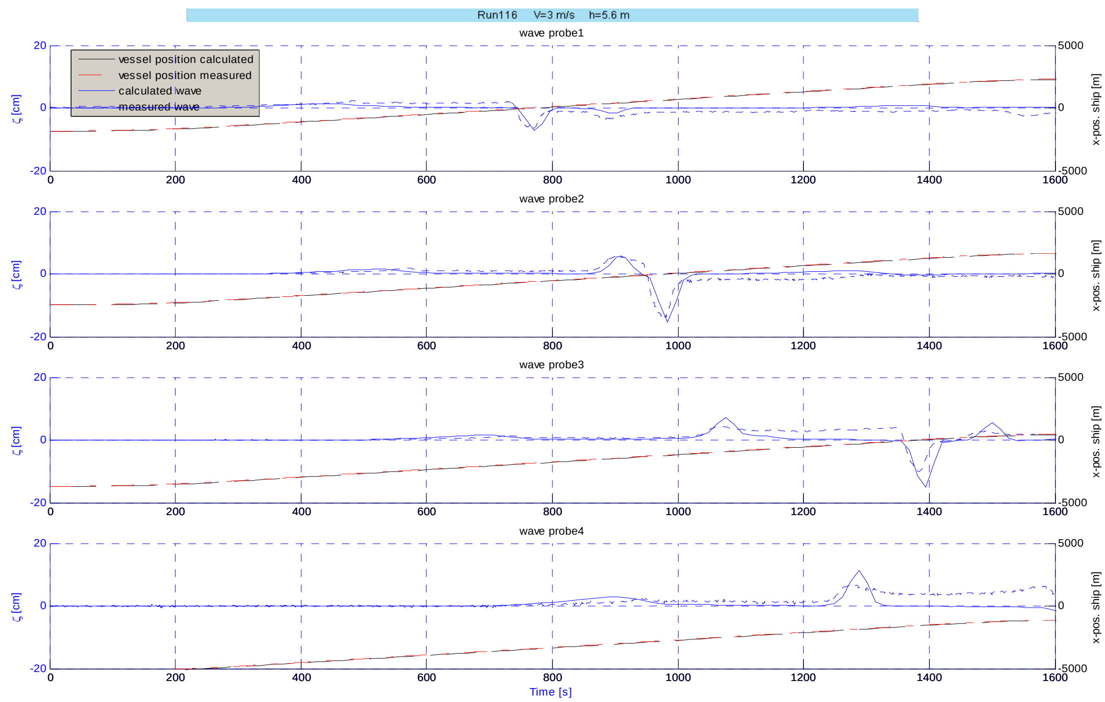

Figure 1, measured and predicted wave in canal configuration

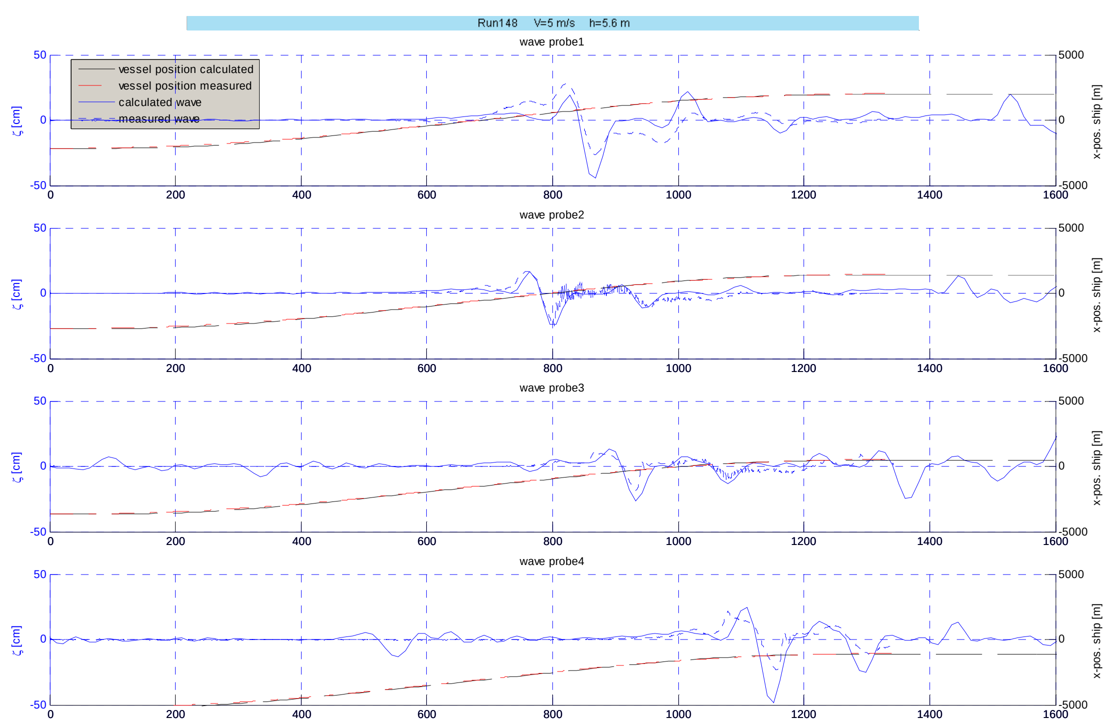

Figure 2, measured and predicted wave in harbour configuration

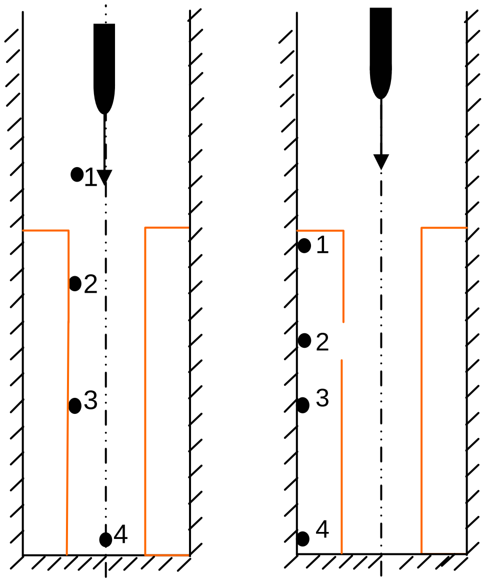

Figure 3, canal (l) and harbour (r) configuration

References

1. Pinkster, J.A.& Naaijen, P. 2003 Predicting the effect of passing ships. *International Workshop on Water Waves and Floating Bodies*
2. Pinkster, J.A. 2004 The influence of a free surface on passing ship effects. *International Shipbuilding Progress*