The OTSS System for Drift and Response Prediction of Damaged Ships

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Abstract. It is important to establish the preventing technique of disabled ships from drifting under the rough weather and towing technique as soon as possible. In the PC system the drift motion, towline tension, unstable motion of towed vessels and effective horse power have been estimated. This towing support tool is called Optimum Towing Support System (OTSS). This system provides the support for towing operation. It also includes the drift motion such as drift speed and direction with different ship types. The paper describes the flow of the system.

1 Introduction

The 5 year research project from the fiscal year of 1998 to 2002 named ‘Drift prevention of disabled ships in rough seas’ sponsored by the Ministry of Land, Infrastructure and Transport finished March in 2003. The purpose of this project is to establish the technology to prevent disabled ships caused by the engine trouble and on. From drifting and to tow them to the safety area, and thus the secondary disasters would be prevented from occurring. The optimum towing support system called OTSS using the personal computer has been developed [1],[2],[3]. It can provide the operators with the information of prediction such as drift motion, towline tension, maneuvering and needed horse power of tow boats. This report describes the outline of the system.

2 Outline of OTSS

OTSS is the computer program which can predict the drift motion, towline tension, unstable motion of towed ships and towing trajectory using the personal computer. The function of the system is by Fig.1.

(1) Similar ship production function

The kinds of type ships for shipwrecks are shown in Table 1. The various data of shipwrecks can be calculated by making input of the loading condition and main particulars such as length, breadth and depth.

1) Similar ship type

The similar ship offset can automatically be produced using the dimension of length L, breadth B and depth D of type ship shown in Table 1.

2) Compartment
The transverse coordinate of ship structure can be converted by the ratio of breadth to depth. The distance from the hull is done by the same manner. The frame number of ship structure is not changed and only the frame space is changed.

3) Light weight

Basic weight, local weight and loading condition can be calculated by multiplying the ratio of L'B'D'/(LBD). The local weight means the partial load such as engine part and deckhouse out of dead weight. L', B' and D' indicates the dimension of towed ship.

(2) Input of upper-structure on the deck

The wind resistance of towed ships above the sea, hydrodynamic resistance and wave drift force below the sea surface can be calculated by making input of geometric shape such as cylinder and rectangle on the deck.

(3) Calculation function of center of gravity

The center of gravity can be calculated and it is used for calculation of ship status and damage stability.

(4) Mesh generation function for calculating wave drift force

The mesh on the ship hull can be generated and that on the submerged part can be output on the display.

(5) Final ship status calculation function (damage stability calculation function)

Calculating the damage stability by making input of the kind of type ship, loading condition and main particulars of dimensions, the final status of the towed ship can be estimated.

(6) Stability calculation function on the capsized and broken condition

GZ curve and final equilibrium condition defined by trim, heel and mean draught by the damage stability on the capsized and broken condition can be calculated. When the ship is broken, the broken tank can automatically be detected considering the broken position.

(7) Longitudinal strength

The shearing force and bending moment along the length can be calculated.

(8) Hydrodynamic force and ship motion

The hydrodynamic force such as added mass force, wave damping force and wave exciting force, ship motion and wave drift force can be calculated[4]. Further, 3-D ship animations at various wave incident angles can be observed [5].

(9) Steady drift motion[6]

Calculating the hydrodynamic resistance, wind resistance, wave drift force and current resistance during tow, the steady equilibrium equation can be solved. The bow direction, drift speed and drift direction can be obtained. The number of the solution can be multiple in some cases.

(10) Maneuvering simulation [7],[8]

The maneuvering simulation in the tow and towed ship system can be carried out. The coefficients used for this simulation can automatically be obtained from the experimental data using the patrol boats models, existing experimental formulae and the database of

<table>
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<tr>
<th>Type ship</th>
<th>Tanker 1</th>
<th>Tanker 2</th>
<th>Container</th>
<th>Barge</th>
<th>PCC</th>
<th>Cargo</th>
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</table>

Table 1 Main particulars of type ships.
Fig. 1 Flow of Optimum Towing Support System.

Fig. 2 Main menu display
Hydrodynamic forces developed by the National Maritime Research Institute and thus the maneuvering equation can be solved.

The behaviors of the towed ship such as the unstable motion and trajectories of tow and towed ship can be calculated in the time domain.

3 Flow of OTSS

The main flow of OTSS is elaborated using the computer display. The flow chart of OTSS is shown in Fig.1.

(1) Selection of input form

The input from can be chosen from the following three kinds of menu.

(a) New input

The general towing calculation can be possible in this case (Fig.2). The display for the new input data appears.

(b) Past results

Fig. 3 Input menu for ship status.

Fig. 4 Input menu for tow ship and towline.
The list of past results is used for the reference of the already stored data of towing operation. If the file to be referred is selected in the folder of 'save' and is loaded, the main data with the date of data input can be shown.

(c) Default
Default means the reference of the calculation results for the case on the assumed towing condition. The weather condition, ship type and loading condition can be selected. The weather condition such as wind speed, wave height and wave period has 7 kinds. There are 7 and 2 kinds for the ship type and loading condition respectively. There are 98 patterns in the total number.

(2) Main display
The needed input data for the towing calculation are shown in the display and each necessary item is also shown. The lower part of the table in the display shows the needed input item for the specified calculation.

(a) Weather condition
   Wind speed and direction
   Current speed and
   Wave height, wave period and wave direction

(b) Main particulars of disabled ship
   Ship type
   The ship type can be selected from the database of mother ships. The mother ships are tanker with double hull, tanker with single hull, cargo, PCC, container, fishing boat and barge.
   Loading condition (full and ballast)
   Main dimensions
   If the detail of the ship dimension is not available, the only ship length can be input. The similar ship form can be automatically produced using the similarity rule concerning the ship length.

(c) Broken condition, center of gravity and damage stability (Fig. 3)
   Broken condition
   As for the broken condition of disabled ships, there are 4 kinds of conditions such as ‘Upright normal’, ‘Upright broken’, ‘Capsize normal’ and ‘Capsize broken’.
   Definition of remained part
   When the ship is broken, the broken position is defined by the distance from after perpendicular (A.P.) and then the remained part (fore or aft) is selected.
   Draft
   There are 2 kinds of input for defining the draft of disabled ship. One is the input of mean draft, heel and trim. The other is the input of the draft at the specified position of port and starboard of bow and stern. The table for the definition of draft appears.
   Center of gravity and damage stability
   After input of above all items, the center of gravity and damage stability calculation can be possible. The results of GZ curve and longitudinal strength curve can be drawn.
   The mesh presentation of the submerged part of ship can also be verified for the next
calculation. This mesh is used for the calculation of the hydrodynamic force using three-dimensional panel method.

(d) Towline and tow ship (Fig. 4)
- Kinds of tow ships and main dimension of tow ship
- Towline material, length and diameter

Fig. 6 Display for drift prediction.

Fig. 7 Display for the results of towline tension and unstable motion.
Tow speed and direction
- Tow speed and direction of the rescue vessel can be specified at every 1 kt and at 10 degree respectively in the calculation range.

(3) Calculation of hydrodynamic force and motion
- The hydrodynamic force such as added mass force, wave damping force and wave exciting force can be calculated after input of all necessary data and the ship motion and wave drift force can be obtained. As the calculation of the ship motion will end instantly, the three dimensional animation of ship motion (Fig.5) can be observed by the input of wave direction. The bare hull can be shown by deleting the sea surface and its compartment can be observed.

(4) Calculation of steady wave drift motion and graphic expression of the result (Fig.6)
- The towing resistance and wind resistance as well as the wave drift force can be calculated. The calculation result of the steady balance equation considering those external forces can be shown by the graphic display of bow direction, drift speed, drift direction as well as the weather condition. Further, the drift speed, drift direction, bow direction, relative drift angle, encounter angle to the wave, relative wind speed, relative wind direction are shown in the table of lower part of the display. The definition of those items is also shown by the figure.

(5) Maneuvering simulation
- The computer program the maneuvering simulation concerning the tow system composed of tow and towed ship can be run. The maneuvering derivatives can automatically calculated by the developed database which has been produced using the experimental data of National Maritime Research Institute and existed experimental formula and the solution of maneuvering equation can be obtained.

(6) Calculation of maneuvering simulation (Fig.7)
- The results of towline tension and unstable motion of towed ship at every 10 degree of tow direction in the specified range of tow speed are shown in the maneuvering simulation. The effective horse power can also be shown in the table. The full-scale simulation can be identified by the difference of the color. The weather condition of wind, wave and current is also shown by the value. Furthermore, the result can be drawn at every 1 kt of tow speed.
Unstable motion (Fig.8)

The trajectory of tow and towed ship in the horizontal sea surface can be drawn and the behavior of the unstable motion of towed ship can be observed. The position and bow direction of both tow and towed ship with the relative direction of weather condition at every 120 second can be drawn. The towline tension in the time series can also be drawn simultaneously. The graphic display can be changed by the input of tow speed and direction. Finally, the results and input condition can be stored. Those data can be referred as the past data at the next operation.

As the sea state is always changing at the site, the new calculation can be started by the change of the only weather condition on the first menu display.

4 Summary

The flow of Optimum Towing Support System (OTSS) on the personal computer was shown and the function of each menu of OTSS was elaborated. It is very important to use this system and evaluate the operational results for an emergency towing on the site. When this system is used on site, the evaluation and operational data are produced at the same time. Thus the towing database can actually be constructed. The computer program for constructing database should be made.

Acknowledgment

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The computer program compiled by Visual Basic software for OTSS has been developed by Mr. Hiroshi Sato of National Maritime Research Institute (NMRI) and Mr. Seiji Kaneko of graduate school of University of Chiba who worked as a part time job at NMRI. Their achievement is very much appreciated.

References