EXPERIMENTAL VALIDATION OF A TWO-PART UNDERWATER TOW

By: S D Ranmuthugala

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S D Ranmuthugala -

Australian Maritime Engineering Cooperative Research Centre (AMECRC),
Launceston, Tasmania, Australia,

ABSTRACT The trajectory of a submerged body being towed by a surface vessel is affected by the wave induced motion of the latter. In an effort to decouple this motion, a two-part tow configuration has been employed. This paper briefly describes a three-dimensional model of the two-part tow, where the two cables are modelled separately and dynamically interfaced. The model is validated against experimental results from scaled model tests in a circulating water channel by comparing the vertical and horizontal motions and the cable tension at the tow point.

1. Introduction

The instantaneous position of a submerged body (fish) being towed by a surface ship will be influenced by the unsteady wave induced motion of the surface vessel, which is transmitted to the fish along the tow cable. One method of reducing this motion is to decouple the surface vessel motion from the fish via the tow cable configuration as shown in Fig. 1.

In order to optimise the configuration, a three-dimensional computer model of the two-part tow was developed to predict the motion of the fish due to the excitation at the surface, ref. [1] & [2]. Since the attachment between the two cables can be varied along the length of the primary cable, it was decided to model the two cables separately and then to dynamically couple them at the junction. This concept allows the investigation of not only varying points of attachment, but also multiple towed bodies, ie. more than one secondary cable.

The model is validated using experimental data from scaled model tests in a circulating water channel. The experimental results presented in this paper compare favourably with the computer model results. Full scale trials are planned for the later part of 1994.

2. Modelling of the System

Modelling techniques for conventional towing arrangements have been presented by various authors, ref. [3] & [4]. If the junction and the depressor coincides, then it is possible to model the system as a single cable system. If however, the attachment point between the cables is relatively high above the depressor, the above method is inadequate and it is required to model the two cables separately and to dynamically interface them at the junction. The authors have previously presented detailed descriptions of the model in ref. [1] & [2].

The modelling of the cable assumed the distributed mass of the tow cable to be represented by a series of discrete masses separated by weightless, elastic straight-line segments as shown in Fig. 2. The motion of the cable can be described by applying Newton's law of motion to each node in turn. Thus for node i shown in Fig. 3,

$$[M_i] \;.\; [\ddot{u}_i] \quad = \quad [F_{ix,y,z}] \qquad (1)$$

- The mass term M_i will represent the mass and added mass of the node. $F_{ix,y,z}$ will include the tension, net weight and drag forces of the cable segment.

The relative motion between the cable and the fluid will lead to a drag force resulting in a damping effect. This drag force will have components in the tangential and normal directions to the cable axis as shown in Fig. 3, and will be proportional to the square of the relative cable velocity. Thus the local drag forces for cable segments are obtained from Morison's equation.

For the node representing the junction, the terms in eqn. (1) will includes in addition to the segments adjacent to the node, the final segment of the secondary cable. This will result in the matrices M_i and $F_{ix,y,z}$ being modified to include the physical mass, added mass, tension and drag forces of this extra cable segment.

The depressor and the towed fish can be dynamically modelled to include their mass, added mass, drag and lift (if any), depending on their shape, mass, hydrodynamic characteristics, velocity and acceleration.

Since the quasi-static solution represents the steady state configuration of the system, it is an ideal starting point for the dynamic analysis. Due to the non-linearities of the tow cable, the quasi-static model uses the same lumped mass approach but with equations for statical equilibrium at each node (neglecting the effect due to inertia). Using the values obtained from the quasi-static model as initial values, the dynamic model is solved to the dynamic boundary conditions during each time interval. These boundary conditions will be the path of motion of the primary cable's upper end at the surface and the equations of motion of the towed fish and depressor at the lower ends.

Numerical integration methods are used to solve, in the time domain, the non-linear differential equations describing the motion of the system. A finite difference technique is used to describe the tentative positions and velocities at the next time step from the tentative accelerations and tensions. These tentative segment tensions can then be corrected by using a Newton-Raphson iteration process, based on the constraint equation of each segment length.

Since the coordinates of a node will be a function of the adjacent tensions, the length error term will also be a function of the adjacent tensions. For a single cable system this would yield a tri-diagonal matrix which on solving yields the correction required to the segment tensions to eliminate the segment length errors. Due to the discontinuity at the junction, the matrix obtained will require some elimination steps to transform it into a true tri-diagonal matrix. See ref. [1].

Since the above method models the two cables separately, which are then dynamically interfaced, it is also possible to model tow configurations having multiple secondary cables.

3. Experimental Validation

The validation is divided into two stages consisting first of scaled model tests in a circulating water channel followed by full scale trials. The former has been carried out at the Flume Tank at the Australian Maritime College. The experimental set up is shown in Fig. 4.

The scaled model of the cylindrical towed fish was built with provision to make it neutrally buoyant and to float upright (Fig. 5). Two depressor types were used. The first was a simple sphere of sufficient net weight, while the second was a fish with positive net weight and an inverted hydrofoil to give negative lift.

The excitation at the top was carried out using an elliptical exciter. It consists of a slider-crank mechanism providing a variety of excitations such as heave, surge, sway and a combination of any two of the above.

The resulting motion of the depressor and the fish was recorded on video through an observation window on the side and an observation float above. This enabled the recording of both vertical and horizontal motions including rotational motion. The upper tension was periodically recorded via a load cell at the tow point.

4. Results and Conclusion

A selection of results from the numerical model and the experiments are presented in Fig. 6-8. These consist of predicted and actual values for the fish and depressor displacements and the tow point tension. From these results, it is seen that there is good agreement between the experimental and predicted values. The tension predicted by the model had to be filtered in order to reduce the high frequency component due to discretization.

By comparing results from tests using the two-part and conventional tows for similar conditions, it was evident that the former reduced the transmission of surface motion. The response also varied depending on the position of the junction. The results also indicated that the sphere was less effective than the fish in decoupling motion when used as a depressor.

At high frequencies of excitation the decoupling effect due to the two-part tow was significant, but diminished as the frequency was reduced. This is due to the longer periods, thus allowing the fish sufficient time to follow the motion of the junction due to the net force in that direction by the secondary cable. The introduction of a drogue fitted to the after end of the fish did improve the low frequency response and this is currently under investigation.

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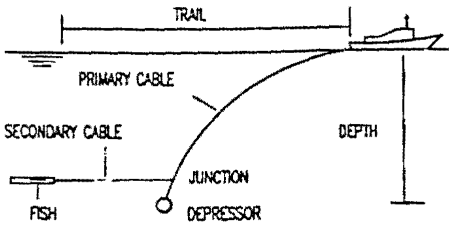

Fig. 1 Two-Part Tow

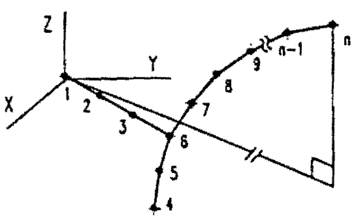

Fig. 2 Lump Mass Model

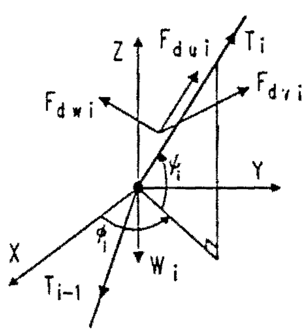

Fig. 3 Node i

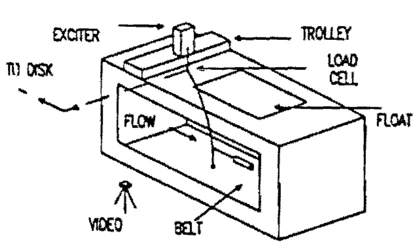

Fig. 4 Experimental Procedure

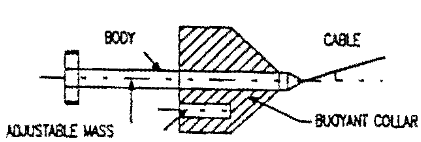

Fig. 5 Towed Fish Model

Primary cable length		=	1.98 m
Secondary cable length		=	1.05 m
Dist. to junction from surface		=	1.52 m
Flow velocity		=	0.75 m/s
Surface	X dirn.	=	0.00 m
excitation	Z dirn.	=	0.10 m
(amplitude)		=	0.44 Hz
Frequency			

– = Model

■ = Experimental

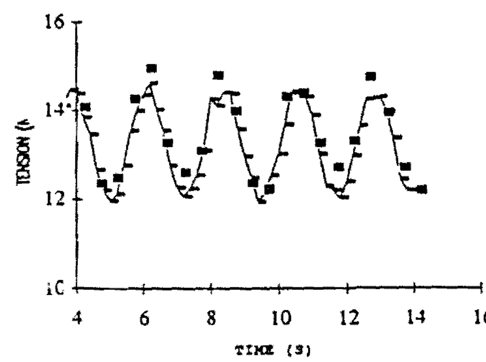

Fig. 6 Tow Point Tension

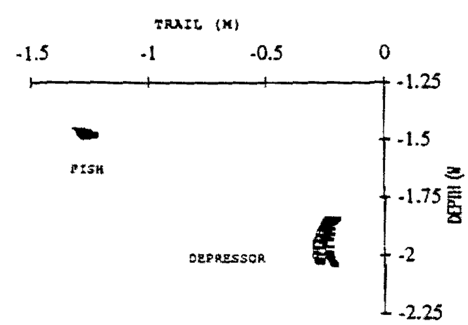

Fig. 7 Fish & Depressor Motion - Model

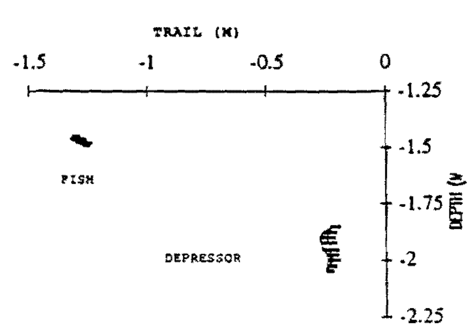

Fig. 8 Fish & Depressor Motion - Experimental