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A method for estimating the gear shape of a mid-water trawl

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Abstract

An estimation of the shape of the gear (gear shape) during a mid-water trawl and the angle of attack of a cambered otter board can be achieved by implementing a three-dimensional semi-analytical treatment of the towing cable (warp) of a trawl system. This can be achieved by processing the field data obtained using the Scanmar system. The shape of the hand rope, bridles and head (or foot) rope attached behind the otter boards in a horizontal plane was assumed to be a function of the form $y_r = Ax_r^B$. The distance between otter boards (otter board spread) estimated using the three-dimensional analysis of a towing cable system should be equal to that obtained using the functional equation. The shape of a trawl net from wing end to bag net was assumed to be of the form $x^2/a_e^2 + y^2/b_e^2 = (z-c)^2/c^2$, i.e., as part of an elliptic cone. The volume covered by the trawl net, the ratio of vertical radius to horizontal radius of the ellipse, the contribution of the side panel to net height and the inclination angle of the head rope (float line) according to towing speed were obtained. The angle of attack of a cambered otter board could be obtained by calculating the equilibrium of forces and moment around the otter board.

Keywords: Gear shape (net, rope); Otter board spread; Angle of attack; Towing cable; Mid-water trawl

1. Introduction

A trawl system has an important role to play in commercial fishery and in resources surveying. The trawl consists of the warp, otter boards, ropes and trawl net. The mid-water trawl system on a commercial fishing vessel can be managed efficiently by the crew.

Many studies on the statics of a mid-water trawl system have been published (Chang, 1968; Chang and Suh, 1982; Lee et al., 1987; Hu and Matuda, 1991; Matuda et al., 1991; Buxton and DeAlteris, 1993; Jang and Lee, 1996; Kim and Lee, 1999). To analyze the towing cable in relation to the warp of the trawl system, two-dimensional analysis by Pode was used (Kawakami, 1981; Chang and Suh, 1982; Park, 1993; Park and Yae, 1999). For a heavy dragged system such as a trawl, the diameter of the cable is increased so that the hydrodynamic drag by the underwater current cannot be ignored, and the cable can no longer be treated as a catenary in the air. Huang and Vassalos (1993) derived a three-dimensional semi-analytical method of observing this. Recently the dynamics of the mid-water trawl system as a flexible unit has been studied by using finite-element method or generalized modeling methods, etc. (Bessoneau and Marichal, 1998; Lee et al., 2000, 2005; Wan et al., 2002). But in the case of the trawl system or purse seine which consisted of many meshes, considerable time was consumed performing the calculations associated with the method. Therefore some meshes were grouped to reduce the number of meshes and the processing time.

In a bottom or mid-water trawl system it is important to measure the distance between otter boards, the angles of attack of the warp and the hand rope and the declination angle at the lower end of the cable which gives information on the fishing gear dragged. For biomass measurement with a trawl survey the net height of the trawl and distance between wing ends or otter boards are needed to estimate the swept area and volume of the trawl. It should be noted that the gear shape of the trawl net changes with different towing speeds when using a separate panel for targeting

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some species or reducing by-catch. The hanging ratio of the panel would therefore change.

In order to estimate the gear performance though, the configuration of the warp, the hand-rope and the bridles were often assumed to be in a straight line (Koyama et al, 1981; Fridman, 1986). However, the drag of a rope streamed (parallel) to the water flow caused its shape to form a curve. While the shape of nets at float line in water flow was approximated to a catenary-shaped central portion with straight lengths extending out to the wing ends (Sangster and Breen, 1998), trawl nets have different net-webbing areas and different drag along the rope from wing end to the center of head rope, and the distribution of floats (or sinkers) was not equal along the lines. Therefore it is sometimes more expedient for calculating the shape of the nets in water flow to use parabola (Fridman, 1986).

In the current study the semi-analytical three-dimensional analysis of a marine cable by Huang and Vassalos (1993) was applied to the towing cable of a mid-water trawl system and then one approximated the shape of the trawl net as part of an elliptic cone, thus giving an easy concept of the trawl net. The field data used in this analysis was obtained using the Scanmar system by Matuda et al. (1991). The angle of attack of a cambered otter board could be obtained by observing the equilibrium of forces and moment around the otter board. The shape of the hand rope, bridles and head (or foot rope) attached behind otter boards was assumed to be a function of the form, $y_r = Ax_r^B$ in which if the value of B is 2, the shape of rope becomes parabola. The shape of the trawl net from wing end to bag net was assumed to be of the form $x^2/a_e^2 + y^2/b_e^2 = (z-c)^2/c^2$, as part of an elliptic cone. Therefore the otter board spread, the volume covered by the trawl net, the ratio of the vertical radius to the horizontal radius of the ellipse (which is the cross-section of the cone), the contribution of the side panel to the net height and the inclination angle of the head rope (float line) according to the towing speed could be obtained.

2. Materials and methods

2.1. Three-dimensional analysis of a towing cable (warp)

With the following assumptions Huang and Vassalos (1993) derived a semi-analytical treatment of three-dimensional statics of marine cables. This is described in this paper. The basic idea of the semi-analytical method is to consider a three-dimensional cable under a given distribution of many point loads.

Assume that there is zero torsional stiffness in a cable, that is to say it is completely flexible and therefore has no internal force other than tension (nonnegative), that the cable is uniform and that the hydrodynamic loading acting on an element of the cable can be resolved into two components of normal and tangential forces. Also assume that the drag of the cable under current depends only upon the dimensions of that element, the angle of that element to the current and the current speed, and is not affected by neighboring elements.

Fig. 1 shows a cartesian coordinate system (x, y, z) adopted in the paper. Let s and p be the unstrained and the strained arch lengths along the cable, respectively. A continuous marine cable can be discretized into many small segments, each under one point load representing the distributed drag force along the cable. An equilibrium condition at a point between the coordinates p_n and p_{n+1} on the strained cable profile gives

$$T\frac{\mathrm{d}x}{\mathrm{d}p} = -V_x - \sum_{i=0}^{n} F_x^i, \tag{1}$$

$$T\frac{\mathrm{d}y}{\mathrm{d}p} = -V_y - \sum_{i=0}^{n} F_y^i, \tag{2}$$

$$T\frac{\mathrm{d}z}{\mathrm{d}p} = -V_z - \sum_{i=0}^{n} F_z^i - \frac{W}{L}s, \tag{3}$$

where T is the cable tension, V_x, V_y, and V_z are the three components of the force acting at the end $s=0$, F_x^i, F_y^i, and F_z^i the external force components acting on the ith cable segment, L is the unstrained length of the whole cable and W its weight in the fluid.

The constitutive relation of the cable is given as follows:

$$T = EA\left(\frac{\mathrm{d}p}{\mathrm{d}s} - 1\right), \tag{4}$$

where E is Young's modulus and A is the cross-sectional area of the cable in the unstrained profile.

The boundary condition such as a mid-water trawl system where one end is fixed and the other is subjected to known force components, gives

$$x(0) = y(0) = z(0) = 0, \tag{5}$$

and

$$T\frac{\mathrm{d}x}{\mathrm{d}p}\bigg|_{s=L} = T_x, \quad T\frac{\mathrm{d}y}{\mathrm{d}p}\bigg|_{s=L} = T_y, \quad T\frac{\mathrm{d}z}{\mathrm{d}p}\bigg|_{s=L} = T_z, \tag{6}$$

where T_x, T_y and T_z are given.

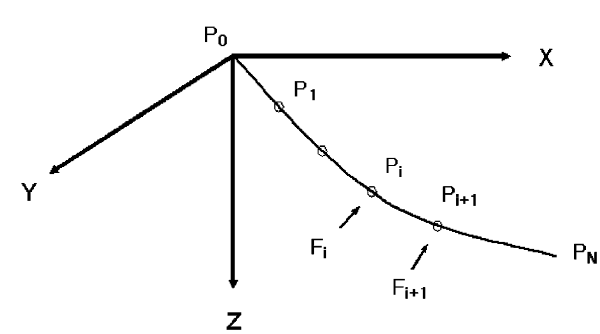

Fig. 1. Three-dimensional coordinate system.