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The geometrical gear shape of a bottom trawl

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ABSTRACT

An estimation of the gear shape during a bottom trawl can be achieved through geometrical modeling of the trawl system. This can be implemented by processing the field data obtained using the Scanmar system. The gear shape from the square through the bag net was assumed to be the upper and lower parts of different elliptic cones of which the cross section was an ellipse and the shape of the float rope to be of exponential function. A system of nonlinear equations was constructed to represent the gear shape of the bottom trawl net in water. When the equations were solved based on the data obtained from bottom trawl experiments with various warp lengths, the cross section of sweep and filtered volume, the eccentricity of the upper ellipse, the functional shape and inclination angle of the float rope, and the contribution of the upper side panel to the net height could be obtained in relation to towing speed and scope ratio. As the cross section of sweep at the mouth and the projected total cross section decreased a little bit with increased towing speed, the filtered volume tended to increase with increased towing speed. The gear shape at mouth of the bottom trawl was not so much changed compared to that of a mid-water trawl.

1. Introduction

Trawl systems play an important role in commercial fishing and in surveying marine resources. Many studies on the statics and dynamics of trawl gear (warp, otter board and trawl net) have been made using dimensions of net width, net height, warp tension, etc. (Cho and Go, 2000; Engås, 1994; Fridman, 1986; Fujimori et al., 2005; Hu et al., 2001; Juza et al., 2010; Lee et al., 2008, 2005, 2001; Matuda, 2001; Park, 2007, 2005, 1993; Prat et al., 2008). Recently the escapement of fish under the ground rope and the effect on gathering fish by sweep line of a trawl has been investigated by Somerton et al. (2007). Prat et al. (2008) proposed a simplified model of the interaction of the trawl warps, the otterboards and netting drag and tested it by simulations and sea trials. Juza et al. (2010) examined the influence of the trawl mouth opening size and net color on catch efficiency during sampling of early fish stages. Fujimori et al. (2005) reported the results of the influence of warp length on trawl dimension and the catch of walleye pollock in a bottom trawl survey. In the analysis the gear shape at the mouth of the trawl was approximated as a polygon with five depth estimates at the mouth and the shape of the head line and fishing line were assumed to be catenary. In another analysis by Sangster and Breen (1998) the shape of nets at float line was approximated as a catenary-shaped central portion with straight lengths extending out to wing ends. Trawl nets have differing net webbing areas which produce different drag along the rope from the wing ends to the center of the head rope, and the distribution of floats (or sinkers) is not equal along the lines, therefore it may not be catenary. Fridman (1986) showed that it is sometimes more expedient to use parabolic functions for calculating the shape of nets in water flow. It should be noted that when using a separate panel for targeting particular species or reducing by-catch the gear shape changes with different towing speeds, thus also changing the hanging ratio of the panel.

The swept area method has often been used simultaneously for planar analysis of a trawl, when estimating biomass of fish by the trawl and acoustic survey. In that analysis the horizontal distance between wing ends (or net width) was used, while the vertical dimension (i.e. net height) was neglected. Dynamic models of fishing gear such as trawl and gill nets have recently been developed using finite element and generalized modeling methods. There are, however, large amounts of data collected, therefore processing time suffers. As a result, the mesh grouping method (which is an approximation method) was adopted to reduce processing time. In the normal design of fishing gear such as trawl nets, each part of the gear should have a constant (or smooth) orientation to the flow direction so as not to distort the gear.

The shape of the trawl gear at the mouth should have a form that can be approximated geometrically. In the current study the

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shape of the trawl net under normal conditions was assumed to be part of an elliptic cone and the shape of the float line to be an exponential function. Thus approximating the shape of a trawl net in a functional form results in a geometric equation and gives us a simple ideation. A system of nonlinear equations was constructed to calculate the gear shape based on the above assumptions. When they are solved simultaneously, the radius of the ellipse, the cross section of sweep and filtered volume of the gear, the shape and inclination angle of the float rope, and the contribution of side panel to the net height can be obtained at several towing speeds and length of warps.

2. Materials and methods

In this section the means of estimating the gear shape of a bottom trawl net is described. Fig. 1 shows the approximation of the shape of a bottom trawl net as an elliptic cone. The shape from the square through the bag net was assumed to be part of an elliptic cone and the sweep line was assumed to be linear. The shape of a bottom trawl is similar to that of a mid-water trawl (Park, 2007), but the main difference from that of the mid-water trawl is that the ground rope of the bottom trawl touches the sea bed, therefore two different (upper and lower) elliptical equations were used to model the cross-section at the mouth, in which the circumferences of the upper and lower parts differ. Though the shape of the float rope as catenary has often been assumed, others have shown that taking a parabolic shape was sometimes more expedient (Fridman, 1986). In the current study the shape of the head rope is assumed to be of exponential function, $y_f = a_f x^{bf}$ as shown in Fig. 2 where O indicates the center of float line, y_f is the vertical projection from the center and x1 is the horizontal projection of the wing end in the x-axis. When the power of the equation bf equals 2, it becomes a parabola. The functional form has an arbitrary power for the shape of the float line that is a more reasonable assumption.

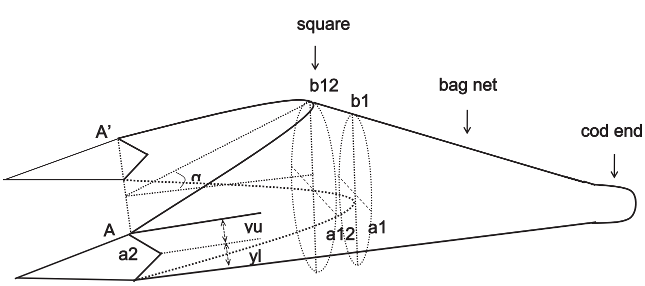

Fig. 1. An approximation of the shape of a bottom trawl net to an elliptic cone. *ai* is half the distance at *i* section, *α* is the inclination angle of float rope, b12 and b1 are the vertical radius of the ellipse at square and bag net section, respectively, *yu* is the contribution of the upper side panel to net height and *yl* is the distance from the horizontal *x*-axis to the bottom, The A and A′ represent the wing ends of the trawl. The horizontal and vertical projections of these labels are shown in Figs. 2–4.

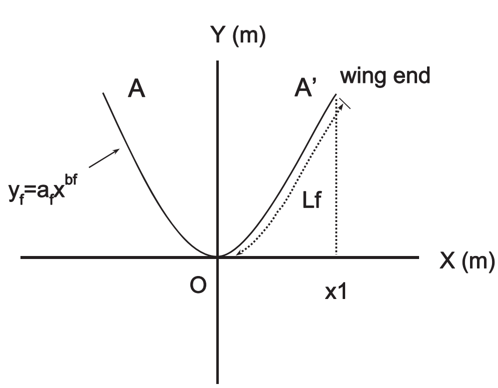

Fig. 2. A coordinate describing the shape of float rope. *Lf* is half the length of the float rope and x1 indicates half the spread between wing ends. The arc AOA′ represents the float rope of a bottom trawl.

The cross section of an elliptic cone is an ellipse that can be written as follows:

$$x^2/ai^2 + y^2/bi^2 = 1 \quad (1)$$

where the *ai* and *bi* are the radii of the major and minor axes of the ellipse, respectively. As shown in Fig. 3 from the characteristic of the elliptic cone with the above assumption, the following nonlinear equations can be constructed which can then be used to describe the shape of a bottom trawl net:

$$(Sob-S1)(aob-a12)-(Sob-S12)(aob-a1) = 0 \quad (2)$$

$$(S2-S1)(aob-a1)-(Sob-S1)(a2-a1) = 0 \quad (3)$$

$$(aob-a12)(S2-S12)-(a2-a12)(Sob-S12) = 0 \quad (4)$$

$$Lu - \int_{xu}^{a1} \sqrt{1+y'^2}dx = 0 \quad (5)$$

$$Lcu - 2a1\int_0^{\pi/2} \sqrt{1-e_u{}^2 \sin^2 t}\, dt = 0 \quad (6)$$

$$Lbl - \int_{xl}^{a1} \sqrt{1+y'^2}\, dx = 0 \quad (7)$$

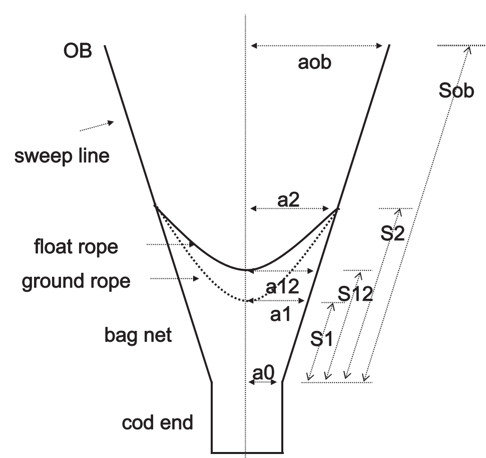

Fig. 3. An upper view of a bottom trawl net. ai is half the distance at i section and Si represents the length from the end of bag net to the forward i section. OB means the position of otter board.

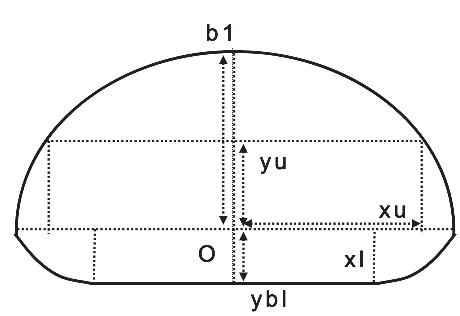

Fig. 4. A front view of the upper and lower parts of an ellipse at the mouth of a bottom trawl. The b1 is minor axis of the ellipse, *yu* is the contribution of the upper side panel to net height and *ybl* is the distance from the horizontal *x*-axis to the bottom.