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Theoretical Studies on the Mechanical Characteristics of Two-seam Trawl Net

Kei NAKASAI and Efren Ed. C. FLORES

The mechanical characteristics of a two-seam trawl net was studied theoretically on the basis of its construction and geometrical configuration in operation. A model net was constructed and tested in a circulating water tank to verify theoretical results. Good coincidence of the observed and calculated values for horizontal spread and towing force of the model net is presented.

Introduction

This study was conducted in line with the series of studies on the mechanical character of drag nets by T. KAWAKAMI and K. NAKASAI[1,2,3,4,5].

T. KAWAKAMI[1] started the study with a rectangular strip of net examining its equilibrium configuration and distribution of tension. Then he modified the strip of net by adding a bag at the center, producing a mechanically simple model drag net[2]. Results of the theoretical analysis proved to be valid being in agreement with the experimental results of the model net under investigation.

With an understanding of the mechanical characteristics of a simple drag net, a four-seam drag net[3,4,5] of similar construction to that of the two-boat trawl of Japanese type was studied. Here, the mode of transmission of tension in the webbing is different from that of the previous model. With modification in consideration of the change in construction, the results of the theoretical computations on the mechanical characteristics, such as the height of the net mouth, showed a good coincidence with experimentally observed values of the model net.

This paper deals with the investigation of a two-seam drag net using the same theoretical considerations, with further modifications, given to four-seam net. The model net used is of the construction resembling that of the two-seam trawl net employed in otter trawling.

Theoretical Analysis

For the sake of simplicity, the model net treated here is constructed as a cylinder as shown in Fig. 1. The configuration of relatively minor part of the net is approximated to a part of a circular arc of various curvatures or to a straight line if possible.

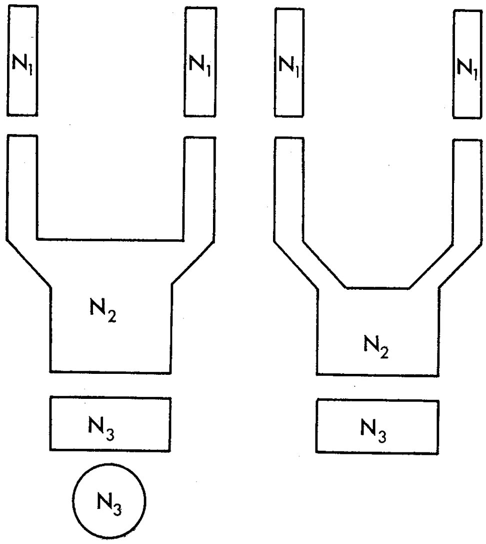

Fig. 1. Layout of webbing of experimental model net.

The experimental model net is composed of three different kinds of webbing, N_1, N_2 and N_3 and a constant rate of hang-in is made on the frame line so as to make an angle of 90° ($=2\phi$) between two adjacent bars. As the mechanical situation and the geometrical shape are symmetrical about the center line, C, let us treat the starboard side of the net and moreover confine our discussions to the upper half of the net. The notations are defined according to the following and illustrated in Fig. 2.

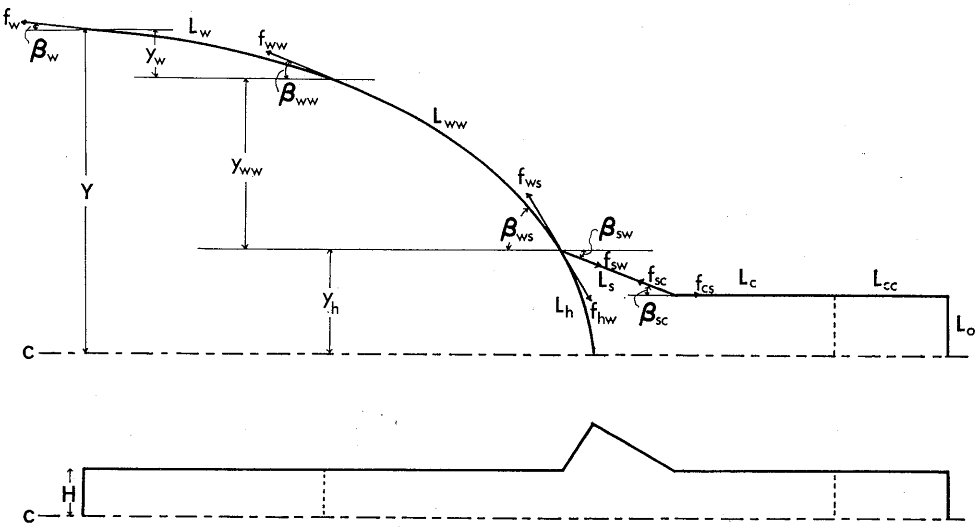

Fig. 2. Top view(upper) and side view(lower) experimental model net.

Notation	Discription	Subscript	
f	Force	w, ww	Forward and rear section of the wing, respectively
T	Force per unit length	s	Shoulder
K	Force per unit area	c, cc	Forward and rear section of the bag net, respectively
L	Length of each section of the net	o	Tail end of the bag net
H	Depth of webbing	h	Headline
Y, y	Transversal distance between two points	m	Ribline
Z	Vertical distance between two points	e	Elevation
R	Radius of curvature	n, t	Normal and tangential, respectively
β	Angle	b	Buoyancy
		bb	Bamboo beam

1. WING

The wing consists of two different kinds of webbing, N_1 and N_2. The forward section, N_1, is of larger mesh than the rear section, N_2, but both are of the same depth, H. The webbing of the wing is framed by three lines, i.e., headline, ribline and groundline. Therefore the tension on the upper half of the webbing is directed to both the headline and the ribline in equal proportion.

Accordingly, for the forward wing, let f_{wh} and f_{wwh} be the tensions at the forward and rear ends of the headline and f_{wm} and f_{wwm} be the tensions at the forward and rear ends of the ribline, respectively. And let β_{wh} and β_{wwh} be their respective angles on the headline, and β_{wm} and β_{wwm} on the ribline deviating from the direction of current. With L_w, the length of the forward wing, and y_{wh} and y_{wm}, the transversal distances of the headline and ribline from their extremities to the center line, C, then the following relation may be obtained :

$$f_{wh}\ (\beta_{wwh}-\beta_{wh})\ =\frac{1}{2}H\ L_w K_{n1}\ \sin\ \beta_{wwh}, \qquad (1)$$

$$f_{wh}-f_{wwh}=\frac{1}{2}H\ L_w\ K_{t1}\ \cos\ \beta_{wwh}, \qquad (2)$$

$$y_{wh}=L_w\frac{\cos\ \beta_{wh}-\cos\ \beta_{wwh}}{\beta_{wwh}-\beta_{wh}}, \qquad (3)$$

$$f_{wm}\ (\beta_{wwm}-\beta_{wm})\ =\frac{1}{2}H\ L_w\ K_{n1}\ \sin\ \beta_{wwm}, \qquad (4)$$

$$f_{wm}-f_{wwm}=\frac{1}{2}H\ L_w\ K_{t1}\ \cos\ \beta_{wwm}, \qquad (5)$$

$$y_{wm}=L_w\frac{\cos\ \beta_{wm}-\cos\ \beta_{wwm}}{\beta_{wwm}-\beta_{wm}}, \qquad (6)$$

where K_{n1} and K_{t1} are the values for K_n and K_t of the webbing N_1, respectively.

The similar relations will be valid for the rear section of the wing. Let f_{wsh}

and f_{wsm} respectively be the tensions on the headline and ribline at the rear ends of this section, and also let β_{wsh} and β_{wsm} respectively be their angles of incidence of the current to the plane of the webbing. With L_{ww}, the length of this section, y_{wwh} and y_{wwm} respectively be the transversal distances of the headline and ribline from their extremities to the center line, and as the depth, H, is constant, we have

$$f_{wwh}(\beta_{wsh}-\beta_{wwh}) = \frac{1}{2}H\ L_{ww}\ K_{n2} \sin \beta_{wsh}, \tag{7}$$

$$f_{wwh}-f_{wsh}=\frac{1}{2}H\ L_{ww}\ K_{t2} \cos \beta_{wsh}, \tag{8}$$

$$y_{wwh}=L_{ww}\frac{\cos \beta_{wwh}-\cos \beta_{wsh}}{\beta_{wsh}-\beta_{wwh}}, \tag{9}$$

$$f_{wwm}\ (\beta_{wsm}-\beta_{wwm})=\frac{1}{2}H\ L_{ww}\ K_{n2} \sin \beta_{wsm}, \tag{10}$$

$$f_{wwm}-f_{wsm}=\frac{1}{2}H\ L_{ww}\ K_{t2} \cos \beta_{wsm}, \tag{11}$$

$$y_{wwm}=L_{ww}\frac{\cos \beta_{wwm}-\cos \beta_{wsm}}{\beta_{wsm}-\beta_{wwm},}, \tag{12}$$

where K_{n2} and K_{t2} are the values for K_n and K_t of the webbing N_2, respectively.

2. SQUARE, SHOULDER and BAG NET

Between the bases of both wings in the upper front of bag net, this net has a "Square" of trapezoidal shape as shown in Fig. 3. The front edge of the square is hung to the headline of length L_h to which floats of buoyancy T_b per unit length are attached.

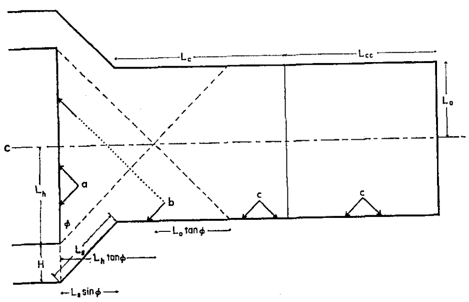

Fig. 3. Schematic representation of square and cod end.

For the sake of simplicity, the shoulder is assumed to be on the same cylindrical plane with the square making an angle of β_{scm} against the current. This is designated by

$$\beta_{swm}=\beta_{scm}. \tag{13}$$

Moreover, the shoulder and the wing are assumed to be on the same against the current. Then we have

$$\beta_{swm}=\beta_{wsm} \tag{14}$$

Next, assume that half of the tension of the square is directed to the ribline and the remaining tension to the headline. Then denoting the tension on the ribline by f_{swm} at the front edge and f_{scm} at the rear edge, and the length by L_s, we have approximately

$$f_{swm}-f_{scm}=\frac{1}{2}H\ L_s \sin \phi\ K_{t2} \cos \beta_{scm}, \tag{15}$$

where 2ϕ is the angle of mesh opening.

The bag net is made up of two kinds of webbing, N_2, the front section (Belly) and N_3 the rear section (Cod end).

The force that acts horizontally on the headline, L_h, is estimated by the same principle as in the previous papers [2,3], and may be approximately given by

$$T_s L_h = \frac{1}{2}(L_h^2 \tan\phi + H\ L_s \sin\phi)\ K_{t2} + \frac{1}{4}\ \{(H+L_o)\ (L_h \tan\phi - L_s \sin\phi) + L_o^2 \tan\phi\}\ K_{t2} + T_h L_h, \quad (16)$$

where T_h is the resistance of the headline per unit length including the floats attached to it.

The remaining resistance will act on the ribline. Thus we have

$$f_{csm} = \frac{1}{4}\ \{(H+L_o)\ (L_h \tan\phi - L_s \sin\phi)\}\ K_{t2} + L_o\ \{L_c - (L_h + L_o) \tan\phi\}\ K_{t2} + L_{cc} L_c K_{t3} + \frac{\pi}{4} L_o 2 K_{n3}, \quad (17)$$

where K_{n3} and K_{t3} are the values of K_n and K_t for the webbing N_3, respectively.

3. HEADLINE

The equations for the headline are all the same as the previous paper[3]. Then we have

$$\frac{f_{hw}}{R} = \frac{T_b}{\sin\beta_e}, \quad (18)$$

$$\frac{T_b}{T_s} = \tan \beta_e, \quad (19)$$

$$L_h = R(\frac{\pi}{2} - \beta_h), \quad (20)$$

$$y_h = r \cos \beta_h, \quad (21)$$

$$Z = R\ (1 - \sin \beta_h) \sin \beta_e \quad (22)$$

4. EQUILIBRIUM CONDITIONS AT THE HEADLINE AND RIBLINE

The equilibrium equations on the headline at the rear wing can be presented as

$$f_{wsh} \cos \beta_{wsh} = f_{hw} \cos \beta_h \cos \beta_e, \quad (23)$$

$$f_{wsh} \sin \beta_{wsh} = f_{hw} \sin \beta_h, \quad (24)$$

and at the ribline from the wing to the shoulder, we have

$$f_{wsm} \cos \beta_{wsm} = f_{swm} \cos \beta_{swm}, \quad (25)$$

$$f_{wsm} \sin \beta_{wsm} = f_{swm} \sin \beta_{swm}, \quad (26)$$

and in addition, at the ribline from the shoulder to the bag net, we have

$$f_{csm} = f_{scm} \cos \beta_{scm}. \quad (27)$$

5. TRANSVERSAL DISTANCE

As regards the transversal distance between the danlenos, we have geometrically

$$Y_h = y_{wh}+y_{wwh}+y_h, \tag{28}$$

$$Y_m = y_{wm}+y_{wwm}+y_m, \tag{29}$$

where

$$y_m = L_s \sin \beta_{scm}+L_o. \tag{30}$$

Numerical Computation

Thirty (30) equations which contain forty-seven (47) variables are thus obtained. If, however, the twine, mesh size, hang-in ratio, float attached to the headline as well as the towing speed are given, we can evaluate the following parameters :

K_{n1}, K_{n2}, K_{n3}, K_{t1}, K_{t2}, K_{t3}, ϕ, T_h and T_b.

From the layout of webbings we have numerical values of

L_w, L_{ww}, L_h, L_s, L_c, L_{cc}, L_o, and H.

Hence the following thirty-one (31) variables will remain undetermined :

f_{wh}, f_{wm}, f_{wwh}, f_{wwm}, f_{wsh}, f_{wsm}, f_{hw}, f_{swm}, f_{scm}, f_{csm},

T_s,

β_{wh}, β_{wm}, β_{wwh}, β_{wwm}, β_{wsh}, β_{wsm}, β_{swm}, β_{scm}, β_h, β_e,

y_{wh}, y_{wm}, y_{wwh}, y_{wwm}, y_h, y_m, Y_h, Y_m, R, Z.

Then if one of them is given, or a relation between these variables representing the towing condition is given, we can completely determine all unknowns by solving these equations simultaneously. In order to get more generality in the solutions, the variables designating the forces in the equations should be divided by $H\ L_h\ K_{n2}$ $(=f)$, those designating force per unit area by K_{n2} $(=K)$, and those representing the length by L_h $(=L)$ or by H. Thus a set of dimensionless equations is obtained corresponding to the above equations as follows :

$$\frac{f_{wh}}{f}\ (\beta_{wwh}-\beta_{wh}) = \frac{1}{2}\ \frac{L_w}{L}\ \frac{K_{n1}}{K} \sin \beta_{wwh}, \tag{31}$$

$$\frac{f_{wh}}{f} - \frac{f_{wwh}}{f} = \frac{1}{2}\ \frac{L_w}{L}\ \frac{K_{t1}}{K} \cos \beta_{wwh}, \tag{32}$$

$$\frac{y_{wh}}{L} = \frac{L_w}{L}\ \frac{\cos \beta_{wh} - \cos \beta_{wwh}}{\beta_{wwh}-\beta_{wh}}, \tag{33}$$

$$\frac{f_{wm}}{f}(\beta_{wwm}-\beta_{wm}) = \frac{1}{2}\ \frac{L_w}{L}\ \frac{K_{n1}}{K} \sin \beta_{wwm}, \tag{34}$$

$$\frac{f_{wm}}{f} - \frac{f_{wwm}}{f} = \frac{1}{2}\ \frac{L_w}{L}\ \frac{K_{t1}}{K} \cos \beta_{wwm}, \tag{35}$$

$$\frac{y_{wm}}{L} = \frac{L_w}{L}\ \frac{\cos \beta_{wm} - \cos \beta_{wwm}}{\beta_{wwm}-\beta_{wm}}, \tag{36}$$

$$\frac{f_{wwh}}{f}\ (\beta_{wsh}-\beta_{wwh}) = \frac{1}{2}\ \frac{L_{ww}}{L} \sin \beta_{wsh}, \tag{37}$$

$$\frac{f_{wwh}}{f}-\frac{f_{wsh}}{f}=\frac{1}{2}\frac{L_{ww}}{L}\frac{K_{t2}}{K}\cos\beta_{wsh}, \tag{38}$$

$$\frac{y_{wwh}}{L}=\frac{L_{ww}}{L}\frac{\cos\beta_{wwh}-\cos\beta_{wsh}}{\beta_{wsh}-\beta_{wwh}}, \tag{39}$$

$$\frac{f_{wwm}}{f}(\beta_{wsm}-\beta_{wwm})=\frac{1}{2}\frac{L_{ww}}{L}\sin\beta_{wsm}, \tag{40}$$

$$\frac{f_{wwm}}{f}-\frac{f_{wsm}}{f}=\frac{1}{2}\frac{L_{ww}}{L}\frac{K_{t2}}{K}\cos\beta_{wsm}, \tag{41}$$

$$\frac{y_{wwm}}{L}=\frac{L_{ww}}{L}\frac{\cos\beta_{wwm}-\cos\beta_{wsm}}{\beta_{wsm}-\beta_{wwm}}, \tag{42}$$

$$\beta_{swm}=\beta_{scm}, \tag{43}$$

$$\beta_{swm}=\beta_{wsm}, \tag{44}$$

$$\frac{f_{swm}}{f}-\frac{f_{scm}}{f}=\frac{\sqrt{2}}{4}\frac{L_s}{L}\frac{K_{t2}}{K}\cos\beta_{scm}, \tag{45}$$

$$\frac{T_s}{T}=\frac{1}{2}\left(1+\frac{\sqrt{2}}{2}\frac{H}{L}\frac{L_s}{L}\right)\frac{K_{t2}}{K}+\frac{1}{4}\left\{\left(\frac{H}{L}+\frac{L_o}{L}\right)\left(1-\frac{\sqrt{2}}{2}\frac{L_s}{L}\right)+\left(\frac{L_o}{L}\right)^2\right\}\frac{K_{t2}}{K}+\frac{T_h}{T}, \tag{46}$$

$$\frac{f_{csm}}{f}=\frac{1}{4}\left\{\left(1+\frac{L}{H}\frac{L_o}{L}\right)\left(1-\frac{\sqrt{2}}{2}\frac{L_s}{L}\right)+\left(\frac{L_o}{L}\right)^2\frac{L}{H}\right\}\frac{K_{t2}}{K}+\frac{L_o}{L}\frac{L}{H}\left(\frac{L_c}{L}+\frac{L_o}{L}-1\right)\frac{K_{t2}}{K}+\frac{L_{cc}}{L}\frac{L_c}{L}\frac{L}{H}\frac{K_{t3}}{K}+\frac{\pi}{4}\left(\frac{L_o}{L}\right)^2\frac{L}{H}\frac{K_{n3}}{K}, \tag{47}$$

$$\frac{f_{hw}}{f}\sin\beta_e=\frac{T_b}{T}\frac{R}{L}\frac{L}{H}, \tag{48}$$

$$\frac{T_b}{T}=\frac{T_s}{T}\tan\beta_e, \tag{49}$$

$$1=\frac{R}{L}\left(\frac{\pi}{2}-\beta_h\right), \tag{50}$$

$$\frac{y_h}{L}=\frac{R}{L}\cos\beta_h, \tag{51}$$

$$\frac{Z}{L}=\frac{R}{L}(1-\sin\beta_h)\sin\beta_e, \tag{52}$$

$$\frac{f_{wsh}}{f}=\frac{f_{hw}}{f}\cos\beta_e, \tag{53}$$

$$\frac{f_{wsm}}{f}=\frac{f_{swm}}{f}, \tag{54}$$

$$\frac{f_{wsh}}{f}\sin\beta_{wsh}=\frac{f_{hw}}{f}\sin\beta_h, \tag{55}$$

$$\frac{f_{wsm}}{f}\sin\beta_{wsm}=\frac{f_{swm}}{f}\sin\beta_{swm}, \tag{56}$$

$$\frac{f_{csm}}{f}=\frac{f_{scm}}{f}\cos\beta_{scm}, \tag{57}$$

$$\frac{y_m}{L}=\frac{L_s}{L}\sin\beta_{scm}+\frac{L_o}{L}, \tag{58}$$

$$\frac{Y_h}{L}=\frac{y_{wh}}{L}+\frac{y_{wwh}}{L}+\frac{y_h}{L}, \tag{59}$$

$$\frac{Y_m}{L}=\frac{y_{wm}}{L}+\frac{y_{wwh}}{L}+\frac{y_m}{L}. \tag{60}$$

Practical procedure of numerical calculation is the same as in the preceding paper[3].

Characteristic Curve of Trawl Net

The characteristic curve of the two-seam net was drawn on the basis of the results of numerical computations. Similar to the preceding paper[3], the impotant behavioral character of trawl net in practical operation is the relationship between the towing force applied to the net and its working performance at different

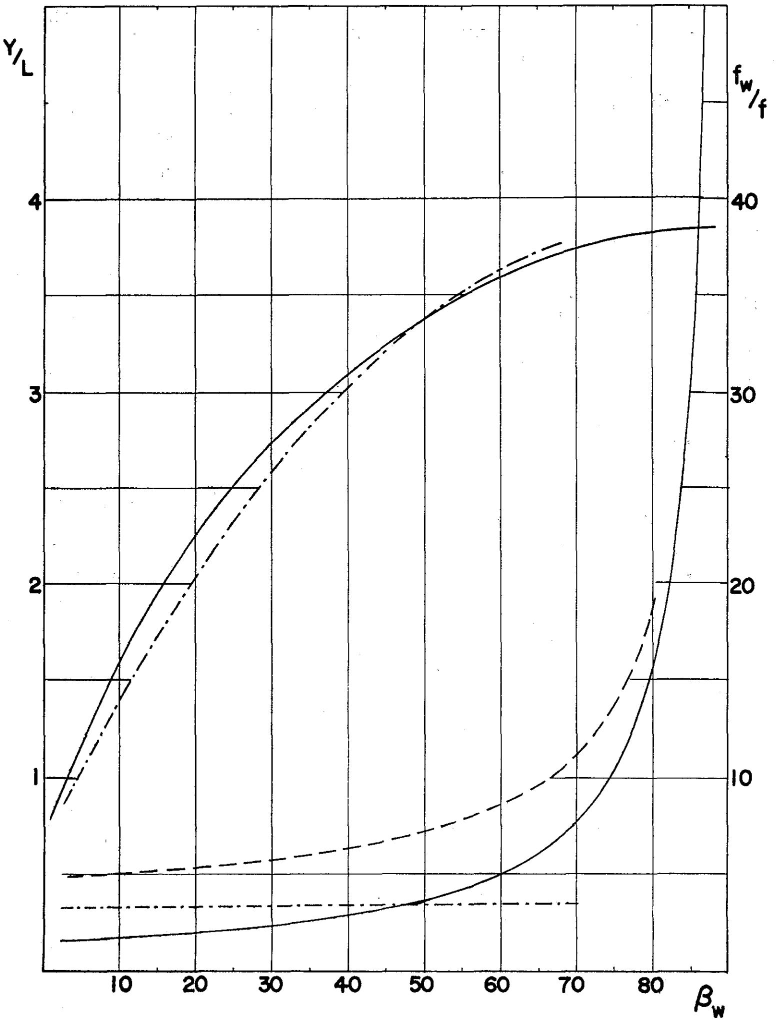

Fig. 4. Theoretical relationship of horizontal spread (Y/L) to towing force (magnitude fw/f, angle βw).

towing speed indicated by the value of K or the resistance of webbing N_2.

The theoretical relationship of horizontal spread of the wing end (Y/L) to the towing force (magnitude f_w/f, and angle β_w) is shown in Fig. 4. In the figure, the relationship of Y/L to β_{wh} is drawn in bold line and to β_{wm} in dot dash line, and also f_{wh}/f to β_{wh} in bold line while f_{wm}/f to β_{wm} in dot dash line which is seen nearly parallel to the abscissa. The relationship between f_w/f (sum of f_{wh}/f and f_{wm}/f) and β_w is shown in broken line in the figure.

The relationship of the sectional horizontal spreads which is shown in Fig. 5, i.e., y_h/L, y_{ww}/L and y_w/L, is not constant at different β_w. Up to β_w 25°, $y_h/L > y_{ww}/L > y_w/L$; β_w 25° to 35°, $y_{ww}/L > y_h/L > y_w/L$; β_w 35° to 63°,

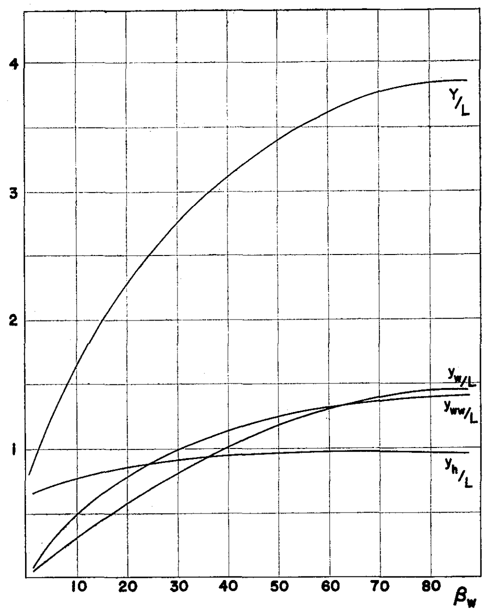

Fig. 5. Theoretical relationship of sectional horizontal spread (y_w/L), (y_{ww}/L) and(y_h/L) to towing angle (βw).

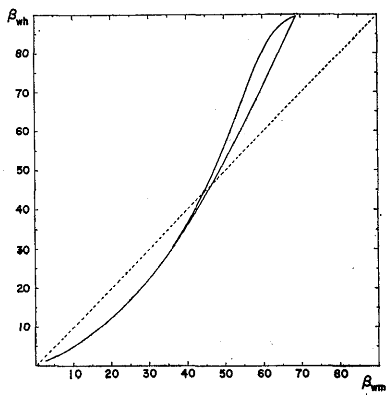

Fig. 6. Theoretical relationship of angle of force at headline (βwh) to angle of force at ribline (βwm).

$y_{ww}/L > y_w/L > y_h/L$ and β_w 63° and up, $y_w/L > y_{ww}/L > y_h/L$.

The wing under towing condition does not stand vertically to the bottom as shown in Fig. 6 by the result of numerical computation. In the case of towing direction below 45°, β_{wh} is smaller than β_{wm}, that is, the headline is deviated inward from the vertical line of the ribline. On the contrary, in the case of towing direction above 45°, β_{wh} is larger than β_{wm}, that is, the headline is deviated outward from the vertical line of the ribline.

The theoretical relationship of the elevation of headline (Z/L) to the angle of forces β_{wh} and β_{wm} is shown respectively in Figs. 7 and 8. And also the

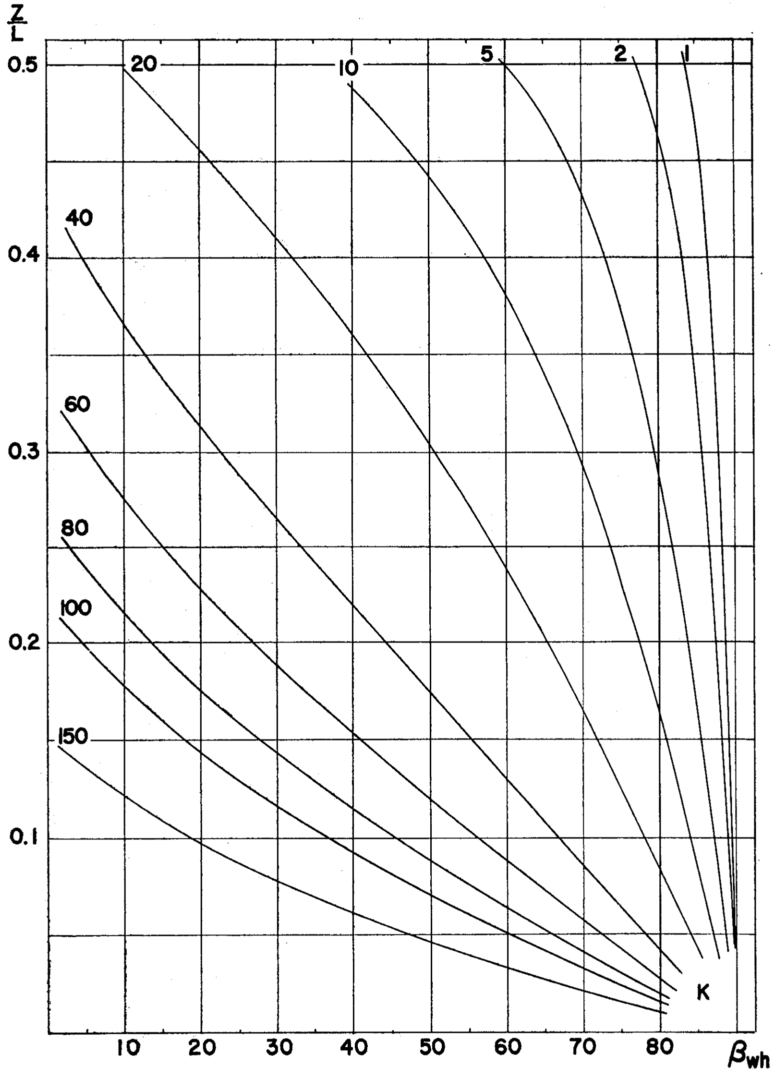

Fig. 7. Theoretical relationship of elevation of headline (Z/L) to angle of force (βwh).

theoretical relationship between the elevation of headline and horizontal spread Y_h/L and Y_m/L is shown in Figs. 9 and 10, respectively.

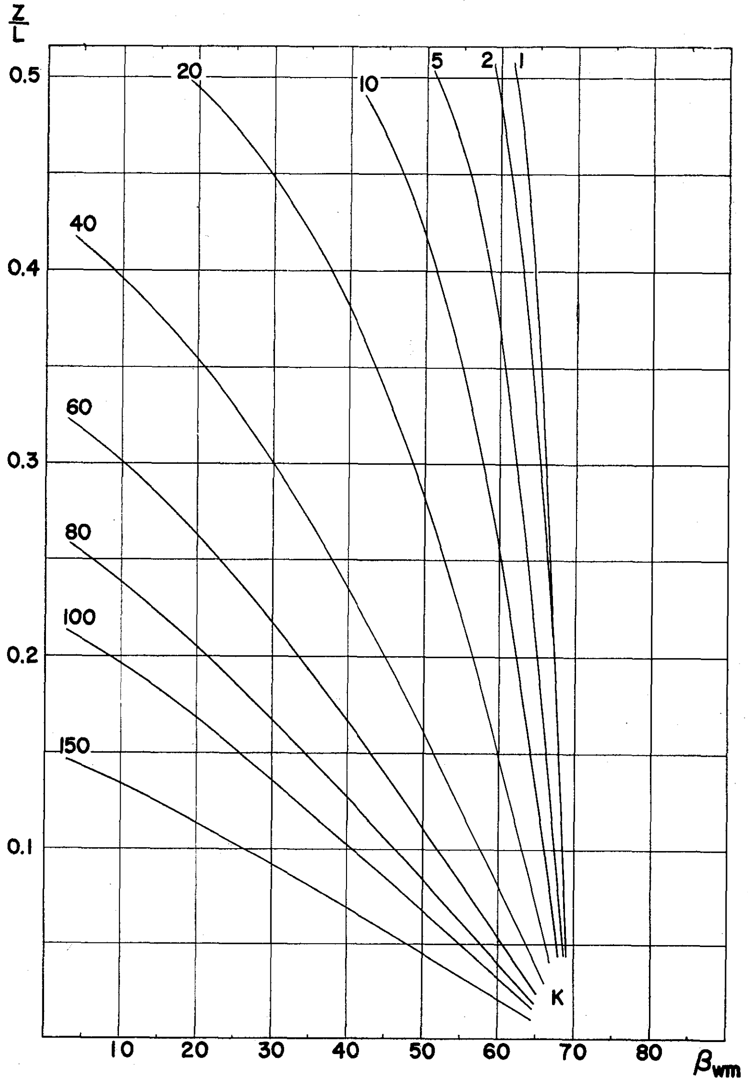

Fig. 8. Theoretical relationship of the elevation of headline (Z/L) to angle of force (βwm).

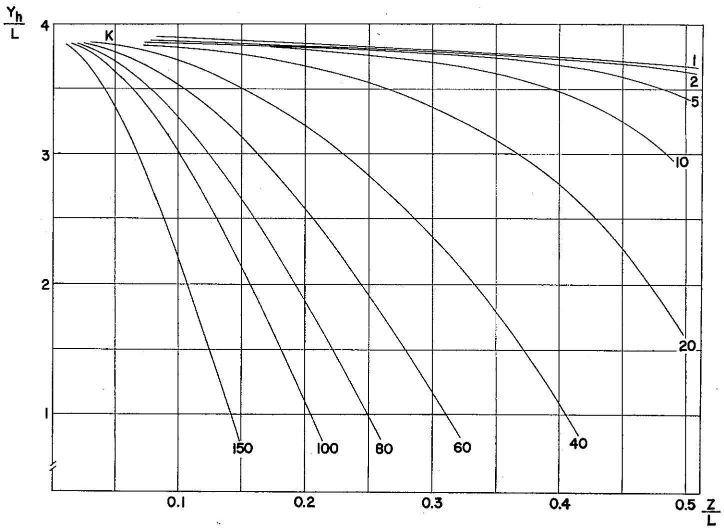

Fig. 9. Theoretical relationship of the horizontal spread (Yh/L) to the headline elevation (Z/L).

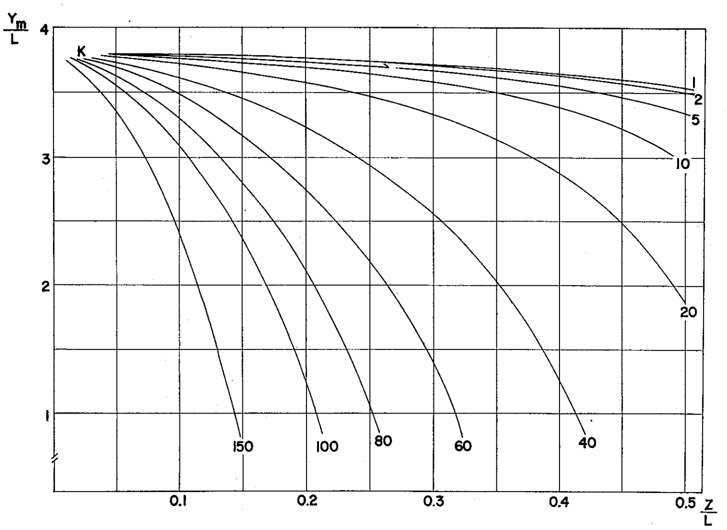

Fig. 10. Theoretical relationship of ribline horizontal spread (Ym/L) to headline elevation (Z/L).

Experiment

To verify the above calculated values, experiments of the model net were carried out in a circulating water tank with an effective area of 80cm by 2 m. The performance of this tank was already described in a previous paper[6].

The dimensions of the model net used for computation of observed values were as follows ;

$D=0.03$cm, $L_1=1.0$cm, $L_2=0.8$cm, $L_3=0.5$cm,
$(D/L_1)=0.03$, $(D/L_2)=0.0375$, $(D/L_3)=0.06$, $\phi=45°$,
$H=4.0$cm, $L_w=14.2$cm, $L_{ww}=13.7$cm, $L_h=9.7$cm,
$L_s=8.0$cm, $L_c=11.4$cm, $L_{cc}=7.0$cm, $L_o=4.0$cm,
$T_h=0.1429V^2$, $T_b=222.26$,
$K_{t1}=0.018V^2$, $K_{t2}=0.0225V^2$, $K_{t3}=0.036\ V^2$,
$K_{n1}=0036V^2$, $K_{n2}=0.045V^2$, $K_{n3}=0.072\ V^2$.

The wing ends of the net were attached to a bamboo bridle (danleno) whose legs were then connected to a bamboo beam (0.4 cm in diameter and 52 cm in length). The bamboo bridle kept the wings upright, whereas the bamboo beam kept the spread of the net.

The length, $2Y_{bb}$, between the two points of connection of the bridle legs on the beam can be controlled arbitrarily. From these two points of attachment, two lines are connected to a warp. The warp goes through the pully of the L-Bar and is connected to a strain gauge (Model 120 T-500 C, Kyowa Electronic Instruments Co., Ltd.) as shown in Fig. 11. The strain gauge was then connected to an oscillograph (Model WTR 281, Watanabe Instuments Corp.) where the resistance of the model net was recorded. A current meter (Model CM-IB, Toho Dentan Co. Ltd.,) was mounted just overhead the model net.

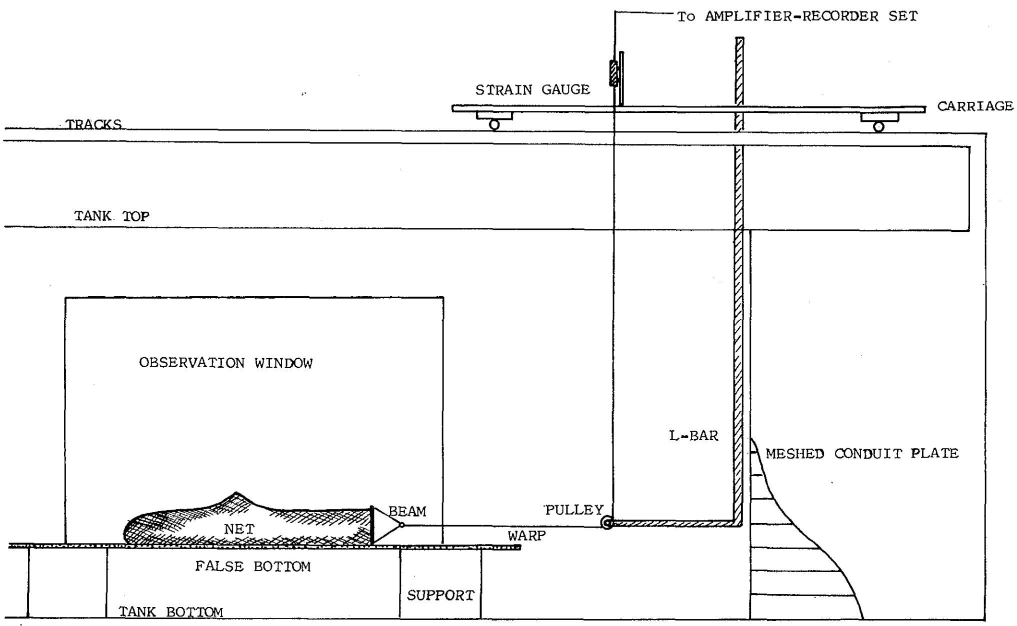

Fig. 11. Arrangement of model net under test in experimental tank.

The net was subjected to water flows ranging from 10 cm/sec to 47 cm/sec and data were recorded at 8 intervals. The spread of the net was changed by adjusting Y_{bb} at intervals of 5cm for every series of water flows.

The beam was also subjected to a series of water flows and its resistance was subtracted from the corresponding resistance of the model net with its accesories.

Pictures were taken for every water flow measurement from the top and from the side through the observation window, simultaneously. A transparent bottom box was mounted on the water surface just above the model net to eliminate wave motion which distorts the picture taken from the top.

The top view pictures were projected to measure Y, y_w, y_{ww}, y_h, β_w, β_{ww}, β_{ws} and β_{sw}. The side view picture were also treated the same way to measure Z and β_e.

Result and Discussion

Since the observed values of β_w ranged only from 5° to 25°, this portion was magnified together with the theoretical curve as shown in Fig. 12. The observed Y/L values were plotted thereon showing a good agreement with the theoretical

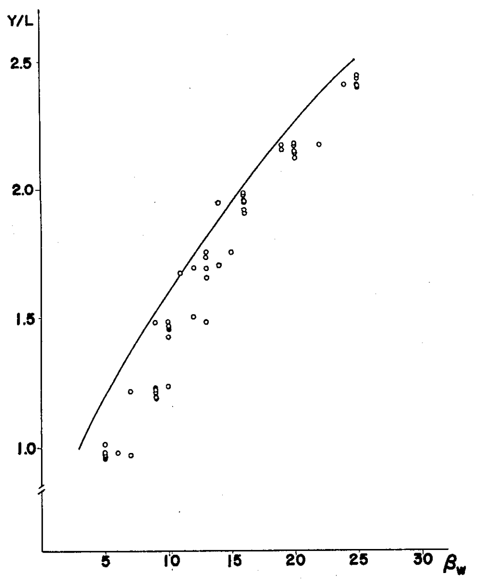

Fig. 12. Observed and calculated values of horizontal spread (Y/L) in relation to towing force (βw).

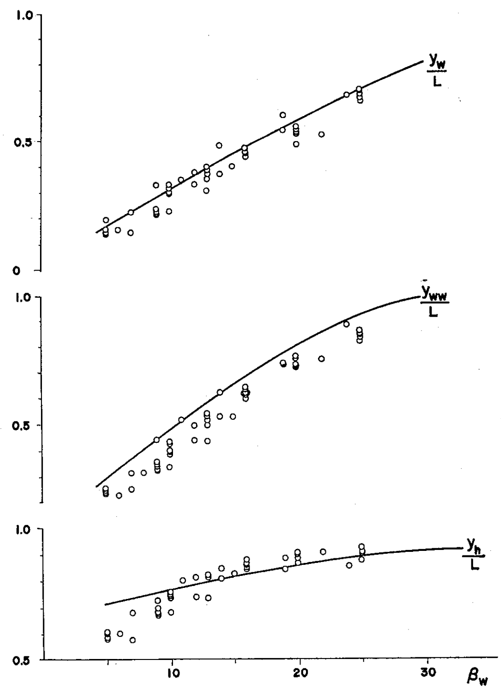

Fig. 13 Observed and calculated values of sectional headline horizontal spread (yw/L, yww/L, yh/L) in relation to towing force (βw).

curve.

Y/L is a transversal distance of the wing extremities and this alone does not show the general configuration of the entire headline. A headline of known Y/L may have a "V" or "U" configuration. To get a clear picture of the headline configuration, the observed values of the sectional horizontal spreads, y_w/L, $y_{ww}/$ and y_h/L were also plotted on their corresponding theoretical curves and this too presented a good agreement as shown in Fig. 13.

It was observed that the general configuration of the headline was not maintained at different β_w as predicted by the theoretical curves. Within the experimental range of β_w, the observed and calculated values coincided. Fig. 14 shows some representative reproduction of actual headline configurations of the model net at different β_w (5°, 10°, 25°) which agree with corresponding theoretical values.

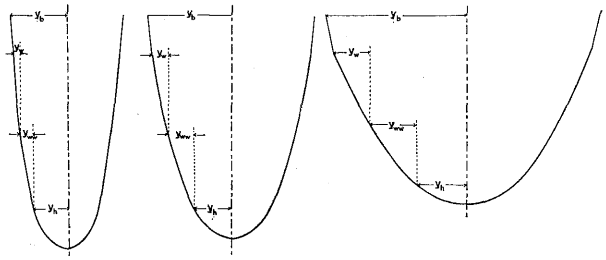

Fig. 14. Representative actual configurations of model net headline at different towing angle (βw 5°, 10°, 25°) whose yw, yww and yh values coincide with corresponding theoretical values.

The observed values of the elevation of the headline (Z/L) is less than the calculated values, and the difference increases at higher water velocities as shown in Fig. 15. The seaming line at the sides of the square are considered to influence the force distribution on the square which exerts force on the headline. It is suggested that the tension applied on the headline at the square section needs further detailed examination.

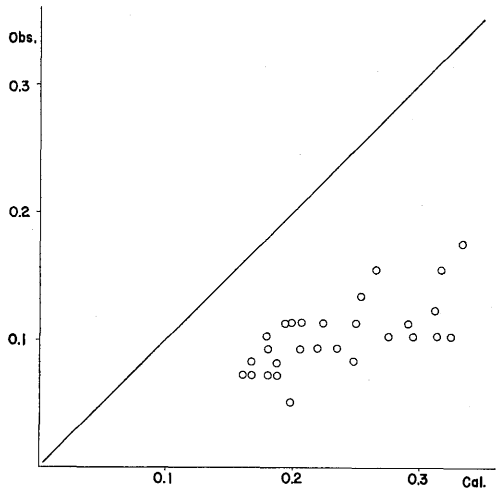

Fig. 15. Observed and calculated values of the elevation of headline (Z/L).

For the towing force (f_w/f) at less than 20° towing angle (β_w), the calculated and observed values as shown in Fig. 16 are in agreement although the latter cluster above and below the characteristic curve. However, at β_w more than

20°, the observed values become larger than the calculated values.

The good coincidence of the observed and calculated values for the horizontal spread and towing force of the model net shows the validity of the theoretical approach in studying the mechanical characteristics of two-seam trawl net.

Expenses for executing this study were partly defrayed by the Ministry of Education of Japan.

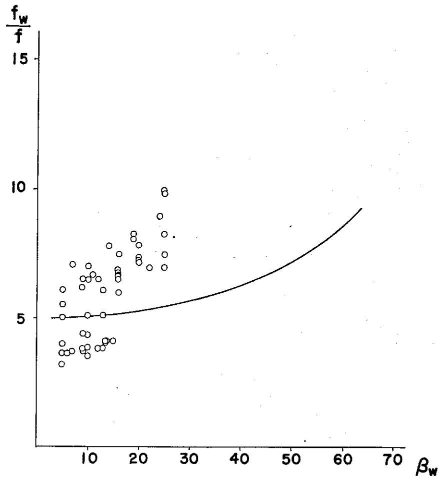

Fig. 16. Observed and calculated values of the towing force (*fw/f*) in relation to the towing angle (*βw*).

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頁	行		誤	正
1	上から	9	mysises	mysids
〃	下から	6	Waite1)	WAITE 1)
5	上から	15	､……小さい。	……小さい。2)
14	上から	1	juvenile	juveniles
17	〃	17	roof	roofing
20	下から	10	roof	roofing
31	〃	18		末尾に was を加える。
〃	〃	16		末尾に・を加える。
40	〃	11	room	rooms
42	上から	9	pregnacy	pregnancy
51	〃	7	*oceancus*	*oceanicus*
53	欄外	上	*Japonicus*	*japonicus*
54	下から	5	*c.helg*	*c.helgo*
〃	欄外	下	*japoniucs*	*japonicus*
60	下から	15	*Auleria*	*Aurelia*
〃	〃	13	〃	〃
61	上から	5	2,000,30	2000,30
73	欄外	上	高魔	高麗
128	下から	1	*Tis*	*This*