The Locus of Towed Net in a Circular Towing

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Abstract

The horizontal position of the towed net in relation to the towing vessel in a circular towing is discussed.

For the sake of simplicity, letting a locus of a towing vessel and a locus of a net be concentric, mechanical equations were obtained. A chart which is drawn by numerical calculation of equations was also obtained.

A series of experiments were carried out in order to verify these equations, and a simple estimation of the horizontal position of the net in relation to the towing vessel in a circular towing is possible with these relationships when the angle made by the towing warp and center line of the towing vessel is below 25°.

Introduction

Recently, the mid-water trawl has widely attracted the attention of fishing gear specialists to catch pelagic species of fish and has been studied in most countries in the world. In Japan, many experiments have been carried out by fisheries scientists and commercial research workers, but their opinions on the values of commercial use differ considerably.

The reason is considered to be based on the fact that the habit of fish in the field is haphazard or that it is quite difficult to obtain the precise informations on the swimming position of fish in the water. But if it is possible to do the matter mentioned above, and if we can obtain or regulate the working depth or position of the net, the mid-water trawl will be a hopeful gear.

The authors have been studying how to estimate the working position of a towed net in the water in relation to the towing vessel, that is, estimation of depth of the net[1,2,3] when the towing direction is not changed and that of position of the net when the towing vessel steers on a circular course.

When a mid-water trawl net is towed in the course along a straight line, the net is towed in the trail of the vessel, but when the towing vessel alters her course because a fish school is detected by a sonar or other detecting instrument in a sideway of the vessel, the net will not follow the same locus of the vessel. Therefore, when

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the vessel towing a net moves along a circular arc, it is of importance to estimate the position of the net. Otherwise, the net cannot sweep the fish school even if the vessel goes over the fish school.

In this paper, the horizontal position of the net relative to the towing vessel in a circular towing is discussed.

Theoretical Consideration

For the sake of simplicity, consider that a vessel towing a net is steering along a circular course of radius r with a steady speed v. Then let L be the length of the towing warp, d the distance between the locus of the vessel and the locus of the net, and r the radius of the circular arc made by the warp, as shown in Fig. 1.

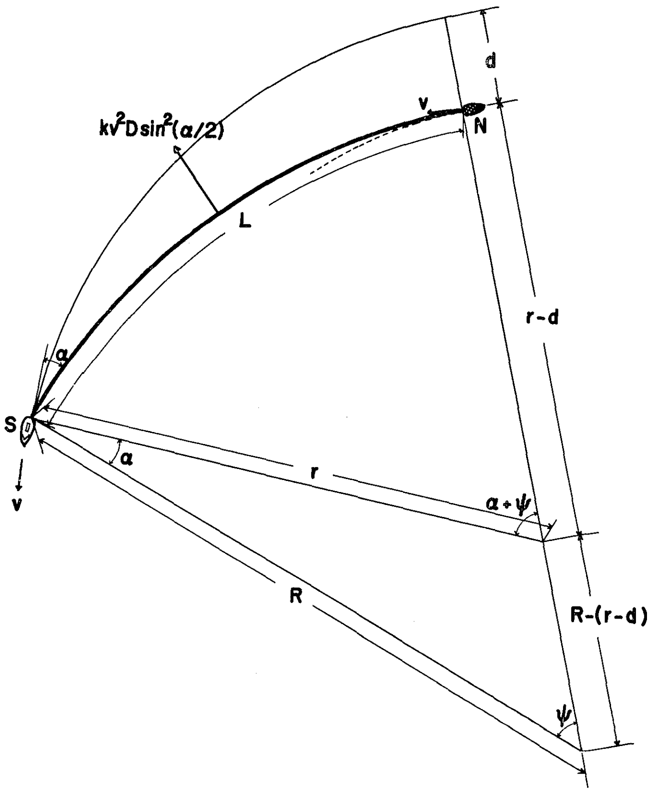

Fig. 1. Schematic sketch of gear in operation

In a steady state, it may be possible to consider that the wake behind the vessel and the locus of the net are concentric, and if d is small enough in comparison with the r net's speed is approximately equal to the vessel's speed. Let α be the angle between the stream and the direction of the warp at the towing point of the vessel, but this angle at the attaching point to the net must zero as the net exerts no yawing force. Therefore, it is assumed that the angle between the stream and the direction of warp is $\alpha/2$ on the average over the whole length of the warp in water.

d being the diameter of the warp, the force acting normally on unit length of the warp is estimated to be

$$kDv^2\sin^2(\alpha/2).$$

Here it is assumed that the magnitude of the force varies proportionally with the square of sine of the angle between the stream and the direction of warp and the current velocity. Denoting the resistance of the net by $Kv,^2$ we have mechanically

$$Kv^2/R = kDv^2\sin^2(\alpha/2).$$

Dividing the length by L,

$$\frac{K}{kLD} = \frac{R}{L}\sin^2(\alpha/2).$$

On the other hand, ψ being the central angle of the arc L, geometrically we have

$$L = R\psi.$$

By the use of the sine law, we have

$$\frac{r}{\sin\psi} = \frac{R-(r-d)}{\sin\alpha} = \frac{R}{\sin(\alpha+\psi)}.$$

From the above equations we obtain

$$\frac{d}{L} = \frac{1}{\psi}\left[\frac{\sin\alpha+\sin\psi}{\sin(\alpha+\psi)} - 1\right] \quad (1)$$

$$\frac{1}{\psi} = \frac{K}{kLD}\cdot\frac{1}{\sin^2(\alpha/2)} \quad (2)$$

Thus the relationship between d/L and α can be calculated numerically for parameter K/kLD

Results Obtained by Computation and Observation

The results obtained by numerical computation of the relations (1) and (2) are shown in Fig. 2. As seen in the figure, in the range of small angle of α, or in the range below 25° of α, there is little difference in the value of d/L by the parameter $K/(kLD)$. Therefore, it can be considered that if the parameter becomes larger up to infinity, the warp assumes a straight line, and the relationship between d/L and α is simplified as

$$\frac{d}{L} = \frac{1-\cos\alpha}{\sin\alpha} \quad (3)$$

and this is illustrated by dotted line in Fig. 2. Equation (3) shows that the relation-

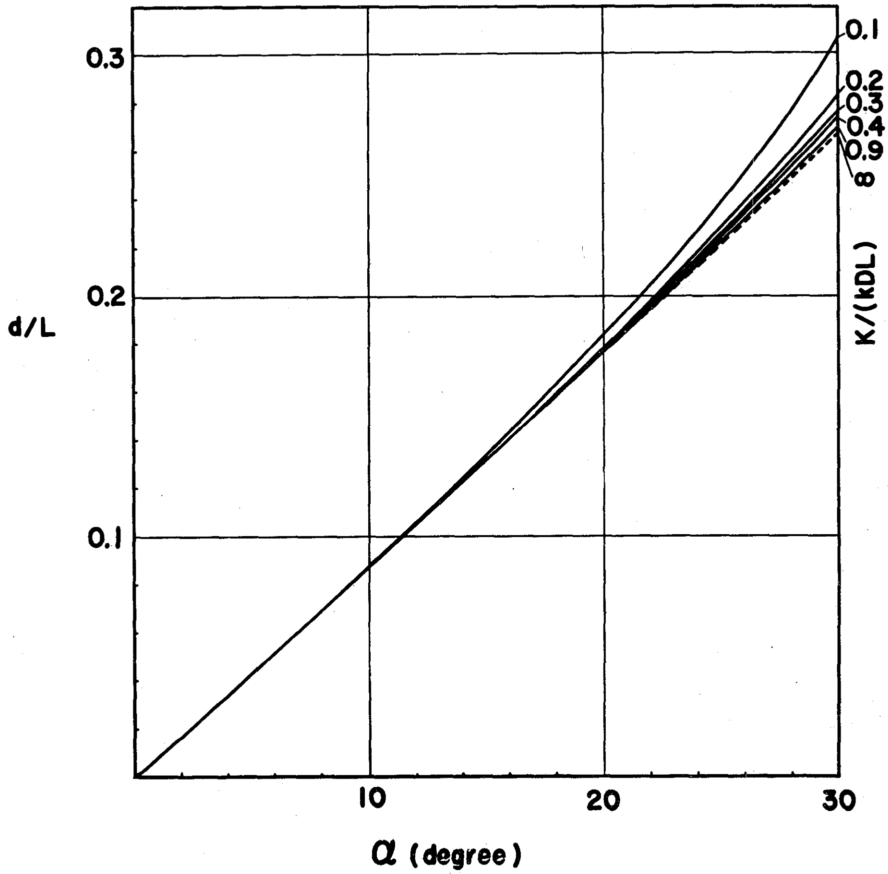

Fig. 2. Relation between d/L and α for K/kLD.

ship between d/L and α is not influenced by the character of net or the size and length of warp.

In order to verify these relationships, a series of experiments was made in Maizuru Bay on board the Research Boat No. 5 Ryokuyo - Maru of Kyoto University.

A bag net, the mouth of which was fixed to a bamboo circular frame, was towed by a manila warp measuring 18mm in diameter, and the distance d was measured by a scaled beam out rigged from the gunwale of other small boat towed on the locus of towing vessel at about the position of towed net. The speed of the towing vessel was estimated by measuring the time interval required by a drifting wooden piece to pass two definite points on the vessel. Instead of direct measuring of the value of K, the tension of the towing rope was measured by a spring balance. If the frictional force of rope can be ignored, this tension may be equal to the value of K. The angle α was measured at the stern of the vessel.

The results obtained in the experiments are tabulated in Table 1. The comparison

Table 1

Exp.	V(cm / sec)	T(kg)	L(m)	d(m)	α(○)	K/ kLD
I	212.3	30.0	20	5.0	25	0.168
II	180.3	27.3	20	4.0	25	0.212
III	236.8	30.0	20	4.2	30	0.135
IV	180.0	25.0	20	3.8	23	0.194
V	166.7	24.0	20	4.8	25	0.218

of the observed and calculated values of d/L is depicted in Fig. 3.

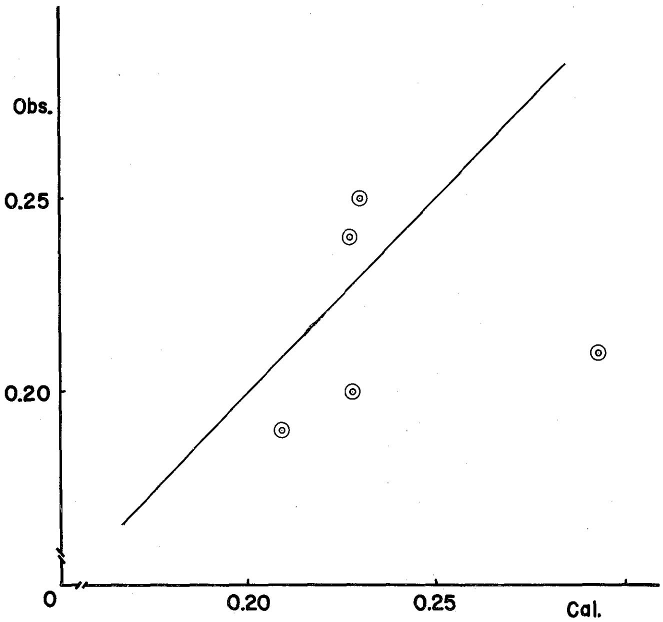

Fig. 3. Relation between the calculated values and the observed ones of d/L.

Both values do not agree exactly, but the difference is only 0.3—0.6m except Exp. III. It is seen in Fig. 2 that the difference between d/L and α for small value of the parameter $K/(kLD)$ is small in the range below 25°of α but it becomes larger as the angle increases. In Exp. III, the angle α was 30°, and therefore, such a large difference appeared. It may be due to the fact that the form of the towing warp in operation does not assume exactly a circular arc. And it is considered to be an error that, in equations (1) and (2), the angle between the stream and the towing warp was assumed to be $\alpha/2$ on an average for the over-all length of the warp. And also it is considered to have an error in measuring the angle α because in this experiment α was substituted by the angle made by the warp and center line of the towing vessel.

The center line of the towing vessel, however, does not exactly agree with the tangent to the locus of the vessel but it inclines to the inside of the circle. Moreover, it must be noted that this fact is watched especially at the beginning of a turn, and therefore, there is a considerable error in measuring the angle α.

After all, it is possible to estimate readily the horizontal position of the net relative to the towing vessel in a circular towing by the equations (1) and (2) in the range below 25° of α and more readily by the equation (3).

References

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