まき網練習船の旋回圏の測定に関する研究

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【研究論文】

A Case Study of Measurement of a Turning Circle of a Purse Seine Training Ship

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Abstract

We have to estimate an action of a school of fish and must surround a school of fish in a short time with American-type bonito-tuna purse sine operation. The net length of a purse seine of the Kakuyo-maru which belongs to the Faculty of Fisheries at Nagasaki University is decided. It is necessary to grasp it for size of the turning circle that corresponds to a speed and a rudder angle, and for necessary time.

By means of GPS, we measured a turning circle of the fishery training ship Kakuyo-maru that has American-type bonito-tuna purse seine operation equipment and can operate with a mono-ship. In result, we were able to measure the size of each turning circle around a right and a left turning at three kinds of speed and rudder angle. The necessary turning times of the Kakuyo-maru differs by speed and rudder angle. However, if rudder angle is more than 15 degrees, the size of turning circle of Kakuyo-maru was able to confirm that, inside the limit of a size of a circle that corresponds to a length of a purse seine net.

1. Introduction

The Kakuyo-maru, which belongs to the Faculty of Fisheries at Nagasaki University, is a fishery training ship that has American-type bonito-tuna purse seine operation equipment. Its main fishing ground is in equatorial waters.

In a bonito-tuna purse seine fishery, in equatorial waters, we are generally aiming at two kinds of schools of fish. For example, one is a school of fish that moves like a jumping shoal, and the other is a school of fish that stops like a shoal of timbers. When fishing for a moving school of fish, casting a net requires estimating the movement of the school of fish, and a knowledge of ship handling technology in order to surround the school of fish. Both control the haul of fish. The weight of the chain has a great influence on a precipitating velocity of a purse seine after casting the net. Further, tidal current direction and velocity of operation and the difference between upward tidal current direction and velocity and under tidal current direction and velocity, direction and a speed of a discharge current of the propeller are all factors influencing the haul. Using the Kakuyo-maru to measure such factors found the precipitating velocity of the net was 10～30 meters per minute. The swimming depth of a school of fish of a well up shoal is concentrated between 0～50 meters. With a purse seine operation, we cast a net to surround a school of fish, and with the receipt of the purse line, immediately start pursing, and fasten the net bottom. We need 5～8 minutes to perform this. Consequently, the net sinks to surround the school of fish in the desired water depth. Like this, by means of casting a net and restricting the stretch of the tow line as much as possible, we can quickly surround a school of fish. As we sum up the above-mentioned, we can say that the success or failure of fishing for a moving school of fish is dependent on whether we can surround a school of fish as quickly as possible, and receive the purse line, and we can end for a pursing or not. I.e., as the length of a purse seine net is limited, if we have a thorough knowledge of the turning circle of the ship and by making use of it, we can increase the haul of fish.

In the case that we surround a school of fish that stops, we cast a net to the center of a school of fish, after confirming the position and the water depth of a school of fish, reel and take out a tow line, as the behavior of net becomes a good state. Cosequently, in this case, the ship handling in consideration of the behavior of the net is necessary rather than surrounding a school of fish quickly.

Data regarding a turning circle is obtained by a trial run and the time taken to complete it. However, the turning circle obtained by an official trial is at full speed in a

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light conditions, with a rudder angle of 35 degrees. Consequently, it isn't possible to grasp a turning circle in an operation state, at other velocities and rudder angles.

There is a lot of literature[1)~5)] on the measurement of operational performance which makes use of GPS. However, measurement data about a purse seiner isn't seen in spite of the fact that a haul of fish of a purse seiner is controled by turning performance. As a year elapses from building a ship, its state changes. Therefore, actually to a person who does the ship handling, the newest data is necessary. There, we measured turning circles with GPS, and analysed it.

By making use of GPS, a standerd purse seiner can conveniently grasp a turning performance of the newest state by the use of this measurement. Further more we are sure that this result is instructive on the occasion of the ship handling of a purse seiner.

2. Measurement method

For measurement, we used our university training ship the Kakuyo-maru, and measured turning circles in a sea area of 70 ~ 120 meters in water depth. This was chosen not to receive a shallow water effect. Measurement dates, sea area and GPS receiver data are shown in **Table 1.**

The GPS receiver that was experimentally used in 1990 and 1991 was one channel sequential receiver, and it was connected to a high stable oscillator. Consequently, measurement with two satellites was possible. However, because receiver we used was a one channel sequential receiver, when switching receipt of message satellite, a break of a measurement sometimes occurred.

IOC (Initial Operational Capability) declaration was formed in end of 1993, and SPS (Standard Positioning Service) was released world wide. Nowadays, 25 satellites are available and it has became that 24 hours three dimensional high level measurement of PDOP (Position Dilution of Precision) 1 is possible. Among such a situation, in 1995, we measured turning circles and examined it again by means of a one channel high speed sequential receiver which didn't have break of a time to switch receipt of the message satellite.

Table 1 Measuremrnt details and used receiver.

Date	Sea	area	GPS Receiver	GPS Number of Satellites	Remarks
1990. 4. 3	34°06′N	129°53′E	JLR-4000F	6	Measurement A
4. 8	32°42′N	129°40′E	JLR-4000F	6	Measurement A
1991. 4. 1	32°45′N	129°22′E	JLR-4000F	15	Measurement A
4. 7	32°45′N	129°40′E	JLR-4000F	15	Measurement A
1995. 5. 15	32°47′N	129°43′E	JLR-4510	25	Measurement B
6. 8	32°44′N	129°24′E	JLR-4510	25	Measurement B
6. 16	31°48′N	127°30′E	JLR-4510	25	Measurement B

Table 2 Principal particulars of Kakuyo-maru.

Gross tonnage	1044. 38 ton
Length between perpendiculars	58. 00 m
Breadth	11. 85 m
Mean draft	4. 28 m
Rudder area	8. 67 m^2
Block coefficient	0. 546
Displacement	1586. 05 ton
Propeller	3 Blades C.P.P.
Prop. diameter	2. 85 m

We connected it with a GPS receiver and a personal computer. Then, we recorded latitude, longitude and other information in FD. The measurement interval was 10 seconds (1990, 1991) and 2 seconds (1995). The position of the antenna was three meters from the hull in the central part of flying bridge. A principal particulars of Kakuyo-maru are shown in **Table 2.**

The operational method of the Kakuyo-maru is that it casts a net while turning left. The ship's speed when casting the net is either "full" or "half" depending on the movement velocity of the target school. Lastly, as the ship approaches the skiff in order to receive the purse line the ship is reduced to slow speed. Up to this time, in relation to the discharge current of the propeller, it is considered that left turning is a good turning direction for casting a net. However, recently, there are ships designed to cast a net while turning right. Therefore, we investigated the effects of both left turning and right turning. Also, we set the ship's speed at three kinds (full, half and slow), and three kinds of rudder angle (30 deg., 15 deg. and 5 deg.).

However, there were some cases where a turning couldn't be executed within a time restriction. And, though turning, there was a case that a measurement with GPS overlaps with an impossible time belt. Wind direction and wind speed were measured it with a wind direction and wind speed anemometer, just before turning. Current was recorded on videotape from a display screen of a current meter.

3. Method of Analysis

We drew a track around a turning depending on the latitude and the longitude that we recorded for FD by means of on XY plotter and read the turning circle from the figure. In this report, we defined an advance (maximum advance : DA) as the distance from a rudder ordered point to a 90 degree turning position along the initial course.

Table 3-1 Measurement (A) result of turning circle.

Rudder angle	Ship's speed	Turning side	Max. adv. DA (m)	Max. tra. DT (m)	Wind rel. dir. (deg.)	Wind vel. (m/s)	Current rel. dir. (deg.)	Current vel. (kt)	GPS Dim.	GPS PDOP	Time for turning (sec.)
30	Full	Right	214	197	Left 15	16	Left 110	0.4	3	4~3	200
30	Full	Left	179	152	Right 15	16	Left 100	0.3	3	3	170
30	Half	Right	228	204	Left 10	25	Right 65	0.3	(2)	3	390
30	Half	Left	191	148	Right 5	16	Left 130	0.6	2	1	290
30	Slow	Right	197	192	Right 5	10	Left 15	0.3	3	2	500
30	Slow	Left	241	299	Right 110	6	Left 130	0.4	(2)	4~5	450
15	Full	Right	396	419	Right 5	16	Left 90	0.3	3	3	340
15	Full	Left	348	360	Right 20	16	Left 100	0.4	3	3	280
15	Half	Right	382	475	Right 10	7	Right 85	0.4	(2)	2	470
15	Half	Left	371	527	Right 10	16	Left 130	0.9	3	7~4	460
15	Slow	Right	435	547	Right 105	4	Right 30	0.4	(2)	2~3	770
15	Slow	Left	427	358	Right 105	4	Left 40	0.4	(2)	3~4	600
5	Full	Right	815	1112	Left 150	16	Right 100	0.5	3	3~4	620
5	Full	Left	1010	1186	Right 5	16	Left 120	0.5	2	2	630
5	Half	Right	587	1543	Right 5	16	Left 115	0.7	3	4~3	1250
5	Half	Left	...	...	...	...	...	...	...	...	...
5	Slow	Right	618	1050	Calm		Left 160	0.5	2	4	1220
5	Slow	Left	...	...	...	...	...	...	...	...	...

Max. adv. : Maximum advance ; Max. tra. : Maximum transfer ; rel. dir. : relative direction ; vel. : velocity ; Dim. : Dimension ;
(2) : 2 dimensional positioning with two satellites

Table 3-2 Measurement (B) result of turning circle.

Rudder angle	Ship's speed	Turning side	Max. adv. DA (m)	Max. tra. DT (m)	Wind rel. dir. (deg.)	Wind vel. (m/s)	Current rel. dir. (deg.)	Current vel. (kt)	GPS Dim.	GPS PDOP	Time for turning (sec.)
30	Full	Right	211	226	Right 167	8	Left 140	0.1	3	1	158
30	Full	Left	207	210	Right 137	8	Right 33	0.1	3	1	152
30	Half	Right	207	262	Right 50	5	Left 53	0.2	3	1	246
30	Half	Left	173	224	Right 50	5	Left 92	0.2	3	1	222
30	Slow	Right	182	204	0	3	Left 38	0.8	3	1	350
30	Slow	Left	144	251	0	3	Left 38	0.8	3	1	310
15	Full	Right	304	482	Left 160	9	Right 122	0.3	3	1	258
15	Full	Left	272	359	Left 160	9	Right 122	0.3	3	1	228
15	Half	Right	300	436	Right 50	5	Left 92	0.2	3	1	364
15	Half	Left	256	385	Right 50	5	Left 116	0.3	3	1	312
15	Slow	Right	337	407	0	2	Left 58	0.5	3	1	530
15	Slow	Left	295	331	0	2	Left 58	0.5	3	1	450
5	Full	Right	615	956	Left 165	10	Left 110	0.2	3	1	532
5	Full	Left	530	778	Left 165	10	Left 97	0.2	3	1	365
5	Half	Right	570	900	Left 15	7	Left 120	0.2	3	1	748
5	Half	Left	485	770	Left 15	7	Left 136	0.2	3	1	584
5	Slow	Right	685	1052	Calm		Left 58	0.3	3	1	1040
5	Slow	Left	544	807	0	2	Left 58	0.5	3	1	800

Max. adv. : Maximum advance ; Max. tra. : Maximum transfer ; rel. dir. : relative direction ; vel. : velocity ; Dim. : Dimension

Tactical diameter (maximum transfer : DT) is defined as the distance between the initial course and a 180 degree turning position. Though we measured true wind direction and wind speed we showed it relatively as compared with the initial course. Similarly, we showed current direction as a relative direction to the initial course. Measurement results, "DA" and "DT" enable us to read the size of a turning circle from the track of the figure. Relative wind direction, wind speed, relative current direction, current velocity, measurement dimension and PDOP of GPS are shown in **Table 3-1** and **Table 3-2.** There are many results measuring the size of a turning circle[6) 7)]. However, they are all cases of the largest rudder angle at full speed (usually a rudder angle are 35 degrees). The relation of speed and turning circle is said at a case of a slow speed, turning circle becomes small[7) 8)]. About the disparity of right turning and left turning, a definite result isn't introduced, as it differs with every ship. However, generally, the one axis right rotation propelling ship is considered that the right turning becomes large[7)~9)]. However, the Kakuyo-maru is a purse seine ship which can operate with a mono-ship, and a creativity that differes from general ships is applied. I.e., in operation, in order to reduce accidents with the net, the port bilge keel is small. It is as approximately 1/2 of the starboard bilge keel (with the Kakuyo-maru, the starboard keel is 45cm, the port keel is 25cm). Further, at the time of fishing, the net enters the bottom of ship from the port side. Therefore, it is on the starboard bottom of ship that the oscillator of the fish-finder and the current meter is installed. Though there are no reports about the influence that a bilge keel affects the turning circle, it is considered that a turning circle becomes smaller by the resistance[9)]. Furthermore, rudder angle changes to 5 degrees from 15 degrees, in case that casting a net finally approaches the skiff gradually. On a usual voyage, rudder angle in many cases for altering course and avoidance is less than 15 degrees. With that, we measured it with a rudder angle 15 degrees and 5 degrees in order to obtain the reference data and grasp a new course distance. Further, in order to examine the appropriateness of the size of the turning circle that is read from a figure, we referred to the result of an official trial.

4. Results and Discussion

1) 30 degrees rudder angle

(1) At full speed

The tracks of right and left turning at full speed are shown in **Fig. 1.** We consider the measurement in 1990 and 1991 as measurement A, and 1995 as measurement B.

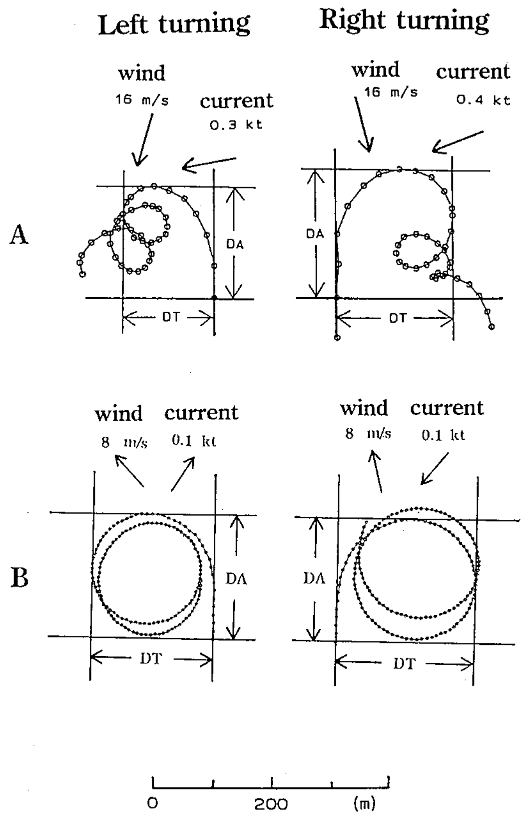

Fig. 1 The tracks of turning circle (Full speed, Rudder angle 30 deg.).

A : measurement A (shown in Table 1)
B : measurement B (shown in Table 1)
DA : maximum advance
DT : maximum transfer

With measurement A, with right and left turning in, an advance distance from 180 degrees turning position to 360 degrees turning position is significant and small. The track of second turning became a track that resembles a small ellipse. And, for this case, there was a strong wind of 16 m/s to the turning side, the turning circle was carried away to the lee side. Further, a track of the second turning and the third turning with the right turning became an ellipse. The size of "DA" and "DT" of the right turning was 214 meters and 197 meters respectively. However, with the left turning, their size was approximately 20% smaller.

The track of a turning circle at measurement B became almost a circle, and in distinction from measurement A, "DT" was somewhat large in both cases of right and left turning. And, similarly to measurement A, though the left turning got small in comparison with the right turning, the difference was 2% with "DA" and was 7% with "DT". Current velocity was 0.1 knots and wind speed was 8 m/s during measurement. However, with the influences of wind and current as the ship turned the time to be necessary for turning varies considerably, with measurement A and measurement B. Consequently, if thinking of measurement B, in a comparatively calm sea condition to be the original object, then in this report, the necessary turning times were 150 ~160 seconds. And further more, in case that we compare results of official trials of the Kakuyo-maru with measurements depending on GPS, the speed at the official trials was full speed and a rudder angle of 35 degrees, more over conditions on those days of trials was different to that of this study. Though a mere comparison isn't possible, as weather and oceanographic phenomena conditions around measurement differs. But, for the size of "DA", for right turning was 196 meters, left turning was 166 meters, and the size of "DT", for the right turning was 234 meters, left turning was 153 meters. As there was a difference of 7% compared with "DA" of the left turning of measurement A and compared it with "DT", there was a difference of merely 1%. And as there was a difference of 7% as we compared it with "DA" of the right turning of a measurement B, and it was a difference of merely 3% compared with "DT". Consequently, if considering the difference of rudder angle and conditions, it is thought that this time measurement depending on GPS was a size that applies.

(2) At half speed

The tracks of right and left turning at half speed are shown in **Fig. 2.** With measurement A, and right and left turning, compared with full speed for "DA" each increase by approximately 10 meters "DT" was generally a similar size. Also, this case, left turning was small. This track was measured making use of two satellites, and depending on two dimensional measurement. Therefore, in a position interval, though a little dispersion was seen, we were able to do a measurement with precision similar to low level measurement as to a measurement making use of three satellites. In comparison to the track that we measured with another dimension, consequently though, we thought that it was precise enough[10]. As we compared it with the full speed case, the track of the left turning became a track that was greatly washed under the lee tide.

In the case of measurement B, a wind speed was 5 m/s, and current velocity was 0.2 knots. Consequently, it was thought that their influence, to the turning circle was small. In this case, "DT" of right and left turning was an approximately 50 meters larger than "DA". However, as it became a steady turning, the size of "DT" and "DA" became equal and the track was the shape that well resembled a circle.

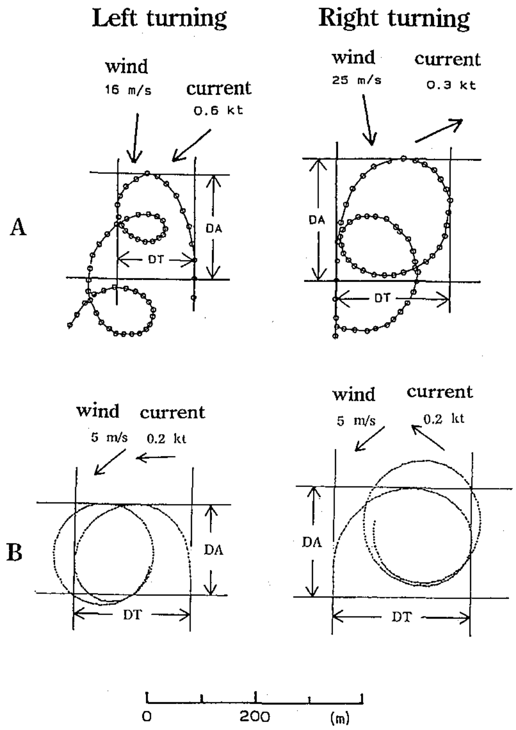

Fig. 2 The tracks of turning circle (Half speed, Rudder angle 30 deg.).

A : measurement A (shown in Table 1)
B : measurement B (shown in Table 1)
DA : maximum advance
DT : maximum transfer

(3) At slow speed

The tracks of right and left turning at slow speed are shown in **Fig. 3.** In the case of right turning measurement A, wind direction and current direction were opposite. "DA" got small and became a similar size to "DT". In this case, the second turning got smaller from the first turning. This tendency was similar to that of full speed and half speed measurements. However, "DA" and "DT" of the left turning got largest. The reason is the following ; i.e., though the wind speed was just 6 m/s, wind direction and current direction were the same direction. As the ship turned, consequently, the wind and tide became a favorable wind, order tide. Therefore, a speed over the ground of the ship didn't decrease like a case of the right turning. Generally to say, there is a tendency that the size of a turning circle gets small in the case of slow speed. However, at slow speed, the influence of wind and current becomes large, and the size of "DA" and "DT" changes with wind direction and current direction. Consequently, when we measure turning circles, we should do it in conditions of calm sea so that the influences of wind and current are minimized.

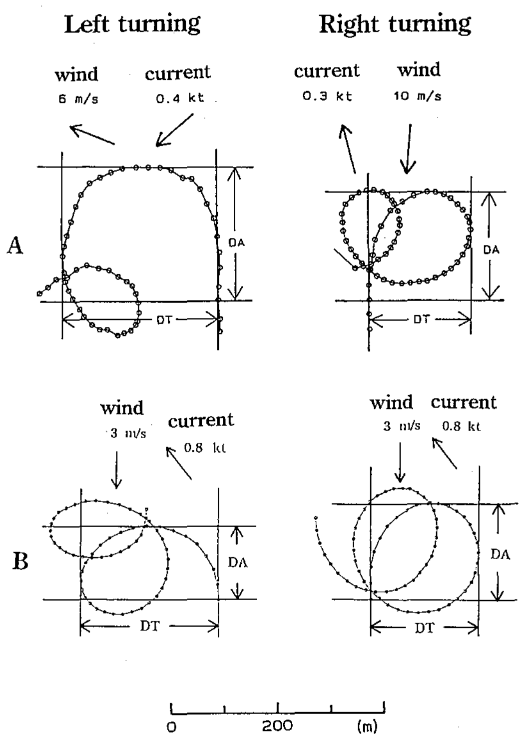

Fig. 3 The tracks of turning circle (Slow speed, Rudder angle 30 deg.).

A : measurement A (shown in Table 1)
B : measurement B (shown in Table 1)
DA : maximum advance
DT : maximum transfer

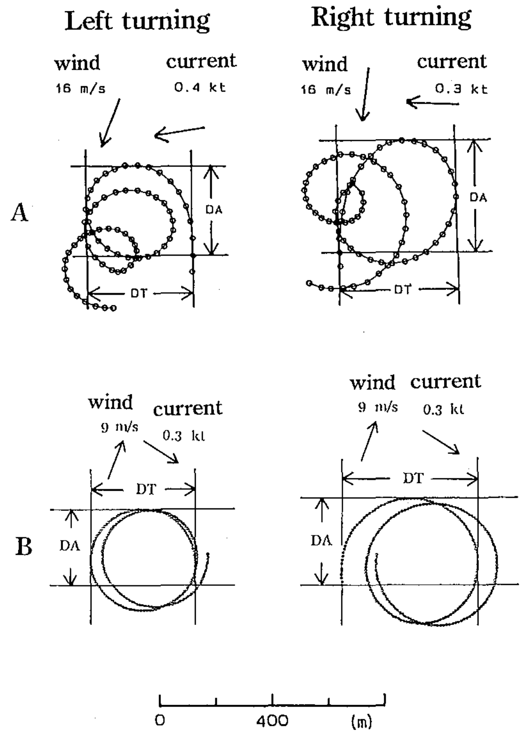

Fig. 4 The tracks of turning circle (Full speed, Rudder angle 15 deg.).

A : measurement A (shown in Table 1)
B : measurement B (shown in Table 1)
DA : maximum advance
DT : maximum transfer

In the case of measurement B, right and left turning in "DT" was larger in comparison with "DA". Then, with the second turning, as it was washed by a similar direction as the current, the shape of a track became an ellipse. Notably, "DT" of the left turning became 251 meters. This is because there was a 0.8 knots order tide in turning (from 90 degrees to 180 degrees). However, "DA" of a left turning, and "DA", "DT" of the right turning got smaller in comparison with that of full and half speed. The time necessary for one turning was 310～350 seconds. Consequently, the time necessary for one turning got approximately 200 seconds longer from the case of full speed, and 100 seconds from the case of half speed.

2) 15 degrees rudder angle

(1) At full speed

The tracks of right and left turning at full speed are shown in **Fig. 4.** For measurement of A, both "DA" and "DT" were 6～7 times the length of a ship. "DT" was larger in comparison with "DA". And, "DT" was more than two times when we compare it with "DT" when the rudder angle is 30 degrees. Comparing the 30 degree rudder angle, the decrease of the ship's speed depending on a steering in case of the 15 degrees rudder angle was little. Consequently, the transformation of the turning circle dependent on the influence of the lee tide was small, it was thought that the track would become a round shape.

A track with measurement B was a shape that well resembled a circle. With right and left turning, "DT" got larger in comparison with "DA". Wind speed was 9 m/s, and current velocity was 0.3 knots. However, it didn't have a significant influence on the turning circle. The necessary time for turning was the same as the necessary time with a 30 degree rudder at half speed.

(2) At half speed

The tracks of right and left turning at half speed are shown in **Fig. 5.** For the right turning measurement A, at the initial course direction, there was a wind of 7 m/s from the right 10 degrees. In this case, it was greatly washed under a wind as compared with the case of the right turning at a full speed. This seems to be greatly influenced by the wind, because the ship's speed slowed. Even though this

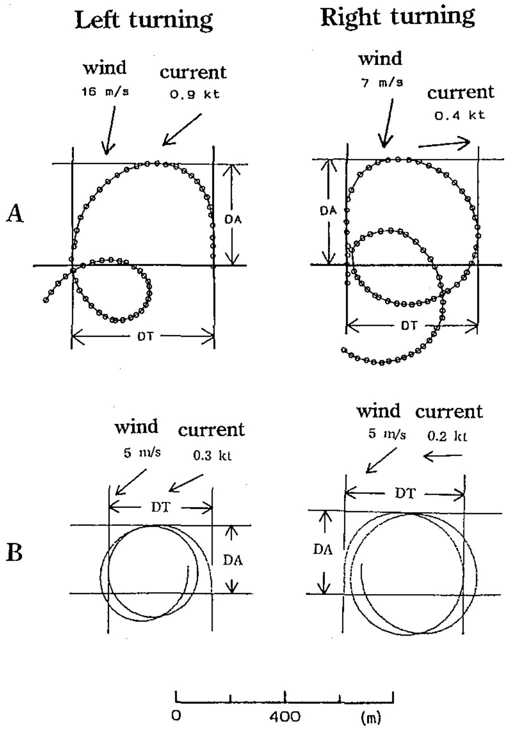

Fig. 5 The tracks of turning circle (Half speed, Rudder angle 15 deg.).

A : measurement A (shown in Table 1)
B : measurement B (shown in Table 1)
DA : maximum advance
DT : maximum transfer

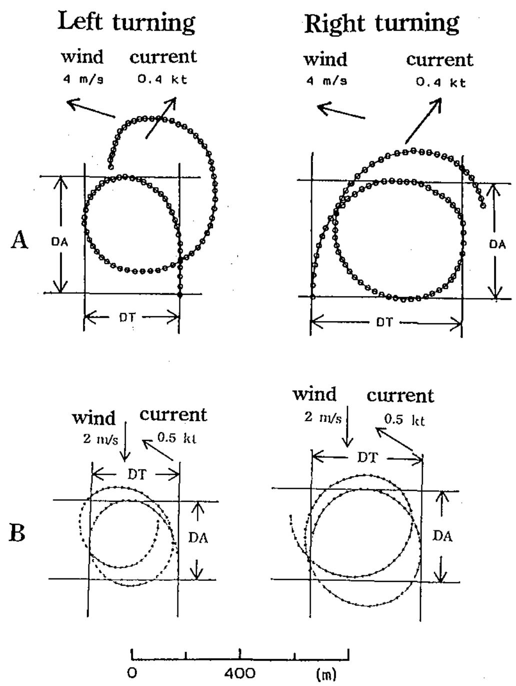

Fig. 6 The tracks of turning circle (Slow speed, Rudder angle 15 deg.).

A : measurement A (shown in Table 1)
B : measurement B (shown in Table 1)
DA : maximum advance
DT : maximum transfer

compared a case of the left turning similarly too. I.e., the track of the left turning at half speed was quite washed and became a thin long ellipse to reach in a synthetic direction of a wind and a current, because of the wind of 16 m/s and in addition to that there was a fast current of 0.9 knots.

The shape of turning circle for the measurement B was almost a circle. However, "DT" tended expand a little in case of left turning. Because there was a favorable wind and order tide from the turning position of 90 degrees through 180 degrees. This was similar to that of right turning at full speed. It was thought that in the case that the wind and current work in order as compared with working in opposition influenced the shape of the turning circle. The necessary time for a turning was the same as the necessary time with 30 degrees rudder angle and ship's speed at slow.

(3) At slow speed

The tracks of right and left turning at slow speed are shown in **Fig. 6.** With measurement A, right and left turning were done under the same sea conditions. The position of the ship that turned 180 degrees only for a distance to correspond to current velocity, slipped off in the right direction. Consequently, "DT" of the right turning got 190 meters larger. Generally, "DT" tended to be larger in comparison with "DA", as a rudder angle got smaller. If wind speed is less than 5m/s, the influence of a current appeared noticeable even if current speed is 0.3～0.4 knots.

The wind speed during measurement B was a weak 2 m/s. Therefore, the track of turning circle became the shape that was washed in a similar direction as the current, by influence of the current. When we compare these results with that of full speed and half speed, slow speed can easily be influenced by many external forces. Therefore, the shape of the turning circle becomes an ellipse. The necessary time that we needed in the right turning was 530 seconds,and the left turning was 450 seconds. Thus, the time difference between right turning and left turning was 80 seconds. As the rudder angle gets smaller the difference of the right turning time and the left turning time got larger. And, as a speed became slower, the time difference for turning got larger. Like the abovementioned, with the right turning and the left turning, there was a difference in a turning performance.

3) 5 degrees rudder angle

We didn't illustrate the track of turning circle for a 5 degree rudder angle. Measuring results are shown in **Table 3-1** and **Table 3-2.** For measurement B, wind and current were comparatively weak. Consequently, sea conditions calm. With that, we looked at measurement B. "DA" under which the rudder angle was 5 degrees was approximately three times as large as "DA" when the rudder angle was 30 degrees (for both full and half speed), and was approximately four times (for slow speed). Further more, the "DA" for a rudder angle of 5 degrees was approximately twice as large as "DT" for a rudder angle of 15 degrees. In the case of measurement A, there was a case that "DA" became six times as large as "DA" for a rudder angle of 30 degrees. Further, there was a case that "DT" with eight times, exceeded 1500 meters. Like the above-mentioned, the ship's speed was slow and the rudder angle was small. Under these conditions the ship is greatly influenced by wind and current. Consequently, in case that we steer a ship at a small angle, the ship handling person has sufficient time to do something and must cope with it.

4) Correction of a wind and a current

In the case of measurement B, SPS of GPS has already

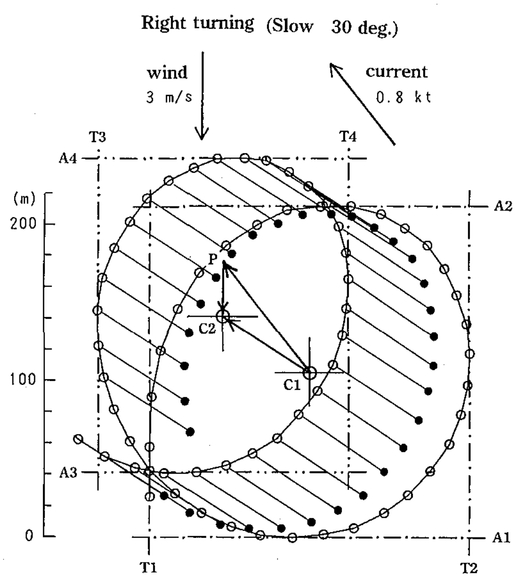

Fig. 7 Correction of the turning circle.

$\overline{A1A2}$: Advance of the first turning
$\overline{T1T2}$: Transfer of the first turning
$\overline{A3A4}$: Advance of the second turning
$\overline{T3T4}$: Transfer of the second turning
C1 : Center of the first turning
C2 : Center of the second turning
$\overrightarrow{C1P}$: movement vector by the current
$\overrightarrow{PC2}$: movement vector by the wind
● : each points of the second turning circle after the correction

Table 4 Movement distance of turning center divided it to the wind and the current direction, and percent of an influence of the wind and the current.

Rudder angle	Ship's speed	Turning side	Velocity W : wind(m/s) C : current(kt)	Distance (meter)	Turning time (sec)	Percent (%)
30deg.	Full	Right	W : 8	28	158	2.2
			C : 0.1	nil		
		Left	W : 8	nil	152	
			C : 0.1	nil		
	Half	Right	W : 5	nil	246	
			C : 0.2	nil		
		Left	W : 5	nil	222	
			C : 0.2	62		271.4
	Slow	Right	W : 3	33	350	3.1
			C : 0.8	89		61.8
		Left	W : 3	74	310	8.0
			C : 0.8	124		97.2
15deg.	Full	Right	W : 9	30	258	1.3
			C : 0.3	81		203.4
		Left	W : 9	15	228	0.7
			C : 0.3	22		62.5
	Half	Right	W : 5	nil	364	
			C : 0.2	nil		
		Left	W : 5	nil	312	
			C : 0.3	41		85.1
	Slow	Right	W : 2	nil	530	
			C : 0.5	67		49.1
		Left	W : 2	nil	450	
			C : 0.5	56		48.4
5deg.	Full	Right	W : 10	89	532	1.7
			C : 0.2	44		80.4
		Left	W : 10	nil	365	
			C : 0.2	nil		
	Half	Right	W : 7	nil	748	
			C : 0.2	163		211.8
		Left	W : 7	nil	584	
			C : 0.2	nil		
	Slow	Right	W : calm	nil	1040	82.9
			C : 0.3	133		
		Left	W : 2	nil	800	
			C : 0.5	119		57.8

Percent :
wind : ((distance/turning time)/wind velocity) × 100
current : (((distance/turning time) × 3600/17852)/current velocity) × 100

been made available. With that, we corrected for wind and current, about measurement B and considered them for their own influence. We considered the center of advance and transfer, of first turning as the center of the turning circle. We similarly determined the center of the 2 nd turning, and considered that direction and distance of the center of the first turning and the center of the 2 nd turning are dependent on wind and current. For each point with respect to the track of 2 nd turning, if making a correcction with direction and distance between the center, the turning circle that resembles the first turning was obtained. As showed the right turning of a slow speed in **Fig. 7**, is an example of a case rudder angle at 30 degree.

About the turning central movement quantity ($\overrightarrow{C1C2}$) that we show in **Fig. 7**, we divided it to the direction of tidal direction ($\overrightarrow{C1P}$) and wind ($\overrightarrow{PC2}$). We used the time that we need for a turning and converted each distance into a velocity. Then, we calculated a rate for velocity of current and measurement of wind speed and showed them in **Table 4.** In case that we don't include movement distance in the Table, it is because the direction moved to the opposite direction of current and wind, though the turning center moved.

With the right turning at full speed, a rate of an influence of wind, is 1.3～2.2% with a wind speed of 8 m/s. However, with the left turning, there was the case that a wind speed 10 m/s even doesn't have an influence on it. We think that this difference is dependent on the difference of turning performance of right and left. With right and left turning at half speed, even though there was a wind of a wind speed of 7 m/s, an influence wasn't seen. At slow speed, though we don't have an influence on them at a wind of 2 m/s, a wind of 3 m/s gave an influence of 3.1～8.0%.

In the case of current, a current velocity of 0.2 kt didn't have an influence on it many cases. However, we had an influence on all cases with a current velocity of 0.3 kt. And, in the case that wind and current affect a similar direction and in case that an initial course direction chases, are windy, there was the case that a turning central movement distance becomes more than 2 times the velocity of current. Like the above-mentioned, in the case that a current is weak with 0.3 kt, we have an influence on a turning. Consequently, in case that a velocity of a ship is slow, it is necessary enough to consider the influence of a current.

5. Summary

Using GPS, we considered whether or not it was an easy matter to measure turning circle. Simultaneously with that, in order to obtain a guide regarding ship handling in the case that we operate a purse seine by Kakuyo-maru, we experimented.

With measurement A, though the left turning got larger in comparison with the right turning with a portion, all turning performance was good for the left turning.

This was able to be confirmed at all cases of measurement B, because turning performance of the left turning was good .

With measurement A, in case that speed was rapid and a rudder angle was large, there was a phenomenon that a turning circle was extremely small on second turning or third turning. However, with measurement B, the phenomenon wasn't seen. Consequently, we thought that the main cause was dependent on the receiver.

Turning time of Kakuyo-maru is the difference of speed and rudder angle. However, in case that rudder angle is above 15 degrees, it is possible what we turn within the limit of the diameter that corresponds to a length of a purse seine net.

Being influenced by wind and current, the track of a turning circle slips off. We were able to reform them, by the casing, correct a turning central movement quantity. And, an influence to a turning circle started appearing at a wind speed of more than 8 m/s. The velocity of current at more than 0.3 kt also influenced turning circle. Consequently, to ship handling in such a conditions, careful attention is necessary.

In case of any rudder angle, if the ship's speed is slow, oceanographic phenomena has an influence on the size of a turning circle. At a small rudder angle, the time that we need for turning gets longer. Consequently, in the case that we perform an avoidance maneuver with a small angle steering only, it is necessary to cope with it as having enough and sparing enough.

In a case that we compared our results with that depending on official trials and a measurement depending on GPS, there is a little point at issue, for example, measurement of official trials is the measurement through the water but measurement of GPS is the measurement of over the ground, more over the influence of wind and current differs from the two measurements.

In this study, we got a reference in ship handling with an operation of a purse seiner. Further, we can say that we can contribute to safe ship navigation.

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まき網練習船の旋回圏の測定に関する研究

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要旨

米国式カツオ・マグロまき網操業においては，魚群行動を予測し，短時間で魚群を包囲しなければならず，また，まき網の長さ（鶴洋丸では1350m）も決まっているため，自船の速力と舵角に対応する旋回圏の大きさや，旋回所要時間を把握しておく必要がある。

著者らは，米国式カツオ・マグロまき網操業装備を擁し，単船操業ができる長崎大学水産学部漁業練習船鶴洋丸の旋回圏の測定を，GPS を用いて行った。

その結果，３種類の各速力，各舵角での左右旋回時の旋回圏の大きさを測定できた。鶴洋丸においては，速力と舵角によって旋回所要時間に差はあるものの，舵角15度以上であれば，ほぼ網の長さに対応する直径の範囲内で旋回することが可能であった。