STUDIES ON MATCHING THE GEAR SIZE TO THE ENGINE POWER OF THE TRAWLER

by

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Abstract

In recent years, the resources for bottom trawling fishery in the northern waters of Taiwan and at the Taiwan Strait have been decreasing day by day. Thus to exploit the pelagic resources becomes the most important goal for the trawling industry of Taiwan. In view of this, the present authors have made experiments on Kwang-Yang No. 82 stern trawler (♯318, 1000HP) in dealing with its rational design of fishing gears and its characteristics of towing force, etc. . In this report, we concluded the results of a series of field experiments of fishing gears' mechanical behaviour.

Introduction

Due to limited fishing grounds of the Taiwan Strait and the northern waters of Taiwan and the increasing number of fishing boats, the resources for bottom-trawling have steadily decreased, thus forcing the trawlers to operate in more distant sea areas and to change their operation to larger type. Consequently, developing the fishing techniques and researching

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fishing gears' construction of large trawlers are certainly most important problems for fisheries industry.

The Research Vessel, Hai-Ching, of Taiwan Fisheries Research Institute has explored and found new fishing grounds north of center Australia and the trawling fishery industries of Keelung and Kaohsing have adopted the fishing technique of stern trawling. These push the trawling fishery of Taiwan to further progress. More and more large stern trawlers over 300 tons are being built and it is anticipated they would become the main post of the fisheries of Taiwan in the future.

In the course of the development of stern trawling fishery, the fishing companies, the shipyards, and the net factories have made many contributions, but it is the Taiwan Fisheries Research Institute that has the double mission of fishing ground exploration and the improvement of fishing gear. The authors, having taken charge of the mission, went to sea on the stern trawler Kwang-Yang No. 82 to carry out a series of experiments for obtaining the data concerning the resistance of the fishing gears, and their mechanical characteristics under trawling conditions.

Materials and methods

The trawling gears used in the experiments are shown in Figures 1 to 4. To decide on the sizes of the gears, the writers first tested the foundamental elements such as towing powers, height of the net mouth, tension in the warp, resistance of the net, and other mechanical characteristics of trawling gears under operation. The experiments were made within March 1-4, 1973, in the Taiwan Strait (water depth from 50 to 132m). The stern trawler, Kwang-Yang, No. 82 was built by the Fong-Kuo Shipyard in 1973, epitome of which is tabulated in Table 1.

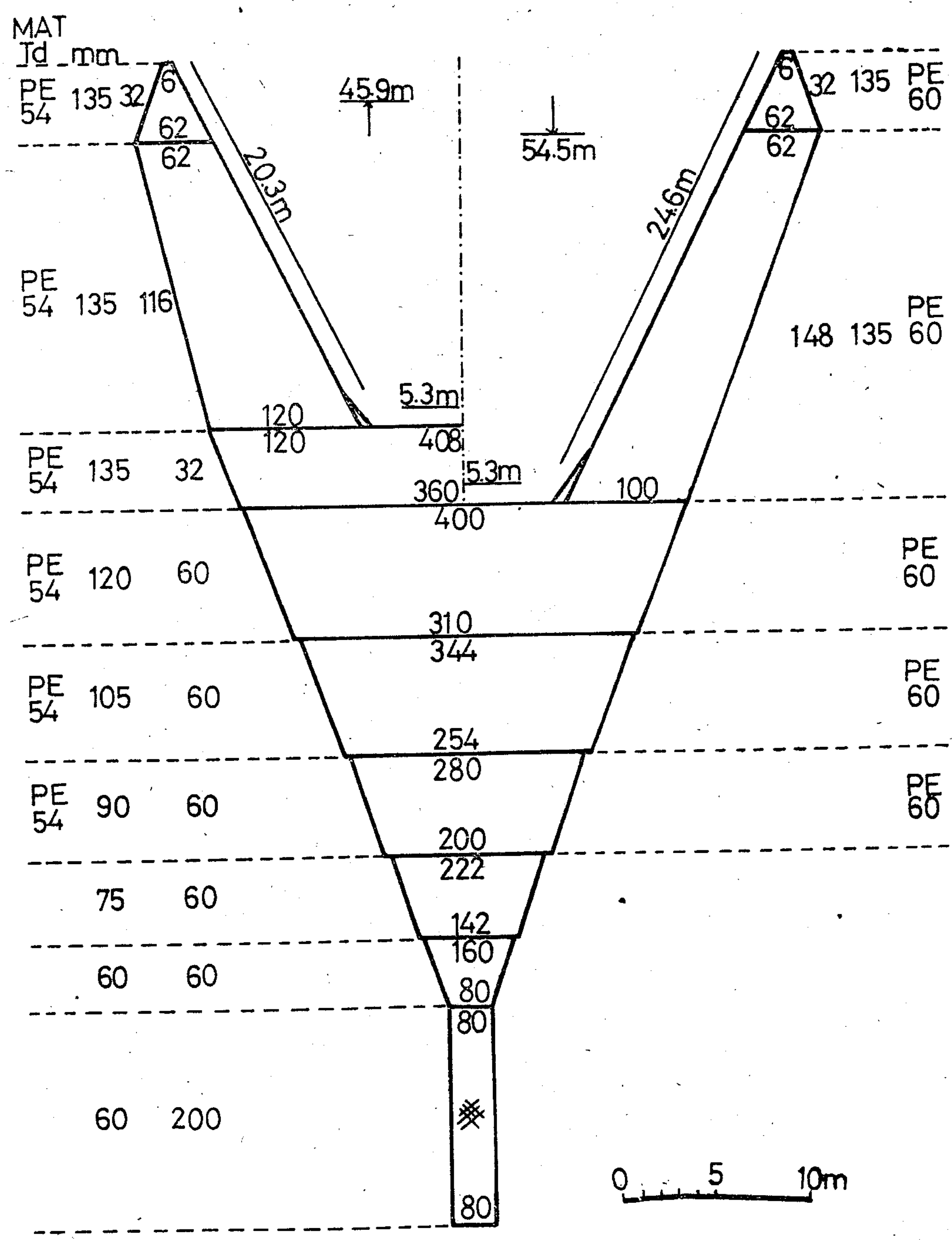


Fig. 1. Plan of a two-panel trawlnet used in Taiwan

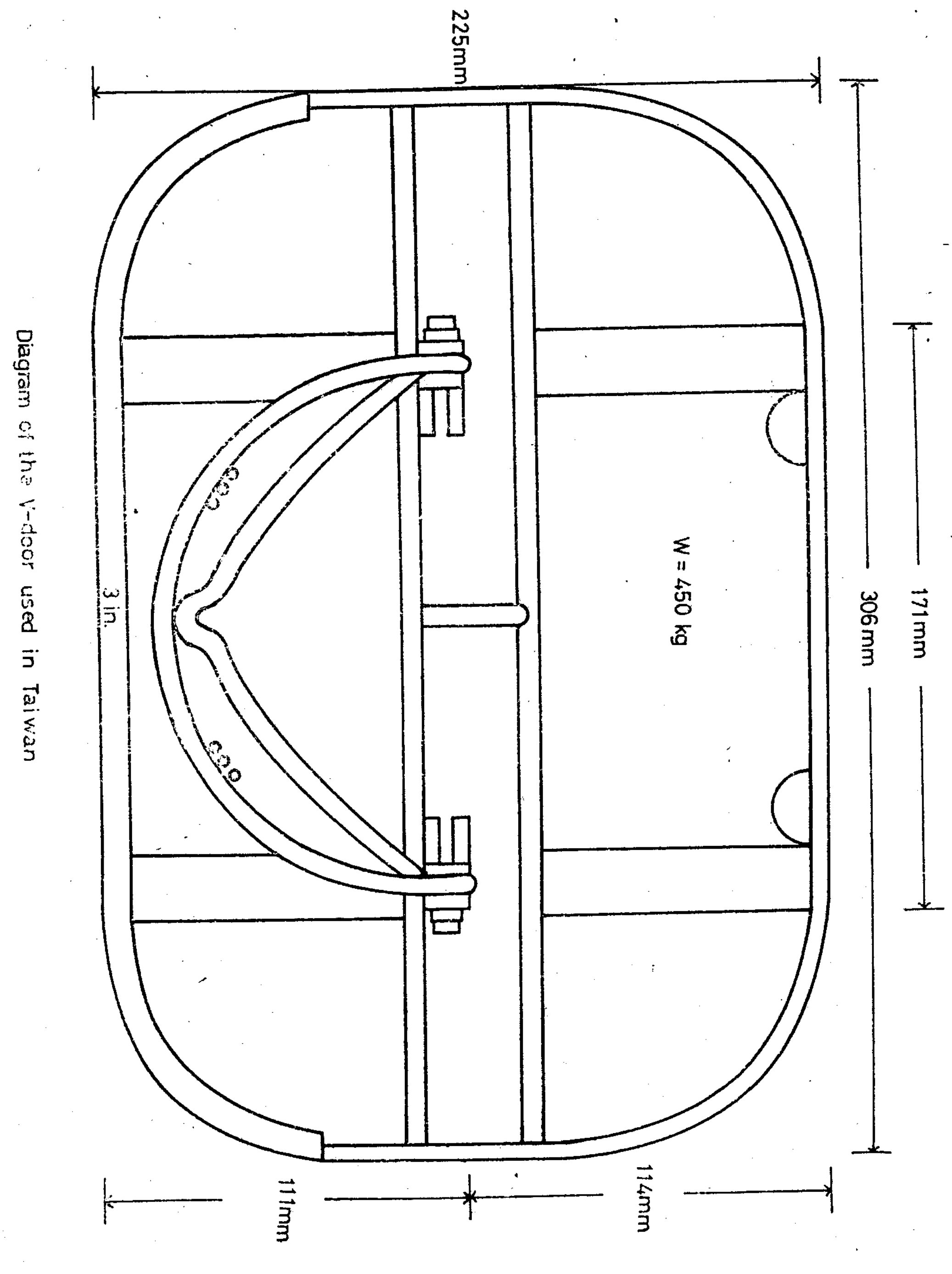


Fig. 2. Diagram of the V-door used in Taiwan

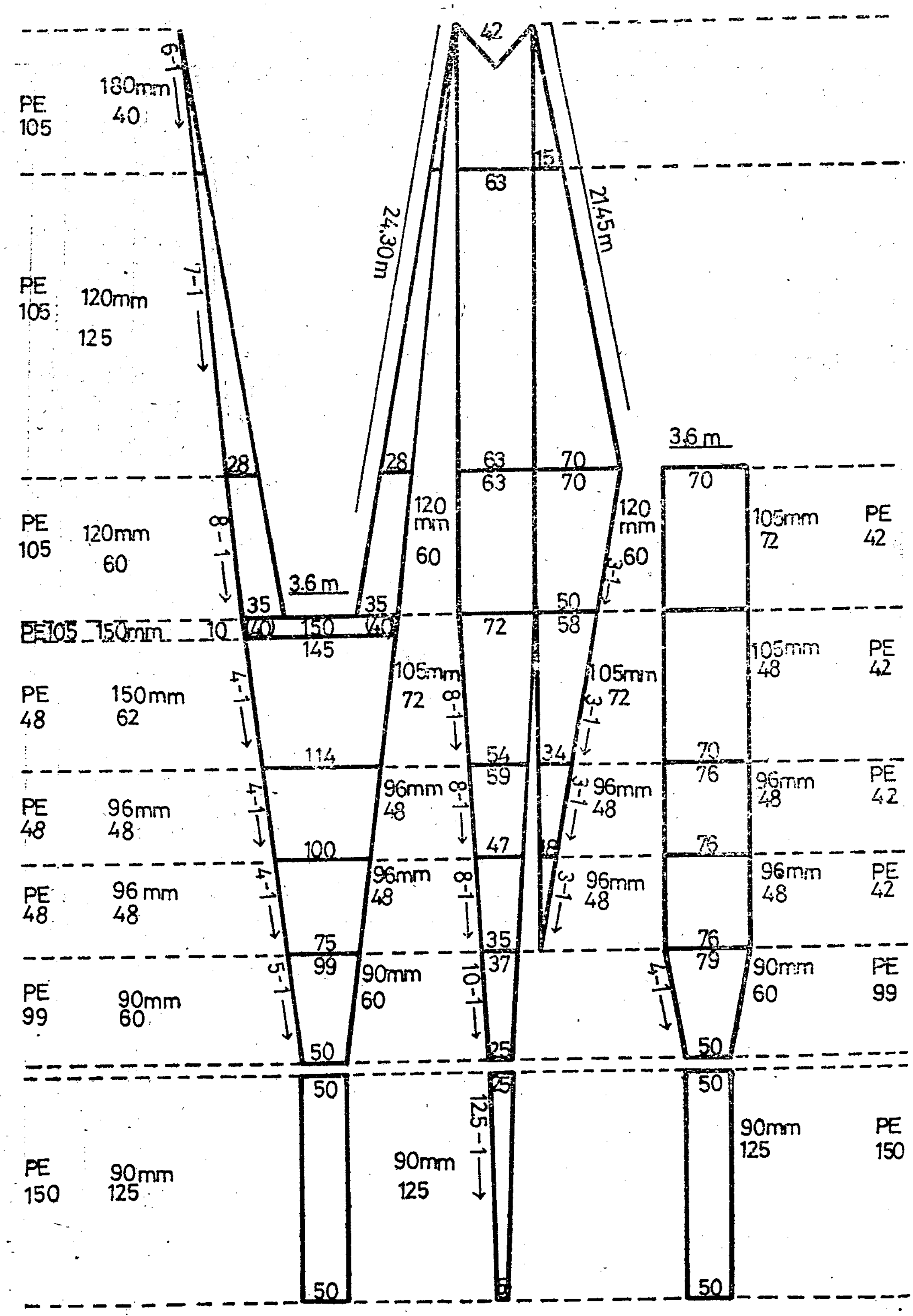


Fig. 3. Plan of a six-panel trawlnet used in Taiwan

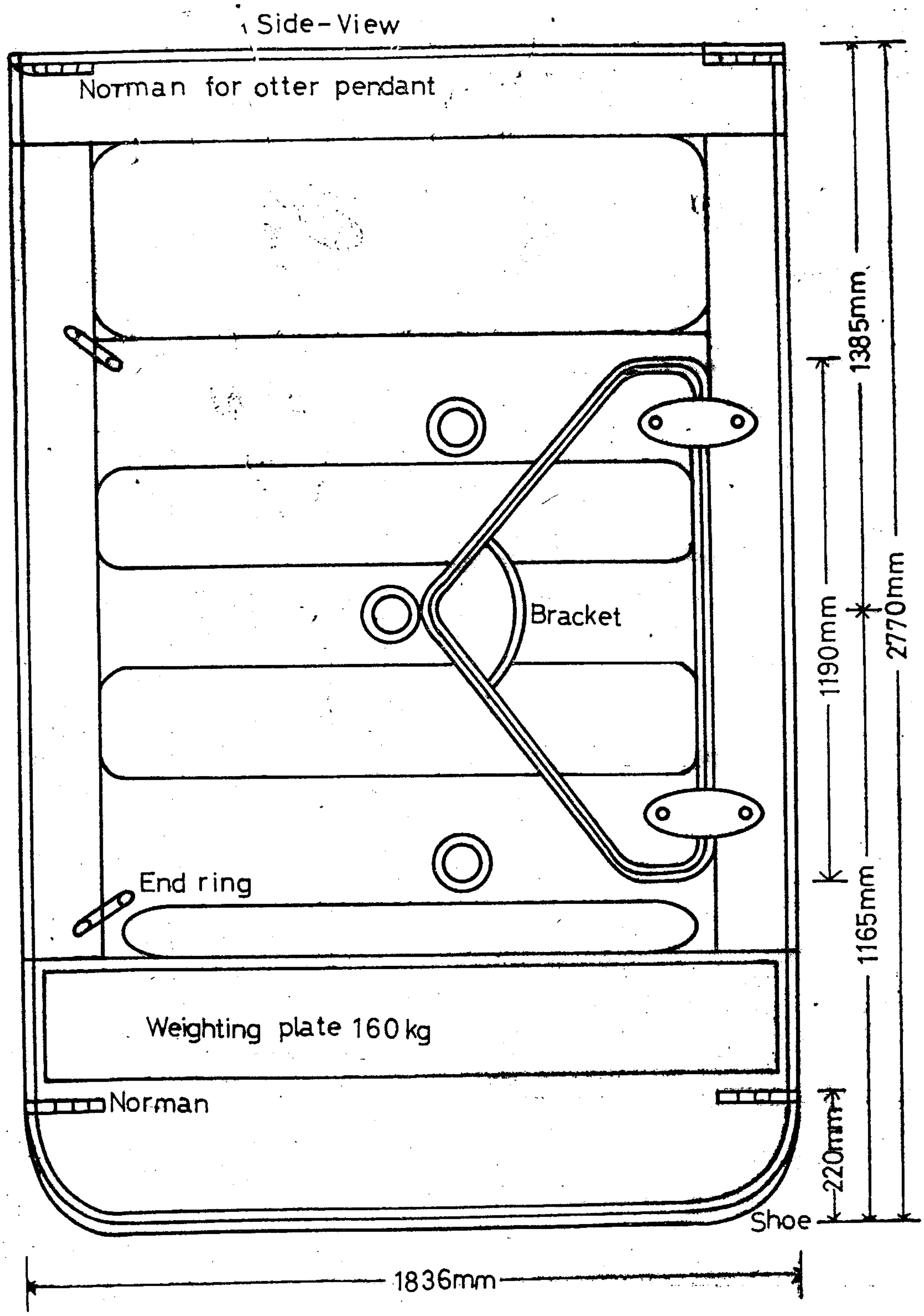


Fig. 4. Diagram of the up-right otter boards used in Taiwan

Table 1 Epitome of No. 82 Kwang-Yang trawler

Length between perpendicular	36.00m
Breadth moulded	7.60m
Depth moulded	3.50m
Gross tonnage	318tons
Main engine type	S6 YDTSS
Maximum continuous shaft horse power	1,000Ps
Maximum engine speed (R.P.M.)	420
Propeller type	C.P.P.
Number of blades	3
Propeller diameter	1,800mm
Propeller: pitch (standard)	720mm
Trawl winch capacity	10tons
Trawling type	stern trawling

The experimental instruments included the CM-1B type electrical current-speed meter (Toho Dentan Co.), a 10-ton warp-tension meter (Kyowa Co.), a net-recorder (FNR-50, Furuno Co.) , and the angle rulers for measuring the "dip angle" and the "cross angle" of the warps.

On the other hand, we should know that maximum continuous shaft horse power S.H.P.) means the gas pressure on the cylinder with its numerical value shown on the indicator reducted the frictional loss. This value can be calculated from the graph to gain mechanical efficiency, or estimated by comparing the trial results of fuel rack & fuel oil heating value. Also it can be tested by torsion meter through slip ring & strain gauge on intermediate shaft.

Experimental results and discusson

The data of experimental results were obtained according to the following steps:

(A) When there were more than two kinds of the observed value, we take the mean value. For example when the warps were subjected to tension of about 3-4 tons, we take its mean value by 3.5 tons. The same case applies to towing speed, dip angle, and height of net mouth.

(B) The tension measured by the load type tension-meter was that of the starboard side warp. Thus the total tension is two times the measured one.

(C) In the observed values of the dip angle of the warp, the mean value of two dip angles of the starboard and port side warps was taken.

According to the steps stated above, the experimental results are shown in Table 2.

1. Characteristics of the towing power of the trawler

On designing the trawling gears, the basic elements for deciding their sizes were the decision about the characteristics of the towing power of the trawler. This means that to understand the relationship between the enginehip revolution, R.P.M., and the shaft horse power, S.H.P., and the relationship between the towing speed and the effective horse power, En.H.P., etc. is most important and urgently needed.

Available detailed reports concerning trawling gears come from certian researchers such as Friedman[1], Koyama[2 4], and Hamuro[6] In field practice, we see that the shaft horse power needed equals the accumulation of the full load main engine revolution times the cubic root of the proportional value of the full load and the required load. That is, when the standard main engine revolution of the trawler of 1,000P's is 420 R.P.M., then the main engine revolution of 500P's should be $\sqrt[3]{\frac{500}{1000}} \times 420 = 0.794 \times 420 = 334$ R.P.M. And to any trawling gear, the towing speed was approximately in proportion to the main engine revolution, R.P.M.

When the sea surface is calm (wind force grade 1 to 3), assuming that the tension in the warp obtained in the course of the experiments that have been shown in Fig. 5 as T (kg), the angle of the warp as α, and the total resistance of the fishing gears as R_T (kg), we can express the relation as follows:

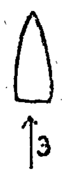
$$R_T = T \cos\alpha \qquad (1)$$

The horse power required for fishing gears under a certain towing speed (V) is generally called the effective horse power. It can always be expressed as

$$\text{En. H. P.} = \frac{R_T . V}{75} \qquad (2)$$

One horse power equals 75 kg.m/sec. V represents the towing speed(m/sec). Therefore, by equations (1) and (2), we calculated the values of En. H. P. and velocity as shown in Fig. 6 from the experimental results of the tension in warp, dip angle α, and towing speed V.

Table 2. Results obtained in the course of the field experiments

Gear Kind	No.	Wind force (Beaufort)	Pitch angle (deg.)	Depth (m)	Engine speed (R.P.M)	Estimated shaft horse-Power (S.H.P.)	Towing speed (m/sec)	Warp length (m)	Dip of warp (m)	Cross angle of warp (deg.)	Tension in warp (ton)	Height of net mouth (m)	Calculated distance of otter boards (m)
V-door with two-panel net	1		10	40	300		1.5	250	18	6	5	5.5	24.7
	2		10	40	330		1.6	250	19.5	6	4.5	5	24.5
	3		10	40	350		1.8	250	19	7	5.6	4	28.8
	4		10	40	370		1.9	250	20	7	6.8	3.5	28.6
	5		10	130	310		1.5	350	—	—	6.2	5.5	—
	6		10	132	330		1.65	350	—	—	6.4	5	—
	7		10	96	330		1.7	350	—	—	5.5	4.5	—
	8		10	110	350		2.0	350	—	—	7	4	—
Up-right otter boards with six-panel net	9		11	75	320	300	1.5	300	19	9	6.3	3.65	44.2
	10		11	78	340	354	1.7	300	20.5	8.5	6.8	3.35	42.7
	11		15	96	330	333	1.8	300	22.5	10	8	3.5	48.2
	12		15	95	350	400	1.95	300	21.5	9.5	9.5	3	45.7
	13		15	92	350		2.02	300	18.5	10.5	10	2.5	53.5
	14		16	81	350		2.05	300	20	9	9.5	3	44
Up-right otter boards with two-panel net	15		14	95	340		1.95	300	20	10.5	6.5	3	51
	16		14	125	340		2.25	300	—	—	—	2.8	—
	17		13	86	340		1.95	300	—	—	8	3	—
	18		12	90	340		1.8	300	—	—	7.5	2.8	—
	19		11	78	340		1.7	300	—	—	6	3	—
	20		11	74	340		1.6	300	—	—	—	3.5	—

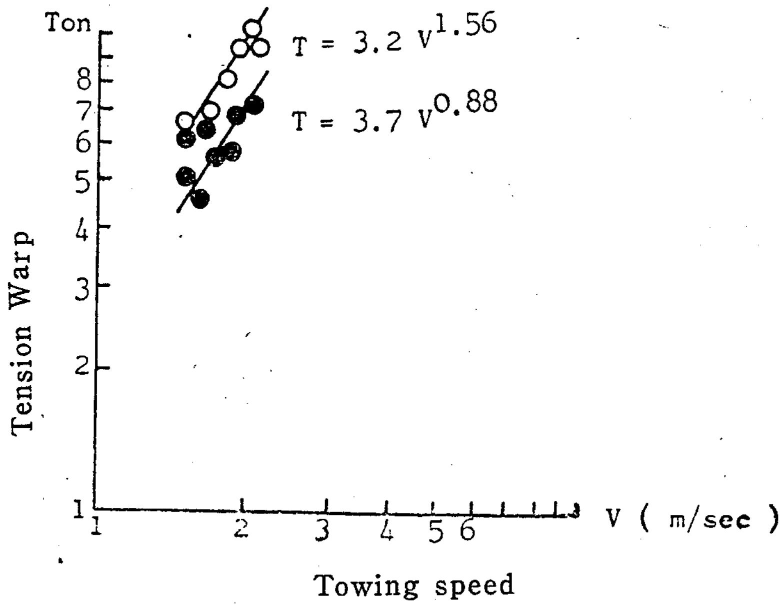


Fig. 5 Relationship between the tension in warp and the towing speed.
Notes: The closed and open circles show the observed values of a two-panel trawlnet with the V-door and a six-panel trawlnet with the up-right type otter board respectively.

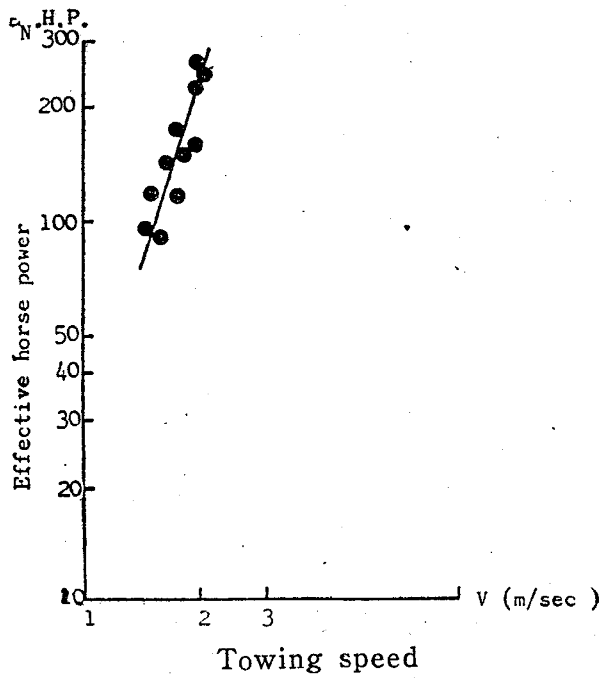


Fig. 6 Relationship between the effective horse power and the towing speed.

On the other hand, the effective horse power under trawling was in proportion to the shaft horse power of the individual trawler, of which the proportional constant fell between 0.18 and 0.3[6]

(1) Main engine revoltion, R.P.M., and shaft horse power, S.H.P.

In the course of the experiments, the relationship between the main engine revolution, R.P.M., and the shaft hore power, S.H.P., from the data in Table 2 can be sketched as in Fig. 7.

In the figure, the open and the closed circles represent the values observed under trawling operation and general navigation respectively. From this figure, we can see the observed values were within a small range and they could not be compared with those gained from general navigation. But the results were the same as those reported by Koyama; the S.H.P. was in proportion to the cubed value of the main engine revolution, R.P.M.

(2) Towing speed and main engine revolution, R.P.M.

From the results in Table 2, the relationship between the towing speed (m/sec) and the main engine revolution, R.P.M., under various conditions were shown as in Fig. 8.

The open circles in the figure represent the field practices using V-door with a two-panel trawlnet. The closed circes represent the field practices using up-right type otter boards with a six-panel trawlnet. The results here show the same tendency as those of Koyama's: whatever trawling gears were used, there were always the proportional relationship between V and R.P.M.

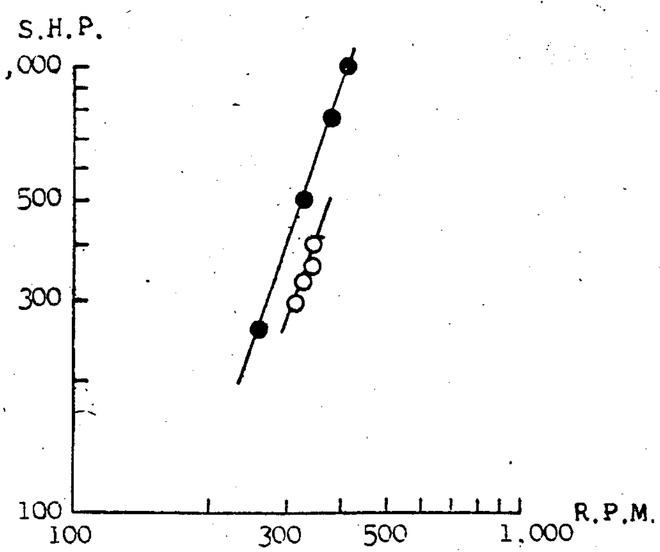


Fig. 7 Relationship between the shaft horse power (S.H.P.) and the engine revolution (R.P.M.)

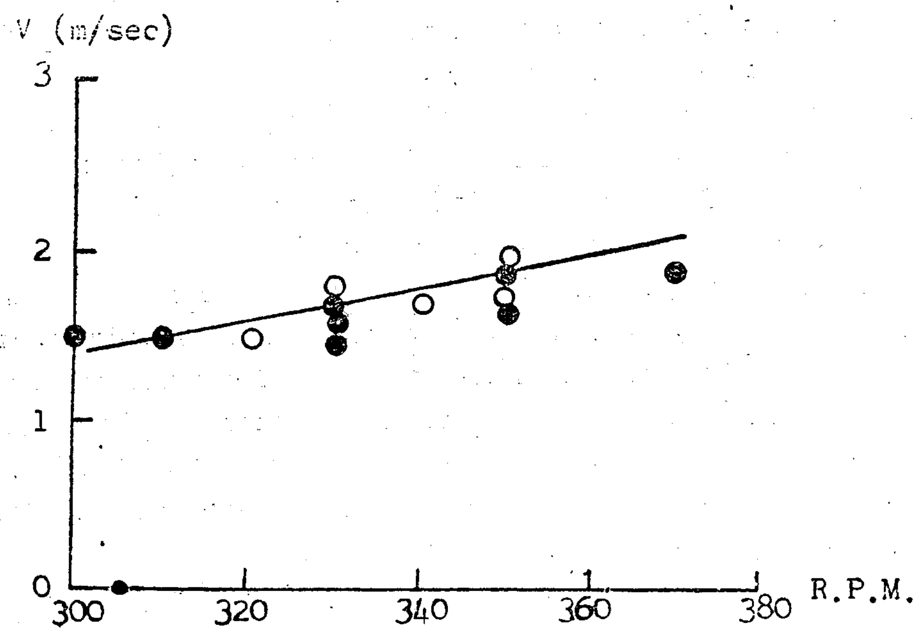


Fig. 8 Relationship between the towing speed (V) of Kwang-Yang No. 82 trawler and the engine revolution (R.P.M) under various net -conditions.

Notes: The open and the closed circles show the observed values at warp length 250 m for a two-panel trawlnet with the V-door and at warp length 300 m for a six-panel trawlnet with the up-right otter board respectively.

2. Towing speed and height of the net mouth

Many researchers such as Lee[7], Boer[8], Takayama[9], and Phillips[10], reported Relationship between the towing speed and opening of the two-panel net. As for the relationship between the towing speed and opening of the four-panel net were also reported by Taniguchi[11], and Hamuro[12], all of these reports indicated that there are exponential relationship between the towing speed and the headline height of net. The results of our experiments on the relationship between towing speed and the headline height of the net were shown in Table 2, and Fig. 9. When the towing speed is at 1.7-2.05m/sec, the height of the six-panel net with the up-right type otter boards declines from 3-3.5m to 6m. These results show differences to those of Chou's[13]. In the course of Chou's experiments, where a two panel or a six-panel trawlnet, he nonetheless used the same pair of otter boards. But in our experiments we used different pairs of otter boards, thus it caused the diffe-rent results. On the other hand, regarding net construction, because the square part of the net is shorter than Chou's, when it is subjected to the large spreading force of the otter boards, it fails to the height as that of Chou's.

3. Resistance of the net

Resistance of the net, by subtract R_n from the fishing gears' total resistance, R_T, the resistance of the otter boards R_o warps R_w and handropes R_h during trawling and can be expressed as

$$R_n = R_T - (R_o + R_w + R_h) \qquad (3)$$

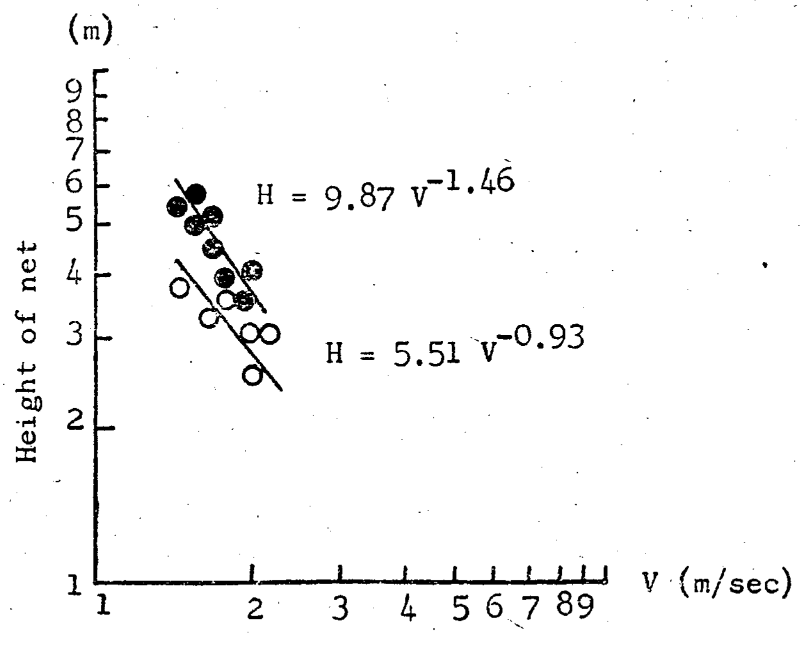


Fig. 9 Relationship between the headline height of net and the towing speed

Notes: The open and the closed circles show the observed values of a two-panel trawl net with V-door and a six-panel.

Since the lengths of the handropes used in trawling are only 50-100 meters, that cause very small resistance compared to the resistance of the net, it can be neglected in practical calculation.

The resistance coefficient of the up-right type otter board is assumed at 0.3. According to Schärfe[14], its maximum and the resistance coefficient of the flat rectangular otter board assumed at 0.6, according to Crew[15], and Koyama[1].

Thus the resistance of the otter board can be expressed as.

$$R_{oi} = \frac{1}{2} C_{Di} \cdot S_i \cdot V^2 \cdot \rho \qquad (4)$$

where suffix i denotes the otter boards 1 and 2, 1 is the V-door, and 2 is the up-right type otter boards. S, the area of the otter board, and ρ is the density of the sea water (105 kg.sec²/m⁴), C_D, the coefficient of resistance. The resistance of the warp in the direction of trawling R_w(kg), as the warp is generally assumed to be linear in the water, is small. It can be expressed as

$$R_w = \frac{1}{2} C_{Dw} \cdot V^2 \cdot D_w \cdot L_w \cdot \rho \qquad (5)$$

Where C_{Dw} is the coefficient of the warp, which assumed to have the value 0.1 according to Koyama, D_w, the diameter of the warp (m), L_w, the warp length, V, the towing speed (m/sec), and ρ is the density of the sea-water (105 kg. sec²/m⁴).

From (3) , (4) and (5), we concluded the formulae of the net resistance as

$$R_{n1} = 2.1V^{1.03}$$

$$R_{n2} = 3.2V^{1.22}$$

4. Distance of the otter boards and the wing nets

The spread distance of the otter boards and the distance between the two wings are closely, correlated. If the spread distance of the otter boards is Y_b and the distance between the two wings is Y_w, then the proportional ratio "a" can be expressed as $a = \frac{Y_b}{Y_w}$, where "a" is always a constant. Y_b was measured directly by using horizontal sonar[17], or indirectly by estimating the spread angle, the dip angle, and the let-go length of warps. In our experiments, we adopted the latter method, and sketched the results as Fig. 10.

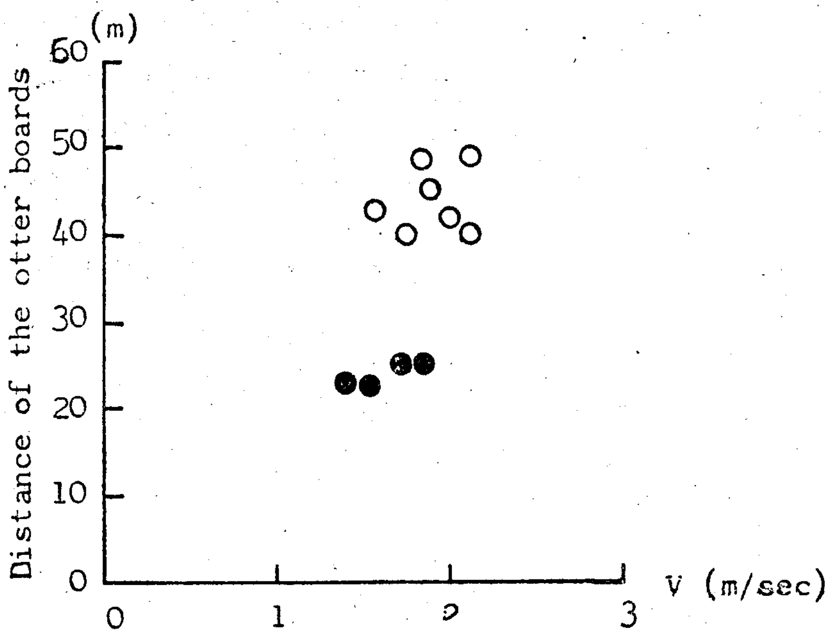


Fig. 10 Relationship between the distance of the otter boards and the towing speed.

Notes: The open and the closed circles show the observed values of a two-panel trawlnet with the V-door and a six-panel trawlnet with the up-right type otter boards respectively.

SUMMARY

The results obtained from the field experiments on the towing power of Kwang-Yang No. 82 stern trawler and on the comparative working behavior of the usual two-panel trawl net with the V-door (Fig. 1-2) and a six-panel trawl net with the up-right otter board (Fig. 3-4). The results obtained are summarized as follows:

1) The tension in the warp, T (ton), of Kwang-Yang No. 82 in relation to the towing speed, V (m/sec), was expressed in the following empirical formulae respectively for different combinations (Fig. 5).

$T=3.7V^{0.88}$ (a two-panel trawl net with the V-door)

$T=3.2V^{1.56}$ (a six-panel trawl net with the up-right otter boards)

2) The towing speed, V (m/sec), was approximately proportional to the towing power; that is proportional to the E_N.H.P. (Fig. 6).

3) The shaft horse power, S.H.P., of the Kwang-Yang No. 82 trawler equals the accumulation of the full load main engine revolution, R.P.M. times the cubic root of the proportional value of the full load and the required load (Fig. 7).

4) The towing speed, V(m/sec), was approximately proportional to the engine revolution, R.P.M., under any conditions (Fig. 8).

5) The headline height of the trawl net mouth of the trawl net in relation to the towing speed, V(m/sec), was expressed in the following empirica formulae (Fig. 9).

$H=9.87\ V^{1.46}$ (a two-panel trawl net with the V-door)

$H=5.51\ V^{0.93}$ (a six-panel trawl net with the up-right otter boards)

6) The resistance of the net, Rn (ton), in relation to the towing speed, V(m/sec), was expressed in the following empirical formulae:

$$R_{n1}=2.1\ V^{1.03}$$

$$R_{n2}=3.2\ V^{1.22}$$

7) The relationship between the spread distance of the otter boards, D(m), and the towing speed within a range of 1-3 m/sec was shown in Fig. 10.

ACKNOWLEDGMENTS

The authors wish to express their thanks to the gentlemen of Kwang-Yang Fishing Company for all their assistance.

The authors are also grateful to the financial assistance of the National Science Council and the encourgement of Dr. H. T. Teng, Director of Taiwan Fisheries Research Institute.

Finally, to the suggestions offered by Mr. T. P. Chen, Consultant, and Mr. C. T. Chueh, Chief of Fisheries Division, of the Joint Commission on Rural Reconstruction, the authors express their deepest gratitude.

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