



**The design and construction of flat rectangular
otter boards for bottom trawling: a review**

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PART I GENERAL

THE DESIGN AND CONSTRUCTION OF FLAT RECTANGULAR OTTER BOARDS FOR BOTTOM TRAWLING — A REVIEW

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Otter boards, or doors as they are frequently called, are devices to keep the trawl net horizontally open under tow. While the conventional shape of an otter board in bottom trawling is rectangular, L-shaped, oval and hydrofoil boards are also in use for certain bottom fisheries. In the present review, however, the author has mainly centred his attention on the flat rectangular doors. Figs 1 and 2 show the design details of a board in common use. Each door is fitted with two triangular brackets (Fig 1) the forward one being shorter than the one at the rear. The brackets are so arranged and connected to the towing warp as to keep the board obliquely to the direction of motion and thus force them sideways by the flow of water (Brandt, 1964; Hodson, 1942). The two doors in a trawl net work on the same principle as that of a kite, the water causing the shearing effect. To facilitate easy adjustment the rear bracket is occasionally replaced with chain bridles (Fig 2). The legs of the trawl net are attached to the rings on the other side of the board.

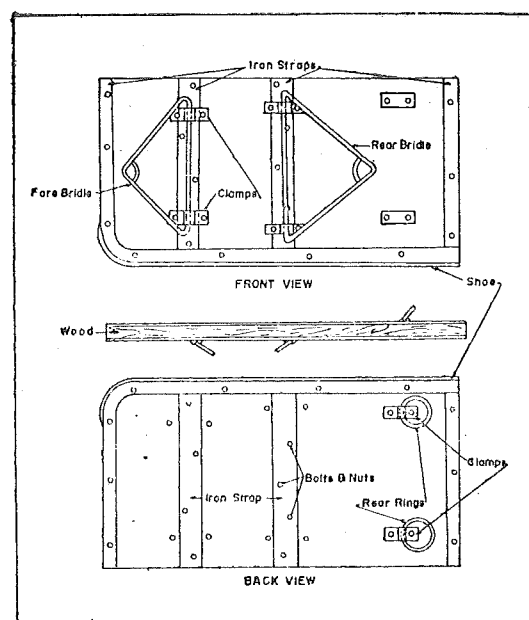


Fig. 1

HISTORICAL

Otter door was used initially in the line fishing and is not an innovation of trawl fishery (Brandt, 1964; Davis, 1958). The name 'otter' was derived from the board called as such and prevalently used in Ireland for the hook and line fishing.

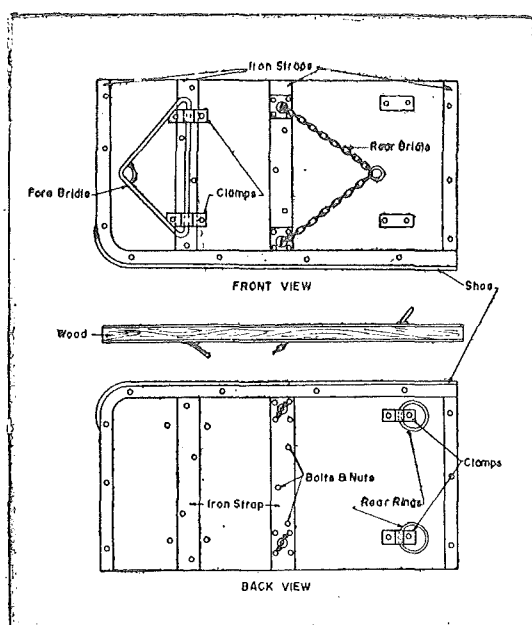


Fig. 2

This board is of rectangular shape and towed by a main line having four or more branch lines with hooks. The board was set in such a way as to move away from the boat and thus keep the main line taut.

Davis (1958) is of the opinion that the actual invention of the otter doors must be credited to Hearder or Musgrave. The experiments carried out in England in 1885 were without success. The following year, Thurlow tried an otter trawl running on a trolley. Danes, in 1888, were using a modern type of otter board on their 'Snurrevaads' or seine net. It was in the year 1892 that the first successful otter board was made from Shields on the English North East Coast.

Initially otter trawl was towed by a single line as in the case of a beam trawl. With the introduction of gallows the two-warp-system came into being. In 1894, Scot of Granton applied for the first patent for the bracketed boards and the following year Neilson patented the chain boards. The otter boards reached Germany through Holland in 1895. During the same year France completed successful

experiments with the doors. In the years that followed otter boards became popular in many countries and eventually replaced the 'beam' on trawls.

The successful introduction of the doors in trawl fishing caused rapid changes in gear and craft. The use of bigger nets to increase the area and depth of exploitation necessitated the introduction of bigger vessels fitted with more powerful engines for prolonged period of operation.

Otter boards are used for other fishing gear as well (Brandt, 1964). In the line fishery they are used as either lateral or downward shearing devices. In the Stow net (Brandt, 1964) of the European rivers a single board is used.

GENERAL PARAMETERS IN THE DESIGN OF OTTER BOARDS.

Size relationship

The matching of the size of the trawl gear to the installed power in the boat is important for the proper functioning of the gear and ensuring maximum efficiency in the operations. This aspect is more significant in small trawlers where relatively high installed power can be justified, if they are effectively utilised for fishing. Basically, the pull, which can be exerted by the trawler, is estimated and the size of the gear matched. On the contrary, if the design of the gear for a particular set of conditions has been optimised on the basis of other considerations, the trawling pull or the required power can be determined. The loading of the engine and the trawling pull are largely dependent on the propeller dimensions and its condition of working. Accurate estimations of these qualities are apparently necessary to ensure optimum size of the trawl gear for maximum utilization of engine power and thus avoid overloading. As there are no authentic calculation methods, the selection of size of gear is

usually based on fitting regression lines with the data collected from existing vessels.

Miyamoto (1958) investigated the size of otter boards used in a number of trawlers operating in India and Japan and suggested the relationship: $S'' = 0.105 P + 4 \dots \dots \dots (1)$, where S'' is the area of the otter board in sq ft and P the horse power of the engine.

Koyama (1962) also worked out a similar relationship after analysing data collected from fourteen trawlers where installed power ranged from 20-2000 H. P. The formula according to him is: $S = 0.095 P^{0.56} \dots \dots \dots (2)$, where S is the area of otter board in sq m and P the horse power of the engine.

Matching the size of the otter board and net is equally important as the doors used should provide the necessary shear force to open the net horizontally. Miyamoto (1958) suggested the following equation to calculate the above relation.

$S' = 415 S'' - 1000 \dots \dots \dots (3)$, where S' is the area of the net represented by the square of the length in feet of the head rope and S'' denotes the area of a pair of doors.

The following equation expresses the relation between size of door and dimension of the trawl used for cod fishing in USSR (Andrev, 1962).

$S = 0.13 / \dots \dots \dots (4)$, where S is the area of the board in sq m and $/$ is the length in metres of the head line of the trawl.

An approximate ratio of 2:1 for length to breadth is commonly used for flat rectangular doors (Miyamoto, 1958). In certain special cases, as noticed in the Gulf of Mexico (Robas, 1958) and in Japan (Miyazaki, 1962) boards of exce-

ptional length are used. Though this type of boards do not help much in opening the mouth of the trawl, it is believed that the board will be much more steady on the ground. Further, the longer length may prevent digging into loose mud.

Weight of the trawl door.

The weight of the board is determined according to the size of the net and horse power of the engine installed in the trawler. Miyamoto (1958) found that the weight of the board is proportional to horse power of the engine and to the cube of expression $\left(\frac{a+b}{2}\right)^3$, where a and b are the length and breadth of the board. The findings can be expressed in the following equations.

upto 100 H. P. $W = 2.7 P \dots (5)$

100 to 660 H.P. $W = 6.5 P - 400 \dots (6)$

upto 4 ft average size of board $W = 3.2$

$\left(\frac{a+b}{2}\right)^3$ More than 4 ft average size of

board $W = 7 \left(\frac{a+b}{2}\right)^3$ where W is the weight of the board in lbs, P the horse power of the engine and $\frac{a+b}{2}$ the size of the door in feet.

Koyama (1962) considers the relation between size and weight is different for large and small trawlers. In the case of a large trawler with an engine power higher than 200 H. P. the relation was found to be

$W = 180 S \dots \dots \dots (7)$

whereas in the small trawlers with engine less than 105 H. P. the relation was

$W = 52 S^{1.73} \dots \dots \dots (8)$

where W is the weight of the board in kg and S is the size of the board.

Materials for boards

Otter doors are generally made of wooden planks or marine plywood with

iron or steel reinforcements (Furk, 1951; O' Grady, 1956; Miyamoto, 1959; Nair, 1960; Kuriyan *et al* 1963).

The thickness of planks and materials used as strengtheners differs according to the size (Miyamoto, 1959; Nair, 1960). Usually 1.90 to 2.54 cm thick planks are used for boards of 76.2 to 127cm in length, 2.54 to 3.81 cm thick planks for boards between 127 and 152 cm in length and 3.81 to 7.62 cm thick planks for 152 to 228 cm in length. Doors made of iron sheets and reinforced with cement are also in use.

The boards made of wooden planks are of less weight than what is required. On the basis of the density of the material, the weight of the wooden part is determined. The size of iron straps, brackets and iron shoes are decided in accordance with reinforcement and additional weight required.

The iron shoe is primarily to protect the board from abrasional wear. The breadth and thickness of the shoe are determined according to the total weight of the board. For soft muddy bottom, broader shoes are advantageous as they prevent ploughing into the mud (Scharfe, 1958 a). The polishing of the shoe on the lower surface is an indication of the performance of the door. On the other hand if the shoe plate develops rust or dirty spots it can be assumed that the doors are not functioning properly and require re-adjustment (Robas, 1958).

Rigging of the trawl door

The setting of the bridle on the otter board is important in deciding its efficiency as a device to open the net, while under tow through water. Each board has a particular attitude at which it will cause maximum spreading effect. As such the magnitude and direction of forces acting on the door are of vital importance in determining the final position of the board on

the bottom and its efficiency as a means of spreading the gear. Usually the settings on the board for the proper functioning of the gear are arrived at by trial and error methods (Haase, 1950; Brett, 1962). The need for changing the settings on the board for deep and shallow waters and keeping a spare pair of boards for different depths and bottoms has been stressed by Brett (1962).

The doors are rigged under three different methods viz; chain bridle, combination of chain and brackets and with collapsible brackets (Robas, 1958; Nair, 1960; Kuriyan *et al*, 1963). Each one of these methods has its own merits and demerits. The chain boards are more difficult to operate as there is a tendency to foul during the operation. However, the rigging facilitates adjustments in settings. The combination of the bracket and chain arrangement is considered more advantageous for altering the settings. The most modern form has been rigged with fixed brackets instead of folding pair type (Scharfe, 1958 a). Very often glass or aluminium floats are attached at the upper edge of such boards so as to keep them upright on the ground particularly when towing is interrupted.

Otter boards with chain bridles

The forward chain, in this method of rigging, is set at a distance of 20% of the total length of the board from the leading edge. The rear chain is set 30% of the total length of the board from the rear of 70% from the leading edge. The perpendicular heights of the fore and rear chains are 25 to 30% and 50% respectively of the total length of the board (Miyamoto, 1959; Nair, 1960). The arrangement is as shown in Fig 3.

Another method is to fix the fore and rear chains at 25% of the total length of the board from the fore and rear ends and

the chains are having perpendicular heights of 25% and 50% respectively, (Miyamoto, 1959; Nair, 1960) as indicated in Fig 4.

In the Gulf of Mexico yet another rigging for the board with chain is followed (Capitra and Rivers, 1960). If L is the total length of the board in inches the front chain is spaced at a distance of $\frac{L}{4} - 1$ from the leading edge of the door.

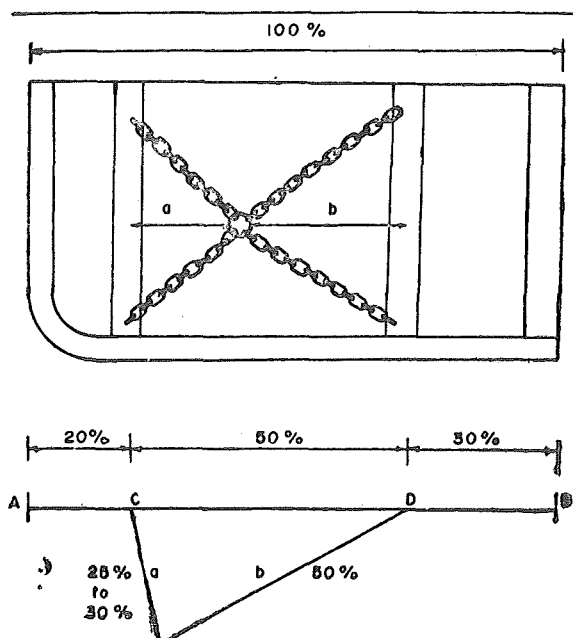


Fig 3

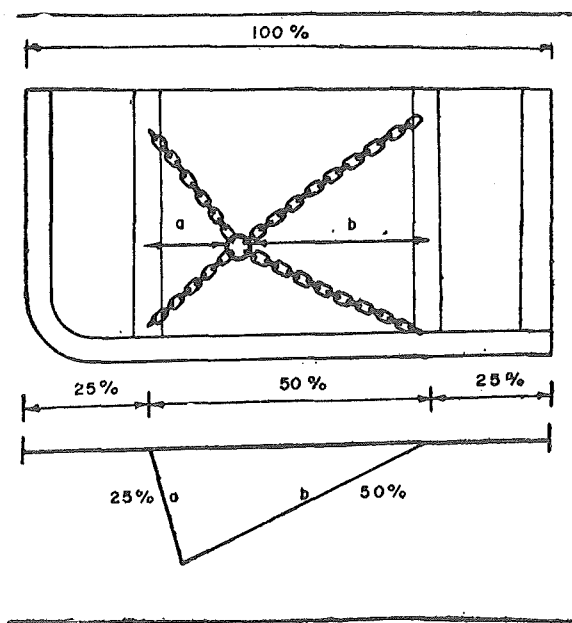


Fig 4

The distance between front and rear chains, $\frac{L}{4} \times 2 \frac{L}{4} + 1$ is the distance from the rear edge of the board at which the rear chain is fixed. In establishing the length of chains it is considered a good practice for the front chains to be about 45 to 50% of the length of the rear chains. Further, the top front chain is set one link longer than its counterpart at the bottom. The top rear chain is set 2 links longer than the bottom rear chain. Both chains are set two inches from the edge of the board. A few extra links are left for adjustments. The details of rigging are given in Fig 5.

Otter boards with collapsible brackets or bracket & chains

The fore bracket is positioned 25% of the length of the board from the leading edge. The rear bracket or chain is placed at 50% of the length of the board from the rear. The fore and rear brackets are having perpendicular heights of 20% and 25% respectively of the length of the board. The method of rigging is illustrated in Fig 6.

Ben-Yami (1959,1963) suggests placing the fore bracket at 18% of the

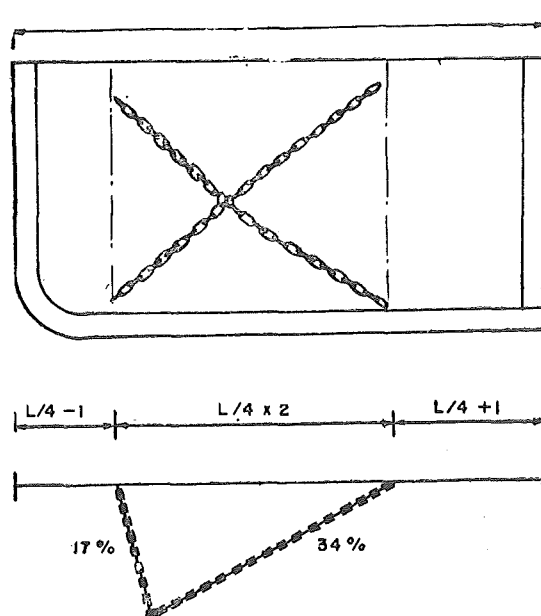


Fig 5

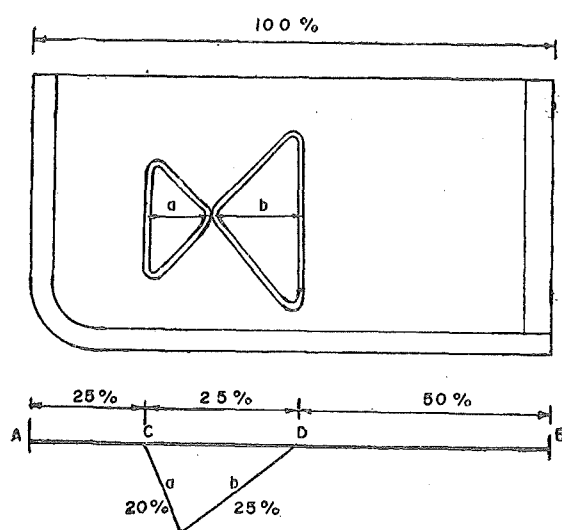


Fig 6

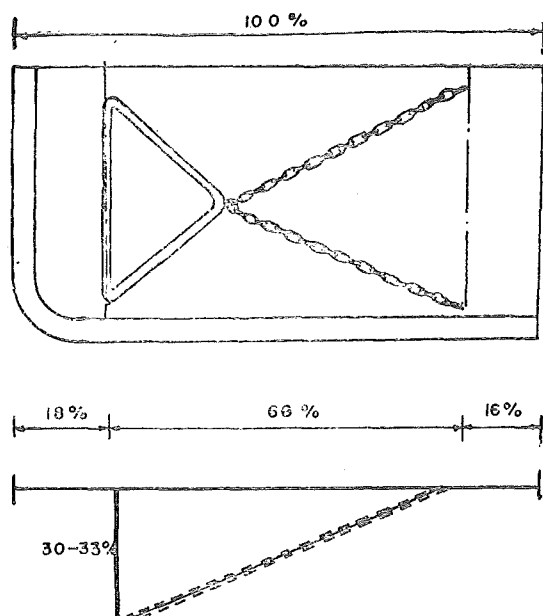


Fig 7

length of the board from the leading edge, the perpendicular height of the fore bracket to be 30 to 33% of the length of the board and the rear chain to be placed 16% of the length of the board from the rear. The positions of the bracket and chain are as indicated in Fig 7.

The length of the chain has to be adjusted for obtaining the most suitable angle by trial and error methods. The position of the fore bracket is to be kept

normal to the plane of the board in the first tow. If the fishing spread obtained is narrow, in the following tows the chain is to be shortened gradually until the required spread is obtained.

Attachment of the net

The trawl net is attached to the board through rings or back stop rings fixed to the aft corners or on the outside face of the boards. If the rings are fixed on the back (outside face), the distance from the rear is about one-third or one-fourth the length of each board (Miyamoto, 1959; Nair, 1960; Kuriyan *et al*, 1963). Ben-Yami (1963) obtained suitable setting of the boards by fixing the back stop ring at a distance of 16% of the length of the board from the rear edge. The leg of the net may be attached either directly or indirectly through sweep lines. The methods of attachment of net to the boards are shown in Figs 8 and 9.

The placing of brackets or chain and attachment of net to the board are important because they decide the direction and magnitude of the shearing forces. In boards used for bottom trawling the brackets are to be arranged in such a way that when they are not in contact with the bottom certain part of the shearing power is directed obliquely downwards. This effect is produced if the point of pull is positioned in the longitudinal central line or slightly below (O'Grady, 1956;

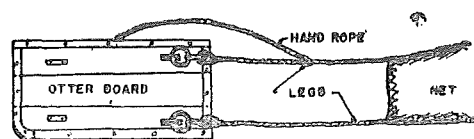


Fig 8

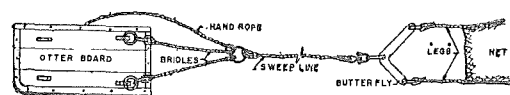


Fig 9

Suberkrub, 1958; Robas, 1958; Capitra and Rivers, 1960). (Fig 2). A properly designed and fabricated board after shooting will have an outward and downward thrust while being towed through water (Robas, 1958). On reaching the bottom the board will plough through. The board has an unsteady and meandering course while under tow (Hamuro 1962). The intermittent turbulence which sets up and detaches itself causes the board to move unsteadily. Due to this, there is variation in horizontal spread and resistance (Hamuro, 1962). By direct observation and motion picture it was observed that doors cause great disturbance and throw mud (Anon, 1951). The disturbance caused in the water and on the sea bed drives fish into the net (Baranov, 1958).

Attitude of the trawl door

While the trawl gear is under tow, the fishing spread and stability of the board depend upon the characteristics of the board. The angle of attack or incidence, which the board assumes during operation, is defined as the angle between the plane of the board and the direction of flow of water. Trawl boards are not always moving with the sole plate having even contact with the sea bed. This is due to the angle of heel (lateral inclination) and tilt (positive or negative, nose up or down, or fore or aft). Besides, otter boards may roll and pitch. Fig 10 illustrates the attitude the board assumes and its direction of unsteady motions.

The above mentioned factors also affect the horizontal spread of the trawl. The spreading action and resistance offered by the board can be changed by altering the angle of attack, heel and tilt. The angle of attack can be adjusted by changing the angle of inclination of the fore and rear brackets or the position of attachment of the net to the trawl door (Ben-Yami, 1963; Catasta, 1958). The heel is altered

by changing the position of the point of pull (Suberkrub, 1958). The tilt can be adjusted by altering the length of the legs of the net or changing the position of back stop rings (Ben-Yami, 1963).

The angle of attack, heel and tilt can be determined by using special underwater recording instruments (de Boer, 1958). Telemetering type indicating instruments for angle of attack (Sivadas, 1969a), heel (Sivadas, 1969b) and tilt (Sivadas, 1968) working on different principles have been developed. Also it can be ascertained by observing the traces caused on the shoe plate by the friction with the sea bed (Scharfe, 1958b). A graphical method for computing the angle of attack is suggested and described by Servostinov (1955). The effect of angle of attack, tilt and heel on fishing spread is described under related headings.

Horizontal spread

The lateral opening of the trawl depends on the type of gear used, nature of bottom, length of warp released during operation and towing speed and more particularly on the type of board and the attitude the door assumes during fishing. It is also noticed that each net and board combination has its own diverging effect. The approximate horizontal opening between the boards can be determined by

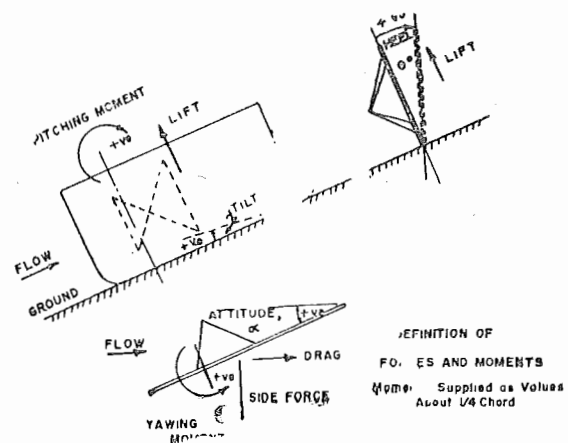


Fig 10

the procedure given by Ben-Yami (1958) and the formula suggested by Deshpande (1960). Another method for determining the angle of attack is described by Wathne (1959). De Boer (1958) used recording type instrument for measuring the spread. An underwater sophisticated electronic instrument for measuring the spread has been described by Nicholls (1964).

Warp depth relationship

The fishing spread of the gear and behaviour of the trawl board depend on the length of the warp released for that depth. John Johnston (1950) prepared a graph to assist the fishermen engaged in trawling to choose the amount of warp required for any depth upto 183 meters. Miyamoto (1958) proposed the following formula.

$$F = (3 + 25/D) D \dots\dots\dots (9)$$

where F is the length of warp to be released in fms, and D the depth of operation of the gear in fms.

While trawling in deep water a scope ratio of 3:1 is generally used. For shallow waters the scope ratio of 3:1 is not adequate and the need for greater scope ratio is suggested by many authors (quoted by Wathne, 1959). De Boer (1958) using various scope ratios in constant depth demonstrated a progressive increase of spread with scope ratio varying from 3.1:1 to 8.1:1. Similar increase in spread with increase in scope ratio was observed by Satyanarayana and Mukundan (1963). Further increase of warp beyond optimum tends to decrease the spread (Satyanarayana and Nair, 1962; Nair *et al.* 1966). The maximum opening also depends on the size of each net and door combination. Bigger net requires a higher scope ratio for optimum fishing spread at a particular depth (Satyanarayana and Nair, 1962).

As the length of warp paid out assumes significance in spreading the gear, Wathne (1959) has discussed in detail, the configuration of the towing warp, direction of pull and its effect on door. During trawling when depth is increased and cable length to water depth ratio and speed are constant, the only factor affected by the operation is the weight of warp. The configuration of the warp changes as shown in Fig 11.

The direction of pull on the door changes from upward to a horizontal direction.

The configuration of warp projected to a horizontal plane in various water depths using a constant scope ratio is shown in Fig 12.

The direction of pull on the door by the towing warp in shallow water is apparently outward and it changes progressively inwards towards the midline as the depth increases. Wathne (1959) states the effect

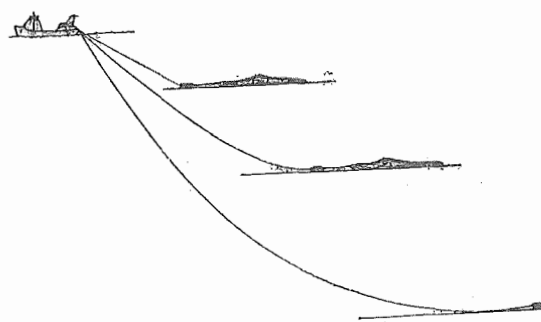


Fig 11

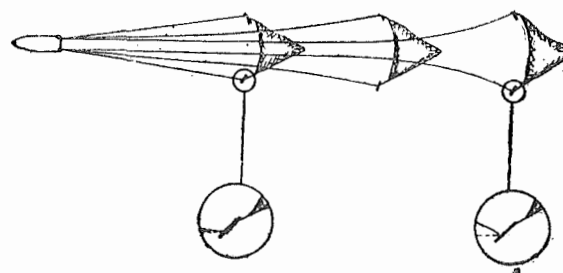


Fig 12

produced by the various directions of pull on the board is indicated by the work of de Boer (1958). The longitudinal tilt of the board, as recorded by his instruments is from forward to aft as the scope ratio increases in constant depth. The heel of the door changes from positive to negative and the angle of attack, from larger to smaller. Fig 13 illustrates the above effect.

As a result of these factors the door spread will vary with water depth and towing speed. The warp pulls the door upwards if small scope ratio is used in shallow water, resulting (because of its construction, direction and magnitude of forces acting on it) in a positive heel and forward tilt for the door. The angle of attack becomes large as the lateral pull is minimum. Due to the forward tilt the contact with the bottom and the shearing force produced are less, resulting in reduced spread. In deep water, using the same scope ratio, the warp pull is apparently forward resulting in minimum tilt and heel, smaller angle of attack and better contact with the bottom. So the shearing effect is more, even though the angle of attack is small, the spread is greater. de Boer found that with a greater increase in scope ratio (analogous to a further increase in depth using the same scope ratio) the

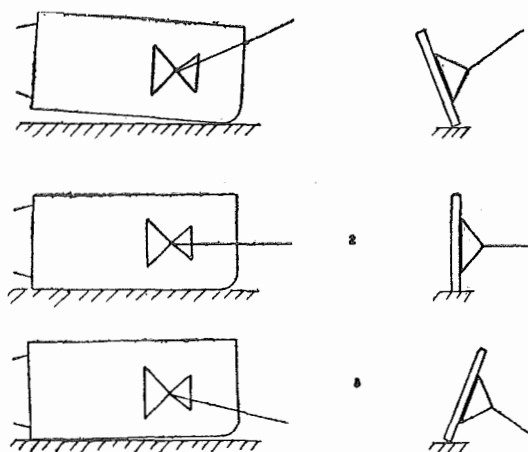


Fig 13

doors slightly tilt aft (0.5°) and heels inward. The angle of attack is decreased further. However, the resulting spread increases. Probably, this is due to the downward pull of the warp (in a vertical plane) since it is on or near bottom ahead of the door and tend to force the door towards the bottom. Although slightly tilted the board has better contact with bottom than in the previous case. Therefore, the shear force is more resulting in greater spread (Wathne 1959). Ben-Yami (1963) is of the opinion that the greater spread is not due to the warp pulling the door down, but is more probably due to the more favourable direction of pull in the horizontal plane.

Door spread and speed

The fishing spread increases as the speed increases. When the towing speed exceeds a certain value the opening between the doors decreases (Matrosov, 1958a; 1958b; Satyanarayana and Nair, 1962; Ben-Yami, 1963; Satyanarayana and Mukundan, 1963). Wathne (1959) observed that in deep water this trend is not so apparent.

The change in towing speed alters the configuration or shape of the cable and its effect on the door spread is discussed by Wathne (1959). On increasing the speed, the hydrodynamic lift of the warp is increased. The warp is therefore, pulled away from the horizontal and the door is pulled upward resulting in reduced spread. In shallow water, this effect is more pronounced, particularly when a small scope ratio is used, as the warp is initially pulling the board upwards. As the speed increases, the upward pull on door increases and reduces its contact with bottom and consequently spread decreases. Using the same scope ratio in deep water, an increase in speed changes the shape of warp. The effect of pull on the door, however, is less and significant changes are not produced

in the position of doors. It seems that the upward pull at the door is due rather to the straightening out of the warp with increased resistance of the gear than to the much less significant hydrodynamic lift of the cable (Nashol, 1960 cited by Ben-Yami, 1963). The lifting of the warp with higher speeds is to be balanced by increasing the scope ratio and this is a rule of thumb practice in trawling (Ben-Yami, 1963; Crewe, 1963).

Door spread as related to catch

Information on the effect of catch on spread between boards is scanty. Effect, if any, of the catch on the door spread may be masked by the inter-drag differences. Wathne (1959) observed a trend of decreasing spread as the dragging time progressed. This can be attributed to the increase of catch in the cod-end.

Forces acting on the board

The underwater behaviour of board is influenced by the following forces.

- 1) Pull of the warp,
- 2) Force of water,
- 3) Weight of the door,
- 4) Pull of the net exerted through the bridles and
- 5) The frictional forces arising due to contact with sea bed (Brett, 1962).

The direction and magnitude of these forces acting on the board depend upon the shape and attitude of the board, towing speed, density of the media and finally the nature of the ground. Recognising the significance of these forces in spreading the gear various workers have endeavoured to estimate or measure them in order to improve the efficacy of the trawl door. These tests are either done in full scale or in model.

The combined action of the various forces complicates a critical analysis of the performance of the door. In essence, its behaviour is like that of small aspect ratio aerofoil, but the angle of attack at

which the door operates is considerably greater and cover a greater range of angles of heel than is usual for the aerofoil (Crewe, 1963). Besides board is having tilt (Crewe, 1963). The aspect ratio of a rectangular board is

$$\lambda = 1/b \dots\dots\dots (10),$$

while in case of a board of non-rectangular form:

$$\lambda = 1^2 / F \dots\dots\dots (11),$$

where λ is the aspect ratio, 1 , the length of the board in a direction perpendicular to the flow, b the breadth of the door co-linear with the direction of flow and F area of the board.

The aerofoil type of forces acting on the board are shown in Fig 14.

The total water force acting on the board is resolved into two components, the lift or shear perpendicular to the direction of the flow and the other, drag parallel to that direction but opposing the motion. The lift is many times greater than the drag. The ratio lift/drag which is a criterion of the quality of the board, depends not only on the angle of attack α but to a great extent also on the aspect ratio.

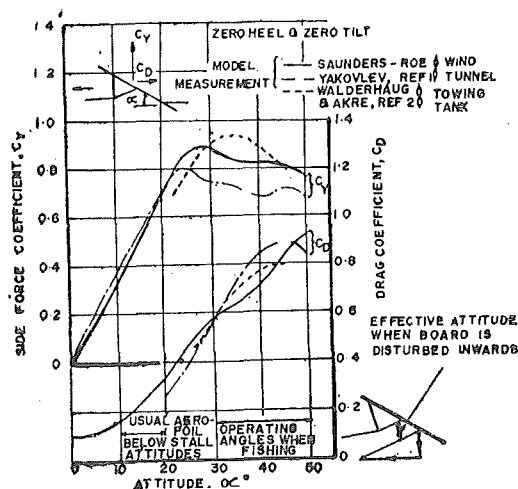


Fig 14

The hydrodynamic shear force of an otter board is defined by the formula (Yakovliev, 1955):

$$R_y = \frac{C_y \rho V^2}{2} F \dots \dots \dots (12)$$

Quite analogous to this, it is possible to define the drag also namely,

$$R_d = \frac{C_d \rho V^2}{2} F \dots \dots \dots (13)$$

where C_y and C_d are shear and drag co-efficients, ρ the density of the media, V the towing speed and F the area of the board.

The forces are determined from measurement of a model in a hydrodynamic testing tank. Valid results for bottom trawls can be obtained if tests are conducted with plates kept on the bottom simulating screen, while for midwater trawls plates have to be kept in free stream (Yakovliev, 1955). When presenting these figures, the co-efficients have been used instead of giving forces in lb and kg (Crewe, 1963).

Similar definitions can be used to find out the upward vertical force, tangential force and resultant force (Crewe, 1963). The co-efficient of vertical force is near enough to zero at zero heel. The co-efficients are, further near enough independent of speed and size (not proportions) of the board (Crewe, 1963). But Yakovliev (1955) states that the aspect ratio has no practical effect on the quality C_y/C_d of rectangular plates at angles of attack exceeding 20° . In practice the drag co-efficient C_d shows more tendency to vary with size and speed than do the co-efficients of shear and vertical force, but the first order constancy can still be maintained (Crew. 1963).

The lift and drag determine the magnitude and direction of the resultant force, but will not specify its point of application. The distance d from the centre of the plate

to the point through which the total force acts is given by Kawakami (1958):

$$\frac{d}{c} = \frac{3}{4} \cos \alpha + \pi \text{ Sine } \alpha \dots (14)$$

where c is the length of the plate and α the angle of attack. Gawn's curves for centre of pressure are reproduced in Fig 15.

As the board is moving in contact with the bottom due to friction, the effective centre of pressure is further aft than indicated in the Fig 15 (Dickson, 1958). The centre of pressure at which the resultant hydrodynamic force acts as determined by various workers is reproduced in Fig 16.

Lift and drag

Experiments to determine the lift and drag of otter boards of various shapes and types have been attempted. Gawn (quoted

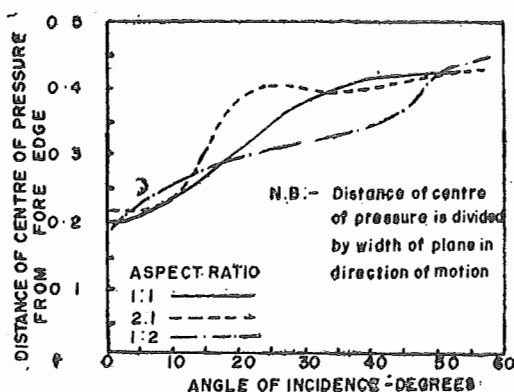


Fig 15

RECTANGULAR FLAT OTTER BOARDS OF ASPECT RATIO 1/2 WITH GROUND EFFECT FROM MODEL BOARD TESTS AT ZERO HEEL

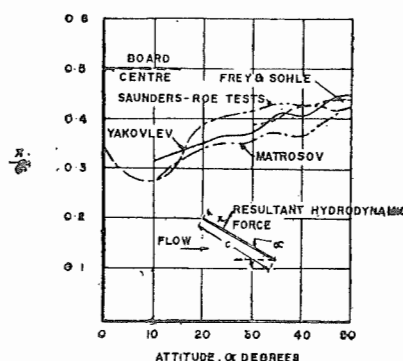


Fig 16

by Dickson, 1958) conducted experiments with flat otter boards of low aspect ratio. These boards (1/2 the scale) were towed at speeds upto 5 knots without apparently much change in the lift and drag co-efficients. These data cover the model range upto one quarter scale. Gawn's curves are reproduced in Fig 17.

Matrosov (1958b) conducted extensive tests with oval and flat rectangular otter boards. Yakovliev (1955) conducted tests in an aerodynamic tube with plates of various shapes and aspect ratios and model of a rectangular otter board with an aspect ratio of 0.5. The effect of thickness of the plates on force co-efficients is also studied. Servostinov (1955) tested model of an oval board. Model tests with trawl doors were conducted by Waldenhaus and Akre and by Frey and Sohle (quoted by Crewe, 1963). Crewe (1963) has determined the aerofoil type of force of models, a ground being placed adjacent to the model (Fig 14). The effect of heel and tilt on force co-efficients has also been investigated. Dale and Moller (1963) report the results of tests with a series of models with and without bottom simulating screens (Figs 18 and 19).

The effect of stream lining, Reynolds number variations and fittings of door, on force co-efficients were also studied.

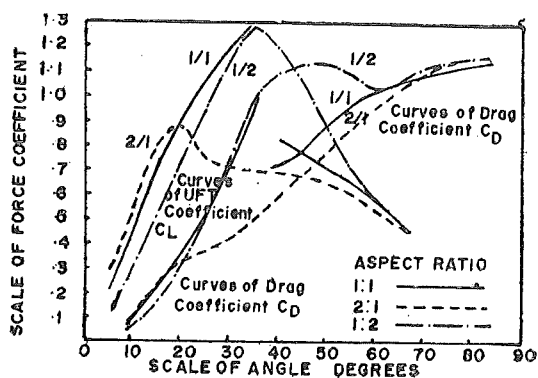


Fig 17

Ground reaction forces

The otter boards of a bottom trawl are dragged in contact with the sea bed. Due to this ground reaction forces arise and act on the board. This system of forces inter-act with that of the hydrodynamic forces. Attempts were made either to estimate or determine this system of forces. The resistance due to ground friction in the total drag varies between 20 to 25% (Ben-Yami, 1963). The ground shear force is estimated to be 25% (Dickson, 1963) or 50% of the weight of the door in water (Crewe, 1963). The vertical component can be about 30% of the weight of the board in water. Fig 20 shows the direction and magnitude of the ground reaction forces (Crewe, 1963).

As such a considerable amount of spreading forces arise from ground re-

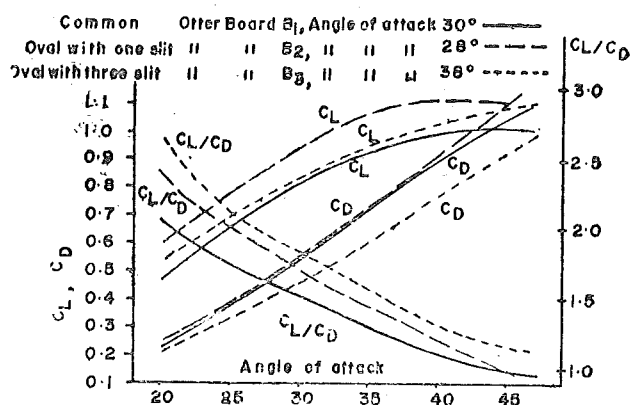


Fig 18

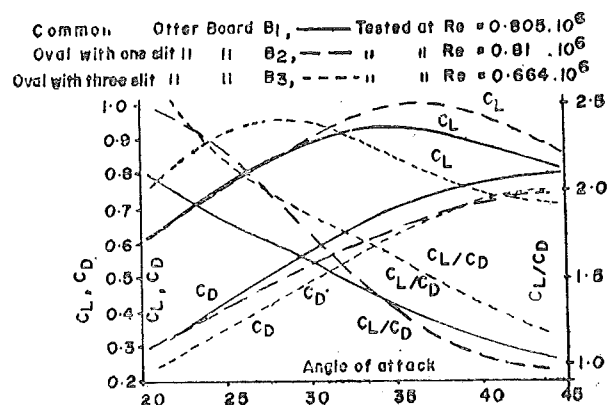


Fig 19

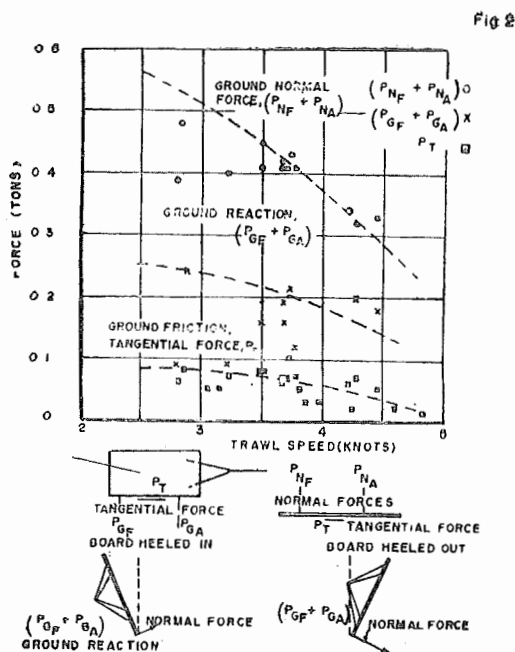


Fig 20

action and are more significant on muddy bottom than on hard bottom. If the door is made rather heavy in water to increase the ground reaction, it can sink into the mud. This may tend to offset the gain in ground shear by a loss in hydrodynamic force. When designing boards to obtain ground shearing effect, careful attention must be paid to the type of ground on which the board is intended to be used (Crewe, 1963, Dickson, 1963).

Angle of attack

The angle of attack the otter board assumes while being towed is one among the factors which determine the spread of the gear. The choice of the most suitable angle is essential for efficiency and economy in trawling. By proper rigging of the door suitable angle of attack can be obtained. The effect of angle of attack on force co-efficients can be observed from Figs 14, 17, 18 and 19. Yakovliev (1955) obtained maximum shear for an otter board at 26° . At wider angles the shear decreased with an additional peak at 45° . Crewe (1963) obtained maximum shear at 30° . Blestikina (1962) and Dale and

Moller (1963) report the effect of variation of angle of attack on force co-efficients.

They observed that maximum shear for doors tested with bottom simulating screen was reached at a smaller angle than for the tests conducted in free stream. In free stream tests stalling is delayed by three dimensional effect (Dale and Moller, 1963).

Angle of attack ranging from $30-39^\circ$ is advised as suitable for trawling with flat rectangular boards or described as being used in common practice (Ben-Yami, 1963). The angle of attack between $20-45^\circ$ has been considered as of practical importance. However, the lift/drag ratio, will have maximum at angle of attack at less than 20° (Dale and Moller, 1963) (Figs 18 and 19).

The magnitude of the shear and drag forces of a door can be calculated from the data available for the force co-efficients. It has been demonstrated that by appropriate selection of angle of attack, considerable decrease in drag and increase in shear could be obtained, resulting in economy in performance (Fisheries Division, FAO, 1959). Model experiments have been conducted by Takayama and Koyama (1958), to determine the angle of inclination of the brackets with the plane of the board and its relation with the angle of attack. Haase (1950) gives experimental data on suitable adjustments of angle of attack and stressed the need for different adjustments while trawling for different fishes at different speeds. Kawakami in his analytical treatment of a rectangular strip of webbing has shown the variation of the spreading action by the board according to the adjustment of the brackets and the optimum spread can be obtained theoretically (quoted by Kawakami, 1958).

de Boer (1958) using the angle of attack meter observed that the angle of attack decreases while lengthening the warp. This may explain the observation of Wathne (1959) that the spread of the gear did not decrease with higher speeds while trawling in deep water. It seems that in greater depths the resulting angle did not exceed the critical value and the former spread could be maintained or even increased (Ben-Yami, 1963).

Ben-Yami (1963) offers a reasonable explanation for increase of angle of attack at increased speed. The resistance of the net increases at a rate less than the second power of speed, while the values of the hydrodynamic forces acting on the board are directly proportional to the second power of the speed. Since the point of application of these forces is situated ahead of the centre of pull, the gain in speed disturbs the rotational equilibrium of the board in the horizontal plane, due to the dominating increase of the hydrodynamic pressure which presses the front end of the board to turn outwards and thus increases the angle of attack. In practice this cannot be detected, either due to insufficient data or due to the variation in frictional resistance of the door at different speeds. The effect of filling the cod end on the resistance of the gear and on the angle of attack is discussed by de Boer (1958) and Ben-Yami (1963). Further experiments are, however, necessary to state conclusively the effect of the catch on the angle of attack and the resulting spread.

Tilt of otter board

The directions of tilt of board can be noticed from Figs 10 & 13. The effect of tilt of the board on the hydrodynamic properties were investigated by Crewe (1963) and his curves are reproduced in Fig 21 from which it can be seen that a small amount of tilt, does not greatly

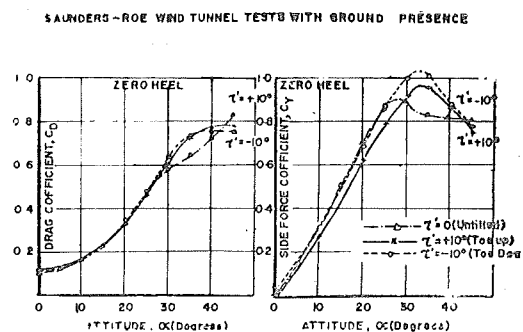


Fig 21

influence the force efficacy if the sole plate be kept at 5° or less to the horizontal.

As might be expected from theoretical considerations the effective aspect ratio of an aerofoil adjacent to a ground, nose-up tilt reduces side forces more than nose down tilt. However, the latter can lead to digging in. de Boer (1958) in his experiments observed that by lengthening the warps the otter board tilts from forward to aft (Fig. 13).

A common method for adjusting the tilt of the board is by adjusting the length of the upper and lower legs or altering the position of the rings on the back side of the otter board. In Mediterranean boards by shortening the upper back strops than the lower one, the nose up trim is obtained (Ben-Yami, 1963). By this only the aft corner of the board is in effective contact with bottom. It is believed that best shear force is obtained by such rigging.

Heel

The heel of otter board is as indicated in Figs 10 & 13. According to the inward or outward heel additional hydrodynamic forces arise such as lifting or depressing force. The direction of these forces is indicated in Fig 10. The results of experiments conducted by Crewe (1963) to find out the effect of heel on force co-efficients are reproduced in Fig 22.

From the curves it will be seen that

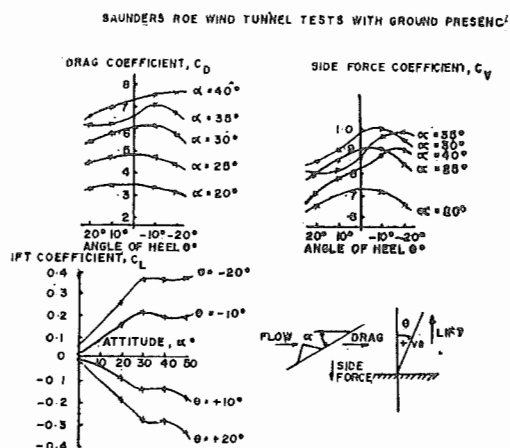


Fig 22

maximum side force obtained was when the plate was kept heeled inwards (negative heel with brackets towards the sea bed). A heel of above 10° is appropriate to a practical angle of attack in 30° – 40° range. In negative angle of heel maximum side force is associated with larger drag than occurs at the positive angle of heel. But for overall efficiency the warp is to be long enough to allow the board a negative heel (Crewe, 1963). The lengthening of warp changes the heel from outward to inward (de Boer, 1958). The heeling in does not increase the contact of the board with the bottom. The force of water acts perpendicular to the surface of board so that while lengthening the towing warp the upward pull of the warp is reduced and heeling in gives a compensatory increase in vertical hydrodynamic force (Crewe, 1963).

In full scale tests a large change in heel is observed with a change of speed. A change of speed of one knot requires a 15% change in warp length in order to keep the given heel (Crewe, 1963; Dickson, 1963). This is a normal practice in trawling.

The heel of otter boards can be adjusted by changing the position of attachment of brackets (Ben-Yami, 1963; Suberkrub, 1958). In otter boards used

in bottom trawling the brackets are either placed on the central line of the board or slightly below. In this case the shearing force is partly directed downward and the board will have an outward heel. If the bracket is placed high above central line the board will heel inward and gain a vertical component. This is of practical importance in mid-water trawling, as the speed increases, the board and net gain height.

It is also noted that while adjusting the tilt by shortening the upper legs in addition to giving the board an aft tilt, it may also cause an outward heel. This is to be balanced by lifting the centre of brackets towards the upper side of board (Ben-Yami, 1963).

Different types of otter boards

Conventional otter boards are simple in design and easy to construct. Hence they are comparatively cheap. This is an important factor considering the chances of losing the gear due to underwater obstacles. However, it is well known that flat rectangular doors are not the best because these boards offer a high resistance and the side force provided is not satisfactory. It is the gear which brings the yield and to further economy in performance, all the available power for towing the trawl has to be used. Hence construction of efficient doors has been considered necessary and attempts were either made to improve the efficiency of flat otter boards or to use altogether different profiles. As a result many new designs of trawl doors have emerged and each claimed by the designer as the most effective device and avoided many undesirable qualities of the ordinary form.

An improved design of flat board reported, is cheaper, easier to construct and adjust to the varying conditions of fishing. It will not fall flat when towing

is interrupted (Wibster, 1959). The effect of falling flat is further studied and modifications suggested by Catasta (1958). Considering the effect of aspect ratio on force co-efficients, a rectangular board, which has a height larger than the base would be more efficient in spreading the gear, because a remarkable increase of shear is expected from towing such boards. With this in view (Tokayama and Koyama, 1961) conducted experiments with vertical boards and found this type of board presents large shearing force than the conventional board and the stability in operation, was quite satisfactory. He recommended this for commercial operation. Board having height to length ratio of 1:1.12 has been tried and found effective (Hamuro, 1963).

In U. S. S. R., extensive tests were carried out on flat plates of various shapes and aspect ratios. The highest values for shear was provided by elliptic plates with an aspect ratio of 0.6 (Yakovliev, 1955). Servostinov (1955) conducted experiments with oval slitted boards. Matrosov (1958b) reports his extensive work on oval slotted boards. The oval door has a window in its centre with 2 or 3 hydrofoil fins placed at an angle of 25–30° to the chord of the door. Tests showed that these doors gave a high shear/drag ratio over a wide range of angle of attack. The position of the centre of hydrodynamic pressure at these angles of attack which assumes the best shear is almost constant and the board gives a constant spread under diverse conditions of trawling. The range of optimal angle of attack of this board is 30°–40°. Dale and Moller (1963) report the results of their tests with different types of oval slotted boards. Round cornered boards were used by Ben-Yami (1963) and found more efficient. Comparative fishing experiments conducted with oval and flat boards showed the spread produced was more or less same. The

resistance produced by the oval door is comparatively small and is explained that the area of the board is 20% less comparatively and due to the smaller area of contact with sea bed (Fisheries Division, FAO, 1959). A rectangular board of the same area can provide the same amount of shear force as the oval. So this fact alone counter balances the greater force provided by the oval board (Crewe, 1963). The increased force efficiency of the oval board arises from its forward surface being at a smaller angle to the direction of motion than in the case of a flat door, thus allowing the water to flow around it more smoothly. This effect is more pronounced at 30° at which these boards behave best (Crewe, 1963). Crewe (1963) states that neither his tests nor other tests with oval boards which have been published show such a large advantage and he settles on cambered boards. A considerable increase in side force can be obtained by giving the board a curvature (Matrosov, 1958b; Crewe, 1963). Conventional flat rectangular, horizontal curved and oval single slitted boards were tested under identical fishing conditions (Mukundan *et al*, 1967). Results indicate that the horizontal curved board gave increased lateral spread to the net. The oval board, in general, gave less resistance, while the curved offered more and the flat one coming in between. Statistical analysis of the data indicated that the variation in tension is not significant. The catch landed by the net rigged with this curved board was more than the other two (Narayanappa, 1968).

Catasta (1958) conducted experiments with three types of boards viz: (i) flat rectangular, (ii) designed in a style of an aeroplane wing with flat and convex surface and (iii) similar to the second but with concave shearing surface. The two new doors offered small resistance due to the hydrodynamic shape. The third one gave the least resistance. However, the

shearing power was less probably due to the concave shearing surface which made the door less efficient.

A pair of hydrofoil otter board of Italian design was tested. This board provided better spread compared with that of the common door particularly at the same resistance. However, these trials were preliminary and indicated the need for further study (FAO, 1959).

Suberkrub otter boards are towed in vertical position and they have the profile of an aerofoil. They are towed at considerably less angle of attack and due to this, friction with sea bed is less. The resistance, offered was found to be very much lower than the flat board. Handling during shooting and towing posed no difficulties (Scharfe, 1958b, Suberkrub, 1958).

An indigenous design of board, the 'V' section, was reported from Formosa (Anon, 1961). The main towing cable is fastened to the board at two points instead of at four points, as in flat doors. Adjustment of towing centre is simple. The door spreads the wings better and can easily ride over obstacles and mud. As the boards are reversible, there is need for keeping one spare board in case of damage.

CONCLUSION

The design and construction of otter boards are important aspects that call for special attention for successful operation of the trawl net. Though the discovery of the board dates back to the year 1885 and the basic form and shape have undergone significant changes, many aspects of design, construction and performance have not been fully evaluated. The present improvement of the otter door has been achieved mostly by trial and error, to suit the local fishing conditions. There is a growing need to improve the efficiency of otter board by making use of engineering principles,

by using recently developed instruments and by modern methods of gear technology. It might be possible to improve the efficiency of the board in the coming years, if research facilities and investigations are there to fill the gap in the existing knowledge.

By improving the efficiency of the board, it is meant greater horizontal opening of the net or reducing the resistance offered by the door. By increasing the shearing force of the board the horizontal opening of the net can be increased resulting in the greater efficiency for trawling. By reducing the resistance of the board, fuel consumption is cut down or towing speed can be increased or a bigger net can be operated. Higher efficiency in the performance of the door can be obtained in two ways, either by improving the flat rectangular board or by using new ranges of hydrofoil profiles. In order to improve the efficiency of flat rectangular boards for bottom trawling, the following aspects have to be investigated in detail.

- i) For the most efficient combination, suitable relation has to be arrived at among the horse power of the engine, the size of net and size of otter board.
- ii) Height/length ratio is an important factor deciding the horizontal spread and this aspect needs investigation with special reference to ground reaction.
- iii) The weight of the board is determined by empirical method. The ground shear forces increase with the weight of the otter board. But, if excessive weight is added, the board dives into the mud and ground shear forces come down. So the optimum relation between the size and weight of the board has to be worked out.

- iv) To extract the greatest fishing power from the net, the most suitable angle of attack under diverse conditions is to be found by way of adjusting the position of brackets.
- v) The effect of tilt and heel on the hydrodynamic forces and ground reaction forces has to be investigated in detail.

The underwater current affects the normal functioning of the gear system especially the boards and this aspect needs experimentation. These studies can either be carried out in model or full scale. Recommendations to the industry are to be based on the practical experience gained on the improved efficiency by conducting commercial fishing.

SUMMARY

The design and construction of the otter board is a subject of great importance for economy in trawling. This review incorporates a historical resume tracing the change and development of otter boards. The size of the otter board and its relationship with the horse power of the engine and size of the net and the methods of rigging are dealt with. The factors influencing the horizontal spread are discussed. The effect of the angles of attack, heel and tilt and the ground reaction on the force co-efficients have been reviewed and discussed with particular reference to flat rectangular otter boards used for bottom trawling. A short account of other designs of otter boards used for improved efficiency is given. Suggestion for improving the efficacy of otter boards based on the work hitherto done has been made. The contributions relating to the various aspects of design and performance of trawl boards carried out till 1969 have been considered.

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