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Effect of Ground Touching on the Drag and Spreading Power of the Otterboard during a Bottom Trawling Operation

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Key words: Spread force; drag force; ground spread; ground drag and friction.

ABSTRAK

Penundaan pada lima kelajuan berlainan dijalankan untuk menganggarkan daya-membuka-dasar dan daya-rintangan-dasar serta geseran. Daya-rintangan-dasar serta geseran bertambah dengan halaju pada kadar pertambahan yang hampir sama dengan pertambahan pada daya-rintangan papan tunda itu sendiri. Daya-membuka-dasar hanya penting pada halaju yang rendah. Apabila halaju bertambah daya-membuka-dasar akan mengurang perlahan-lahan. Daya-membuka-dasar hanya berfaedah sebelum halaju mencapai 1.41 mls. Selepas halaju ini, daya-rintangan-dasar serta geseran menjadi tinggi, dan menghapuskan segala faedah membuka yang dihasilkan oleh daya-membuka-dasar. Daripada percubaan ini juga, boleh dibuat kesimpulan bahawa papan tunda jenis mendatar yang mempunyai "titik sentuh" yang kecil (kadar tegap yang rendah), adalah yang paling sesuai untuk operasi penundaan dasar.

ABSTRACT

Trawling at five different speeds was carried out to estimate the ground spread and the ground drag and friction. The ground drag and friction increases with towing speed at almost the same rate as the actual drag force of the otterboard. The ground spread is only significant at low speeds. When speed increases, the ground spread gradually decreases. The ground spread can be used to advantage only before the speed reaches around 1.41 m/s, afterwhich the ground drag and friction will become higher and thus nulify all the spreading advantages provided by the ground spread. From this experiment, it may also be deduced that a flat type otterboard with a small "point of contact" (high aspect ratio) is the most suitable otterboard for bottom trawling operations.

INTRODUCTION

Although the importance of trawling has been declining in the past few years, it is still the most important fishing gear in Malaysia. In 1982, 40% of the total catch in Peninsular Malaysia was landed by trawls (Annual Fisheries Statistics, 1982). For all kinds of trawling operations, conventional flat type otterboards with an aspect ratio of 1:2 are used. Only bottom trawlings are carried out in Malaysia.

In trawling, the otterboard is used as a spreading device and is supposed to open the netmouth horizontally by utilizing the hydraulic resistance against the flow of water (Fridman, 1969). Vertical opening of the netmouth can be easily attained by varying the weight of footrope and the buoyancy force of the floats along the headrope.

In a bottom trawling operation, the proximity of the seabed alters the effective aspect ratio of the otterboard and causes 'ground shear' forces to develop due to seabed material piling up against the lower face of the otterboard and sliding along it, or due to the otterboard catching on the bottom and proceeding in a jerky fashion (Hamuro, 1963; Crewe, 1964;). This touching between the ground and the otterboard produces ground spread and, ground drag and friction. These forces directly affect the sheering and drag forces of the otterboard (Nomura and Yamazaki, 1975).

It has been known for some time that the touching between the otterboard and the seabottom during trawling operation produces these ground shear forces but what has never been noted is the extent to which they affect the overall performance of the otterboard. These ground shear forces directly affect the estimated spreading power of the otterboard. The effect varies with the nature of seabottom and seems to be more significant on muddy bottoms than on hard bottoms (Crewe, 1964; Kowalski and Gianotti, 1974).

The objective of this paper is to investigate how ground spread, and ground drag and friction affect the drag and spreading power of the otter board during trawling operations.

Basic Hypotheses and Assumptions

The otterboard spreads the netmouth horizontally by utilizing the hydrodynamic resistance against the flow of water. In the act, it produces two components of forces namely lift and drag forces. The lift force spreads the netmouth horizontally while the drag force contributes to the total resistance of the gear (Koyama, 1974; Imai and Oyama, 1975). The preferable function of otterboard is thus to have a big liftforce and a small drag force.

In bottom trawling operations, the touching between the ground and the otterboard produces ground spread and, ground drag and friction. These forces affect the sheering and drag forces of the otterboard *(Figs.1 and 2)* (Nomura and Yamazaki, 1975).

In motion, the various forces that act on the otterboard help balance it dynamically. The quantities of these forces change with the change in the angle of attack of the otterboard (Koyama, 1975).

In practical operations, otterboards are used under the condition where their developing force is kept at its maximum by means of adjusting the bracket angles (Koyama, 1971 and 1975). In this experiment, the riggings of the otterboards were done such that the otterboards would move at the desired angle of attack of 21°. And for the purpose of validation of the experiment, it is assumed that the otterboards are moving at an angle of attack of 21°.

Under normal fishing conditions, a full-scale otterboard does not significantly change its angle of attack when only the towing speed is changed. This means that the sheer and drag coefficients will be constant with speed (Crewe, 1964; Nomura and Yamazaki, 1975). In this experiment, only the change in the vessel's speed was controlled. However, in the final calculations, the otterboard speed relative to the seabottom, as recorded by the tidal current recording machine available on the ship, was used.

During trawling, the otterboards are also tilted in the transverse and vertical directions but experimental measurements show that the hydrodynamic drag coefficient and spread coefficient are not significantly affected by these angles (Crewe, 1964).

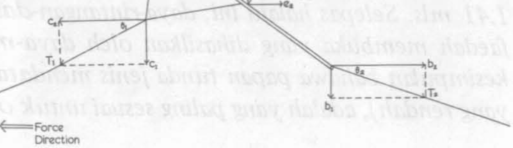

Fig. 1: Otterboard forces when in motion (Nomura and Yamazaki, 1975)

Abbreviation:

T_1 : Tension in the towing warp
c_1 : Warp in-pull force
c_2 : Towing force

T_2 : Tension in the handrope
b_1 : Handrope in-pull force
b_2 : Net resistance

r : Total hydrodynamic forces acting on the
r_1 : Spread force
r_2 : Drag force

e : Ground sheer
e_1 : Ground spread
e_2 : Ground drag and friction

$b_2 : T_2 \cos \theta_2$
$b_1 : T_2 \sin \theta_2$

The equilibirium of these forces is represented by:

$$c_2 = b_2 + r_2 + e_2$$
$$c_1 + b_1 = r_1 + e_1$$

Where,

$$c_2 = T_1 \cos\theta_2$$
$$c_1 = T_1 \sin\theta_1$$
$$b_2 = T_2 \cos\theta_2$$
$$b_1 = T_2 \sin\theta_2$$

Considering the role of the otterboard in a total system of a trawling operation, it may be presented as follows:

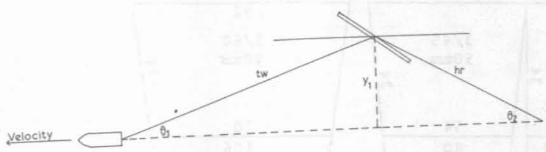

Fig. 2: The calculation of fishing spread and drag (Nomura and Yamazaki, 1975).

Abbreviations:

θ_1 : Angle between towing warp and force direction
θ_2 : Angle between handrope and force direction
Y_1 : Half of the otterboard spread distance
tw : Length of towing warp
hr : Length of handrope and a part of net

Then approximately:

$$\sin\theta_1 = y_1/tw$$
$$\sin\theta_2 = y_1/hr$$

If the tensions T_1 and T_2 are given, then,

The drag force of otterboard,

$$r_2 + e_2 = c_2 - b_2 \quad \text{..........................} \quad (i)$$

The spread force of otterboard,

$$r_1 + e_1 = c_1 + b_1 \quad \text{..........................} \quad (ii)$$

The ground drag & friction,

$$e_2 = c_2 - b_2 - r_2 \quad \text{..........................} \quad (iii)$$

The ground spread,

$$e_1 = c_1 + b_1 - r_1 \quad \text{..........................} \quad (iv)$$

MATERIALS AND METHODS

This experiment was carried out on a vessel of 100 G.T. with a 470 H.P. engine. The length overall (LOA) is 22.9 m. This vessel is well-equipped for stern trawling.

The net *(Fig. 3)* was towed on the seabottom from the stern of the vessel and the required measurements were taken.

The maximum CL and CD values, and the corresponding attitudes of the otterboard used *(Fig. 4)* was determined earlier by conducting a model experiment in a water circulating tank (Tauti, 1934; Dickson, 1959; Kowalski and Giotti, 1974).

Tensions in the towing warp and the handrope were recorded by tension gauges fixed in front and behind the otterboard respectively. The tensions were read with the help of calibration graphs *(Fig. 5)*.

The tension gauge on the towing warp was fixed about 30 meters from the otterboard. The one on the handrope was fixed about 32.3 meters from the otterboard *(Fig. 6)*. These are the two nearest possible places from the otterboard available for fixing the tension gauges as they have to be placed at the joint between two ropes. They were not fixed immediately in front and behind the otterboard where there were joints available as in doing so, it was feared that the tension gauges would directly hinder the expected performance of the otterboard.

The mere presence of warps contributes to the total resistance of the system. The tension in one warp does not reduce to zero as the speed is reduced to zero since it has to continue holding the warp taut, which can theoretically be shown to require a value equal to (depth of water) x (weight of warp in water per unit length) (Crewe, 1964). When the gear is underway, the tension at the bottom of the warp is less than that at the top by the above-mentioned quantity together with the component of force parallel to the warp that is produced by the water flowing past it.

In this experiment, 30 meters of towing warp was used between the otterboard and the front tension gauge (on the towing warp). Since the tension involved is relatively very small, this force is not considered in the calculation.

Otterboard distances were measured by means of an otter-graph transmitter fixed to the star-

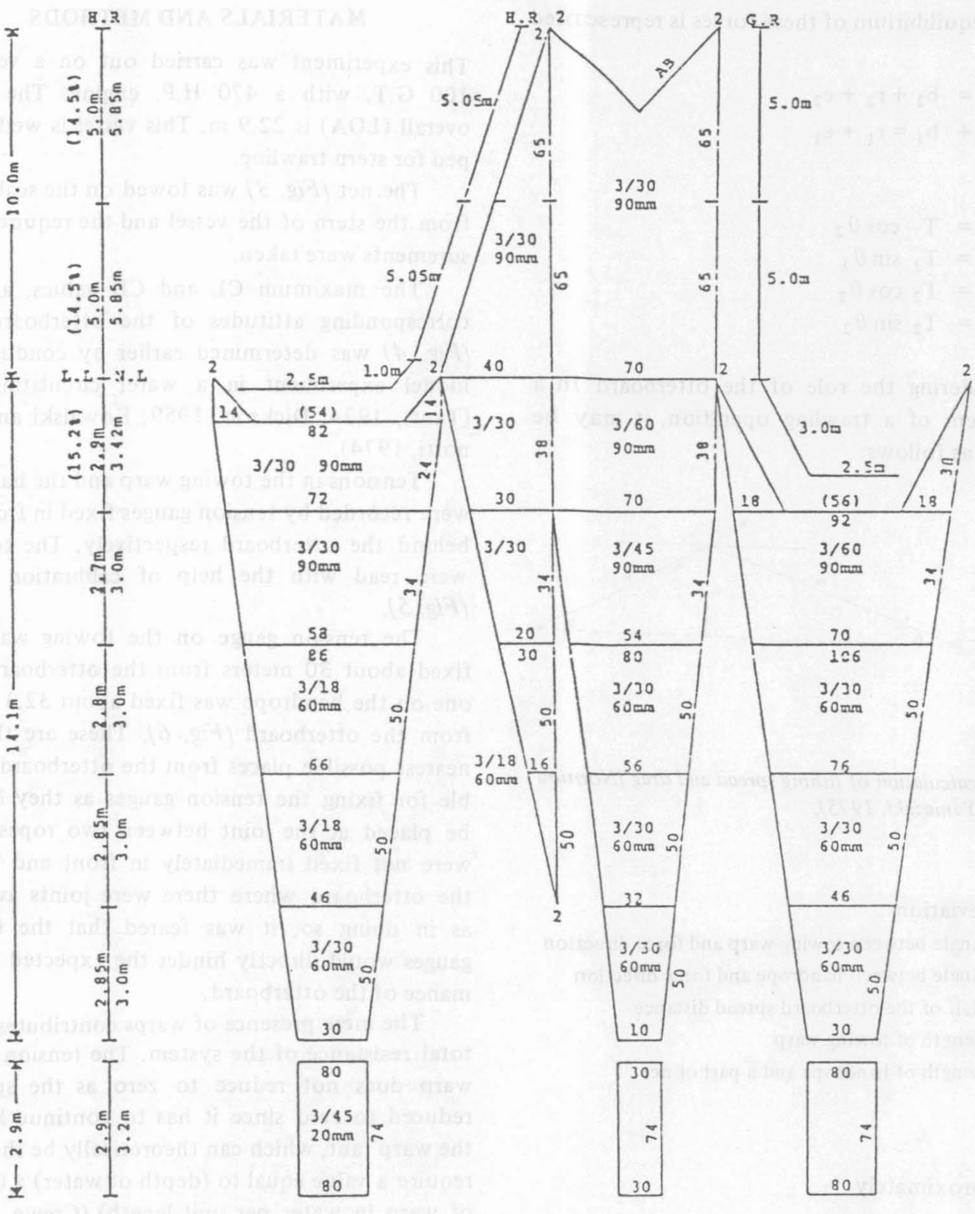

Fig. 3: Plan of the net used.

board otterboard so as not to interfere with the performance of the port otterboard where tensions were recorded. The calibrations of the tension gauges were carried out in the laboratory using a tensile testing machine. Known horizontal pulls were applied to each tension gauge. The recorded readings inside the tension gauges were read by means of a Scale Lupe in units (space intervals as marked inside the Lupe). These units were then plotted with the applied pulls in Kg. The tensions in the experiment were read with the help of these calibration graphs.

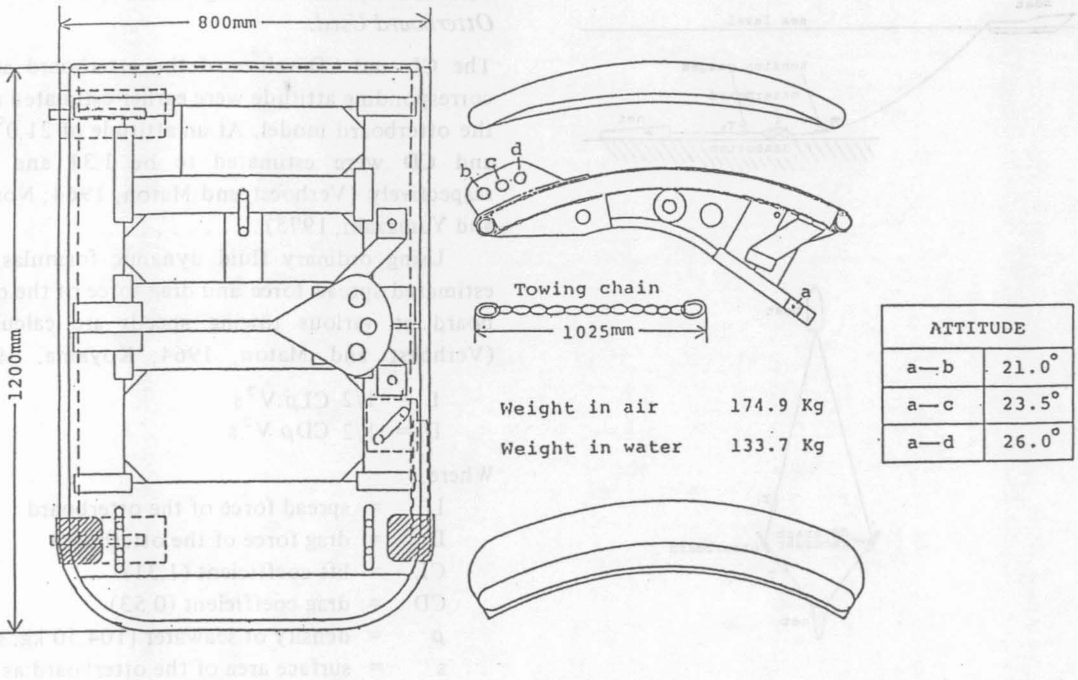

Fig. 4: Plan of the otterboard used.

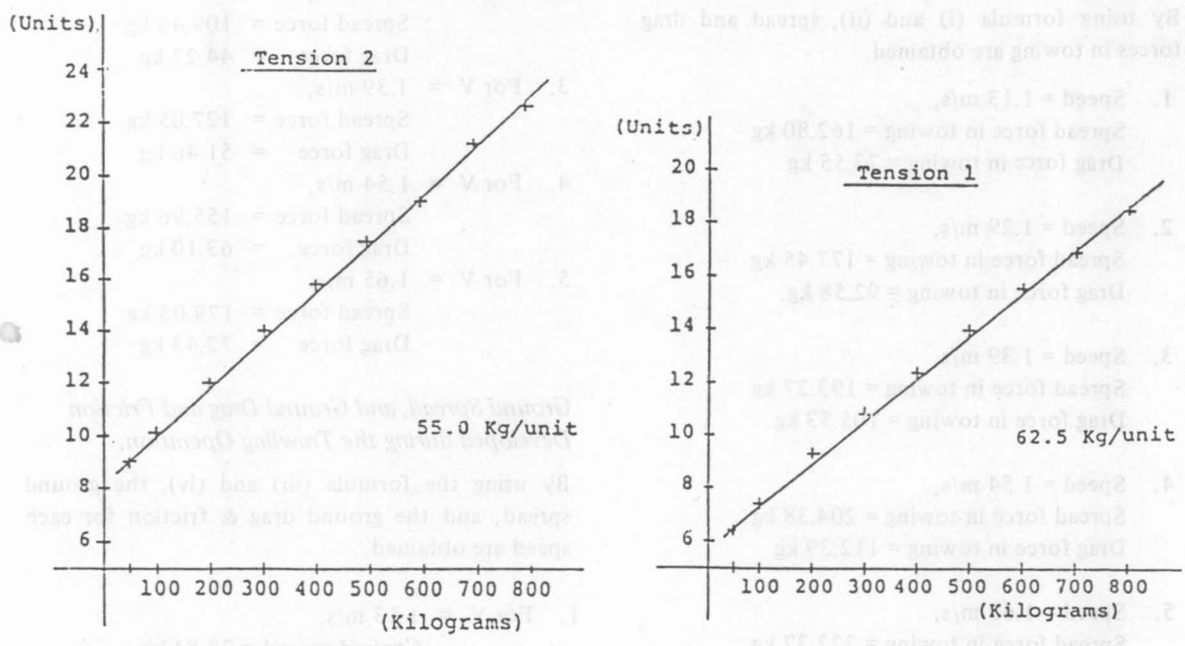

Fig. 5: Calibration graphs of the tension gauges.

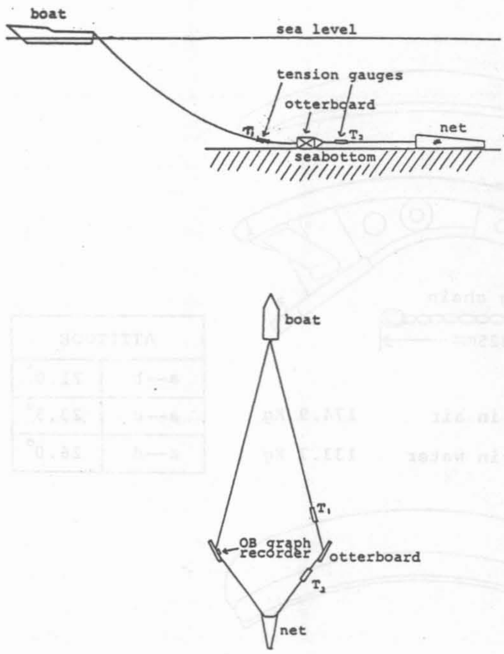

Fig. 6: The experimental setup.

RESULTS AND DISSCUSSIONS

Spread and Drag Forces of the Otterboard during Towing.

By using formula (i) and (ii), spread and drag forces in towing are obtained.

1. Speed = 1.13 m/s,
   Spread force in towing = 162.80 kg
   Drag force in towing = 73.55 kg

2. Speed = 1.29 m/s,
   Spread force in towing = 177.45 kg
   Drag force in towing = 92.58 kg.

3. Speed = 1.39 m/s,
   Spread force in towing = 193.27 kg
   Drag force in towing = 105.53 kg

4. Speed = 1.54 m/s,
   Spread force in towing = 204.38 kg
   Drag force in towing = 112.39 kg

5. Speed = 1.65 m/s,
   Spread force in towing = 222.37 kg
   Drag force in towing = 167.50 kg

Estimated Spread and Drag Forces of the Otterboard Used.

The CL and CD values of the otterboard at the corresponding attitude were earlier estimated using the otterboard model. At an attitude of 21.0°, CL and CD were estimated to be 1.31 and 0.53 respectively (Verhoest and Maton, 1964; Nomura and Yamazaki, 1975) . . . .

Using ordinary fluid dynamic formulas, the estimated spread force and drag force of the otterboard at various towing speeds are calculated (Verhoest and Maton, 1964; Koyama, 1974).

$$L = 1/2\ CL\rho\ V^2 s$$
$$D = 1/2\ CD\rho\ V^2 s$$

Where,

L = spread force of the otterboard
D = drag force of the otterboard
CL = lift coefficient (1.31)
CD = drag coefficient (0.53)
ρ = density of seawater (104.50 kg. sec^2/m^4)
s = surface area of the otterboard as projected directly from above (0.96 m^2)
V = = towing speed in m/s

1. For V = 1.13 m/s,
   Spread force = 83.96 kg
   Drag force = 33.97 kg
2. For V = 1.29 m/s,
   Spread force = 109.43 kg
   Drag force = 44.27 kg
3. For V = 1.39 m/s,
   Spread force = 127.05 kg
   Drag force = 51.40 kg
4. For V = 1.54 m/s,
   Spread force = 155.96 kg
   Drag force = 63.10 kg
5. For V = 1.65 m/s,
   Spread force = 179.03 kg
   Drag force = 72.43 kg

Ground Spread, and Ground Drag and Friction Developed during the Trawling Operation.

By using the formula (iii) and (iv), the ground spread, and the ground drag & friction for each speed are obtained.

1. For V = 1.13 m/s,
   Ground spread = 78.84 kg
   Ground drag and friction = 39.58 kg

TABLE 1:
Data gathered from the experiment.
Collection of experimental data

Water depth (m)	Net speed (m/s)	Warp length (m)	Handrope length + net length(m)	Otterboard Spread Distance(m)/2	Tension 1 (Kg)	Tension 2 (Kg)
99.0	1.13	300.0	86.4	16.0	731.50	668.50
100.0	1.29	300.0	86.4	17.0	762.50	782.00
99.0	1.39	300.0	86.4	17.5	812.50	720.50
101.0	1.54	300.0	86.4	17.5	859.83	761.75
103.0	1.65	300.0	86.4	17.5	970.80	818.60

2. For V = 1.29 m/s,
   Ground spread = 68.02 kg.
   Ground drag and friction = 48.31 kg
3. For V = 1.39 m/s,
   Ground spread = 66.22 kg
   Ground drag and friction = 54.13 kg
4. For V = 1.54 m/s,
   Ground spread = 48.42 kg
   Ground drag and friction = 49.29 kg
5. For V = 1.65 m/s,
   Ground spread = 43.34 kg
   Ground drag and friction = 95.07 kg

The results obtained may be summed up as follows (Tables 1 and 2). To aid the analysis of the experimental results, curves were plotted.

As seen in *Fig. 7*, both the total spread and drag forces of the otterboard during towing increase with speed. However, the rate of increase of the spread force is relatively lower than that of the drag force.

Fig. 8 shows how actual spread and drag forces of the otterboard increase with speed. The actual spread and drag forces were calculated using the estimated CL and CD values from the experiment on model. The rate of increase of the actual drag force of the otterboard is relatively lower than that of the actual spread force.

In Fig. 9, it can be seen that the ground drag and friction increase with the otterboard speed, while the ground spread decreases with speed. The curves intersect at the otterboard speed of approximately 1.41 m/s, afterwhich the ground drag and friction become higher than the ground spread.

Refering to *Fig. 10*, at the speed of 1.13 m/s, the ground spread force is about the same as the actual spread force of the otterboard, that is they both have a share of 50% of the total spread force in towing. However, when the speed increases, the actual spread force's share of the total spread force in towing increases while the ground

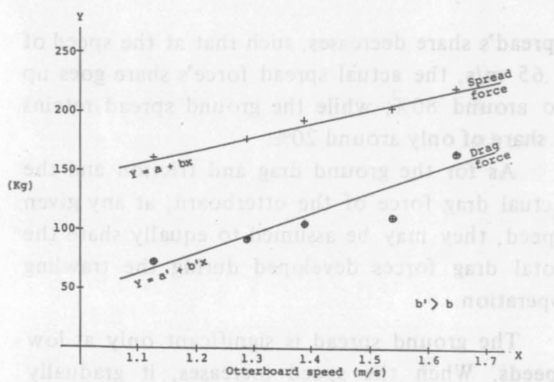

Fig. 7: Spread and drag forces in towing vs otterboard speed.

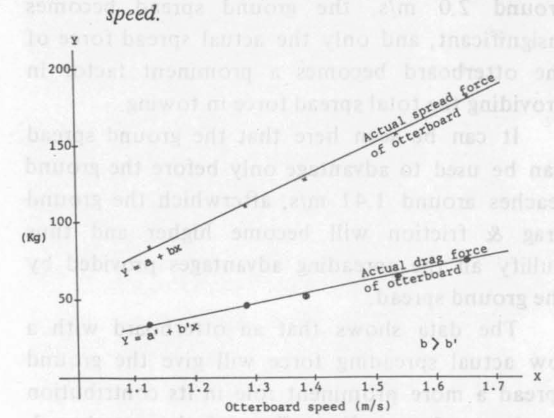

Fig. 8: Actual spread and drag forces vs otterboard speed

TABLE 2
The experimental results.

Forces \ Velocities	1.13 m/s	1.29 m/s	1.39 m/s	1.54 m/s	1.65 m/s
Otterboard distance (m)	32.0	34.0	35.0	35.0	35.0
Spread force in towing (Kg)	162.80	177.45	193.27	204.38	222.37
Drag force in towing (Kg)	73.55	92.58	105.53	112.39	167.50
Actual spread force of otterboard (Kg)	83.96	109.43	127.05	155.96	179.03
Actual drag force of otterboard (Kg)	33.97	44.27	51.40	63.10	72.43
Ground spread (Kg)	78.84	68.02	66.22	48.42	43.34
Ground drag and friction (Kg)	39.58	48.31	54.13	49.29	95.07

spread's share decreases, such that at the speed of 1.65 m/s, the actual spread force's share goes up to around 80%, while the ground spread retains a share of only around 20%.

As for the ground drag and friction and the actual drag force of the otterboard, at any given speed, they may be assumed to equally share the total drag forces developed during the trawling operation.

The ground spread is significant only at low speeds. When the speed increases, it gradually decreases. And if the projected speed comes to around 2.0 m/s, the ground spread becomes insignificant, and only the actual spread force of the otterboard becomes a prominent factor in providing the total spread force in towing.

It can be seen here that the ground spread can be used to advantage only before the ground reaches around 1.41 m/s, afterwhich the ground drag & friction will become higher and thus nullify all the spreading advantages provided by the ground spread.

The data shows that an otterboard with a low actual spreading force will give the ground spread a more prominent role in its contribution to the total spreading effect of the otterboard. This is because an otterboard with a lower spread-

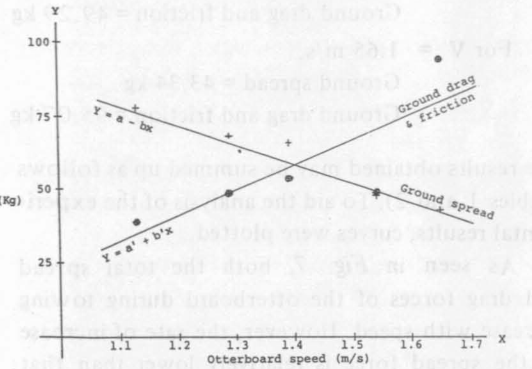

Fig. 9: Ground spread and ground drag & friction vs otterboard speed.

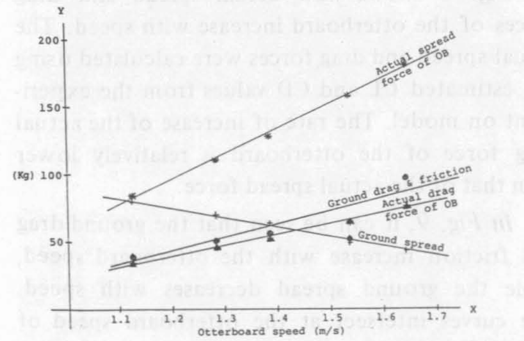

Fig. 10: Actual spread and drag forces of otterboard, ground spread and ground drag & friction vs otterboard speed.

ing force will also have a relatively lower drag force and will thus move the "point of advantage" to the right *(Fig. 10)*. This means that the spreading advantages provided by the ground spread will be nullified at a higher speed.

A flat type otterboard with an aspect ratio of 1:2 has a relatively lower spreading force and also a lower drag force, as compared to a cambered otterboard with the same aspect ratio. (In Malaysia, flat type otterboards with an aspect ratio of 1:2 are used for all kinds of trawling). In this case, since the actual drag force of a flat type otterboard is relatively lower, the "point of advantage" will move to the right. This means that the spreading advantages provided by the ground spread will be nullified at a higher speed.

The result will be contrary if the otterboard is given a little camber. This relatively increases its spreading and drag forces. This will then move the "point of advantage" to the left, which means that the spreading advantages provided by the ground spread will be nullified at a lower speed, a factor which is very unfavorable for an otterboard.

It can be deduced here that a flat otterboard is the favorable type of otterboard for bottom trawling operations.

The ground drag and friction developed by a moving otterboard on the sea-bottom is proportional to the linear dimension of the "point of contact" (part of the otterboard which is in contact with the ground) of the otterboard. If the "point of contact" is high, the ground drag and friction will also be high, and will cause the total drag force in towing (actual drag force of otterboard + ground drag and friction) to increase. On the other hand, an otterboard with a small "point of contact" will give a low total drag force in towing. Lowering the total drag force in towing will push the "point of advantage" to the right, which means that the ground spread can still be effective at a higher speed, a factor most favorable for an otterboard. Considering this fact, an otterboard with a small "point of contact" is more favorable for bottom trawling operations.

From the discussion above, it may be further concluded that a flat type otterboard with a small "point of contact" (high aspect ratio), is the most suitable otterboard for bottom trawling operations.

CONCLUSION

As apparent from the results of this experiment the touching between the otterboard and the seabottom produces some favorable effects, in addition to the resistance developed. Of course these forces vary with the nature of the seabottom. And if well manipulated, this spreading effect could be used to advantage.

With some careful consideration of the nature of the seabottom, otterboards may be built to give a certain spread force with some added advantage provided by nature.

Using flat rectangular otterboards with high aspect ratios will enable the effect of touching between the otterboards and the ground to be well-utilized.

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