

Method and means for dynamic trim of a fast,
planing or semi-planing boathull

5 The present invention relates to a method for continuous
control and trimming of the floating position of a fast, planing
or a semi-planing ship hull during the operation thereof. The
present invention also provides the mechanism for carrying out
the method. The present invention also relates to a support
10 plane having a profile of a wing for dynamically trimming a ship
hull according to the description below.

15 The need for higher speeds during sea transportation has
lately produced a plurality of technical improvements. The
primary goal of these improvements has been to reduce the drag
during the forward movement of the ship hull and thus the need
for power at higher speeds. Some of these improvements have in
common that the wet surface is reduced and therefore the
frictional drag is reduced. Wet surface means the part of the
ship hull that is in contact with the water surface or the part
20 that is submerged below the water surface.

25 Together with the need for higher speeds is the need for
improved comfort for both passengers and the goods. These
requirements make many of the designs of hovering vessels
impractical because variations in the pressure of the air cushion
is a big problem because they affect the performance of the
vessel.

30 Conventional fast and planing ships with good performance
characteristics and designs typically have the center of gravity
positioned behind the mid section of the ship. This type of hull
makes the ship sensitive to pitching, that is vertical oscilla-
ting movements along the length of the hull. These movements may
cause the stem to oscillate vertically in an accelerated manner
35 while the stern remains relatively stationary.

THIS SHEET HAS BEEN
REPLACED

2

Another problem, that is related to planing ships, is the difficulty of achieving an optimal operational angle between the keel or the bottom of the ship hull and the surface of the water. The optimal operational angle is generally about 5 degrees. Ship hulls that operate with such an operational angle have the center of gravity far behind the mid section of the ship hull and have, therefore, little or non-existent longitudinal stability. In practice, these types of ship hulls are only suitable for racing. Even if a dynamic trimming angle of about 5 degrees is attainable in certain designs, it is often impractical due to problems related to navigation, handling of goods and the comfort of passengers.

A technic that, in many aspects, satisfies the requirements of reduced drag and improved comfort of this type of a ship hull is the use of controllable and submerged support planes or hydro foils.

The existing systems of submerged and controllable support planes are all directed to having a support plane only at the stem of the ship hull and, in the alternative, to having support planes both at the stem and at the stern of the ship hull. The former is only moderately efficient and the latter requires expensive and complex systems. One problem with designing a system having support planes both at the stem and the stern is the trough between two waves that is generated by the front support plane. This interferes with the function and efficiency of the rear support plane resulting in increased drag. Another problem relates to the insufficient strength and reliability of the support plane that may occur if the support plane and/or the control system of the support plane is damaged.

The object of the present invention is satisfied by the method, mechanism and the use thereof according to the claims herein included.

This Sheet Has Been Replaced



The present invention is described in detail below with reference to the attached figures, of which:

5 Fig. 1 is a schematic showing a side view of a planing ship hull during operation,

Fig. 2 is a partially sectioned view of the stem of the ship hull of Fig. 1,

10 Fig. 3a is an end view of an embodiment of a support plane according to the present invention,

Fig. 3b is a plan view of the support plane of Fig. 3a,

15 Fig. 4 is a graphical illustration of the lifting coefficient (C_L) of the support plane as a function of the load (p) in the described example of calculations,

20 Fig. 5 is a graphical illustration of the depth of the wave,

Fig. 6 is a graphical illustration of the angle of operation in the area where the wave contacts the bottom of the ship hull,

25 Fig. 7 is a graphical illustration of the shape of the induced wave showing the inner and outer points of intersection with an imaginary horizontal water surface,

30 Fig. 8 is a view of the stern showing a trimming foil according to one aspect of the present invention,

Fig. 9 is a cross sectional view along the line IX-IX of Fig. 8,

Fig. 10 is a side view of the trimming foil in a submerged operational mode,

35 Fig. 11a and 11b are side views of an alternative embodiment of the trimming foil, and



THIS SHEET HAS BEEN
REPLACED

Fig. 12 is a side view of another alternative embodiment of the trimming foil.

5 The invention is based on the concept of using a fully submerged support plane 1 that is movably attached to or secured to a ship hull 2 as shown in Fig. 1. The support plane 1 is especially designed to generate a wave or trough disposed behind the support plane 1. The wave has a predetermined length and width that cause the water to engage the rear portion of the bottom of the ship hull at an increased operational angle. The contact area with the water surface typically corresponds to about 5-20% of the length of the bottom of the ship hull, see B in Fig. 1. By controlling the shape of the wave, it is possible to take advantage of the lifting power of the wave to reduce the frictional drag of the ship hull resulting in lower construction costs and less complexity of the ship hull as some of the advantages.

20 The wave or the trough may therefore be controlled to affect the following parameters:

- The length of the wave is controlled by the cord length (b) of the support plane.
- The width of the wave is controlled by the span (a) of the support plane.
- The depth of the wave is controlled by the load (p) of the support plane.

30 By using the above reference points, it should be understood that it is possible to design and position a support plane that is adapted to a specific planing ship hull so that the planing shown in Fig. 1 may be achieved during operation of the ship.

35 According to calculations and tests, the concept of the invention produces the desirable technical effect predicted. A front support plane, designed to absorb a substantial load, possibly in combination with a trimming plane or trimming foil

mounted to the stern of the ship hull, lifts the ship hull out of the water so that the resulting dynamic angle of operation, as measured relative to the horizontal plane, is typically about 2.5 to 3 degrees, see γ (gamma) in Fig. 1. This typical range of the angle is often acceptable. The vertical angle of the water flow, as measured relative to the horizontal plane also, is typically -2 to -4 degrees in the area where the water flow of the waves comes into contact with the bottom of the ship hull, see β (beta) of Fig. 1. Consequently, a total operational angle of 4.5 to 5 degrees may easily be maintained between the water and the bottom of the ship hull. This is believed to be an optimal angle of operation.

In addition, the deliberately generated wave or trough produces an increased free height difference C between the bottom of the ship hull and the water surface, which corresponds to the depth of the wave.

It has been shown that the net reduction of drag of the ship typically results in a reduction of about 35 to 50% of the required power to run the ship. This reduction obviously results in substantially lower investment costs and operation costs.

In addition, extensive tests have shown that continuous control of the setting of the operational angle of the trimming foil or trimming plane results in a significantly improved handling of the ship in rough sea. Improvements of more than 50% of the vertical movements and acceleration are typical. The support plane may thus be controlled by turning a pair of parallel strut members. The strut members have outer ends that are attached to the support plane and inner ends that are rotatably attached to the ship hull, see Fig. 2. It is to be understood that in ship designs having a plurality of ship hulls, a support plane may be attached to the stem of each ship hull. The earlier mentioned rotation of the strut members should be about -4 to about +5 degrees as measured counter clockwise from a normal to the water surface and through the point of rotation.

With reference to Fig. 2, a partial cross section is shown through the stem of the planing ship hull 2 having a support plane 1, according to an embodiment of the present invention. The support plane is supported by two parallel rod or strut members 4, 4' that are rotatably attached to the ship hull 2. It is preferable that the common rotation axle 5 is positioned above the water surface VI in all positions. The axle 5 may, for example, be rotated by hydraulic, electro-hydraulic or mechanical driving mechanisms as is known by the person of ordinary skill in the art. The rotation is adjusted in response to the vertical movements of the ship hull in the direction of the length of the ship hull. These movements may be detected by, for example, a gyro.

Figs. 3a and 3b show an embodiment of the support plane 1. The end view of Fig. 3a shows that the cross section of the support plane has the shape of an air foil. That is, it has the shape of a wing having an arching upper side and a relatively plane under side and is therefore providing a lifting force when it is driven through the water. The cord length b may be determined as described above and is further described in detail below to control the length of the wave that is adapted to the shape of the ship hull.

The plan view of Fig. 3b shows that the cord length b is reduced in the direction of the end portion of the support plane 1. In this way, the shape of the induced wave is adjusted so that the trough is gradually reduced in the direction toward the areas of the outer edges. This leads to a water flow that is free of interference in these areas. Also, the trough is refilled at the stern portion of the ship hull without generating interfering turbulence or air mixing. A vertical fin 6 is attached to each end of the support plane 1 to prevent turbulence at the outer edges of the support plane. Turbulence may be generated by compensating for the pressure difference between the under side and the upper side of the support plane.



THIS SHEET HAS BEEN
REPLACED

The support plane is formed according to calculation methods for wing profiles. The position of the support plane, the required lifting force or the load p , and the flow velocity V over the wing profile may be used in interactive calculation methods to determine the size of the span (a) and the cord length (b) of the support plane which in turn may be used to determine a suitable length and shape of the induced wave 3. With reference to Figs. 4-7 an example of calculations are used to illustrate the correlations that are used to carry out the invention (see Ivan T. Egorov, Vitaly T Sokolov: Hydrodynamics of High Speed Craft, Sudostroyenie, Leningrad, 1965 (pages 254-256)).

Fig. 4 shows a graphical illustration of the lifting coefficient C_l as a function of the load p . The example assumes that a load in the order of 34-46,000 kp and a velocity V of 26 knots are used. It is further assumed that the density of water ρ is 1.025 (salt water) and that the required lifting force F is the product of the gravitational constant 9.81 and the load used. By solving the equation below for the loading interval, a graphical illustration as shown in Fig. 4 is provided:

Equation 1
$$C_y(p) \equiv \frac{F(p)}{\frac{\rho \cdot v^2}{2} \cdot S}$$

wherein S is the area of the support plane. In the example, this area is 3.234 m². The span is 4.2 meter and the cord length is 0.77 meter. In the example, it is assumed that the flow of water over the profile of the support plane is free from air mixture and that the relative depth of the support plane in the water is, as a rule of thumb, 1 through the cord length b .

It may be realized that the profile of the support plane affects the gradient of the velocity of the flow over the profile. It may also be realized that a person of ordinary skill in the art of aviation may know this affect. However, as far as

the inventor is aware, these relationships have not been used before in the manner according to the invention. That is, to generate a predetermined wave for dynamic trimming of the floating position of the ship hull.

By using the above parameters, the angle of operation between the wave and the bottom of the ship hull and the free height distance C may be determined at different load levels. Characteristic values of the above support plane are illustrated in graphical form in Figs. 5 and 6.

Fig. 5 relates to the angle of operation α (alpha) between the wave and the bottom of the ship hull at different load values and the table value $\alpha(p)$ may be obtained from the equation below:

Equation 2

$$\alpha(p) = 75 \cdot \frac{C_l(p)}{(Fr)^{2 \cdot v}} \cdot \left[e^{\frac{-h}{Fr^{2 \cdot v}}} + \frac{.5}{\lambda} \cdot [Fr^{2 \cdot v} - 2] \right] \cdot \cos \left[\frac{l}{Fr^{2 \cdot v}} \right] \cdot 57.3$$

wherein p is the load (34-46.000 kp)

$C_l(p)$ is the lifting coefficient of the support plane

Fr is the Froude value of the support plane

$$v(ny) = \frac{-73}{\lambda^2}$$

$v \approx 8$

h is the relative depth of the support plane in the water

λ (lambda) is the aspect ratio of the support plane

l is a relational value between the support plane and center point of the wet surface through the cord length.

e (2,718....) is the natural logarithm value

The table values $H_w(p)$ can be determined by solving the equation below regarding the free height distance C between the

induced wave and the bottom of the ship hull, as shown in Fig. 6:

Equation 3

$$Hw(p) := \left[e^{\frac{-h}{Fr^{2 \cdot v}}} + \frac{.5}{\lambda} \cdot [Fr^{2 \cdot v} - 2] \right] \cdot Cy(p)$$

10

Fig. 7 is a graphical illustration of the shape of the induced wave as seen from above. The m or x-axis shows the length of the ship hull between the support plane and the stern plate and n- or x-axis shows the propagation of the wave sideways relative to half the span width of the support plane. Half the span width is shown as 1 in the diagram and 0 represents the center line of the ship hull. The dotted line Wm,1 shows the inner intersection points between the wave and an imaginary horizontal and stagnant water surface. The solid line Wm,2 shows the outer intersection points between the wave and the horizontal water surface.

It should be noted that the above example of calculations should not be interpreted to represent the best embodiment but only to serve as guidance to the person of ordinary skill in the art to carry out the invention and to emphasize that the desirable effect is possible to calculate and is therefore predictable and reproducible.

The advantages of the present invention are more apparent if the support plane 1 is combined with a trimming plane or trimming foil at the stern of the ship hull. It has been shown that a trimming foil according to the embodiment described below significantly improves the advantageous technical results and reduces drag and energy requirements.

This Sheet Has Been Replaced





THIS SHEET HAS BEEN
REPLACED

Fig. 8 shows an embodiment of the mechanism of the present invention that is generally referred to with reference numeral 100. The mechanism is mounted at the lower end of the stern of the ship hull 2. The illustrated embodiment includes the mechanism 100, that is from here on referred to as trimming foil 100, a substantially plane disc or plate 103, a vertically adjustable and a rotatable stern plate 104. The stern plate includes, in the illustrated position, a downwardly extending edge 105. Rotatable movements may be performed by guide bars 106 that slide within parallel inwardly extending grooves 107 disposed in the trimming foil. The movements of the trimming foil are activated by hydraulic, electro-hydraulic or mechanical driving mechanisms that are not shown. The movements are transferred to the trimming foil 100 by bar members 108, 109. In the alternative, the movements may be activated directly by bar members 108, 109 by an hydraulic piston/cylinder unit.

The trimming foil has a length of 1 that substantially corresponds to the width of the lower edge of the stern plate. The foil is preferably split into two halves so that each half is rotatably attached so that the foils may be submerged to a desired depth in the relative water flow below the bottom of the ship hull. The foils may be moved by drivable transferring members and/or directly by the driving members. The movements of each half of the trimming foil may therefore be controlled together or independently to counter or reduce the pitching or rolling movements of the ship hull. Fins 110, 111 are attached to each side of the trimming foil 100. The fins extend mainly vertically along the length of the ship hull, at least from the trimming foil and forward. The fins have a height that at least corresponds to the height of the portion of the trimming foil that is submerged when the trimming foil is submerged to a maximum in the water flow. The length of the fins 110, 111 may be adapted to the shape of the ship hull. However, the length should not be shorter than the height of the portion of the trimming foil, that is submerged to a maximum, and is preferably longer than this submerged portion. In the alternative, the fins

**THIS SHEET HAS BEEN
REPLACED**

110, 111 may be attached to the ends of the trimming foil 100 or to the ship hull and preferably in the area of the bottom of the ship hull as shown in Fig. 8.

5 Fig. 9 shows the trimming foil 100 in a raised rest position so that the edge 105 is disposed at the same level as the bottom 112 of the ship hull or at least so that it does not extend below the bottom. The function of the fin 110, which may have a
10 suitable shape with regard to the above mentioned size conditions, is described below in connection with Fig. 10. During movements in the direction of the arrow F in Fig. 9, a load is applied against the bottom of the ship hull when the water is transected by the ship hull. Thus, this load is gradually
15 reduced toward to the stern of the ship hull. This is illustrated as a schematic in Fig. 9 by the arrows P that extend vertically against the ship hull.

 Fig. 10 shows the trimming foil 100 in a operational position when the trimming foil has been lowered to a maximum so
20 that the edge 105 protrudes under the bottom 112 of the ship hull at a depth A which may vary depending on the application. In the lowered position, the trimming foil produces a surface 105' that extends perpendicular to the direction of the relative water flow so that the water flow is slowed down against the surface.
25 The fins 110, 111 therefore serve to prevent the water volume that has been slowed down from escaping the outer end areas of the trimming foil. In this way, the water volume that is caught is exposed to a compression or pressure increase. It may be realized that the submerged trimming foil 100 provides an
30 increased drag during the operation of the ship hull. However, it has been shown in models and full scale tests that this increased drag is negligible and is outweighed by the overall improved energy efficiency of the ship hull due to the advantageous effects of the trimming foil. These tests have, however,
35 indicated that it is advantageous that the depth A, that is the lowest depth of the edges 105 and surface 105' of the trimming foil account for about 3% of the total length of the trimming

foil 100 and preferably should, at a maximum, be about 2.7% of the length.

Fig. 10 illustrates a schematic of an embodiment of the trimming foil 100 that is arranged to slope at an angle α (alpha) in the vertical direction relative to the length of the ship hull so that the angle α is below determined relative to a line N that is the normal to the bottom of the ship hull. The angle α includes a shifting of the angle from the line N which, according to the tests and trials mentioned above, preferably should be within the interval of about 3 (three) to plus/minus 5 (five) degrees. That is, according to Fig. 10, this interval is within -2 to +8 degrees as measured from the line N and toward the stem of the ship hull.

By introducing a surface immediately behind the bottom of the ship hull that is perpendicular to the water flow L, a main vortex V is generated that has a velocity component that is directed upwardly and forwardly compared to the bottom of the ship hull. A plurality of minor whirls are also generated but are not shown. The main vortex V has the same length α as the length of the trimming foil 100 and extends between the fins 110, 111. The vortex rotates to create a water flow that is directed upwardly/forwardly below the bottom of the ship hull and in front of the trimming foil. In this way, a zone of increased pressure is created which is directed to the bottom surface as illustrated with a P' in the schematic shown in Fig. 10. The magnitude of the pressure in the area of increased pressure depends on the velocity of the ship and the height of the submerged portion of the trimming foil 100.

It is to be understood with reference to the above description that changes of the depth of the submerged trimming foil directly affect the trimming position of the ship at velocities above a certain critical limit.

Extensive tests have thus shown the above characteristics relating to the operational depth of the trimming foil and the sloping angle at the bottom of the ship hull. The same test has shown that the drag that is generated by a trimming foil that is formed according to the present invention, is negligible. The test results show an increased effectiveness that may be calculated for all ship sizes that are operated at a FNL value that is higher than 0.6. The FNL value refers to the dimension free Froude value which takes the constant of gravity into account and depends on the length of the ship and the velocity thereof.

With reference to Figs. 11a and 11b, a schematic of an alternative embodiment of the trimming foil of the present invention is shown. In this embodiment, a trimming foil 100', having a bow shaped cross section, and a surface 105'', that is turned in the direction of the movement of the ship hull, are secured to a peripheral end of a rotatable rod member 113 to transfer a peripheral movement to the trimming foil 100'. In this way, the rod member 113 may be mounted into a recess 114 disposed in the stern plate of the ship. It should be understood that a certain number of rod members 113 are required to provide stable rotatable attachment and movement of the trimming foil 100' although only one rod member is shown in the figure. The trimming foil 100' is formed so that it may rotate about a pivot point 115 so that its radius is a distance R. The pivot point 115 may be attached to the sides or to a bottom 116 disposed in the recess 114. The rod member 113 may be controlled to raise or lower the trimming foil 100' to the position, as shown in Fig. 11b. This movement may be performed by hydraulic, electro-hydraulic or mechanical driving mechanisms not shown. In this way, a piston/cylinder unit may, for example, be attached within the recess 114 or extend to the outside of the stern plate as is known to the person of ordinary skill in the art due to the known and conventional construction thereof. Naturally, the alternative embodiment of the trimming foil 100' must be designed so that the portion of the trimming foil 100' that is submerged in the

water flow satisfy the geometrical requirements regarding length, sloping angle, and depth in the water as was determined above for the trimming foil 100. Similar to the trimming foil 100, the trimming foil 100' cooperates with fins attached to each side of the foil 100'. Also, the foil 100' preferably is divided into two halves which are individually movable by separate driving members.

It should here be pointed out that the gap 117 that may be created between the stern plate and the trimming foil in all applications should be kept to a minimum to prevent water from escaping through an opening which would lower the efficiency of the increased pressure that is generated in front of the trimming foil.

With reference to Fig. 12, yet another embodiment of the trimming foil of the present invention is shown.

In this embodiment, the trimming foil 100'' includes a bow shaped surface 105''' that is turned in the direction of the movement. A rod 124 is adapted to transfer peripheral movements to the surface 105''' by being rotatably attached to a pivot point 118. The trimming foil 100'' is shown as having two separate halves that are each rotatably attached to holding devices 119, 120, respectively. The holding devices 119 are shown with dotted lines in the figure. To create enough space for the discharge portion of the driving device, both of the inner holding devices 119 extend away from the stern plate 104 at a certain angle. Both of the halves of the trimming foils are maneuvered individually by rotatably attached piston/cylinder units 122, 123 respectively. These units shift the trimming foil 100'' in a bow shaped path about the peripheral end portion of the rod 124. It should be understood that the two separate and individually maneuvered halves of the trimming foil provide continuous counter force to rolling movements and side ways movements of the ship. By coordinating the activation of both

of the halves, the pitching movements and movements along the length of the ship may be reduced.

Obviously, the activation of the trimming foils may, in all
5 embodiments, be controlled automatically to counter act the movements of the ship which are detected by for example a gyro. This detection is then converted into control signals for the driving mechanism of the trimming foil.

10 In the latter embodiment, the pivot point 118 should be positioned so that the operational position of the bow shaped surface 105''' of the trimming foil 100'' is adapted to achieve the expected effect of desirable length, sloping angle and depth so that the parameters outlined above also apply to the trimming
15 foil 100''. A detailed description of the dimensions are not going to be provided here because it is up to the person of ordinary skill in the art to adjust the dimensions of the trimming foil including its suspension and rotation members to achieve the desired results based on the above description of the
20 invention.

The trimming foil of the present invention provides a mechanically simple and reliable, effective and easily maintained mechanism at a moderate investment cost. The invention enables
25 continuous, dynamic trimming of a fast moving ship hull while counter acting rolling and pitching movements during the operation of the ship. Some of the desirable results can be summarized as follows:

- Quick response and low energy requirements.
- 30 - High efficiency of the trimming energy provided.
- Low mechanical load of the moving parts.
- No disturbance of a reversed water jet stream.

By providing a rotatably attached support plane at the stem
35 of the ship, possibly in combination with a trimming plane or preferably a trimming foil that is attached to the stern of the ship, a very effective method for reducing the drag and reducing

the wet surface of a fast moving, planing or semi-planing ship is achieved. By providing the support plane with a suitable span and cord length, according to the present invention, and by designing the support plane, as shown above, so that the length, width, and operational angle of the induced wave are adapted to a specific ship, an optimal floating position of the ship may be achieved. Additionally, by rotatably attaching the support plane so that its operational angle and lifting force is continuously adapted to the tonnage of the ship and its speed during acceleration and operation, the vertical movements of the ship may be minimized while maintaining an optimal floating position even during rough sea. The method is usable for ships having one ship hull or several ship hulls and may preferably be used with catamaran ship hulls.

PATENT CLAIMS



5 1. A method for dynamic trimming of a fast moving, planing or semi-planing ship hull, comprising the steps of:

10 - arranging a continuously adjustable support plane (1) to a stem of the ship hull, the support plane having a wing shaped cross section, the support plane being adjustable relative to the operational angle of the support plane during the operation of the ship hull,

15 - generating a wave (3) by the support plane that is submerged during the operation of the ship hull, the wave having a length, width, and depth that is controlled to be adjusted to the length and the tonnage of the ship hull so that the generated wave engages the bottom of the stern portion of the ship hull at a negative angle (β , beta) relative to the horizontal plane, the wave providing an increased free height distance (C) disposed in front of the stern portion so that

20 - the length of the wave is controlled by the cord length (b) of the support plane,

- the width of the wave is controlled by the span (a) of the support plane, and

25 - the depth of the wave is controlled by the load (p) of the support plane.

30 2. A method according to claim 1, wherein the generated wave is adjusted to engage the stern portion of the ship hull that is within an area that corresponds to 5-20% of the length of the bottom of the ship hull as measured from the stern plate.

35 3. A method according to claim 1, wherein the support plane (1) is adapted to be lowered to a depth, during the operation of the ship hull, that corresponds to 1 through the cord length b, the support plane being adjustable relative to the angle of operation



that is within an angle interval in the order of a magnitude of 10 degrees.

4. A method according to claim 1 wherein the support plane is combined with a trimming plane that is disposed behind the bottom of the ship hull.

5. A method according to claim 1 wherein the support plane is combined with a trimming foil (100,100',100'') that is disposed behind the bottom of the ship hull.

6. A method according to claims 1 and 5 wherein a surface (105',105'',105''') is disposed immediately behind the bottom of the ship hull and is perpendicular to the water flow (L) to generate at least one main vortex (V) having an upwardly and forwardly directly velocity component in front of the surface to create a water volume having an increased pressure that is positioned in front of the surface at the bottom of the ship hull.

7. A method according to claims 1, 5 and 6 wherein the surface (105', 105'', 105''') is inserted into a continuously adjustable depth (A) that corresponds to about 0-3% of the length of the surface, preferably up to a maximum of 2.7% of the length.

8. A support plane (1) for dynamic trimming of the floating position of a fast moving, planing or semi-planing ship hull, the ship hull including, during operation, a continuously submerged, rotatably attached and continuously adjustable wing (1), the wing being adjustable relative the vertical movements of the ship hull and the wing having a wing shaped cross section, comprising:

the wing/support plane (1) being dimensioned with regard to the angle of operation, span (a) and cord length (b) so that the support plane generates a wave during the operation of the ship that is adjusted to the length and tonnage of the ship, the wave engaging the stern portion of the ship hull at a negative angle relative the horizontal plane, the wave providing for an



increased free height distance disposed in front of the stern portion so that

- the length of the wave is controlled by the cord length (b) of the support plane,

5 - the width of the wave is controlled by the span (a) of the support plane, and

- the depth of the wave is controlled by the load (p) of the support plane.

10 9. The use of a support plane, having a wing shaped cross section, to generate a wave that is adjusted to the shape and tonnage of a fast moving, planing or semi-planing ship hull, the wave engaging the bottom of the stern portion of the ship hull at a negative angle, the wave providing an increased free height
15 distance disposed in front of the stern portion for dynamic trimming of the floating position of the ship hull.

20 10. The use according to claim 9 wherein a support plane is used at the stem portion of the ship, the support plane being continuously adjustable relative to the operational angle and the support plane being dimensioned so that

- the length of the wave generated is controlled by the cord length (b),

25 - the width of the wave is controlled by the span (a), and

- the depth of the wave is controlled by the load (p) of the support plane.

30 11. The use according to claims 9 and 10 wherein a support plane is used having a cord length (b), a span (a), and load (p) to generate a wave during operational speed having a length so that the wave engages the stern portion of the bottom of the ship hull at a negative angle relative the horizontal plane, the engagement being within an area that corresponds to 5-20% of the length of
35 the bottom of the ship hull.

1/8

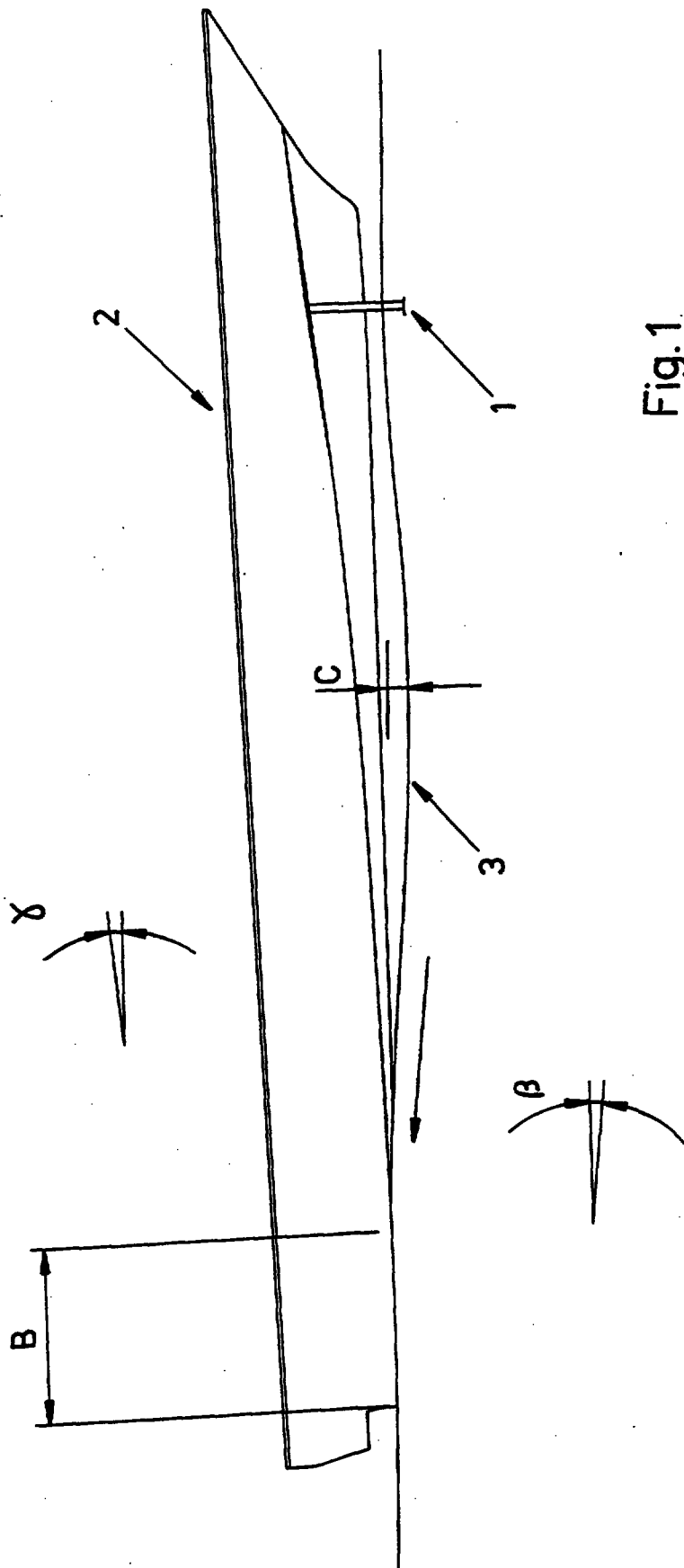


Fig. 1

2/8

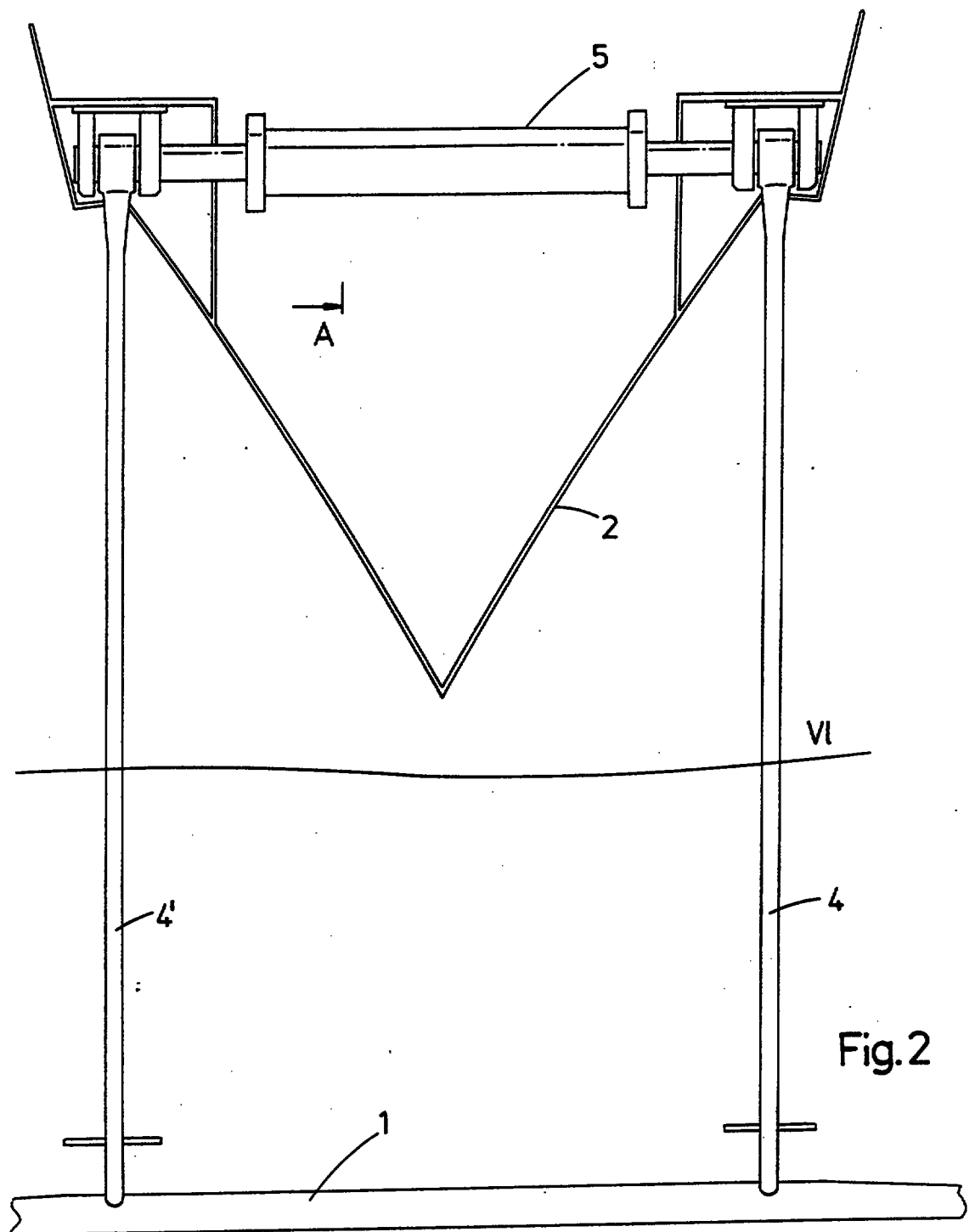


Fig. 2

3/8

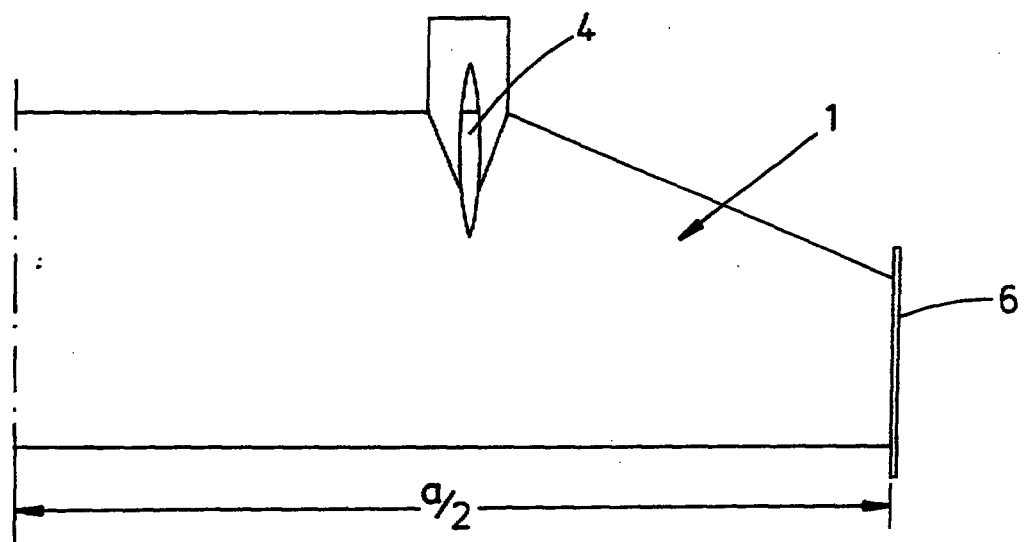
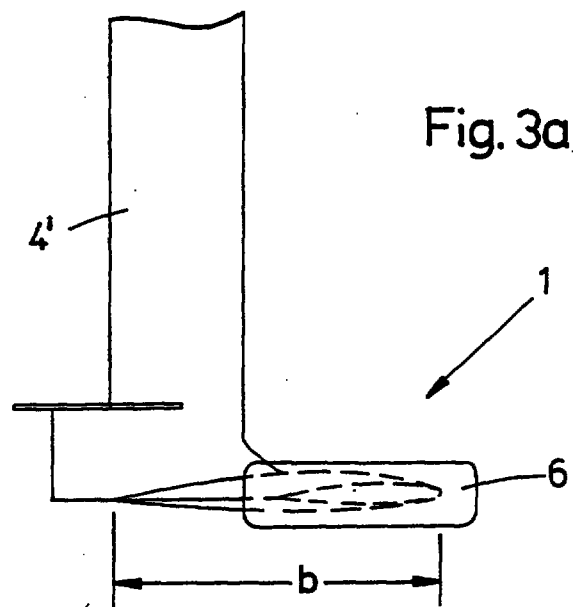


Fig. 3b

4/8

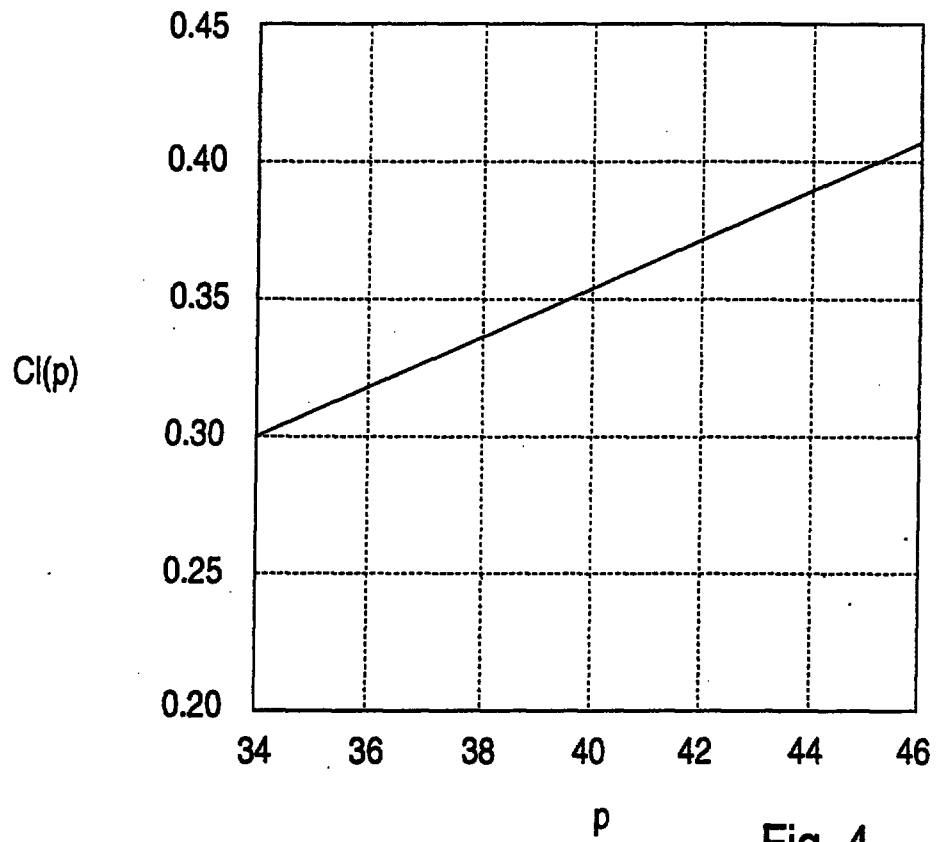


Fig. 4

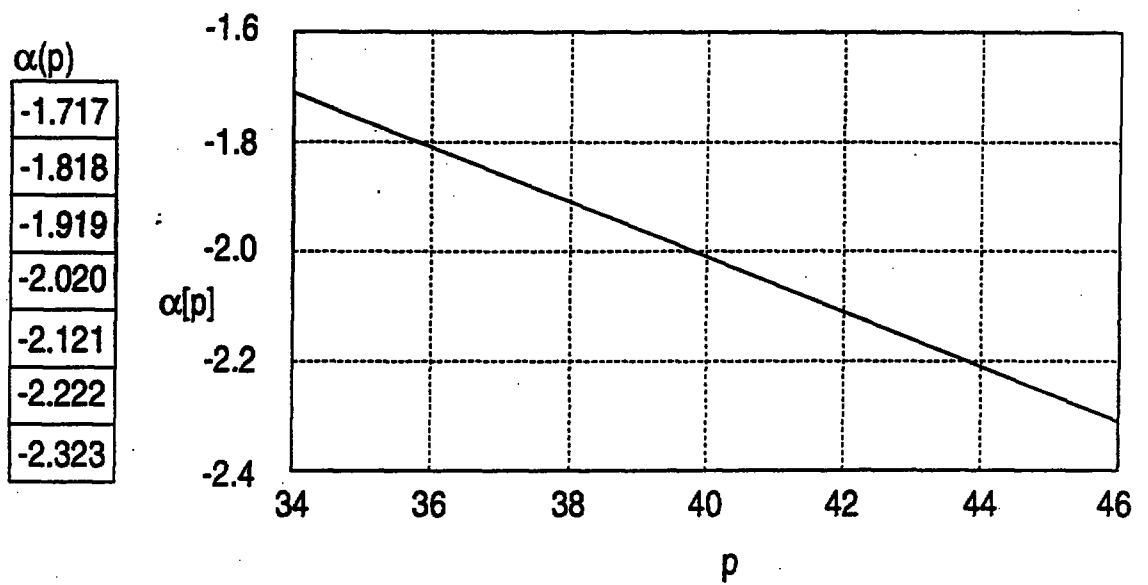


Fig. 5

5/8

Hw (p)

0.612
0.648
0.684
0.720
0.756
0.792
0.829

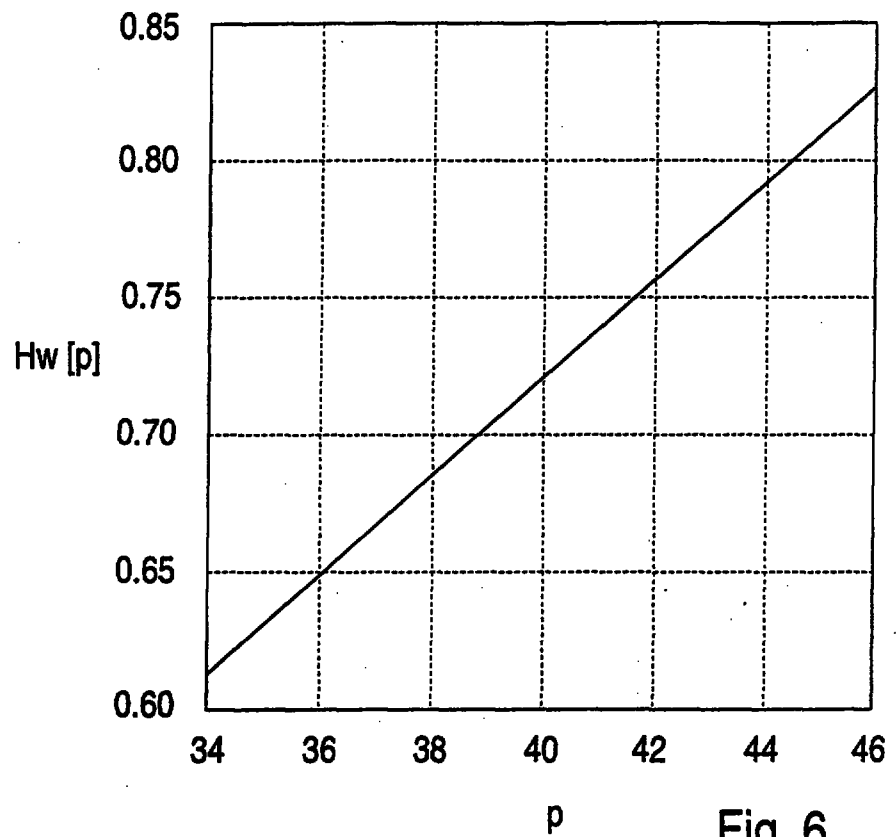


Fig. 6

 $\frac{W_{m,2}}{W_{m,1}}$ $\frac{W_{m,1}}{W_{m,3}}$ $\frac{W_{m,3}}{W_{m,0}}$

m:=0.4
n:=0.3

W:=

0.191	0.867	1.800	0.780
0.340	0.933	1.813	0.780
0.488	1.000	1.635	0.780
0.741	0.783	1.383	0.780
1.000	0	1.133	0.780

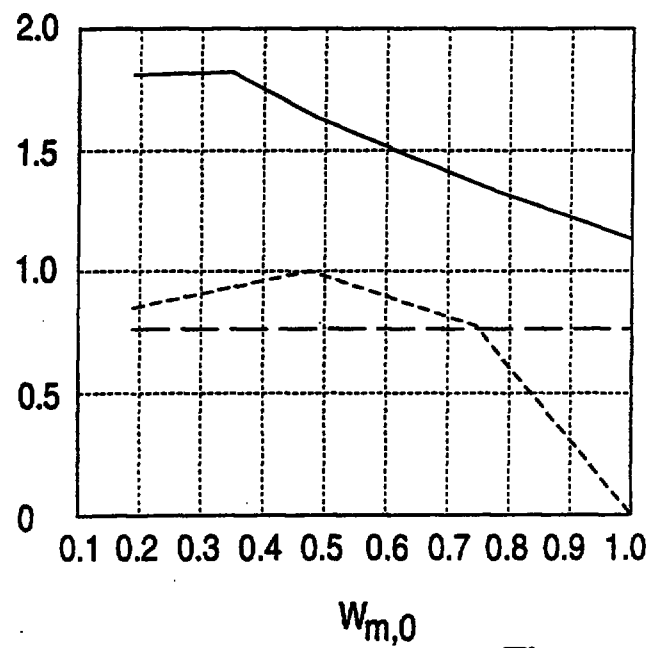
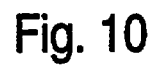


Fig. 7



7/8

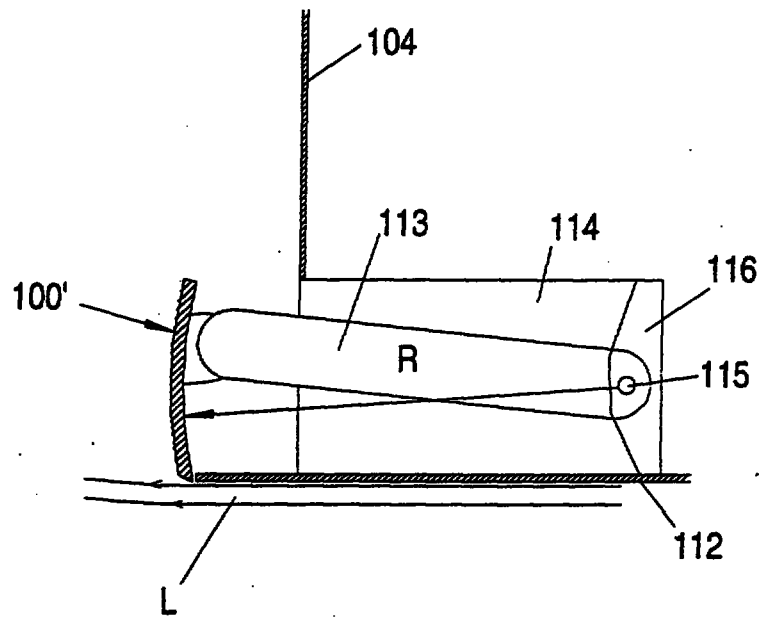


Fig. 11a

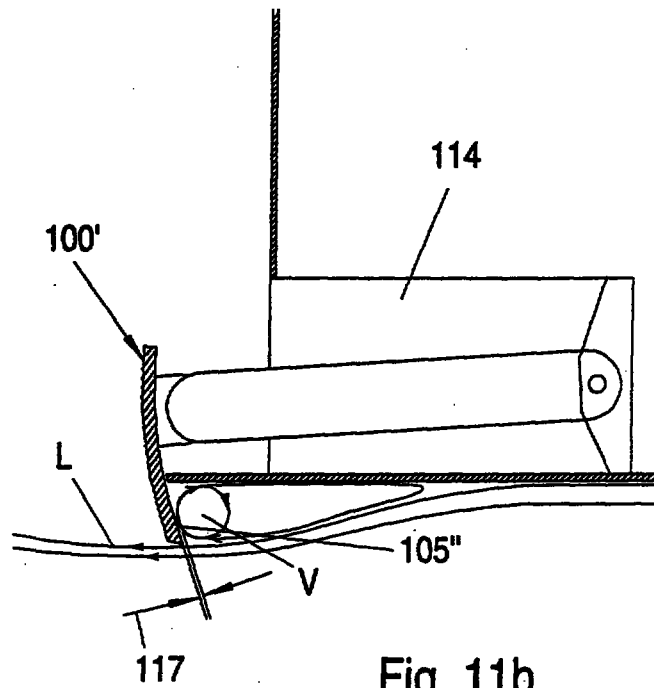
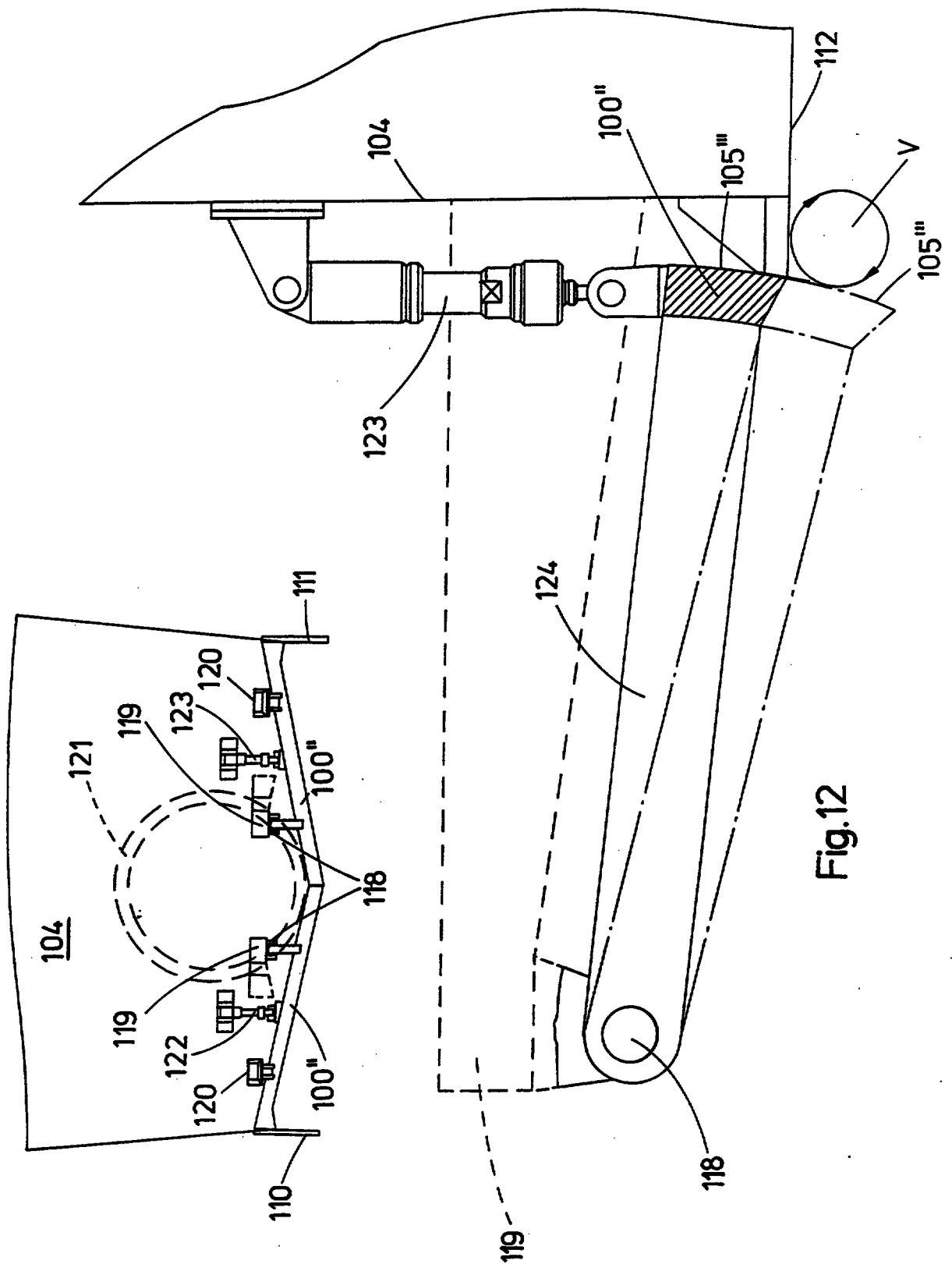


Fig. 11b

8/8



Another problem, that is related to planing ships, is the difficulty of achieving an optimal operational angle between the keel or the bottom of the ship hull and the surface of the water. The optimal operational angle is generally about 5 degrees. Ship hulls that operate with such an operational angle have the center of gravity far behind the mid section of the ship hull and have, therefore, little or non-existent longitudinal stability. In practice, these types of ship hulls are only suitable for racing. Even if a dynamic trimming angle of about 5 degrees is attainable in certain designs, it is often impractical due to problems related to navigation, handling of goods and the comfort of passengers.

A technic that, in many aspects, satisfies the requirements of reduced drag and improved comfort of this type of a ship hull is the use of controllable and submerged support planes or hydro foils.

The existing systems of submerged and controllable support planes are all directed to having a support plane only at the stem of the ship hull and, in the alternative, to having support planes both at the stem and at the stern of the ship hull. The former is only moderately efficient and the latter requires expensive and complex systems. One problem with designing a system having support planes both at the stem and the stern is the trough between two waves that is generated by the front support plane. This interferes with the function and efficiency of the rear support plane resulting in increased drag. Another problem relates to the insufficient strength and reliability of the support plane that may occur if the support plane and/or the control system of the support plane is damaged.

The object of the present invention is to provide a method and mechanism for dynamic trimming of a fast, planing or semi-planing ship hull, the implementation of which will set aside the mentioned problems in existing trimming systems.

The object of the present invention is satisfied by the method, mechanism and the use thereof according to the claims herein included.

21 JUN 1997

4

Fig. 12 is a side view of another alternative embodiment of the trimming foil.

5 The invention is based on the concept of using a fully submerged support plane 1 that is movably attached to or secured to a stern portion of a ship hull 2 as shown in Fig. 1. The support plane 1 is especially designed to generate a wave³ or trough disposed behind the support plane 1. The wave has a predetermined length and width that cause the water to engage the rear portion of the bottom of the ship hull at an increased operational angle. The contact area with the water surface typically corresponds to about 5-20% of the length of the bottom of the ship hull, see B in Fig. 1. By controlling the shape of the wave, it is possible to take advantage of the lifting power of the wave to reduce the frictional drag of the ship hull resulting in lower construction costs and less complexity of the ship hull as some of the advantages.

20 The wave or the trough may therefore be controlled to affect the following parameters:

- The length of the wave is controlled by the cord length (b) of the support plane.
- The width of the wave is controlled by the span (a) of the support plane.
- The depth of the wave is controlled by the load (p) of the support plane.

30 By using the above reference points, it should be understood that it is possible to design and position a support plane that is adapted to a specific planing ship hull so that the planing shown in Fig. 1 may be achieved during operation of the ship.

35 According to calculations and tests, the concept of the invention produces the desirable technical effect predicted. A front support plane, designed to absorb a substantial load, possibly in combination with a trimming plane or trimming foil

AMENDED SHEET

21 JUN 1997

The support plane is formed according to calculation methods for wing profiles. The position of the support plane, the required lifting force or the load p , and the flow velocity V over the wing profile may be used in iterative calculation methods to determine the size of the span (a) and the cord length (b) of the support plane which in turn may be used to determine a suitable length and shape of the induced wave 3. With reference to Figs. 4-7 an example of calculations are used to illustrate the correlations that are used to carry out the invention (see Ivan T. Egorov, Vitaly T Sokolov: Hydrodynamics of High Speed Craft, Sudostroyenie, Leningrad, 1965 (pages 254-256)).

Fig. 4 shows a graphical illustration of the lifting coefficient C_l as a function of the load p . The example assumes that a load in the order of 34-46,000 kp and a velocity V of 26 knots are used. It is further assumed that the density of water ρ is 1.025 (salt water) and that the required lifting force F is the product of the gravitational constant 9.81 and the load used. By solving the equation below for the loading interval, a graphical illustration as shown in Fig. 4 is provided:

Equation 1
$$C_y(p) = \frac{F(p)}{\frac{\rho \cdot v^2}{2} \cdot S}$$

wherein S is the area of the support plane. In the example, this area is 3.234 m². The span is 4.2 meter and the cord length is 0.77 meter. In the example, it is assumed that the flow of water over the profile of the support plane is free from air mixture and that the relative depth of the support plane in the water is, as a rule of thumb, 1 through the cord length b .

It may be realized that the profile of the support plane affects the gradient of the velocity of the flow over the profile. It may also be realized that a person of ordinary skill in the art of aviation may know this affect. However, as far as

AMENDED SHEET

21 JUN 1997

induced wave and the bottom of the ship hull, as shown in Fig. 6:

Equation 3

$$Hw(p) := \left[e^{\frac{-h}{Fr^{2-v}}} + \frac{.5}{\lambda} [Fr^{2-v} - 2] \right] \cdot Cy(p)$$

10

Fig. 7 is a graphical illustration of the shape of the induced wave as seen from above. The m or x -axis shows the length of the ship hull between the support plane and the stern plate and n - or y -axis shows the propagation of the wave sideways relative to half the span width of the support plane. Half the span width is shown as 1 in the diagram and 0 represents the center line of the ship hull. The dotted line $Wm,1$ shows the inner intersection points between the wave and an imaginary horizontal and stagnant water surface. The solid line $Wm,2$ shows the outer intersection points between the wave and the horizontal water surface.

It should be noted that the above example of calculations should not be interpreted to represent the best embodiment but only to serve as guidance to the person of ordinary skill in the art to carry out the invention and to emphasize that the desirable effect is possible to calculate and is therefore predictable and reproducible.

The advantages of the present invention are more apparent if the support plane 1 is combined with a trimming plane or trimming foil at the stern of the ship hull. It has been shown that a trimming foil according to the embodiment described below significantly improves the advantageous technical results and reduces drag and energy requirements.

21 JUN 1997

10

Fig. 8 shows an embodiment of the mechanism of the present invention that is generally referred to with reference numeral 100. The mechanism is mounted at the lower end of the stern of the ship hull 2. The illustrated embodiment includes the mechanism 100, that is from here on referred to as trimming foil 100, a substantially plane disc or plate 103, a vertically adjustable and a rotatably ^{attached to the} stern plate 104. The stern plate includes, in the illustrated position, a downwardly extending edge 105. Rotatable movements may be performed by guide bars 106 that slide within parallel inwardly extending grooves 107 disposed in the trimming foil. The movements of the trimming foil are activated by hydraulic, electro-hydraulic or mechanical driving mechanisms that are not shown. The movements are transferred to the trimming foil 100 by bar members 108, 109. In the alternative, the movements may be activated directly by bar members 108, 109 by an hydraulic piston/cylinder unit.

The trimming foil ¹⁰⁰ has a length of l that substantially corresponds to the width of the lower edge of the stern plate. The foil is preferably split into two halves so that each half is rotatably attached so that the foils may be submerged to a desired depth in the relative water flow below the bottom of the ship hull. The foils may be moved by drivable transferring members and/or directly by the driving members. The movements of each half of the trimming foil may therefore be controlled together or independently to counter or reduce the pitching or rolling movements of the ship hull. Fins 110, 111 are attached to each side of the trimming foil 100. The fins extend mainly vertically along the length of the ship hull, at least from the trimming foil and forward. The fins have a height that at least corresponds to the height of the portion of the trimming foil that is submerged when the trimming foil is submerged to a maximum in the water flow. The length of the fins 110, 111 may be adapted to the shape of the ship hull. However, the length should not be shorter than the height of the portion of the trimming foil, that is submerged to a maximum, and is preferably longer than this submerged portion. In the alternative, the fins

AMENDED SHEET

110, 111 may be attached to the ends of the trimming foil 100 or to the ship hull and preferably in the area of the bottom of the ship hull as shown in Fig. 8.

5 Fig. 9 shows the trimming foil 100 in a raised rest position so that the edge 105 is disposed at the same level as the bottom 112 of the ship hull or at least so that it does not extend below the bottom. The function of the fin 110, which may have a
10 suitable shape with regard to the above mentioned size conditions, is described below in connection with Fig. 10. During movements in the direction of the arrow F in Fig. 9, a load is applied against the bottom of the ship hull when the water is transected by the ship hull. Thus, this load is gradually reduced toward to the stern of the ship hull. This is illustrated as a schematic in Fig. 9 by the arrows P that extend
15 vertically against the ship hull.

 Fig. 10 shows the trimming foil 100 in a operational position when the trimming foil has been lowered to a maximum so
20 that the edge 105 protrudes under the bottom 112 of the ship hull at a depth_ A which may vary depending on the application. In the lowered position, the trimming foil produces a surface 105' that extends perpendicular to the direction of the relative water flow so that the water flow is slowed down against the surface.
25 The fins 110, 111 therefore serve to prevent the water volume that has been slowed down from escaping the outer end areas of the trimming foil. In this way, the water volume that is caught is exposed to a compression or pressure increase. It may be realized that the submerged trimming foil 100 provides an
30 increased drag during the operation of the ship hull. However, it has been shown in models and full scale tests that this increased drag is negligible and is outweighed by the overall improved energy efficiency of the ship hull due to the advantageous effects of the trimming foil. These tests have, however,
35 indicated that it is advantageous that the depth A, that is the lowest depth of the edges 105 and surface 105' of the trimming foil account for about 3% of the total length of the trimming



21 JUN 1997

that is within an angle interval in the order of a magnitude of 10 degrees.

5 4. A method according to claim 1 wherein the support plane is combined with a trimming plane that is disposed behind the bottom of the ship hull.

10 5. A method according to claim 1 wherein the support plane is combined with a trimming foil (100,100',100'') that is disposed behind the bottom of the ship hull.

15 6. A method according to claims 1 and 5 wherein a surface (105',105'',105''') is disposed immediately behind the bottom of the ship hull and is perpendicular to the water flow (L) to generate at least one main vortex (V) having an upwardly and forwardly directed velocity component in front of the surface to create a water volume having an increased pressure that is positioned in front of the surface at the bottom of the ship hull.

20 7. A method according to claims 1, 5 and 6 wherein the surface (105', 105'', 105''') is inserted into a continuously adjustable depth (A) that corresponds to about 0-3% of the length of the surface, preferably up to a maximum of 2.7% of the length.

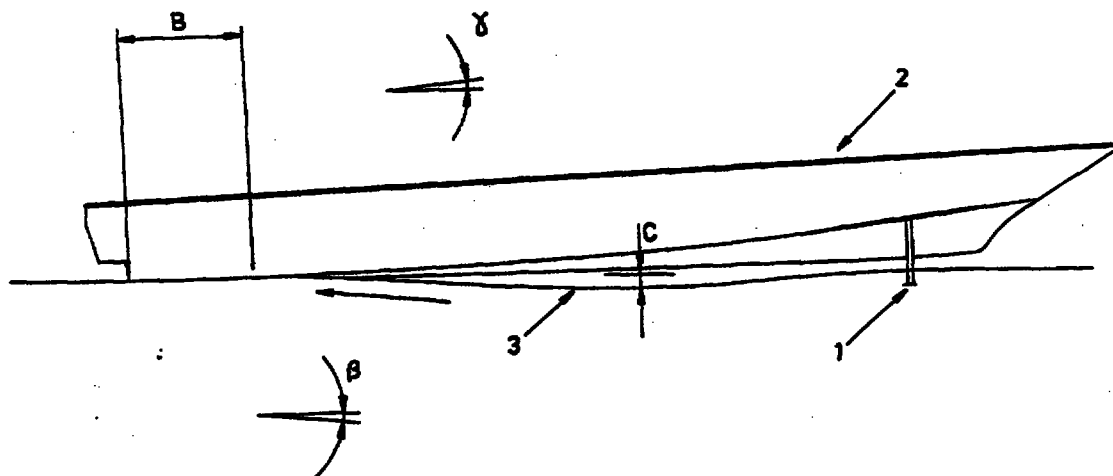
25 8. A support plane (1) for dynamic trimming of the floating position of a fast moving, planing or semi-planing ship hull, the ship hull including, during operation, a continuously submerged, rotatably attached and continuously adjustable wing (1), the wing
30 being adjustable relative the vertical movements of the ship hull and the wing having a wing shaped cross section, comprising:

35 the wing/support plane (1) being dimensioned with regard to the angle of operation, span (a) and cord length (b) so that the support plane generates a wave during the operation of the ship that is adjusted to the length and tonnage of the ship, the wave engaging the stern portion of the ship hull at a negative angle relative the horizontal plane, the wave providing for an

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : B63B 1/24	A1	(11) International Publication Number: WO 96/20100 (43) International Publication Date: 4 July 1996 (04.07.96)
(21) International Application Number: PCT/SE95/01583 (22) International Filing Date: 22 December 1995 (22.12.95) (30) Priority Data: 9404503-6 23 December 1994 (23.12.94) SE (71) Applicant (for all designated States except US): MARINE TECHNOLOGY DEVELOPMENT LTD. [GB/GB]; P.O. Box 15, Frances House, Sir William Place, St. Peter Port, Guernsey GY1 4HQ (GB). (72) Inventors; and (75) Inventors/Applicants (for US only): PAVLOV, Stanislav D. [RU/RU]; 2/40 M. Torez Street, PI Nr. 39, St. Petersburg (RU). PORODNIKOV, Serguej A. [RU/RU]; 9/1 Ruddneva Street, PI Nr. 88, St. Petersburg (RU). NORRSTRAND, Clas [SE/SE]; Trollgatan 21, S-742 33 Östhammar (SE). ERIKSSON, Hans [SE/SE]; Hasselgatan 5, S-740 71 Öregrund (SE). (74) Agents: ANDERSSON, Carlåke et al.; Dr. Ludwig Brann Patentbyrå AB, Drottninggatan 7, P.O. Box 1344, S-751 43 Uppsala (SE).		(81) Designated States: AL, AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TT, UA, UG, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, LS, MW, SD, SZ, UG). Published <i>With international search report.</i> <i>In English translation (filed in Swedish).</i>

(54) Title: METHOD AND MEANS FOR DYNAMIC TRIM OF A FAST, PLANING OR SEMI-PLANING BOATHULL



(57) Abstract

A mechanism and method for dynamic trimming of a floating position of a planing or semi-planing ship hull. The ship hull has a continuously adjustable support plane relative to the operational angle at the stem of the ship hull. The support plane has a wing shaped profile. The submerged support plane has a cord length (b), span (a) and a load (p) that are adapted, during the operation of the ship hull, to generate a wave (3) having a length, width and depth that is controlled to be adapted to the length and tonnage of the ship hull so that the wave engages a stern portion of the bottom of the ship hull at a negative angle relative to the horizontal plane. Additionally, the wave provides an increased free height distance (C) disposed in front of the stern portion of the ship hull.