United States Patent

Tomiyama et al.

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[54] HULL FORM OF A SHIP PROVIDED WITH A CYLINDRICAL BOW

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[52] **U.S. Cl.**..**114/56**

[51] **Int. Cl.**..**B63b 1/04**

[58] **Field of Search**..114/56

[56] **References Cited**

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[57] **ABSTRACT**

According to the invention the hull of the ship has at its bow a substantially cylindrical configuration at the full-load line and the configuration of a forwardly projecting fin at the ballast line. The upper portion of the forwardly projecting fin has the configuration of a convex ridge providing a transition between the cylindrical portion and forwardly projecting portion of the fin which is beyond the convex ridge configuration of the upper fin portion.

9 Claims, 8 Drawing Figures

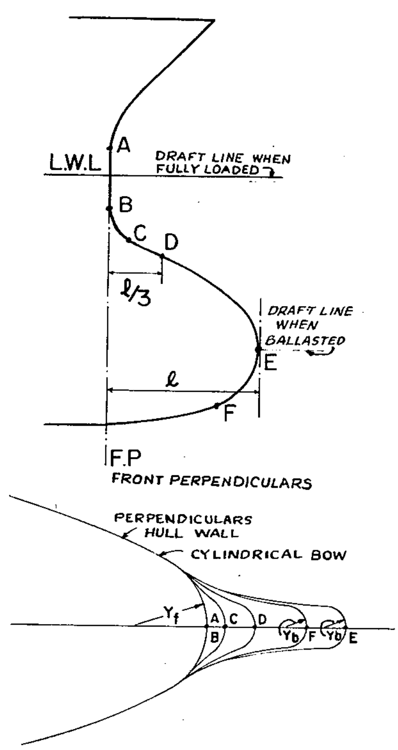

FIG. 1

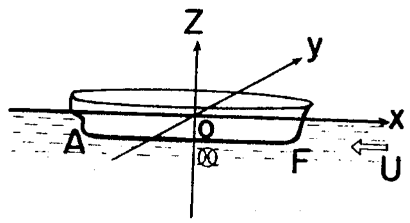

FIG. 2

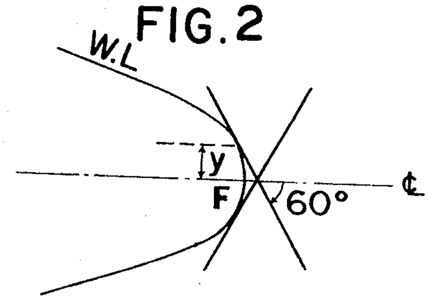

FIG. 3A

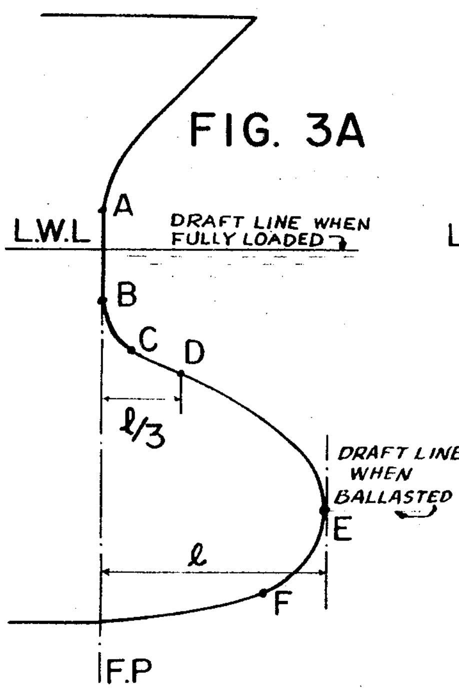

FIG. 4

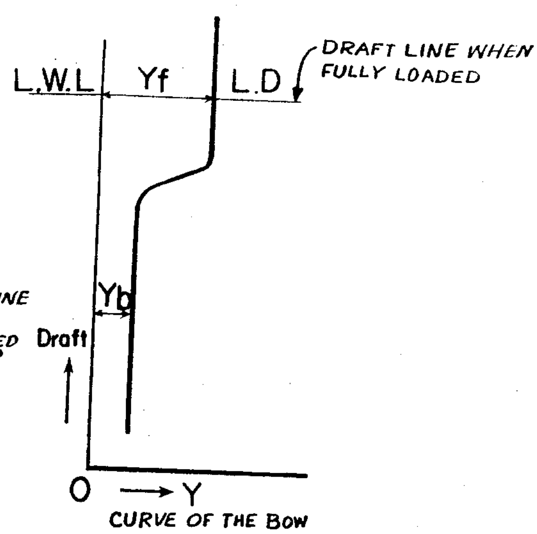

FIG. 3B

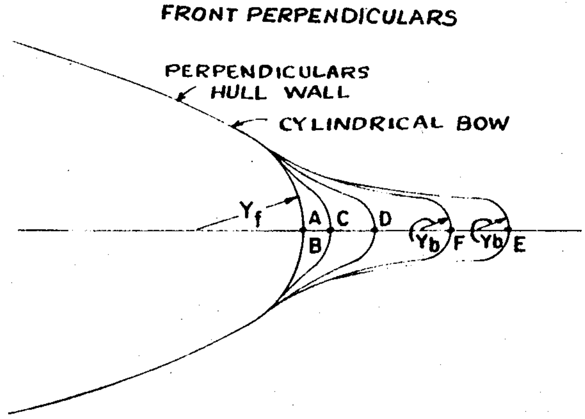

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FIG. 5

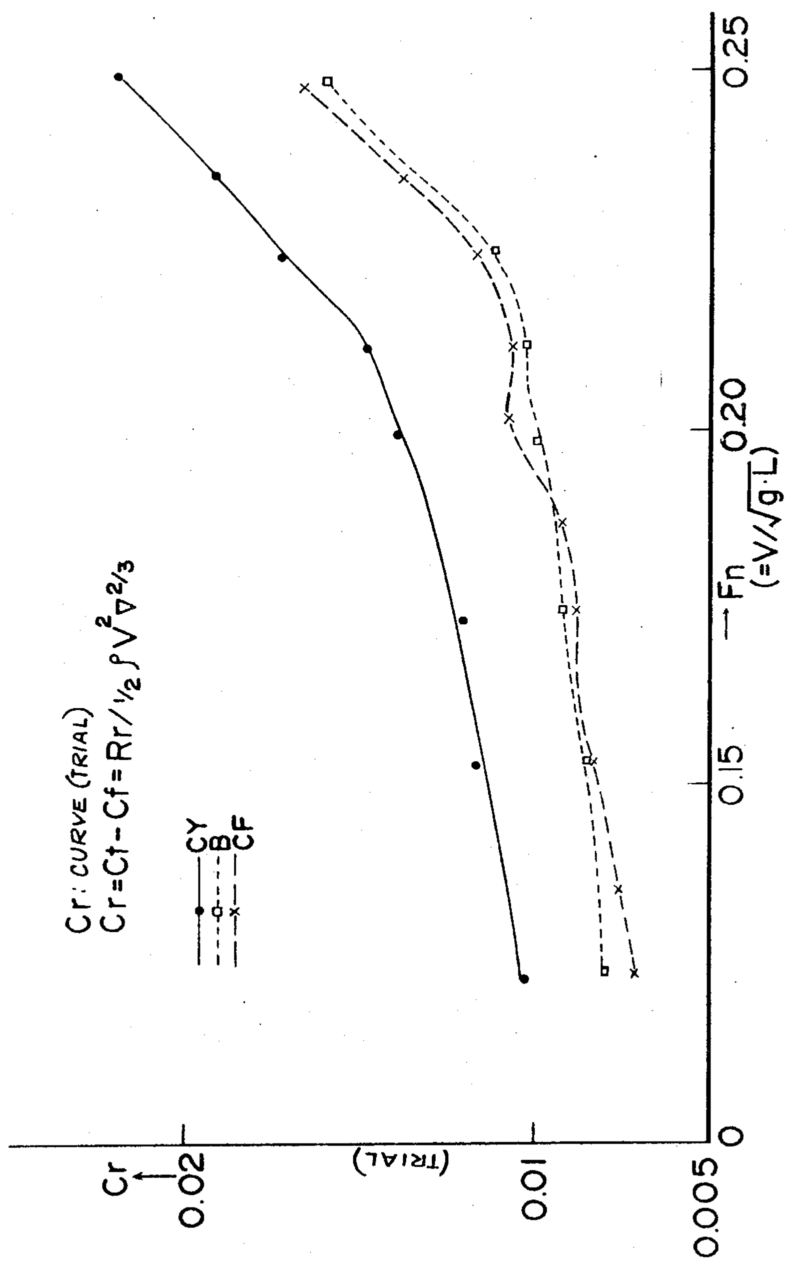

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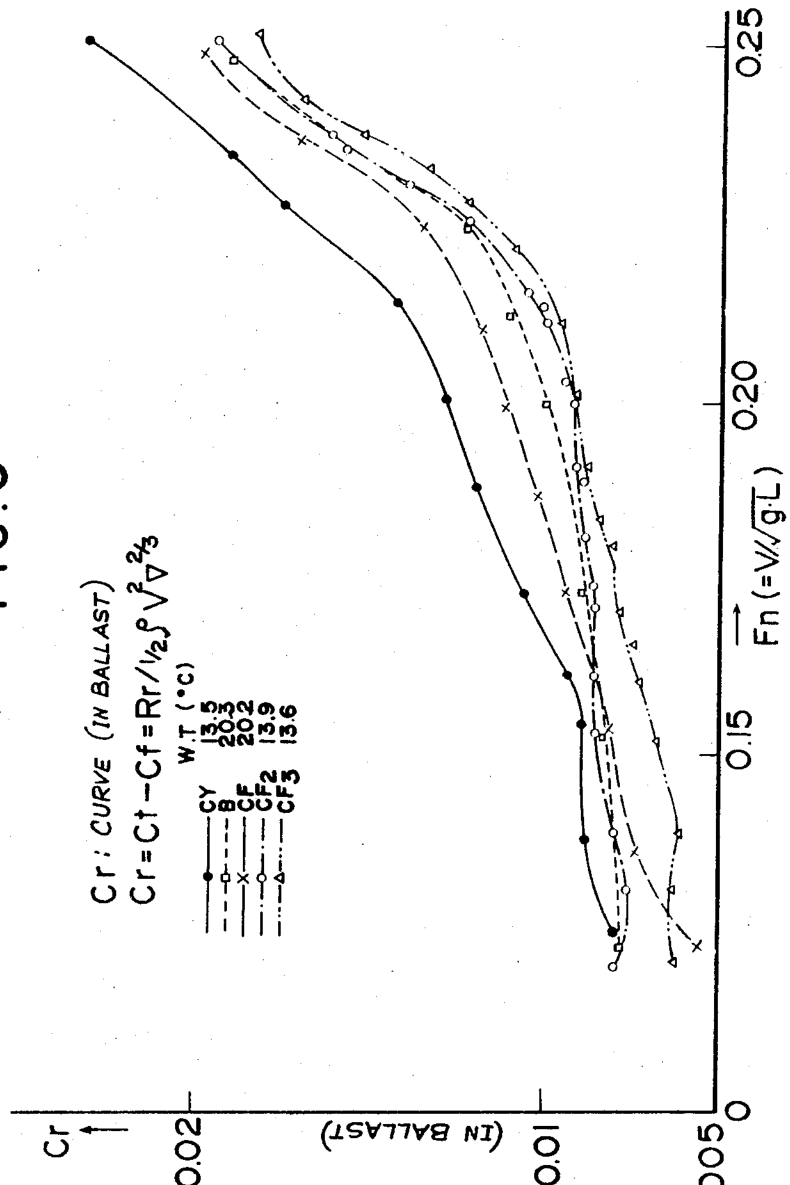
FIG. 6



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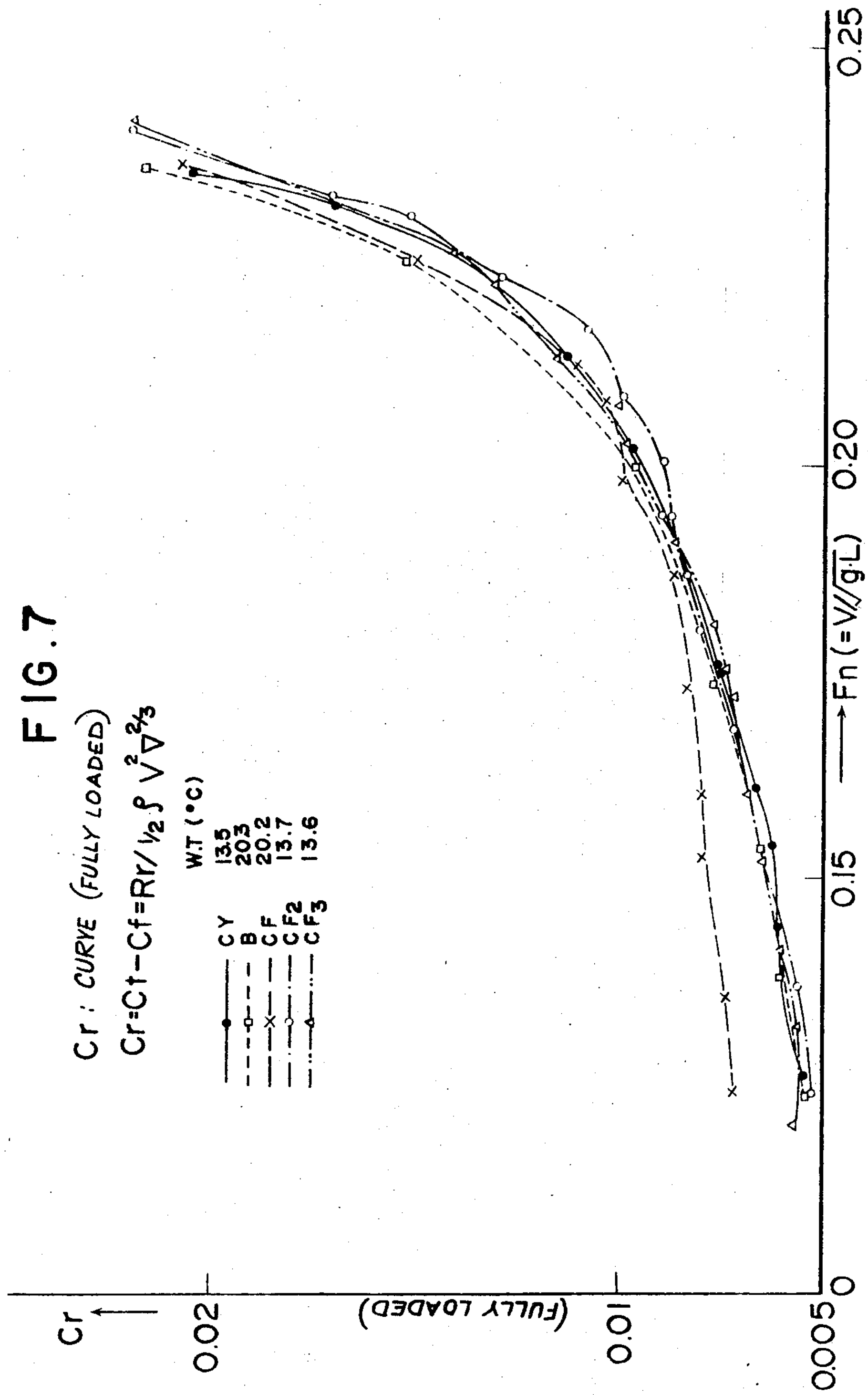

FIG. 7

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HULL FORM OF A SHIP PROVIDED WITH A CYLINDRICAL BOW

BACKGROUND OF THE INVENTION

This invention relates to hull forms of full form ships.

As is well known in the art, there are at present two main bow types for full form ships, namely so-called bulbous bows and non-bulbous bows. In either case, the bow may have a variety of forms, and the propulsive performance of each bow form has its merits and demerits. This presents problems in the determination of a suitable hull form for a ship.

The total hull resistance of a ship includes many components having different physical causes. When the total hull resistance of a full form ship is analyzed into, or mainly consists of, viscous resistance and wave making resistance, the greater part of the total resistance is the viscous resistance. However, theory in the field of viscous resistance has not developed sufficiently to enable a practically useful theoretical approach even to design of the forward portions of a ship.

It has been found that with existing full hull forms, none of the usual bow forms can show low resistance, or high propulsive performance, with the ship in both the fully loaded condition and the ballasted condition.

The bow form generally known as a cylindrical bow has a minimum resistance in the full loaded condition when properly designed to suit the main hull portion, but is inferior, in the ballasted condition as regards resistance, to a well designed bulbous bow suited to the main hull portions, which latter gives low resistance in a ballasted condition. The resistance and propulsive performance of the bulbous bow are, however, very sensitive to changes of the forward draft due to the alteration of load or other conditions, and so in extreme cases the bulbous hull form can give the worst results in overall comparison tests.

SUMMARY OF THE INVENTION

It is accordingly a primary object of the present invention to provide the hull of a ship with a configuration at its bow which will provide for superior performance not only in the fully loaded condition but also when the ship travels in ballasted condition.

Thus, it is a more specific object of the invention to provide for the bow of a ship hull a configuration which will achieve a performance superior to that which would be achieved simply from providing the bow of the ship with the optimum configuration for performance at the full-load line and the optimum configuration for performance at the ballast line.

It is one of the more important objects of the invention to achieve a highly satisfactory solution to the problem of combining the optimum bow configuration at the full-load line and the optimum bow configuration at the ballast line in such a way as to achieve a better ship performance under both fully loaded and ballasted traveling conditions.

It is particularly an object of the present invention to provide the achievement of the above objects in ships which have a block coefficient of at least 0.75 and a length between perpendiculars of at least 120 meters.

Thus, it is an object of the invention to provide a hull form having substantially the merits of the cylindrical bow hull form without being significantly inferior to a bulbous hull form even in ballasted condition.

BRIEF DESCRIPTION OF DRAWINGS

The invention is illustrated by way of example in the accompanying drawings which form a part of this application and in which:

FIG. 1 is a diagrammatical illustration of a coordinate system for the hull of a ship;

FIG. 2 is a diagrammatic representation of a measure of the bluntness of a hull form of the invention;

FIG. 3A is a diagrammatic side view of the bow or stem portion of a hull form embodying the present invention;

FIG. 3B is a diagrammatic plan view of hull sections of FIG. 3A taken at the several elevations A-F of FIG. 3A;

FIG. 4 is a graph diagrammatically illustrating the variation in bluntness of the bow or stem portion of FIG. 3, with changing draft;

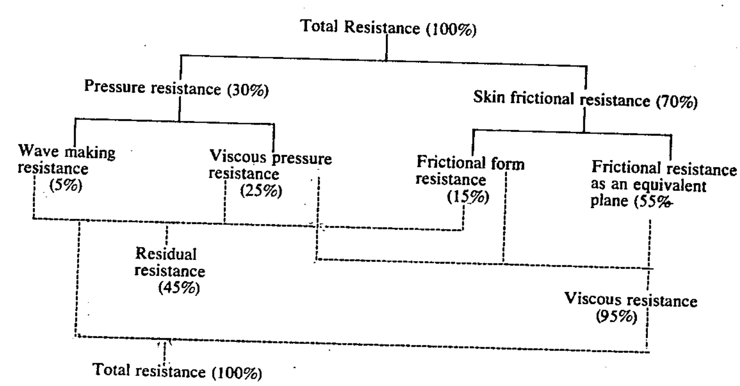
FIG. 5 is a graph diagrammatically illustrating the results of tests on conventional cylindrical and bulbous bow hull forms and a hybrid of both types; and

FIGS. 6 and 7 diagrammatically represent the results of comparative model tests on the three hull forms of FIG. 5 and on two additional forms constructed in accordance with the present invention, the graph of FIG. 6 representing the performance under ballasted conditions while the graph of FIG. 7 illustrates the performance under fully loaded conditions.

DESCRIPTION OF PREFERRED EMBODIMENTS

The advantages of a cylindrical bow lie in the excellent propulsive performance in the fully loaded conditions, and also in the reduced construction cost resulting from the fact that any double curvature on the bow surfaces extend over very large areas.

In more detail, the total resistance of the hull of a ship may be broken down in general as follows, according to the cause of the various resistance components:



The broken lines in the above diagram indicate a convenient way of classifying the resistance components. The figures in parentheses show the quantitative order of each resistance component of a typical full form ship in a low speed range but, of course, these figures are variable to a great extent depending on the size, shape, draft and speed of a particular ship.

The "frictional resistance as an equivalent plane" portion of the skin frictional resistance is related only to the wetted surface area of the hull, and so only the components of the residual resistance can be regarded as offering possibilities for decreasing the total resistance. Considering the forward half of the hull, of all the residual resistance components the wave making resistance and the frictional form resistance contribute significantly to the residual resistance.

It has been demonstrated in theory and in tests that both the wave making resistance and the frictional form resistance are largely determined by the angle of incidence of a main stream line against the water plane, as will now be illustrated.

As for wave making resistance, the well known Michell's integral formula gives (see FIG. 1 for coordinate axes)

$$R_w=\frac{4\rho g K o}{\pi}\int_0^{\pi/2}(p^2+Q^2)\sec^3\theta d\theta \qquad (1)$$

where R_w = Wave making resistance

$K_o=g/U^2$

U = Forward velocity of ship relative to water

$$\left.\begin{matrix}P\\Q\end{matrix}\right\}=\int\int\frac{dy}{dx}\exp\,(K_oz\sec^2\theta)^{\cos}_{\sin}\,(K_ox\sec\theta)\,dx\,dz$$

P: Water density

g: Gravitational acceleration

This formula (1shows directly that the tangent $(dy)/(dx)$ of the angle between water line and forward velocity is an important factor in wave making resistance. A comparable practically useful theoretical formula for frictional form resistance has not yet been established, but there is the following formula for giving the form factor K_{2f} (Ref. "Form Affects Viscous Resistance of Ships" by Ichiro Tanaka, Journal of the Society of Naval Architects of Japan, Vol. 113).

$$K_{2f}=2\left(\frac{8}{\pi}C_w-1\right)\frac{B}{L} \qquad (2)$$

K_{2f} = Frictional form resistance / Frictional resistance as an equivalent plane

L: Length of ship

B: Breadth of ship

C_w: Water plane coefficient (Water plane area / $L\times B$)

In the above formula (2), there is no such clearly indicated tangent factor as $(dy)/(dx)$ in formula (1), but when one considers that B/L represents the mean tangent of the angle between water and the stream, and the nature of the factor C, it will be apparent that the tangent of the angle between water line and the main stream line is again dominant.

Further, according to the theory of minimum wave resistance (Ref. "Ships of Minimum Wave Making Resistance," H. Maruo and others; Journal of the Society of Naval Architects of Japan, Vol. 114), it has been theoretically demonstrated that a hull form having minimum wave making resistance has a cylindrical bow form with finite bluntness of the stem edge when the draft is deep, and with smaller bluntness when the draft is shallow. This theoretically gives substance to the superiority of a cylindrical bow in the fully loaded condition.

On the basis of the above theories and experimental results, we have considered the idea of making the bow almost cylindrical in the region of the load water line and of leading a lower portion of the bow forwards to reduce the bluntness of the stem edge on this portion, paying particular attention to the optimum combination of the variation of bluntness of the stem edge with draft, and the angle the water line of the immediately following hull portions makes with the forward direction.

The term "bluntness" where used below and in the following claims in relation to the fore edge of the stem, means the half molded breadth of the hull at the point of contact between a water line parallel to the keel line and a tangent to that water line which tangent is at an angle of 60° to the center line of the hull. FIG. 2 illustrates this definition, the bluntness at the cross section illustrated therein being Y.

The invention provides a full form ship hull having a block coefficient of 0.75 or more and a length of 120 meters or more between perpendiculars, in which

(1) the bluntness Y_f (as hereinbefore defined) of the portion of the fore edge of the stem in the region of the fully loaded water line lies within the following limits:

$$\frac{B}{45}\leq Y_f\leq\frac{B}{15}\quad (B \text{ is the maximum molded breadth of the hull})$$

(2) said portion of the fore edge of the stem extends perpendicularly below the fully loaded water line at the fore edge of the stem by at least 15 percent of the fully loaded draft with substantially the same bluntness;

(3) below said portion of the fore edge a protruding portion extends forwards therefrom for a distance l where

$0.02\,L_{pp}\leq l\leq 0.04\,L_{pp}$ (L_{pp} is the length between perpendiculars)

(4) the bluntness (Y_b) of the fore edge of that part of the protruding portion more than $l/3$ ahead of the perpendicular portion is substantially constant and

$$0<Y_b\leq Y_f/3$$

In order that the invention may be more clearly understood, an embodiment in accordance with it will now be described, by way of example, with reference to the accompanying drawings.

Now the considerations underlying a hull form in accordance with the invention will be set out.

(I) The shape of the water plane at the bow in the region of the full loaded water line:

Here it is better to have a greater bluntness in the fore edge, thus reducing the angle of the immediately following water line leading to the maximum breadth of the hull. In this way, the local disturbances in the neighborhood of the bow end becomes greater in comparison with a finer form but, when the draft is deep, the flow along the hull surface is considered to be virtually two-dimensional, and the influences of such disturbances is not large. Therefore, the reduction of the angle of the water line immediately following the stem portion will be justified.

(II) The shape of the water plane at the bow in the neighborhood of the ballast line:

Here conditions are different, and it is better to reduce the local disturbances in the neighborhood of the fore edge because, as draft becomes shallower, the influences of the local disturbances becomes greater and their range also spreads because the flow becomes more three-dimensional. The position of the fore edge at the ballasted water line position does not affect the length of a ship L_{pp} as determined by the usual regulations, so in order to reduce the angle of the immediately succeeding water line the fore edge can here project ahead of the fore perpendicular as far as is permissible for practical use, thus producing a forward projection which is not bulbous but rather has the form of a forward projecting fin.

(III) Change of bluntness of the fore edge with draft:

This item relates to the fore edge region between the load and ballast water lines. The reasoning of item (I) is applicable to the region immediately below the full load water line. Thus the cylindrical stem portion can continue perpendicularly to a certain depth below the full load water line. The extent of the perpendicular portion below the full load water line should be determined according to the depth at which the undesirable influence of the term $\exp(K_oZ\sec^2\theta)$, resulting from the existence of a bulbous part in the aforementioned formula (I) becomes small, if the advantages of a cylindrical bow in the full-loaded condition are to be maintained. Then, the principles of item (II) can be applied to the upper part of the forward projection, making it less blunt, and it may be formed as a slightly convex ridge up to about the height of the wave surface generated at service speed in the ballasted condition. This requires a rapid decrease in the bluntness of the fore edge of the stem in the downward direction, but this can be arranged by suitably pairing the lines around the bow.

Tests have been carried out on models of a 23-type bulk carrier, having six different examples of bow form. In comparison tests a conventional cylindrical bow form (Hull form CY) showed the best propulsive performance in the fully loaded draft condition, while a thin bulbous form (Hull form B) was best in the ballasted draft condition.

Therefore, an attempt was made to combine the bow form in the neighborhood of the full load draft line from the hull form CY with the bow form in the neighborhood of the ballasted draft line from the hull form B, to determine whether a model ship of such a hybrid form will show the benefit of both.

Using only the principles of items (I) and (II) above, a new model ship of hull form CF was produced with a view to the fair drawing of the lines, and resistance tests in three conditions of load were made, together with the parental hull forms CY and B in the circulating water channel of the Applicants and the towing tank of the National University of Yokohama. The results of these tests are shown in FIGS. 5, 6 and 7 which relate respectively to a trial draft (shallowest) condition, ballasted condition and fully loaded condition. In each case the ordinate is Cr, the residual resistance coefficient, and the abscissa is Fn, Froude's number. However, except in the trial draft condition, the performance of the new model CF, lay between those of the two parental hull forms and the expected results were not achieved.

Accordingly, two other model ships, one having a hull form CF_2 in which the radius of the curvature of the fore edge on the fully loaded water line "R" was 2 meters, the same as it had been for the hull form CY, and the other having a hull form CF_3 (R = 3 meters), both satisfying the requisites of the present invention, were produced by utilizing the third principle, item (III), in addition to items (I) and (II).

In the hull form CF_2, the aforesaid Y_f was B/22.8, l was 0.027L and Y_b was a little less than $Y_f/3$, while in the hull form CF_3, Y_f was B/15.2, l was 0.027L and Y_b was a little smaller than $Y_F/3$.

Both hull forms CF_2 and CF_3 satisfied the conditions:

a. block coefficient $\geqslant$ 0.75

b. length between perpendiculars (L_{pp}) $\geqslant$ 120 meters

c. bluntness Y_f (as herein defined) of fore edge at fully loaded water line is between B/45 and B/15

d. length of protruding portion (l) is between $0.02L_{pp}$ and $0.04L_{pp}$ (see FIG. 3A)

e. bluntness of protruding portion fore edge projecting by more than $l/3$ is between 0 and $Y_f/3$ (see FIG. 4)

f. bluntness Y_f extends below water line by at least 15 percent of fully loaded draft (see FIGS. 3 and 4)

The graphs in FIGS. 6 and 7 show that the hull forms CF_2 and CF_3 surpassed their parental hull forms in both ballast and fully loaded conditions.

The water temperature in the comparison tests including the hull form CF was different from that in comparison tests including the hull form CF_2 and the hull form CF_3, but the hull form CY which was common to both tests showed almost the same coefficient of residual resistance. Thus, the respective coefficients of residual resistance of the five model ships are collectively indicated by comparison in FIG. 6 and FIG. 7.

The result of providing the substantially constant bluntness Y_f for the substantially cylindrical bow in the region of the full-load line and the substantially constant bluntness Y_b for the fin, as illustrated in FIG. 4, is particularly apparent from FIG. 3B from which the simplicity of the structure of the invention is clearly apparent and from which it is apparent that the results of the invention are achieved primarily by improving a cylindrical bow. The forwardly projecting fin, as is apparent from the lower portion of FIG. 3A, has a continuous convex curvature extending forwardly and downwardly to the front tip of the fin and then rearwardly and downwardly to a point beneath the cylindrical bow at the full-load line region. Moreover, it will be noted that the fin has a relatively small radius of curvature with the center of the curvature of the fin at least at its front tip region being situated behind the tip but forwardly of the bow portion which is of substantially cylindrical configuration at the full-load line.

Thus, a hull form according to the present invention has the merits both of a cylindrical bow and a bulbous bow simultaneously and, as will be apparent from the above test results, enables a decrease of the water resistance offered by the hull in both the fully loaded condition and the ballasted condition.

What is claimed is:

1. In a ship, a hull having a full-load line and a ballast line, said hull having in the region of said full-load line a bow of substantially cylindrical configuration extending vertically through a given depth and having a substantially constant first bluntness, and said hull having in the region of said ballast line a forwardly projecting continuously curved, convex fin of a substantially constant second bluntness which is substantially less than said first bluntness, and said fin having an upper portion of the configuration of a convex ridge forming a transition between the cylindrical portion at the full-load line and the forwardly projecting fin at the ballast line.

2. The combination of claim **1** and wherein said convex ridge at said upper portion of said forward projection extends approximately to the height of a wave surface generated at service speed in the ballasted condition of the ship.

3. The combination of claim **1** and wherein said cylindrical portion of the hull bow at the full-load line extends vertically through a depth below the full-load line of at least 15 percent of the fully loaded draft.

4. The combination of claim **1** and wherein said fin projects forwardly from said cylindrical portion by a distance which is between 0.02 and 0.04 of the length of the ship between perpendiculars.

5. The combination of claim **4** and wherein said transition region of the upper portion of said forward projection extends through approximately one-third of the total forward projecting length of said projection.

6. The combination of claim **1** and wherein said cylindrical portion of said bow has a bluntness which is between one forty-fifth and one-fifteenth of the maximum molded breadth of the hull.

7. A full form ship hull, said hull having a block coefficient of 0.75 or more, a length between perpendiculars of at least 120 meters, a stem, said stem having a fore edge and a fully loaded water line, in which:

1. the bluntness Y_f (as hereinbefore defined) of a portion of said fore edge of said stem in the region of said fully loaded water line lies within the following limits;

$$\frac{B}{45} \leqslant Y_f \leqslant \frac{B}{15}$$ (B is the maximum molded breadth of the hull)

2. said portion of said fore edge of said stem extends perpendicularly below said fully loaded water line at said fore edge of said stem by at least 15 percent of the fully loaded draft with substantially the same bluntness;

3. below said portion of said fore edge a protruding portion is provided, said protruding portion extending forwards therefrom for a distance l where;

$0.02\ L_{pp} \leqslant l \leqslant 0.04\ L_{PP}$ (L_{pp} is the length between perpendiculars)

4. the bluntness (Y_b) of said fore edge of that part of said protruding portion more than $l/3$ ahead of said perpendicular portion is substantially constant and

$$0 < Y_b \leqslant Y_f/3$$

8. The combination of claim **1** and wherein said fin curves forwardly and downwardly from said cylindrical portion at the full-load line to a front tip region of said fin, and said fin curving rearwardly and downwardly from said front tip region to a point situated beneath said cylindrical portion at the full-load line.

9. The combination of claim **8** and wherein said front tip region of said fin has a center of curvature situated rearwardly of said front tip region but forwardly of said cylindrical portion at the full-load line.

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