FORM OF THE HULL OF A LOW SPEED, FULL FORM SHIP
Kaname Taniguchi, Nippon Kisen Kaisha, Ltd., Japan, assignor to
Mitsui, Mitsubishi Jukogyo Kabushiki Kaisha,
Tokyo, Japan
Filed Mar. 31, 1966, Ser. No. 539,166
Claims priority, application Japan, Apr. 5, 1965, 40/20,782
10 Claims. (Cl. 114—56)

ABSTRACT OF THE DISCLOSURE
A hull for a low speed, full form ship, designed to operate either fully loaded or in ballast is disclosed as having a bow or stem divided into separate entrances, one for operation in the ballasted condition and the other for operation in the full load condition. The hull has forward and after perpendiculars and a bottom and the portion of the forward of the stem intersecting the water surface in the loaded condition projects rearwardly of the portion of a substantially vertical fore edge of the stem intersecting the water surface in the ballasted condition, by a substantial distance which is between 2% and 5% of the length of the forward and after perpendiculars.
The full form ship is designed to have a block coefficient of at least 0.75 and a Froude number of less than 0.2 in the loaded condition, with the fore draft in the ballasted condition between 30% and 50% of the fore draft in the loaded condition. The forward perpendicular is located rearwardly of that point on the fore edge of the stem which is at a height from the bottom of the hull of between 40% and 60% of the loaded fore draft.

Background of the invention
This invention relates to ship hulls and, more particularly, to a novel hull for a slow speed, full form ship, such as a tanker, a bulk carrier, an ore carrier, etc., having a block coefficient in excess of about 0.75 and a Froude number less than 0.2, operating as frequently in the ballasted condition as in the full load condition, but infrequently in an intermediate or partially loaded condition.

Heretofore, improvements in the hulls of full form ships having a block coefficient of more than about 0.75 have been made taking into consideration substantially only the design full load condition and substantially not taking into consideration the ballasted condition. In other words, neither an improvement nor a particular design of the hull form for the ballasted condition has been made, and the only thing taken into consideration is whether the hull, designed primarily for the full load condition, is, at least to a certain extent, satisfactory for the ballasted condition.

If a ship such as a liner is designed in such a manner, no particular difficulties arise. However, in the case of a tanker, a bulk carrier, or the like, the ballasted condition is fully as important as the full load condition. Consequently, it is highly desirable to provide, in the case of full form ship of the mentioned types, a hull having improved performance, with respect to propulsion in both the ballasted and the full load conditions of the ship.

Various proposals to improve the hull shape from the standpoint of obtaining better propulsive performance have been made. As one example, a so-called bulbous bow is known. However, such a bulbous bow is provided for preventing, though not fully, a bow wave from arising. In the case of a tanker or a bulk carrier, however, the loaded draft differs substantially from the ballasted draft. Consequently, if a bulbous bow is designed on the basis of a fully loaded condition, then the propulsive performance in the ballasted condition will be substantially decreased, and vice versa. Thus, a bulbous bow will produce a higher propulsive performance only in either the full load condition or the ballasted condition but not in both. A decrease in the propulsive performance in either condition in which the ship runs infrequently will be inevitable. It will be apparent that the problem of providing a hull for a full form ship of such a nature as to provide improved performance from the propulsive standpoint in both the fully loaded and the ballasted condition is difficult of solution.

As is well known to those familiar with naval architecture, the hull resistance of a ship consists of wave making resistance and viscous resistance. In the case of the usual freighter, the wave making resistance depends on the mutual interference of wave systems arising chiefly at a bow, a forward shoulder, an after shoulder, and a stern. The so-called Froude number is used as a measure of the relative speed of a ship, defined by taking into consideration the wave making resistance. The reason for this is that the Froude number is physically significant in indicating a degree of the interference among wave systems arising at the above-mentioned parts. And also in the case of a low speed (a Froude number of 0.2 or less) and full form ship having a block coefficient of 0.75 or more, the magnitude of wave making resistance has hitherto been regarded as a function of the Froude number, and has been used in the practical design of ships.

When the shape of a ship hull is designed on the basis of the conventional practice in which the wave interference and viscous resistances of the entire hull are taken into consideration, it is necessary to gather a large amount of information on different forms and combinations of forms for the several parts of the hull. For example, there are a great many ways in which various entrance or prow sections may be combined with various run or stern sections based upon a condition that the ratios of the main parts, the length of the cylindrical part of the hull and the position of the center of buoyancy are subject to change. In order to obtain such information, it has been necessary to conduct extensive tow tank experiments on various forms over a long period of time. As a matter of fact, only a minimum amount of information on the hull shape of a full form ship has been obtained.

In accordance with the present invention, it has been found that the hull of a low speed, full form ship is well designed, then resistance due to wave making occurs almost solely at the entrance, and is negligible at the after shoulder and the stern. Consequently, the interference among these wave resistances is also negligible. This is directly contrary to the present teaching that wave making resistance is dependent upon the mutual interference of wave systems arising chiefly at a bow, a forward shoulder, an after shoulder and a stern. Trial runs and tow tank tests have indicated that with a well designed hull shape for a low speed, full form ship, wave resistance is noticeable at the entrance only, but is negligible along the cylindrical part and the stern or run section, and that the interference of these resistances is also negligible. These tests have indicated that the wave making resistance substantially depends solely on the form of the entrance, and this has been confirmed experimentally with various lengths of cylindrical sections combined with various forms of runs.

From these considerations, the following principles may be stated:

1. In order to design a hull shape or form wherein the wavemaking resistance is low, it is necessary initially
to design an entrance section having a low wave making resistance.

(2) A cylindrical section and a run or stern section may be determined so that the designed displacement and length can be obtained taking into account the initially designed entrance section.

(3) After initially designing the entrance section, the cylindrical section and the run or stern section, a complete check on the hull shape is conducted.

The principle stated above is entirely new and will be hereinafter referred to as the “hull-form separation principle.”

In designing a hull in accordance with the “hull-form separation principle,” only the following three data are necessary for obtaining, including the best ratios of the main parts, the best hull shape for the ship:

(a) Data on an entrance section having a minimum wave making resistance obtained under a given speed, breadth, draft and entrance volume.

(b) Data on a run or stern section which has a good performance and in which viscous resistance and self- propulsion factors are taken into account.

(c) Data on the calculation of the viscous resistance of a determined or designed hull form.

Thus, designing of a hull in accordance with the “hull-form separation principle” of the present invention requires less data for systematic tests for the best possible hull shape than does the conventional design procedure in which wave making resistance is considered dependent upon the mutual interference of wave systems arising chiefly at a bow, a forward shoulder, an after shoulder, and a stern. It has been confirmed by the results of trial runs that the propulsive resistance of the best hull shape obtained by the present invention is, on an average, 10% less than that obtained by the conventional design method when hulls having the same dead weight tonnage and designed for operation at the same speed are compared.

In developing the present invention, the design according to the “hull-form separation principle” was used first to improve the propulsive performance in the full load condition. However, the propulsive performance in the ballasted condition was not improved as much as the full load condition. At the normal horsepower of a main engine, the speed in the ballasted condition is generally 1.0 to 1.2 knots greater than the speed in the full load condition. However, in the case of a hull designed in accordance with the invention, the propulsive performance of which was substantially improved in the full load condition, the difference in speed in the both conditions was equal to only about 0.6 knots.

The principles of the invention were then used to design a hull shape for best propulsive results in the ballasted condition so as to obtain design data on an entrance section which has a better propulsive performance in the ballasted condition, and thus efforts were directed to a new way of designing an entrance section. As a result, it has been possible to design a hull shape whose propulsive performance is at a maximum in both the full load condition and in the ballasted condition.

From these considerations, it was found that, to obtain a speed, in the ballasted condition, which is one or more knots higher than the speed in the full load condition, an entrance in the ballasted condition must be longer than an entrance in the full load condition.

It has been confirmed that, in the loaded condition of a relatively low speed ship having a block coefficient of a large value, its bow, of a relatively full form, results in an economically very efficient propulsive performance while, in the ballasted condition, its bow has a relatively fine form likewise resulting in economically excellent propulsive performance. The reason for this appears to be that, in the ballasted condition, the Froude number corresponding to the operating speed becomes larger than in the full load condition, and that, furthermore, the ratio of breadth to draft becomes larger.

Accordingly, an object of the present invention is to provide a hull for a slow speed, full form ship which has a maximum propulsive performance in both the fully loaded condition and the ballasted condition without raising the construction cost of the ship.

Another object of the invention is to provide a hull for low speed, full form ships which has a novel form of entrance providing maximum propulsive efficiency in both the fully loaded condition and in the ballasted condition.

A further object of the invention is to provide a hull for a low speed, full form ship in which the entrance, in the ballasted condition, is substantially longer than the entrance in the fully loaded condition.

Yet another object of the invention is to provide a hull for a low speed, full form ship, as thus described, in which, when the fore draft in the ballasted condition is 0.4 to 0.6 the loaded draft, the forward perpendicular is situated behind the point where the approximately vertical forward edge of the stem intersects the water surface by from 2 to 5% of the length between perpendiculars.

For an understanding of the principles of the invention, reference is made to the following description of a typical embodiment thereof as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a partial side elevation view of the fore part of the hull of a ship illustrating the comparison between a hull shape in accordance with the present invention and a conventional hull shape;

FIG. 2 is a plan view of water lines of the hull section shown in FIG. 1 in both the fully loaded and the ballasted condition;

FIG. 3 is a diagram illustrating a comparison of the propulsive performance of a hull in accordance with the present invention and a conventional hull;

FIG. 4 is a schematic plan view of the conventional hull form of a low speed, full form ship;

FIG. 5 is a graph diagrammatically illustrating, in the case of a tanker, the relation between speed and wave making resistance; and

FIG. 6 is a graph diagrammatically illustrating the results of studies upon which the present invention is based.

Referring first to FIG. 4, a low speed, full form ship is schematically shown in plan as generally comprising three parts. These parts are a cylindrical part 01 whose cross sectional shape is substantially constant, an entrance or prow section 02 and a run or stern section 03. The junctions of the cylindrical part 01 with the entrance and run sections are called, respectively, a forward shoulder 04 and after shoulder 05. As mentioned above, wave making resistance hitherto has been regarded as dependent upon the mutual interference of wave systems arising chiefly at the bow 06, forward shoulder 03, after shoulder 05 and stern 07.

As stated, it has been found, in accordance with the invention, that wave making resistance is noticeable substantially only at the entrance section 02 but is negligible at the run or stern sections 03 as well as along the cylindrical part 01, and the interference of such wave resistances is also negligible. This fact has been confirmed by the results of tests. For example, referring to FIG. 5, the relation between speed and wave making resistance in the case of a 67,000 d.w.t. tanker is shown. Four kinds of points are plotted, indicating the results of resistance tests of four large-size model ships which differ respectively from each other in the shape of their run sections but which have similar entrance sections. As will be apparent from FIG. 5, values indicating the wave making resistance of the several ships are substantially equal to one another. This indicates that wave making resistance depends substantially only on the entrance section.

Data from the research, upon which the present inven-
tion is based, are shown, by way of example, in FIG. 6. In this figure, the abscissa represent the degree of fullness of entrance expressed non-dimensionally, while the ordinates represent a length \( d \) which is equal to the difference in length when an entrance in the ballasted condition is made longer than the entrance in the fully loaded condition so that the speed in the ballasted condition may be, at the main output of a main engine or engine of such as one knot higher than that in the full load condition. It is assumed that a ratio \( m \) of displacement in the ballasted condition to that in the full load condition is equal to 0.5. The relation between these variables is shown by a group of curves, with the Froude number \( F_{\text{Hull}} \) expressed with respect to the breadth of the ship being used as a parameter. For example, if \( F_{\text{Hull}} \) is equal to 0.46, which is a mean value among the usual large size tankers, and the degree of fullness of an entrance \( X_e^* \) is equal to 0.43 then the entrance in the ballasted condition must be extended forwardly so as to be longer, by as much as 2.7% of the length between perpendiculars \( L_{pp} \), than the length in the fully loaded condition.

Referring now to FIG. 1, an entrance of a ship having a hull designed in accordance with the present invention is indicated at 1 in full lines. A broken line 2 and a dash dot line 3 indicate parts of conventional entrance sections.

In FIG. 2, the full line 1a represents the water line of a hull designed in accordance with the present invention and corresponding to a load water line 4 such as shown in FIG. 1. Full line 1b represents that water line of a hull designed in accordance with the present invention corresponding to a ballasted water line 5 when the hull is trimmed by the stern. The broken line 2b of FIG. 2 represents the water line of the conventional entrance section 2, shown in FIG. 1, corresponding to the ballasted water line 5. The dash dot line 3a of FIG. 2 represents that water line of the conventional entrance 3, shown in FIG. 1, corresponding to the load water line 4.

As will be clear from FIG. 1, in a hull designed in accordance with the invention, the lower part of the fore edge of the stem, represented by a curve passing through points C, D, and E, coincides with the dash dot line 3. An upper part of the fore edge of the stem, represented by a curve running from point F to point A where the fore edge intersects the load water line 4, coincides with the broken line 2 indicating a conventional hull shape. An intermediate part of the fore edge of the stem is shown by the combination of two fair curves, one of which runs from point A to point B while the other of which runs from point B to point C.

It will thus be understood that a hull in accordance with the present invention may be obtained, based on the conventional hull form 3, by moving backward, by a distance \( d \), that part of the entrance which is situated above the load water line 4. In this case, the distance \( d \) is chosen to be from 2% to 5% of the length \( L_{pp} \) between perpendiculars, and the height \( h \) from the bottom of the ship to the point C is fixed to be 0.4 to 0.6 times as much as the load draft \( H \). The reason for the selection of these values will be apparent hereinafter.

Based on the concept that entrances in the loaded condition and in the ballasted condition should differ in length, in accordance with the present invention there is provided a double or dual entrance consisting of an upper entrance and a lower entrance which differ in length from each other. It has been proven by tank tests, conducted using the actual model ship, that any interference between the upper entrance and the lower entrance was substantially non-existent, and that desirable characteristics for both the loaded condition and the ballasted condition were maintained. By way of example, data of these tests are indicated hereinafter.

In the diagram of FIG. 3, the shaft horsepower is represented on one coordinate axis and the speed on the other. This diagram shows the propulsive performances in the fully loaded and in the ballasted conditions, with the performances of a hull designed in accordance with the present invention being compared with those of a conventionally designed hull. The performance of a conventionally designed hull is shown by the lines \( d=4\% \) of \( L_{pp} \). The performance of a conventionally designed hull in accordance with the present invention is illustrated by the curves 1 shown in full lines, assuming that \( d \) is 4% of \( L_{pp} \). The performance of a conventionally designed hull is shown by broken lines 2 and dash dot lines 3, respectively. In the case of the fully loaded condition, the propulsive performance of a hull designed in accordance with the invention is clearly superior to that of a conventionally designed hull, as indicated at 2, and is almost equal to that of the conventionally designed hull form indicated at 3. The same applies to the case of the ballasted conditions, except that the curves 1 and 3 overlap each other.

From this it will be clear that the propulsive performance of a hull designed in accordance with the present invention is very much better than that of a conventionally designed hull form 2 having the same length \( L_{pp} \) between perpendiculars, and is almost equal to that of the conventional hull form 3 having a length \( L_{pp}+d \) between the perpendiculars. Thus, in accordance with the present invention, the weight of the hull and the construction costs can be reduced.

The reason why the aforementioned relations between the height \( h \) and the load draft \( H \) are chosen will now be explained. In the case of the ship mentioned above, the mean draft in the ballast condition is about 50% of the draft in the loaded condition. It varies in the range of 30 to 50% of the fore draft in the fully loaded condition, because generally such a ship runs trimmed by the stern. In addition, due to the forward movement of the ship, water rises upon the entrance section thereof. Taking these facts into consideration, the value of \( h \) has been determined to be as much as 10% of the load draft larger than the fore draft in the ballast condition, and namely from 40 to 60% of the load draft.

The reason why the value \( d \) has been determined to be from 2 to 5% of the length between perpendiculars, will now be explained. If the distance \( d \) is smaller than 2%, then the aimed effect of the present invention is not appreciable. Also, if \( d \) is larger than 5%, then the buoyancy of the hull part below the load water line is gradually increased. Accordingly, the hull portions near point A have to be reinforced so as to withstand the increased buoyancy. As a result, a decrease in the hull weight or a reduction of the material required cannot be obtained, while the cost of the ship increases. Moreover, the longer the horizontal distance from the point A to the point B, the less the usefulness of the ship becomes because of difficulties in maneuvering and docking the ship.

In the case described above, it is assumed that the fore edge \( C-D \) of the stem, in the ballasted condition, extends perpendicularly as shown in FIG. 1. Nevertheless, the fore edge may assume the form of either a straight line inclined at a small angle to the vertical or a smooth curve radius of whose curvature is large.

While a specific embodiment of the invention has been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A hull for a low speed, full form ship having forward and after perpendiculars, a stem including a fore edge having a substantially vertical portion, and a bottom; the portion of the fore edge of said stem intersecting the water surface in the loaded condition projecting rearwardly of the substantially vertical portion of the fore edge of said stem, which intersects the water surface in the ballasted condition, by a substantial distance.

2. A hull for a low speed, full form ship, as claimed in claim 1, in which said distance is from 2% to 5% of the length between said perpendiculars.

3. A hull for a low speed, full form ship, as claimed...
in claim 2, in which the fore draft in the ballasted condition is from 30% to 50% of the fore draft in the loaded condition.

4. A hull for a low speed, full form ship, as claimed in claim 2, in which the fore draft, in the ballasted condition, is from 0.4 to 0.6 of the loaded draft.

5. A hull for a low speed, full form ship, as claimed in claim 1, in which said forward perpendicular, when the fore draft is of the order of 1/2 the loaded draft, is located rearwardly of the point where the substantially vertical portion of the fore edge of the stem intersects the water surface by from 2 to 5% of the length between said perpendiculars.

6. A hull for a low speed, full form ship, as claimed in claim 1, having a block coefficient of at least 0.75 and a Froude number, in the loaded condition, of less than 0.2.

7. A hull for a low speed, full form ship, as claimed in claim 1, in which the ship operates only in the loaded condition or in the ballasted condition.

8. A hull for a low speed, full form ship, as claimed in claim 1, in which said forward perpendicular is located rearwardly of that point on the fore edge of said stem which is at a height from said bottom of between 40% and 60% of the loaded fore draft by a distance of between 2% and 5% of the length between said perpendiculars; the portion of the fore edge of said stem extending downwardly from said point being substantially vertical.

9. A hull for a low speed, full form ship, as claimed in claim 7, in which said ship operates only in the loaded condition on in the ballasted condition, and has a block coefficient of at least 0.75 and the Froude number, in the loaded condition, of less than 0.2; the fore draft in the ballasted condition being between 30% and 50% of the fore draft in the loaded condition.

10. A hull for a low speed, full form ship having forward and after perpendiculars, a stem and a bottom; said ship having a block coefficient of at least 0.75 and a Froude number, in the loaded condition, of less than 0.2 and operating only in the loaded condition or in the ballasted condition; the fore draft in the ballasted condition being between 30% and 50% of the fore draft in the loaded condition; said forward perpendicular being located rearwardly of that point on the fore edge of said stem which is at a height from said bottom of between 40% and 50% of the loaded fore draft, by a distance of from 2% to 5% of the length between said perpendiculars; the portion of the fore edge of said stem extending downwardly from said point being substantially vertical.

References Cited
UNITED STATES PATENTS
3,180,299 4/1965 Takao Inui -------------- 114--56
3,302,603 2/1967 Eckert -------------------- 114--56
FOREIGN PATENTS
1,033,968 6/1966 Great Britain.

ANDREW H. FARRELL, Primary Examiner.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,362,369
Kaname Taniguchi

January 9, 1968

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 56, "forward shoulder 03," should read "forward shoulder 04, --.

Signed and sealed this 2nd day of September 1969.

(SEAL)
Attest:
Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents