

DESCRIPTION

Title of Invention

LIFT GENERATOR

5 Technical Field

[0001]

The present invention relates to a lift generator which is positioned in front of a propulsion propeller in a ship.

10

Background Art

[0002]

In the related art, in some cases, a duct is provided as a lift generator in front of a propulsion propeller of a stern of a ship. A water flow flowing from a front side of the ship to a rear side thereof is generated in the lift generator by a rotation of the propulsion propeller. A cross section of the lift generator is an airfoil shape, and thus, a lift is generated in the lift generator by the water flow. The lift has a component (forward component) in a direction facing the front of the ship. As a result, power for rotating the propulsion propeller decreases. For example, the lift generator is described as a duct in PTLs 1 and 2.

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Citation List

Patent Literatures

[0003]

PTL 1: Japanese Patent Publication Laid-Open No. 2011-42204

PTL 2: Japanese Patent No. 4079742

Summary of Invention

Technical Problem

[0004]

A lift generator capable of further decreasing power for rotating a propulsion propeller is desired.

Embodiments of the present invention provide a lift generator capable of propelling a ship more largely in a case where a propulsion propeller is rotated by the same power as that of the lift generator (duct) of the related art.

Solution to Problem

[0005]

According to an aspect of the present invention, there is provided a lift generator which is positioned in front of a propulsion propeller in a ship having the propulsion propeller, in which the lift generator includes a wall portion which extends in a circumferential direction around an extension line of a center axis of the propulsion propeller, the wall portion having a flow path which penetrates in a direction of the extension line and is formed inside the wall portion, a shape of a cross section of the wall portion by a virtual plane

including the extension line is an airfoil shape in a set range in the circumferential direction wherein a lift including a forward component is generated in the airfoil shape, in the airfoil shape, an outer surface forming an outer peripheral surface of the wall portion is bent inward so as to form a recess, a thickness of the airfoil shape gradually decreases from a set position at which the thickness becomes the maximum value toward a rear side, and the airfoil shape satisfies $|dt/dx| \leq 0.15$ over an entire range from the set position to a trailing edge of the airfoil shape, in the inequality, dx indicates a minute change amount of a positional coordinate x in a chord direction of the airfoil shape, dt indicates a minute change amount of a thickness t with respect to dx , and $|dt/dx|$ indicates a magnitude of dt/dx .

[0006]

In embodiments of the present invention, in the airfoil shape, the outer surface forming the outer peripheral surface of the wall portion is bent inward so as to form the recess. Accordingly, in the airfoil shape, a circulation of a flow increases, and as a result, a pressure on the inner surface decreases and a lift increases. According to the increase in the lift of the airfoil shape, a forward component of the lift of the airfoil shape increases (hereinafter, this effect is referred to as an increase effect in a lift forward component).

[0007]

In addition, in embodiments of the present invention, a

magnitude of the ratio dt/dx between the minute change amount dx at the position x in the chord direction and the minute change amount dt of the thickness t at the position x is 0.15 or less over the entire range from the set position to the trailing edge (units of dx and dt are the same as each other). Accordingly, even when the above-described recess is formed, a fluid resistance of the airfoil shape is kept small (hereinafter, this effect is referred to as a fluid resistance reduction effect).

[0008]

Compared to a lift generator of the related art, in embodiments of the present invention, according to the above-described forward component increase effect of the lift and the above-described fluid resistance reduction effect, it is possible to propel the ship more largely by the same power (for example, refer to comparison of Comparative Examples 1 and 2 described later).

[0009]

The above-described lift generator may be configured as follows.

[0010]

In the airfoil shape, each of the outer surface and an inner surface forming an inner peripheral surface of the wall portion is curved toward the flow path side as a whole.

[0011]

In this way, each of the outer surface and the inner

surface of the airfoil shape is curved inside as a whole. Accordingly, a fluid is easily separated from the airfoil shape (particularly, inner surface), and thus, the fluid which has passed through the lift generator is disturbed and a flow rate of the fluid decreases. Therefore, the water stream having the reduced flow rate flows into the propulsion propeller. As a result, efficiency of the propulsion propeller is improved (hereinafter, this effect is referred to as a propeller efficiency improvement effect).

[0012]

Accordingly, compared to a lift generator of the related art, in embodiments of the present invention, according to the above-described increase effect of the lift forward component, the above-described fluid resistance reduction effect, and the above-described propeller efficiency improvement effect, it is possible to propel the ship more largely by the same power.

[0013]

The wall portion includes a lower end portion in which the outer peripheral surface faces vertically downward, and in the direction of the extension line, a length of the lower end portion is shorter than a length of an upper end portion of the wall portion.

[0014]

In the wall portion, a drag is easily generated in the lower end portion in which the outer peripheral surface faces vertically downward.

Meanwhile, according to the above-described embodiment, in the wall portion, the length of the lower end portion is shorter than the length of the upper end portion, and thus, the drag in the lower end portion is suppressed.

[0015]

A shape of the cross section of the lower end portion is an airfoil shape with no recess, or is not an airfoil shape.

[0016]

As described above, the cross section of the recess or the airfoil shape is not required in the lower end portion in which the drag is generated. Accordingly, the cross sectional shape of the lower end portion is able to be simplified.

[0017]

The set range includes at least a portion of a circumferential range in which the outer peripheral surface of the wall portion faces obliquely upward.

[0018]

In this range, a large lift is generated in the airfoil shape.

Advantageous Effects of Invention

[0019]

According to embodiments of the present invention, the outer surface of the airfoil shape is bent inward so as to form the recess, and thus, a large lift is generated in the airfoil shape. As a result, the forward component of the lift of the

airfoil shape increases.

In addition, the magnitude of the ratio dt/dx between the minute change amount dx at the position x in the chord direction and the minute change amount dt of the thickness t at the position x is 0.15 or less over the entire range from the set position to the trailing edge. Accordingly, even when the above-described recess is formed, a fluid resistance of the airfoil shape is kept small.

Compared to the lift generator of the related art, in embodiments of the present invention, according to the increase of the forward component of the lift and the fluid resistance reduction of the airfoil shape, it is possible to propel the ship more largely by the same power.

Brief Description of Drawings

[0020]

Fig. 1A illustrates a stern of a ship to which a lift generator according to an embodiment of the present invention is applied.

Fig. 1B is a view when viewed in a direction of arrows B-B in Fig. 1A.

Fig. 2A is a cross sectional view taken along line II-II of Fig. 1B.

Fig. 2B is a cross sectional view taken along line II-II of Fig. 1B and illustrates another characteristic of

an airfoil shape.

Fig. 3A is a view for describing a comparison between an airfoil shape of Specific Example of the embodiment of the present invention and an airfoil shape of Comparative Example 1.

Fig. 3B is another view for describing the comparison between Specific Example and Comparative Example 1.

Fig. 3C is a graph for describing the comparison between Specific Example and Comparative Example 1.

Fig. 4A is a view for describing a comparison between the airfoil shape of Specific Example of the embodiment of the present invention and an airfoil shape of Comparative Example 2.

Fig. 4B is another view for describing the comparison between Specific Example and Comparative Example 2.

Fig. 5A illustrates a difference between a shape of the airfoil shape of Specific Example and a shape of the airfoil shape of Comparative Example 2.

Fig. 5B is another graph illustrating the difference between the shapes of Specific Example and Comparative Example 2.

Fig. 6 illustrates Modification Example of the lift generator.

Description of Embodiments

[0021]

A preferred embodiment of the present invention will be described with reference to the drawings. In addition, the same reference numerals are assigned to the common portions in each drawing, and overlapping descriptions thereof are omitted.

[0022]

Fig. 1A is a side view illustrating a stern 1a of a ship 1 to which a lift generator 10 according to an embodiment of the present invention is applied.

[0023]

The ship 1 sails on the sea, a lake, or a river. For example, the ship 1 is a vessel or a warship. The ship 1 includes a propulsion propeller 3 in the stern 1a. The propulsion propeller 3 may be a screw propeller. The propulsion propeller 3 is rotationally driven underwater and generates a forward thrust of the ship 1. By a rotation of the propulsion propeller 3, a flow directed to the propulsion propeller 3 generated in a direction (hereafter, referred to as a backward direction) from a front side of the ship 1 toward a rear side thereof. Moreover, in the present application, the front side means a front side (bow side) of the ship 1 and the rear side means a rear side (stern side) of the ship 1.

[0024]

The lift generator 10 is provided in front of the propulsion propeller 3. That is, the lift generator 10 (an

airfoil shape 9 described later) is disposed in the backward flow generated by the propulsion propeller 3. In Fig. 1A, the lift generator 10 is positioned immediately front of the propulsion propeller 3.

5 [0025]

Fig. 1B is a view when viewed in a direction of arrows B-B in Fig. 1A. The lift generator 10 includes a wall portion 7 which extends in a circumferential direction (hereinafter, simply referred to as a circumferential direction) around an extension line Ce of a center axis C of the propulsion propeller 3. The wall portion 7 is formed inside the flow path 5 penetrating in a direction of the extension line Ce. The extension line Ce is positioned in the flow path 5. In addition, in Fig. 1, a circumferential end surface of an upper end portion in the wall portion 7 of the lift generator 10 is connected to the stern 1a, and the lift generator 10 is connected to the stern 1a via a connection member 6. However, the lift generator 10 may be connected to the stern 1a by other means. The center axis C may be directed in a direction (right-left direction in Fig. 1A) of a center line of a ship body in the ship 1 or may be inclined to one or both of right, left, upper, and lower sides of the ship 1.

[0026]

25 Fig. 2A is a cross sectional view taken along line II-II of Fig. 1B. In a set range (hereinafter, simply referred to as a set range) in the circumferential

direction, a shape of a cross section of the wall portion 7 by a virtual plane including the extension line Ce is an airfoil shape 9. This airfoil shape 9 will be described based on Fig. 2A. The shape of the cross section at any position in the circumferential direction in the set range may be the same as the airfoil shape 9 described later.

[0027]

The set range includes at least a circumferential range $\theta 1$ (refer to Fig. 1B) in which an outer peripheral surface 7a of the wall portion 7 faces obliquely upward. In the present embodiment, the set range is the entire range in which the wall portion 7 extends in the circumferential direction. In this case, in Fig. 1B, the set range includes the range $\theta 1$, a circumferential range $\theta 2$ (refer to Fig. 1B) in which the outer peripheral surface 7a of the wall portion 7 faces horizontally or obliquely downward, and a circumferential range $\theta 3$ in which the outer peripheral surface 7a of the wall portion 7 faces vertically downward.

[0028]

A chord Bc (that is, a straight line of the airfoil shape 9 which connects a leading edge Pf and a trailing edge Pr of the airfoil shape 9 in Fig. 2A to each other) of the airfoil shape 9 is inclined from the center axis C of the propulsion propeller 3. In addition, points on the chord Bc are away from the extension line Ce of the center axis C toward the front side. That is, a distance D1

between each of the points on the chord Bc and the extension line Ce increases in a direction (radial direction) orthogonal to the extension line Ce as the points on the chord Bc move toward the front side.

5 Accordingly, a lift having a forward component is generated in the airfoil shape 9. For convenience, in Fig. 2A, the extension line Ce moves close to the airfoil shape 9 from an actual position in a parallel manner for illustration.

[0029]

10 In the airfoil shape 9 (that is, an outline of the airfoil shape 9), an outer surface 9a forming the outer peripheral surface 7a (refer to Figs. 1A and 1B) of the wall portion 7 is bent inward (flow path 5 side) so as to form the recess 11. In the present embodiment, in the
15 airfoil shape 9, each of the outer surface 9a and an inner surface 9b forming an inner peripheral surface 7b of the wall portion 7 is curved inward as a whole. In this regard, the lift generator 10 is close to the propulsion propeller 3 such that a turbulence due to fluid separation on the
20 outer surface 9a and the inner surface 9b (particularly, the inner surface 9b) flows into the propulsion propeller 3.

[0030]

A thickness t of the airfoil shape 9 becomes the maximum value at a set position P_s in a chord direction.
25 The chord direction is a direction parallel to the chord Bc. In the present embodiment, the set position P_s is positioned on the front side from a center (that is, a

point which bisects the chord Bc) of the chord Bc. However, the set position Ps may be the center of the chord Bc or may be positioned on the rear side from the center of the chord Bc.

5 [0031]

The thickness t of the airfoil shape 9 is a thickness in a direction orthogonal to a camber line Lc of the airfoil shape 9. The camber line Lc is a line which extends from the leading edge Pf to the trailing edge Pr and is a line equidistant from the outer surface 9a and the inner surface 9b of the airfoil shape 9 (that is, a one-dot chain line in Fig. 2A). In addition, the thickness t of the airfoil shape 9 in a positional coordinate x in the chord direction is a length of a line which is orthogonal to the camber line Lc at a position on the camber line Lc at which the position in the chord direction becomes the coordinate x and extends from the outer surface 9a to the inner surface 9b. The thickness t of the airfoil shape 9 gradually increases from the leading edge Pf to the set position Ps toward the rear side and gradually decreases from the set position Ps to the trailing edge Pr toward the rear side.

[0032]

As understood from Fig. 1A, a chord length (or a dimension of the airfoil shape 9 in the direction of the extension line Ce) of the airfoil shape 9 in the cross section of the wall portion 7 decreases toward the lower

side. Accordingly, the chord length of the lower end portion (that is, a portion in the range 03) of the wall portion 7 is shorter than the chord length of the upper end portion of the wall portion 7.

5 [0033]

The lift generator 10 of the present embodiment has the following characteristics A to C.

[0034]

(Characteristic A)

10 In Fig. 2A, the airfoil shape 9 satisfies the following inequality over the entire range from the set position Ps to the trailing edge Pr.

$$|dt/dx| \leq 0.15$$

Here, dx indicates a minute change amount of the positional coordinate x in a chord direction of the airfoil shape 9, dt indicates a minute change amount of the thickness t with respect to dx in the positional coordinate x, and $|dt/dx|$ indicates a magnitude (absolute value) of dt/dx. dt/dx may be a differential of the thickness t by the positional coordinate x. In other words, dt/dx is a ratio of dt to minute change amount dx. The units of the positional coordinate x and the thickness t are the same as each other. $|dt/dx|$ is 0.15 or less in the entire range from the set position Ps to the trailing edge Pr, and thus, a fluid resistance of the airfoil shape 9 is kept low.

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[0035]

(Characteristic B)

Fig. 2B is a cross sectional view taken along line II-II of Fig. 1B and illustrates another characteristic of an airfoil shape 9. A length of the chord Bc is defined as C, the maximum value of the thickness t of the airfoil shape 9 is defined as t_m , and the maximum distance between the chord Bc and the outer surface 9a in the direction orthogonal to the chord direction is defined as D_m .

It is preferable that t_m/C satisfies $0.05 \leq t_m/C \leq 0.3$.

It is preferable that D_m/t_m satisfies $0.06 < D_m/t_m \leq 0.4$,
10 $0.2 < D_m/t_m \leq 0.4$, or $0.3 < D_m/t_m \leq 0.4$.

[0036]

D_m/t_m is an index which indicates a size of the recess 11. By setting the magnitude of D_m/t_m to the above-described ranges, compared to a case where the recess 11 is not present, a circulation of the flow in the airfoil shape 9 increases. As a result, a pressure on the inner surface 9b decreases, and the lift generated in the airfoil shape 9 increases. Accordingly, the forward component of the lift of the airfoil shape 9 increases.

20 [0037]

(Characteristic C)

In Fig. 1A, when viewed in the direction (right-left direction in Fig. 1A) of the center line of the ship body in the ship 1, the entirety of a rear end 13 (that is, a rear end 13 extending in the circumferential direction) of the wall portion 7 is positioned inside a region R (hereinafter, referred to as a passage region R of the

propulsion propeller 3) in which the propulsion propeller 3 rotates and passes. According to this configuration, the flow passes through the airfoil shape 9 and becomes the turbulence as described above, and thus, all or almost all of the flows having a reduced flow rate flow into the passage region R of the propulsion propeller 3. As a result, efficiency of the propulsion propeller 3 is more reliably improved.

[0038]

However, according to the present invention, when viewed in the direction of the center line of the ship body in the ship 1, a lower end of the wall portion 7 may be positioned in the passage region R of the propulsion propeller 3. In this case, preferably, the extension line Ce of the center axis C of the propulsion propeller 3 is positioned in the flow path 5 (that is, inside the wall portion 7).

[0039]

Next, Specific Example of the airfoil shape 9 according to the present embodiment will be described in comparison with Comparative Example 1.

[0040]

Fig. 3A illustrates the airfoil shape 9 of Specific Example of the embodiment and an airfoil shape of Comparative Example 1. In Fig. 3A, a solid line illustrates Specific Example and a broken line illustrates Comparative Example 1. The airfoil shape 9 of Comparative

Example 1 does not substantially have the recess on the outer surface.

[0041]

As illustrated in Fig. 3B, lifts in the same
5 direction are generated in the airfoil shapes of Specific Example and Comparative Example 1. However, the lift in Specific Example is larger than that of Comparative Example 1. As a result, the forward component of the lift of Specific Example is larger than that of Comparative Example
10 1.

[0042]

Fig. 3C illustrates a reduction effect (hereinafter, referred to as a power reduction effect) of power for rotationally driving the propulsion propeller 3 as a fluid
15 resistance reduction amount of the ship 1 in a case where a certain thrust is generated in the ship. That is, Fig. 3C illustrates a value obtained by converting the power reduction effect obtained by integrating the thrust obtained by the rotation of the propulsion propeller 3 and
20 the fluid resistance and lift of the lift generator 10 into the fluid resistance reduction amount of the ship 1. The results in Fig. 3C were obtained by simulation by Computational Fluid Dynamics (CFD). In this simulation, in Specific Example and Comparative Example 1, the airfoil
25 shapes were different from each other as illustrated in Fig. 3A, and other conditions were the same as each other.

[0043]

As illustrated in Fig. 3C, in a case where the fluid resistance reduction amount of Comparative Example 1 was 100%, the fluid resistance reduction amount of Specific Example is slightly larger than 110%. Accordingly, the fluid resistance (power) of Specific Example is reduced slightly larger than 10% compared to Comparative Example 1.

[0044]

Next, Specific Example of the airfoil shape 9 according to the present embodiment will be described in comparison with Comparative Example 2.

[0045]

Fig. 4A illustrates the airfoil shape 9 of Specific Example of the embodiment and an airfoil shape of Comparative Example 2. In Fig. 4A, a solid line illustrates Specific Example similarly to the case of Fig. 3A and a broken line illustrates Comparative Example 2. The airfoil shape of Comparative Example 2 includes a recess having approximately the same size as the size of the recess of Specific Example. However, the differential dt/dx of the thickness t by the positional coordinate x in the chord direction of Comparative Example 2 is different from that of Specific Example.

[0046]

Fig. 5A is a graph illustrating a relationship between the positional coordinate x in the chord direction and the thickness t of the airfoil shape 9. In Fig. 5A, a horizontal axis illustrates the coordinate x in a case

where the coordinate x of the leading edge P_f is set to zero and the chord length is set to 1. In Fig. 5A, a vertical axis illustrates a value (thickness/chord length) obtained by dividing the thickness t of the airfoil shape 9 by the chord length.

[0047]

Fig. 5B is a graph illustrating a relationship between the positional coordinate x in the chord direction and the above-described differential dt/dx . In Fig. 5B, a horizontal axis illustrates the coordinate x in a case where the coordinate x of the leading edge P_f is set to zero and the chord length is set to 1. In Fig. 5B, a vertical axis illustrates a value of the differential dt/dx .

[0048]

In Specific Example and Comparative Example 2, as illustrated in Fig. 5A, the thickness t of the airfoil shape 9 becomes the maximum value at the set position P_s at which the coordinate x is 0.3.

In Specific Example, as shown in Fig. 5B, the magnitude (absolute value) of the dt/dx is smaller than 0.15 over the entire range from the set position P_s to the trailing edge P_r (that is, the position of the rear end 13) of the airfoil shape 9. Comparative Example 2 is different from Specific Example. That is, in Comparative Example 2, the magnitude of dt/dx is more than 0.15 over the range in which the coordinate x is from the position of 0.86 to the rear end of the airfoil shape.

[0049]

Similarly to the case of Fig. 3C, Fig. 4B illustrates the value obtained by converting the power reduction effect into the fluid resistance reduction amount of the ship. The results in Fig. 4B were obtained by simulation by Computational Fluid Dynamics (CFD). In this simulation, in Specific Example and Comparative Example 2, the airfoil shapes were different from each other as illustrated in Fig. 4A, Fig.5A, and Fig.5B and other conditions were the same as each other.

[0050]

As illustrated in Fig. 4B, in a case where the fluid resistance reduction amount of Comparative Example 2 was 100%, the fluid resistance reduction amount of Specific Example was slightly less than 115%. Accordingly, the fluid resistance (power) of Specific Example is reduced slightly smaller than 15% compared to Comparative Example 2.

[0051]

The present invention is not limited to the above-described embodiment, and it is needless to say that various modifications are able to be applied to the present invention within the scope of the technical idea of the present invention. For example, any one of the following Modification Examples 1 to 3 may be singly adopted or two or more of Modification Examples 1 to 3 may be arbitrarily selected and adopted. In this case, matters not described below may be the same as described above.

[0052]

(Modification Example 1)

The above-described set range in which the shape of the cross section of the wall portion 7 is the above-described airfoil shape 9 is not limited to the above-described range. For example, the set range may not include a portion or all of one or both of the range 02 and the range 03 which are illustrated in Fig. 1B. In addition, the set range may include only a portion of the above-described range 01. In this case, the set range may not include a portion or all of one or both of the range 02 and the range 03.

[0053]

(Modification Example 2)

Fig. 6 corresponds with Fig. 1B and illustrates Modification Example 2 of the lift generator 10. As illustrated in Fig. 6, the flow path 5 inside the wall portion 7 is open vertically downward (in the radial direction). In addition, the flow path 5 may be open in another radial direction (that is, a direction orthogonal to the extension line Ce).

[0054]

(Modification Example 3)

In a case where a plurality of propulsion propellers 3 is provided in the stern 1a, the lift generator 10 may be provided in front of each propulsion propeller 3.

[0055]

(Modification Example 4)

The shape of the cross section of the lower end portion in the wall portion 7 is the airfoil shape but may not have the recess 11. Alternatively, the shape of the cross section of the lower end portion may not be the airfoil shape.

Reference Signs List

[0056]

1: ship, 1a: stern, 3: propulsion propeller, 5: flow path, 6: connection member, 7: wall portion, 7a: outer peripheral surface, 7b: inner peripheral surface, 9: airfoil shape, 9a: outer surface, 9b: inner surface, 10: lift generator, 11: recess, 13: rear end, Bc: chord, C: center axis, Ce: extension line of center axis, D1: distance between extension line of center axis and point on chord, Ps: set position, Pf: leading edge, Pr: trailing edge

CLAIMS

1. A lift generator which is positioned in front of a propulsion propeller in a ship having the propulsion propeller,

wherein the lift generator includes a wall portion which extends in a circumferential direction around an extension line of a center axis of the propulsion propeller, the wall portion having a flow path which penetrates in a direction of the extension line and is formed inside the wall portion,

wherein a shape of a cross section of the wall portion by a virtual plane including the extension line is an airfoil shape in a set range in the circumferential direction wherein a lift including a forward component is generated in the airfoil shape,

wherein in the airfoil shape, an outer surface forming an outer peripheral surface of the wall portion is bent inward so as to form a recess,

wherein a thickness of the airfoil shape gradually decreases from a set position at which the thickness becomes the maximum value toward a rear side, and

wherein the airfoil shape satisfies $|dt/dx| \leq 0.15$ over an entire range from the set position to a trailing edge of the airfoil shape, in the inequality, dx indicates a minute change amount of a positional coordinate x in a chord direction of the airfoil shape, dt indicates a minute change amount of a thickness t with respect to dx , and $|dt/dx|$ indicates a magnitude of dt/dx .

2. The lift generator according to claim 1,
wherein in the airfoil shape, each of the outer
surface and an inner surface forming an inner peripheral
surface of the wall portion is curved toward the flow path
side as a whole.

3. The lift generator according to claim 1 or 2,
wherein the wall portion includes a lower end
portion in which the outer peripheral surface faces
vertically downward, and
wherein in the direction of the extension line, a
length of the lower end portion is shorter than a length of
an upper end portion of the wall portion.

4. The lift generator according to claim 3,
wherein a shape of the cross section of the lower
end portion is an airfoil shape with no recess, or is not
an airfoil shape.

5. The lift generator according to any one of
claims 1 to 4,
wherein the set range includes at least a portion of
a circumferential range in which the outer peripheral
surface of the wall portion faces obliquely upward.