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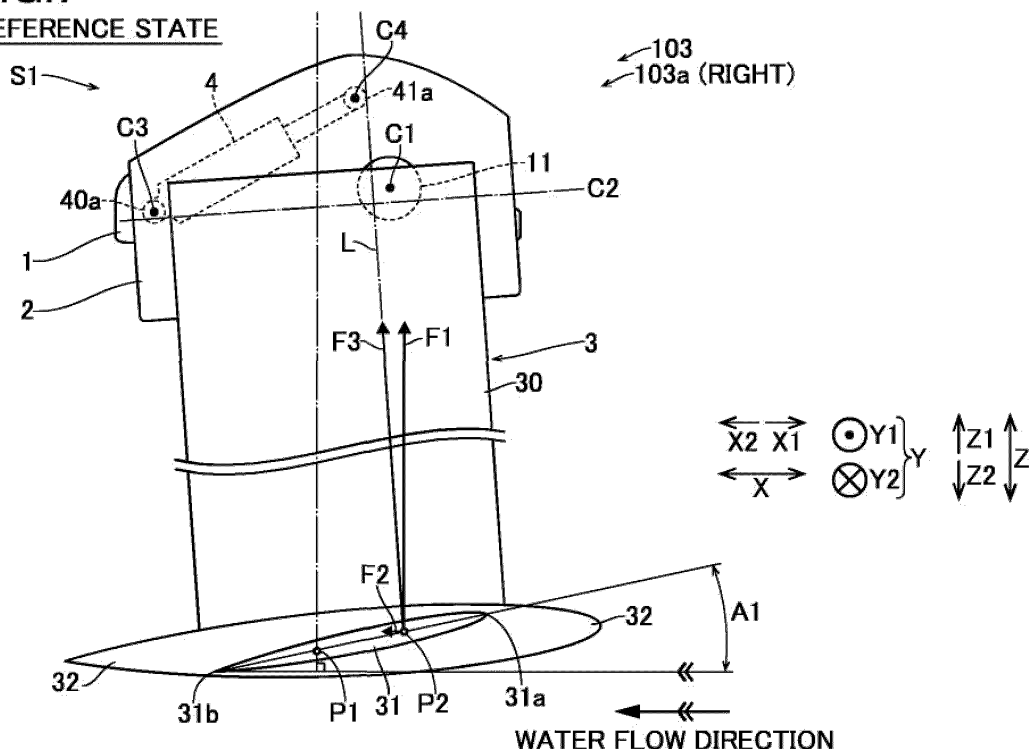
(54) **HYDROFOIL MODULE**

(57) A hydrofoil module (103, 203) includes a clamp bracket (1), a swivel bracket (2), a wing (3), a rotation actuator (4), and a pair of hydrofoil modular portions (103a) each including the clamp bracket, the swivel bracket, the wing, and the rotation actuator, and in a

reference state (S1) in which angles of attack of hydrofoils (31) of the pair of hydrofoil modular portions are same as each other, a first rotation shaft (11) is located forward of a center of area (P) of a hydrofoil (31).

FIG. 7

REFERENCE STATE



Description

[0001] The present invention relates to a hydrofoil module including hydrofoils and a marine vessel having a hull provided with a hydrofoil module.

[0002] A hydrofoil module and a marine vessel each including a hydrofoil are known in general. Such a marine vessel is disclosed in JP 9-207872 A, for example.

[0003] JP 9-207872 A discloses a marine vessel including a wing including a hydrofoil strut and a hydrofoil fixed to a lower end of the hydrofoil strut, a telescopic actuator to change the angle of attack of the hydrofoil, and a hull. The actuator adjusts the angle of attack of the hydrofoil by extending and retracting to press the wing and rotate the hydrofoil around a predetermined rotation center. A resultant force of a lift force and a drag force that raises the hull acts on the hydrofoil.

[0004] Although not clearly described in JP 9-207872 A, a resultant force of a lift force and a drag force acts on the hydrofoil when the hydrofoil is raising the hull, and thus the resultant force causes a moment around the rotation center of the hydrofoil to act on the wing. Therefore, when the angle of attack of the hydrofoil is maintained, it is necessary to maintain the position of the wing by applying a pressing force to the wing using the actuator in order to resist the moment acting on the hydrofoil so as to prevent the wing from rotating. Therefore, a relatively large load is imposed on the actuator that changes and maintains the angle of attack of the hydrofoil, and it is desired to reduce the load on the actuator.

[0005] It is an object of the present invention to provide a hydrofoil module and a marine vessel having a hull provided with a hydrofoil module that each reduce a load on a rotation actuator that changes and maintains the angle of attack of hydrofoils. According to the present invention, said object is solved by a hydrofoil module having the features of independent claim 1. Moreover, said object is solved by a marine vessel having a hull provided with the hydrofoil module according to claim 14. Preferred embodiments are laid down in the dependent claims.

[0006] A hydrofoil module according to an example embodiment includes a clamp bracket including a first rotation shaft having a first rotation center axis extending in a right-left direction and removably attached to a hull, a swivel bracket rotatably attached to the clamp bracket via the first rotation shaft, a wing including a hydrofoil located in water, and a strut having a pillar shape and including a lower end on which the hydrofoil is provided and an upper end attached to the swivel bracket, a rotation actuator configured to rotate the wing together with the swivel bracket in a forward-rearward direction around the first rotation center axis to change an angle of attack of the hydrofoil, and a pair of hydrofoil modular portions provided on both sides of the hull in the right-left direction, each including the clamp bracket, the swivel bracket, the wing, and the rotation actuator. The pair of hydrofoil modular portions are configured to provide the hull with

a lift force during sailing to raise the hull, and in a reference state in which angles of attack of hydrofoils of the pair of hydrofoil modular portions are same as each other, the first rotation shaft is located forward of a center of area of the hydrofoil. The "center of area of the hydrofoil" described above refers to the center of mass (center of gravity) of the hydrofoil in a plan view when the mass of the hydrofoil is uniformly distributed in a horizontal direction.

[0007] A hydrofoil module according to an example embodiment includes the wing including the hydrofoil and the strut, and the rotation actuator to rotate the wing in the forward-rearward direction around the first rotation center axis to change the angle of attack of the hydrofoil. In the reference state in which the angles of attack of the hydrofoils of the pair of hydrofoil modular portions on both sides of the hull in the right-left direction are the same as each other, the first rotation shaft is located forward of the center of area of the hydrofoil. It is known that in the horizontal direction, the center of lift, which is a point of action at which the lift force acts on the hydrofoil, is located forward of the center of area of the hydrofoil. Therefore, with the structure described above, in the reference state, the first rotation shaft is located on the center of lift side, which is forward of the center of area of the hydrofoil, and thus the line of action of the resultant force of the lift force and the drag force of the hydrofoil is located relatively close to the first rotation shaft. Therefore, in the reference state, a moment around the first rotation center axis generated by the resultant force of the hydrofoil is reduced. Consequently, in the reference state, the load on the rotation actuator that changes and maintains the angle of attack of the hydrofoil is reduced. Furthermore, the hydrofoil module includes the clamp bracket removably attached to the hull, and the swivel bracket rotatably attached to the clamp bracket via the first rotation shaft, and the wing is attached to the swivel bracket. Accordingly, attachment of the swivel bracket and the wing to the hull is completed simply by attaching the clamp bracket to the hull, and thus the hydrofoil module is easily attached to the hull.

[0008] In a hydrofoil module according to an example embodiment, in the reference state, the first rotation shaft is preferably located forward of the center of area of the hydrofoil and rearward of a leading edge of the hydrofoil. It is known that the center of lift, which is the point of action at which the lift force acts on the hydrofoil, is located rearward of the leading edge of the hydrofoil in the forward-rearward direction. Therefore, with the structure described above, in the reference state, the first rotation shaft is located on the center of lift side, which is rearward of the leading edge of the hydrofoil, and the line of action of the resultant force of the lift force and the drag force of the hydrofoil is located closer to the first rotation shaft. Consequently, in the reference state, the load on the rotation actuator that changes and maintains the angle of attack of the hydrofoil is further reduced.

[0009] In a hydrofoil module according to an example

embodiment, the clamp bracket preferably has a plate shape, preferably includes a bolt hole through which a bolt passes to fix the clamp bracket to the hull, and is preferably removably fixed to the hull by the bolt passing through the bolt hole. Accordingly, the hydrofoil module is more easily attached to the hull by the bolt passing through the bolt hole of the clamp bracket.

[0010] In a hydrofoil module according to an example embodiment, a reference angle of attack, which is the angle of attack of the hydrofoil in the reference state, is preferably set to a predetermined angle of 4 degrees or more and 8 degrees or less. Accordingly, the hydrofoil is set at the reference angle of attack of 4 degrees or more and 8 degrees or less, and thus an upward lift force is generated to cause the hull to stably rise during sailing.

[0011] In such a case, an initial angle of attack, which is the angle of attack of the hydrofoil in a state in which the strut extends in a vertical direction, is preferably greater than 0 degrees and less than the reference angle of attack. Accordingly, at the reference angle of attack, which is greater than the initial angle of attack, the lower end of the strut is located forward of the upper end, and thus the inclination direction of the strut is oriented along the line of action of the resultant force of the drag force and the lift force acting on the hydrofoil. Therefore, the resultant force of the drag force and the lift force acting on the hydrofoil is caused to act along the longitudinal direction of the strut, and thus the resultant force is effectively transmitted to the hull.

[0012] In a hydrofoil module according to an example embodiment, in the reference state, the strut is preferably inclined such that the lower end is located forward of the upper end, and preferably extends in a direction along a line of action of a resultant force of a lift force and a drag force acting on the hydrofoil. Accordingly, the resultant force is generated along a direction in which the strut extends, to push up the strut to raise the hull, and thus the hull is effectively raised by the resultant force via the strut.

[0013] In a hydrofoil module according to an example embodiment, the swivel bracket preferably includes a second rotation shaft having a second rotation center axis extending in the forward-rearward direction, and is preferably configured to support the wing via the second rotation shaft such that the wing is rotatable, and the wing is preferably configured to rotate around the second rotation center axis to switch between an underwater position at which the hydrofoil is located underwater, and an above-water position at which the hydrofoil is located above the water. Accordingly, the wing switches between the underwater position and the above-water position without moving the hydrofoil in the forward-rearward direction in which a relatively large resistance is encountered from the water.

[0014] In a hydrofoil module according to an example embodiment, the rotation actuator preferably includes a hydraulic cylinder configured to press the swivel bracket by extending and retracting to rotate the swivel bracket around the first rotation center axis, and the hydraulic

cylinder preferably includes a first end attached to the clamp bracket, and a second end attached to the swivel bracket. Accordingly, the hydraulic cylinder easily rotates the swivel bracket around the first rotation center axis relative to the clamp bracket. Furthermore, the hydraulic cylinder is attached to the clamp bracket and the swivel bracket, and thus attachment of the hydraulic cylinder to the hull is completed simply by attaching the clamp bracket to the hull.

[0015] In such a case, a hydrofoil module further includes a hydraulic oil feeder including a pump configured to supply hydraulic oil to the hydraulic cylinder and a motor configured to drive the pump, and the hydraulic oil feeder being attached to the clamp bracket. Accordingly, the hydraulic cylinder is easily driven by the motor that drives the pump. Furthermore, the hydraulic oil feeder is attached to the clamp bracket, and thus attachment of the hydraulic oil feeder to the hull is completed simply by attaching the clamp bracket to the hull.

[0016] In a hydrofoil module including the hydraulic oil feeder including the pump and the motor, the hydraulic cylinder and the hydraulic oil feeder are preferably located side by side in the right-left direction, and are preferably located rearward of the first rotation shaft. Accordingly, the hydraulic cylinder and the hydraulic oil feeder are located side by side in the right-left direction, and thus an increase in the size of the device in the forward-rearward direction is reduced or prevented. In addition, the angle of attack is changed by the hydraulic cylinder that presses the first rotation shaft from the rear.

[0017] In a hydrofoil module including the hydraulic cylinder and the hydraulic oil feeder located side by side and located rearward of the first rotation shaft, the second end of the hydraulic cylinder is preferably located forward of the first end of the hydraulic cylinder and above the first rotation shaft, and the hydraulic cylinder is preferably configured to extend a rod to rotate the wing rearward and decrease the angle of attack, and to retract the rod to rotate the wing forward and increase the angle of attack. Accordingly, the second end of the hydraulic cylinder is located above the first rotation shaft, and thus an increase in the size of the device in the horizontal direction is reduced or prevented.

[0018] In a hydrofoil module according to an example embodiment, in the reference state, the first rotation shaft is preferably located on a line of action of a resultant force of a lift force and a drag force acting on the hydrofoil as viewed in the right-left direction. Accordingly, in the reference state, the line of action of the resultant force is located closer to the first rotation center axis, and thus in the reference state, the moment around the first rotation center axis generated by the resultant force of the hydrofoil is extremely small.

[0019] In a hydrofoil module according to an example embodiment, in the reference state, the first rotation center axis of the first rotation shaft is preferably located forward of a line of action of a resultant force of a lift force and a drag force acting on the hydrofoil. Accordingly,

when the angle of attack of the wing is no longer able to be maintained by the rotation actuator due to a large resistance acting on the hydrofoil from the water, for example, the wing is rotated rearward such that the angle of attack becomes smaller, and thus the possibility that the wing is rotated forward such that the stability of the hull is impaired is reduced or prevented.

[0020] The above and other elements, features, steps, characteristics and advantages of preferred embodiments will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 is a perspective view showing the overall structure of a marine vessel including a hydrofoil module according to an example embodiment.

FIG. 2 is a plan view showing the overall structure of a marine vessel including a hydrofoil module according to an example embodiment.

FIG. 3 is an enlarged view of a right hydrofoil modular portion in FIG. 2.

FIG. 4 is a perspective view showing the overall structure of a right hydrofoil modular portion according to an example embodiment as viewed from the rear side.

FIG. 5 is a perspective view showing an upper portion of a right hydrofoil modular portion according to an example embodiment as viewed from the front side.

FIG. 6 is a schematic side view illustrating the operation of a hydraulic cylinder when a foreign object such as driftwood collides with a wing of a hydrofoil modular portion according to an example embodiment.

FIG. 7 is a schematic side view showing hydrofoils of a hydrofoil modular portion in a reference state according to an example embodiment.

FIG. 8 is a schematic side view showing hydrofoils of a hydrofoil modular portion in an initial state according to an example embodiment.

FIG. 9 is a plan view illustrating the center of area and center of lift of hydrofoils of a wing of a hydrofoil modular portion according to an example embodiment.

FIG. 10 is a diagram illustrating a rotator that rotates a wing of a hydrofoil modular portion according to a modified example.

DETAILED DESCRIPTION OF THE EXAMPLE EMBODIMENTS

[0022] Example embodiments are hereinafter described with reference to the drawings.

[0023] The structure of a marine vessel 100 including a hydrofoil module 103 according to example embodi-

ments is now described with reference to FIGS. 1 to 8.

[0024] In the figures, a direction X (second direction) indicates the forward-rearward direction of a hull 101. Directions X1 and X2 indicate the front side and the rear side, respectively. A direction Y (first direction) indicates the right-left direction (the width direction of the hull 101) of the hull 101. Directions Y1 and Y2 indicate starboard and port directions, respectively. A direction Z indicates a vertical direction. Directions Z1 and Z2 indicate upward and downward directions, respectively.

[0025] The direction Y also represents a direction in which a first rotation center axis C1, which is the rotation center of a swivel bracket 2, extends. The swivel bracket 2 rotates around the first rotation center axis C1 together with a wing 3. At this time, the swivel bracket 2 rotates relative to a clamp bracket 1. The direction X also represents a direction in which a second rotation center axis C2, which is the rotation center of the wing 3, extends. The wing 3 rotates around the second rotation center axis C2. At this time, the wing 3 rotates relative to the swivel bracket 2 and the clamp bracket 1. In a plan view, the first rotation center axis C1 and the second rotation center axis C2 are perpendicular to each other.

[0026] In the figures, the rotation directions of the swivel bracket 2 and the wing 3 around the first rotation center axis C1 are indicated by a direction r. The rotation direction of the wing 3 around the second rotation center axis C2 is indicated by a direction R. When not in use, the wing 3 is rotated in the direction R to be moved from an underwater position to an above-water position.

[0027] As shown in FIGS. 1 and 2, a marine vessel 100 includes the hull 101, an outboard motor 102, and a hydrofoil module 103 provided on the hull 101.

[0028] The marine vessel 100 is a monohull. The marine vessel 100 is a so-called hydrofoil boat that sails at high speed by raising the hull 101 above the water surface with a lift force F1 (see FIG. 7) obtained from the hydrofoil module 103. The hydrofoil module 103 raises the hull 101 by providing the hull 101 with the lift force F1 during sailing using a pair of hydrofoil modular portions 103a provided on both sides of the hull 101 in the right-left direction. The lift force F1 is obtained from hydrofoils 31 with an angle of attack. The marine vessel 100 reduces a resistance that the hull 101 receives from the water during sailing by raising the hull 101 using the pair of hydrofoil modular portions 103a. The hydrofoil modular portions 103a include the same structures as each other, such as the clamp bracket 1, the swivel bracket 2, the wing 3, and a hydraulic cylinder 4. The hydraulic cylinder 4 is an example of a "rotation actuator".

[0029] The outboard motor 102 is mounted on a stern of the hull 101. The hydrofoil module 103 is provided in the vicinity of a midpoint between the bow and stern of the hull 101 in the forward-rearward direction. The marine vessel 100 includes not only the hydrofoil module 103 but also a rear hydrofoil (not shown) provided in the vicinity of the stern of the hull 101 as a hydrofoil. One rear hydrofoil is provided on a centerline C (see FIG. 2) of the hull 101 in

the right-left direction. The hydrofoils 31 of the hydrofoil module 103 and the rear hydrofoil are both located below the belly of the hull 101.

[0030] A vessel operator 104 protruding upward from a deck 101a is provided in the center of the hull 101. The vessel operator 104 includes a front windshield 104a, a steering wheel (not shown), etc.

[0031] As shown in FIG. 1, a rope holder T1 is provided on each of the right and left sides of the vessel operator 104 to hook and hold a first end of a rope T. As an example, the rope holder T1 includes a U-shaped hook. A second end of the rope T is connected to a rope holder T2 of the wing 3 of the hydrofoil module 103. The rope T is used to manually pull up the wing 3 (hydrofoils 31) when the wing 3 is switched from the underwater position to the above-water position. The rope T is also used to maintain the above-water position of the wing 3. For ease of understanding of the drawings, the rope T is illustrated only in FIG. 1, and is omitted in the other drawings.

[0032] The pair of hydrofoil modular portions 103a (hydrofoil module 103) include symmetric structures with respect to the centerline C (see FIG. 2) of the hull 101 in the right-left direction. An angle-of-attack controller 9 (see FIG. 2) is mounted on the hull 101 of the marine vessel 100. The angle-of-attack controller 9 adjusts the angle of attack of the hydrofoils 31 by controlling driving of the hydraulic cylinder 4 (described below) to rotate the wing 3 (hydrofoils 31).

[0033] When the right and left balance of the hull 101 is maintained, i.e. when an external force such as wind and waves that disrupts the right and left balance of the hull 101 is not acting on the hull 101, the hydrofoil module 103 is in a reference state S1 (see FIG. 7) in which the angles of attack of hydrofoils 31 of the pair of hydrofoil modular portions 103a are the same as each other. The angle of attack of the hydrofoils 31 in the reference state S1 is called a reference angle of attack A1 (see FIG. 7). As an example, the reference angle of attack A1, which is the angle of attack of the hydrofoils 31 in the reference state S1, is set to a predetermined angle of 4 degrees or more and 8 degrees or less. As a specific example, the reference angle of attack A1 is set to 6 degrees.

[0034] When an external force that disrupts the right and left balance of the hull 101 acts on the hull 101, the angle of attack of a right hydrofoil modular portion 103a and the angle of attack of a left hydrofoil modular portion 103a are controlled by the angle-of-attack controller 9 to vary in opposite directions and by equal angular amounts around the reference angle of attack A1 (see FIG. 7). Thus, the hull 101 is stabilized in a raised state by the hydrofoil module 103. In other words, when an external force that disrupts the right and left balance of the hull 101 acts on the hull 101, the angle of attack of the right hydrofoil modular portion 103a varies by an angular amount of $+\alpha$ degrees from the reference angle of attack A1, and the angle of attack of the left hydrofoil modular portion 103a varies by an angular amount of $-\alpha$ degrees from the reference angle of attack A1.

[0035] As described above, the pair of hydrofoil modular portions 103a include symmetric structures with respect to the centerline C (see FIG. 2) of the hull 101 in the right-left direction, and thus the right (direction Y1 side) hydrofoil modular portion 103a is described below, and description of the left (direction Y2 side) hydrofoil modular portion 103a is omitted.

[0036] As shown in FIGS. 3 to 5, the right hydrofoil modular portion 103a (hydrofoil module 103) includes the clamp bracket 1, the swivel bracket 2, the wing 3, the hydraulic cylinder 4, and a hydraulic oil feeder 5. Illustration of the hull 101 is omitted in FIG. 3 and the subsequent figures.

[0037] The clamp bracket 1 shown in FIGS. 3 to 5 is removably attached to the hull 101 (see FIG. 1). Specifically, the clamp bracket 1 has a plate shape and includes a plurality of bolt holes 10 through which bolts B pass to fix the clamp bracket 1 to the hull 101. The plurality of bolt holes 10 of the clamp bracket 1 are horizontally spaced apart. The upward-downward direction of the plate-shaped clamp bracket 1 is defined as a thickness direction. The clamp bracket 1 is removably fixed to a gantry 101b (see FIG. 1) of the hull 101 by the bolts B passing through the bolt holes 10. The clamp bracket 1 is directly fixed from above to the gantry 101b by the bolts B. The gantry 101b includes a plurality of female threads (not shown) aligned in the forward-rearward direction, into which the bolts B are screwed, and the position of the clamp bracket 1 in the forward-rearward direction relative to the hull 101 is allowed to be adjusted.

[0038] The clamp bracket may not be directly fixed to the gantry, but may be indirectly fixed to the gantry via a dedicated mounting plate, for example. In such a case, the mounting plate may include a plurality of bolt holes aligned in the forward-rearward direction, and the mounting position of the clamp bracket in the forward-rearward direction relative to the mounting plate (hull) may be allowed to be changed.

[0039] The clamp bracket 1 is a base member to fix each portion of the hydrofoil module 103 to the hull 101. That is, the swivel bracket 2, the wing 3, the hydraulic cylinder 4, and the hydraulic oil feeder 5 are attached directly or indirectly to the clamp bracket 1, and are attached to the hull 101 via the clamp bracket 1. Therefore, when the clamp bracket 1 is attached to the hull 101, attachment of the swivel bracket 2, the wing 3, the hydraulic cylinder 4, and the hydraulic oil feeder 5 to the hull 101 is also completed.

[0040] The clamp bracket 1 includes a first rotation shaft 11 and a cylinder support 12.

[0041] The first rotation shaft 11 is provided on the front side within the clamp bracket 1. The first rotation shaft 11 has the first rotation center axis C1 extending in the right-left direction. The swivel bracket 2 is attached to the first rotation shaft 11 so as to be rotatable in the R direction. An angle sensor 9a (see FIG. 3) is provided at a left end of the first rotation shaft 11. The angle sensor 9a detects the rotation angle (the angle of attack of the hydrofoils 31) of

the swivel bracket 2 relative to the clamp bracket 1. The angle-of-attack controller 9 (see FIG. 2) adjusts the angle of attack of the hydrofoils 31 based on the measurement value of the angle sensor 9a.

[0042] The hydraulic cylinder 4 extends in the forward-rearward direction in the plan view. A first end 40a of the hydraulic cylinder 4 is attached to the cylinder support 12 of the clamp bracket 1. The cylinder support 12 of the clamp bracket 1 includes a rotation shaft having a rotation center axis C3 extending in the right-left direction. The rotation center axis C3 is parallel to the first rotation center axis C1. The hydraulic cylinder 4 is rotatably attached to the clamp bracket 1 via the cylinder support 12.

[0043] As shown in FIG. 5, a buffer 13 is provided on the upper surface of a front end of the clamp bracket 1. The buffer 13 is located in front of the first rotation shaft 11. As shown in FIG. 6, the hydraulic cylinder 4 includes a front oil chamber 401, a rear oil chamber 402, and a piston 403 that divides the oil chamber 401 from the oil chamber 402. The piston 403 includes an oil passage 403a that communicates the oil chamber 401 with the oil chamber 402, and a valve 403b that normally blocks the oil passage 403a and maintains the oil passage 403a in a closed state. The valve 403b is a relief valve that switches to an open state when a load (pressure) of a predetermined value or more is applied thereto from the oil chamber 401. The piston 403 is fixed to a rod 41.

[0044] When a foreign object K such as driftwood collides with the wing 3 during sailing and a large force acts to push the wing 3 rearward, a large force (a force to move the rod 41 in a direction of a white arrow pointing forward) acts on the hydraulic cylinder 4 in a direction to extend the rod 41 via the wing 3 and the swivel bracket 2. Consequently, a pressure in the oil chamber 401 is increased by the piston 403, and when the valve 403b receives the load (pressure) of the predetermined value or more from the oil chamber 401, the valve 403b switches to the open state. Then, the oil chamber 401 and the oil chamber 402 communicate with each other via the oil passage 403a such that a state in which the rotation position of the wing 3 in the r direction is maintained by the hydraulic cylinder 4 is released. Consequently, the wing 3 rotates largely around the first rotation center axis C1 together with the swivel bracket 2 so as to be lifted rearward. Thus, the hydrofoil module 103 deflects (pass) the foreign object K such as driftwood to the rear of the wing 3. When the wing 3 rotates largely rearward around the first rotation center axis C1 together with the swivel bracket 2 due to collision with the foreign object K such as driftwood, the buffer 13 contacts the swivel bracket 2 to prevent the swivel bracket 2 from directly colliding with the clamp bracket 1.

[0045] The buffer 13 is made of an elastic material. As an example, the buffer 13 is made of a block-shaped rubber material. Alternatively, the buffer may be made of a spring material, for example. The swivel bracket 2 indirectly contacts the clamp bracket 1 via the elastic

buffer 13, and thus the impact that occurs when the swivel bracket 2 contacts the clamp bracket 1 is absorbed and reduced.

[0046] The swivel bracket 2 shown in FIGS. 3 to 5 is rotatably attached to the clamp bracket 1 via the first rotation shaft 11. The swivel bracket 2 is a member to indirectly attach the wing 3 attached to the swivel bracket 2 to the clamp bracket 1. The swivel bracket 2 is attached to the clamp bracket 1 from above.

[0047] The swivel bracket 2 integrally includes an upper portion 20 located above the clamp bracket 1 and a side portion 21 located to the side (right) of the clamp bracket 1. The side portion 21 includes a main wall 21a, a front wall 21b, and a rear wall 21c. An upper end of the main wall 21a is connected to the upper portion 20 and extends in a direction (the forward-rearward direction and the upward-downward direction) perpendicular to the right-left direction. The front wall 21b protrudes from a front end of the main wall 21a to the right, which is the side away from the hull 101. The rear wall 21c protrudes from a rear end of the main wall 21a to the right, which is the side away from the hull 101. The front wall 21b and the rear wall 21c are configured as a pair facing each other in the forward-rearward direction. A strut 30 of the wing 3 located at the underwater position is provided along the main wall 21a.

[0048] The swivel bracket 2 includes a cylinder support 22 provided on the upper portion 20 and a second rotation shaft 23 provided on the side portion 21.

[0049] A second end 41a of the hydraulic cylinder 4 is attached to the cylinder support 22 of the swivel bracket 2. The second end 41a is located forward of the first end 40a and above the first rotation shaft 11. The cylinder support 22 of the swivel bracket 2 includes a rotation shaft having a rotation center axis C4 extending in the right-left direction. The rotation center axis C4 is parallel to the first rotation center axis C1. The hydraulic cylinder 4 is rotatably attached to the swivel bracket 2 via the cylinder support 22. Unlike the cylinder support 12, the position of which is fixed, the cylinder support 22 of the swivel bracket 2 moves along an arcuate trajectory extending in the direction r above the first rotation shaft 11 when the swivel bracket 2 and the wing 3 rotate in the direction r around the first rotation center axis C1.

[0050] The second rotation shaft 23 has the second rotation center axis C2 extending in the forward-rearward direction. The second rotation shaft 23 is located between the front wall 21b and the rear wall 21c. The wing 3 is attached to the second rotation shaft 23 so as to be rotatable in the direction R. In other words, the swivel bracket 2 supports the wing 3 via the second rotation shaft 23 such that the wing 3 is rotatable.

[0051] The wing 3 shown in FIGS. 3 and 4 includes the pillar-shaped (plate-shaped) strut 30 and the hydrofoils 31.

[0052] The hydrofoils 31 are provided at a lower end 30a of the strut 30. An upper end 30b of the strut 30 is attached to the second rotation shaft 23 of the swivel

bracket 2. The "lower end 30a" and the "upper end 30b" described above refer to the lower end 30a and the upper end 30b of the strut 30 when the hydrofoils 31 are at the underwater position, respectively.

[0053] When the hydrofoils 31 are at the underwater position, the strut 30 extends in the upward-downward direction. When the hydrofoils 31 are at the underwater position, the strut 30 has a rectangular shape with its long side in the upward-downward direction and its short side in the forward-rearward direction as viewed in the right-left direction. A bullet-shaped central portion 32 extending in the forward-rearward direction is provided at the lower end 30a of the strut 30. A front portion of the central portion 32 is rounded, and a rear portion of the central portion 32 protrudes rearward in a tapered manner.

[0054] The hydrofoils 31 are located in the water. The hydrofoils 31 are configured as a pair on both sides of the central portion 32 in the right-left direction. That is, the pair of hydrofoils 31 are connected to the central portion 32 from both sides in the right-left direction. The hydrofoils 31 extend in the right-left direction and are wings, the upward-downward direction of which is defined as a thickness direction. In the right-left direction, the hydrofoils 31 each have a shape such that a leading edge 31a gradually approaches a trailing edge 31b as the leading edge 31a is away from the central portion 32. That is, in the right-left direction, the sizes of the hydrofoils 31 in the forward-rearward direction decrease as a distance from the central portion 32 increases. The hydrofoils 31 each have a streamlined shape in a longitudinal section (a section taken along a plane perpendicular to the right-left direction). That is, the hydrofoils 31 are thicker on the front side and gradually become thinner toward the rear. In the longitudinal section, forward portions of the hydrofoils 31 including the leading edges 31a are rounded, and rearward portions of the hydrofoils 31 including the trailing edges 31b protrude rearward in a tapered manner.

[0055] An initial angle of attack A2 (see FIG. 8), which is the angle of attack of the hydrofoils 31 in a state (initial state) in which the strut 30 extends in the vertical direction, is greater than 0 degrees and less than the reference angle of attack A1 (see FIG. 7). Preferably, the initial angle of attack A2 is 1 degree or more and 5 degrees or less. As a specific example, the initial angle of attack A2 is 3 degrees.

[0056] The wing 3 rotates around the second rotation center axis C2 to switch between the underwater position at which the hydrofoils 31 are located underwater and the above-water position at which the hydrofoils 31 are located above the water. This switching is performed using the rope T (see FIG. 1), the first end of which is held by the rope holder T1. The rope holder T2 is provided on the strut 30 to hook and hold the second end of the rope T. A rope passing member T3 is provided on the strut 30 to pass the rope T between the rope holder T1 and the rope holder T2. In the upward-downward direction, the rope passing member T3 is located below the second rotation shaft 23 and above the rope holder T2.

[0057] The rope holder T2 includes a U-shaped hook that protrudes to the right (in a direction away from the hull 101) from the strut 30 when the hydrofoils 31 are at the underwater position. When the hydrofoils 31 are in the underwater position, The rope passing member T3 includes a rope contact portion T30 that contacts the rope T when the hydrofoils 31 are at the underwater position, and a holder T31 that holds the rope contact portion T30 at its right end when the hydrofoils 31 are at the underwater position. The holder T31 is a U-shaped portion that protrudes to the right (in the direction away from the hull 101) from the strut 30, and protrudes further to the right than the rope holder T2. Therefore, the rope contact portion T30 is spaced apart by a predetermined distance to the right (in the direction away from the hull 101) from the strut 30 (second rotation shaft 23).

[0058] The rope passing member T3 causes the rope T (see FIG. 1) to be located at a position away from the second rotation shaft 23. Therefore, when the rope T is manually pulled to switch the hydrofoils 31 from the underwater position to the above-water position, a relatively large moment around the second rotation center axis C2 of the second rotation shaft 23 is generated on the wing 3 including the strut 30 and the hydrofoils 31. In other words, the rope passing member T3 allows a user to easily switch the hydrofoils 31 from the underwater position to the above-water position. Although not shown, when the hydrofoils 31 are at the above-water position, the wing 3 is maintained in a state in which the hydrofoils 31 are located directly above the strut 30 and the strut 30 extends in the upward-downward direction. Forces acting on the hydrofoils 31 from the water during sailing are described below.

[0059] The hydraulic cylinder 4 shown in FIGS. 3 and 4 rotates the wing 3 together with the swivel bracket 2 in the forward-rearward direction (in the direction r) around the first rotation center axis C1 to change the angle of attack of the hydrofoils 31. The hydraulic cylinder 4 presses the swivel bracket 2 by extending and retracting to cause the swivel bracket 2 to rotate around the first rotation center axis C1.

[0060] The hydraulic cylinder 4 includes a cylindrical cylinder body 40 and the rod 41 that moves back and forth from the cylinder body 40.

[0061] The first end 40a (cylinder body 40) of the hydraulic cylinder 4 is attached to the clamp bracket 1. Specifically, the first end 40a is rotatably supported by the cylinder support 12 of the clamp bracket 1. The second end 41a (rod 41) of the hydraulic cylinder 4 is attached to the swivel bracket 2. Specifically, the second end 41a is rotatably supported by the cylinder support 22 of the swivel bracket 2. The hydraulic cylinder 4 is located rearward of the first rotation shaft 11 of the clamp bracket 1.

[0062] The second end 41a of the hydraulic cylinder 4 is located forward of the first end 40a of the hydraulic cylinder 4 and above the first rotation shaft 11. The hydrofoils 31, the angle of attack of which is to be deter-

mined, are located below the first rotation shaft 11 of the clamp bracket 1. The hydraulic cylinder 4 extends the rod 41 to rotate the wing 3 rearward (a first side in the direction r) to reduce the angle of attack. The hydraulic cylinder 4 retracts the rod 41 to rotate the wing 3 forward (a second side in the direction r) to increase the angle of attack. Therefore, for example, in order to change the angle of attack from the initial angle of attack A2 to the reference angle of attack A1 that is larger than the initial angle of attack A2, the hydraulic cylinder 4 retracts the rod 41 to rotate the wing 3 forward (the second side in the direction r).

[0063] The hydraulic oil feeder 5 is attached to the clamp bracket 1. The hydraulic oil feeder 5 is located rearward of the first rotation shaft 11 of the clamp bracket 1. The hydraulic oil feeder 5 and the hydraulic cylinder 4 are located side by side in the right-left direction. The hydraulic cylinder 4 is located leftward of the hydraulic oil feeder 5.

[0064] The hydraulic oil feeder 5 includes a pump 50 that supplies hydraulic oil to the hydraulic cylinder 4, and a motor 51 that drives the pump 50. The pump 50 is connected to the two oil chambers 401 and 402 (see FIG. 6) of the hydraulic cylinder 4 by two hoses 52 through which the hydraulic oil flows.

[0065] The forces acting on the hydrofoils 31 from the water when the marine vessel 100 (see FIG. 1) sails forward are described with reference to FIG. 7. The forces acting on the hydrofoils 31 from the water during sailing include an upward lift force F1 and a rearward drag force F2. The lift force F1 and the drag force F2 act in directions perpendicular to each other. The lift force F1 and the drag force F2 vary by adjusting the angle of attack of the hydrofoils 31. A resultant force F3 of the lift force F1 and the drag force F2 constantly acts in an upward direction and a rearward direction.

[0066] Referring to FIGS. 7 and 9, in the reference state S1 in which the angles of attack of the hydrofoils 31 of the pair of hydrofoil modular portions 103a are the same as each other, the first rotation shaft 11 is located forward of the center of area P1 of the hydrofoils 31. Furthermore, in the reference state S1, the first rotation shaft 11 is located forward of the center of area P1 of the hydrofoils 31 and rearward of the leading edges 31a of the hydrofoils 31. The "center of area P1 of the hydrofoils 31" described above refers to the center of mass (center of gravity) of the hydrofoils 31 in the plan view when the mass of the hydrofoils 31 is uniformly distributed in a horizontal direction.

[0067] In the horizontal direction, a center of lift P2, which is a point of action at which the lift force F1 acts on the hydrofoils 31, is located forward of the center of area P1 of the hydrofoils 31. This is a finding known in the field of lift. In the forward-rearward direction, the center of lift P2, which is the point of action at which the lift force F1 acts on the hydrofoils 31, is located rearward of the leading edges 31a of the hydrofoils 31. This is also a finding known in the field of lift. The drag force F2 is

smaller than the lift force F1. The center of lift P2 is located at a distance of about 25% from the leading edges 31a, assuming that a distance from the leading edges 31a to the trailing edges 31b is 100%. In FIG. 7, the position at a distance of about 25% from the leading edges 31a is indicated by a line L1.

[0068] Therefore, in the reference state S1, the first rotation shaft 11 is located relatively close to the center of lift P2 in the forward-rearward direction. The term "relatively close" indicates a concept including both the first rotation shaft 11 being located at the same position as the center of lift P2 in the forward-rearward direction and the first rotation shaft 11 being located at a position slightly deviated from the center of lift P2 in the forward-rearward direction.

[0069] In the reference state S1, the strut 30 is inclined such that the lower end 30a is located forward of the upper end 30b, and extends in a direction along a line of action L of the resultant force F3 of the lift force F1 and the drag force F2 acting on the hydrofoils 31. Preferably, in the reference state S1, the line of action L of the resultant force F3 is parallel to a centerline of the strut 30 in the short-side direction (forward-rearward direction). In short, in the reference state S1, the hydrofoils 31 raise the hull 101 by generating the resultant force F3 that pushes up the strut 30 along the longitudinal direction of the strut 30 so as not to generate a large moment on the wing 3.

[0070] In the reference state S1, the first rotation shaft 11 is located on the line of action L of the resultant force F3 of the lift force F1 and the drag force F2 acting on the hydrofoils 31 as viewed in the right-left direction. Furthermore, in the reference state S1, the first rotation center axis C1 of the first rotation shaft 11 is located forward of the line of action L of the resultant force F3 of the lift force F1 and the drag force F2 acting on the hydrofoils 31. Therefore, in the reference state S1, a moment around the first rotation center axis C1 is generated on the wing 3 by the resultant force F3, although the moment is small. The direction of this moment causes the wing 3 to rotate rearward since the first rotation center axis C1 is located forward of the line of action L of the resultant force F3.

[0071] Therefore, in the reference state S1, the hydraulic cylinder 4 constantly applies a small maintaining force to the wing 3 to maintain the position (angle of attack) of the wing 3 against a small moment in the direction that causes the wing 3 to rotate rearward. In the reference state S1, the moment is small, and thus the load on the hydraulic cylinder 4 is small. Since the first rotation center axis C1 is located forward of the line of action L of the resultant force F3, when the hydraulic cylinder 4 is damaged or the hydrofoils 31 are subjected to a large resistance from the water such that the hydraulic cylinder 4 is no longer able to maintain the position of the wing 3, the wing 3 rotates rearward such that the angle of attack is decreased. In such a case, the wing 3 and the swivel bracket 2 rotate around the first rotation center axis C1 so as to be lifted rearward. Then, the

swivel bracket 2 contacts the buffer 13.

[0072] According to the various example embodiments described above, the following advantageous effects are achieved.

[0073] According to an example embodiment, the hydrofoil module 103 includes the wing 3 including the hydrofoils 31 and the strut 30, and a rotation actuator (hydraulic cylinder 4) to rotate the wing 3 in the forward-rearward direction around the first rotation center axis C1 to change the angle of attack of the hydrofoils 31. In the reference state S1 in which the angles of attack of the hydrofoils 31 of the pair of hydrofoil modular portions 103a on both sides of the hull 101 in the right-left direction are the same as each other, the first rotation shaft 11 is located forward of the center of area P1 of the hydrofoils 31. It is known that in the horizontal direction, the center of lift P2, which is the point of action at which the lift force F1 acts on the hydrofoils 31, is located forward of the center of area P1 of the hydrofoils 31. Therefore, with the structure described above, in the reference state S1, the first rotation shaft 11 is located on the center of lift P2 side, which is forward of the center of area P1 of the hydrofoils 31, and thus the line of action L of the resultant force F3 of the lift force F1 and the drag force F2 of the hydrofoils 31 is located relatively close to the first rotation shaft 11. Therefore, in the reference state S1, the moment around the first rotation center axis C1 generated by the resultant force F3 of the hydrofoils 31 is reduced. Consequently, in the reference state S1, the load on the rotation actuator (hydraulic cylinder 4) that changes and maintains the angle of attack of the hydrofoils 31 is reduced. Furthermore, the hydrofoil module 103 includes the clamp bracket 1 removably attached to the hull 101, and the swivel bracket 2 rotatably attached to the clamp bracket 1 via the first rotation shaft 11, and the wing 3 is attached to the swivel bracket 2. Accordingly, attachment of the swivel bracket 2 and the wing 3 to the hull 101 is completed simply by attaching the clamp bracket 1 to the hull 101, and thus the hydrofoil module 103 is easily attached to the hull 101.

[0074] According to an example embodiment, in the reference state S1, the first rotation shaft 11 is located forward of the center of area P1 of the hydrofoils 31 and rearward of the leading edges 31a of the hydrofoils 31. It is known that the center of lift P2, which is the point of action at which the lift force F1 acts on the hydrofoils 31, is located rearward of the leading edges 31a of the hydrofoils 31 in the forward-rearward direction. Therefore, with the structure described above, in the reference state S1, the first rotation shaft 11 is located on the center of lift P2 side, which is rearward of the leading edges 31a of the hydrofoils 31, and the line of action L of the resultant force F3 of the lift force F1 and the drag force F2 of the hydrofoils 31 is located closer to the first rotation shaft 11. Consequently, in the reference state S1, the load on the rotation actuator (hydraulic cylinder 4) that changes and maintains the angle of attack of the hydrofoils 31 is further reduced.

[0075] According to an example embodiment, the clamp bracket 1 has a plate shape, includes the bolt holes 10 through which the bolts B pass to fix the clamp bracket 1 to the hull 101, and is removably fixed to the hull 101 by the bolts B passing through the bolt holes 10. Accordingly, the hydrofoil module 103 is more easily attached to the hull 101 by the bolts B passing through the bolt holes 10 of the clamp bracket 1.

[0076] According to an example embodiment, the reference angle of attack A1, which is the angle of attack of the hydrofoils 31 in the reference state S1, is set to a predetermined angle of 4 degrees or more and 8 degrees or less. Accordingly, the hydrofoils 31 are set at the reference angle of attack A1 of 4 degrees or more and 8 degrees or less, and thus an upward lift force F1 is generated to cause the hull 101 to stably rise during sailing.

[0077] According to an example embodiment, the initial angle of attack A2, which is the angle of attack of the hydrofoils 31 in a state in which the strut 30 extends in the vertical direction, is greater than 0 degrees and less than the reference angle of attack A1. Accordingly, at the reference angle of attack A1, which is greater than the initial angle of attack A2, the lower end 30a of the strut 30 is located forward of the upper end 30b, and thus the inclination direction of the strut 30 is oriented along the line of action L of the resultant force F3 of the drag force F2 and the lift force F1 acting on the hydrofoils 31. Therefore, the resultant force F3 of the drag force F2 and the lift force F1 acting on the hydrofoils 31 is caused to act along the longitudinal direction of the strut 30, and thus the resultant force F3 is effectively transmitted to the hull 101.

[0078] According to an example embodiment, in the reference state S1, the strut 30 is inclined such that the lower end 30a is located forward of the upper end 30b, and extends in the direction along the line of action L of the resultant force F3 of the lift force F1 and the drag force F2 acting on the hydrofoils 31. Accordingly, the resultant force F3 is generated along a direction in which the strut 30 extends, to push up the strut 30 to raise the hull 101, and thus the hull 101 is effectively raised by the resultant force F3 via the strut 30.

[0079] According to an example embodiment, the swivel bracket 2 includes the second rotation shaft 23 having the second rotation center axis C2 extending in the forward-rearward direction, and is configured to support the wing 3 via the second rotation shaft 23 such that the wing 3 is rotatable. The wing 3 is configured to rotate around the second rotation center axis C2 to switch between the underwater position at which the hydrofoils 31 are located underwater, and the above-water position at which the hydrofoils 31 are located above the water. Accordingly, the wing 3 switches between the underwater position and the above-water position without moving the hydrofoils 31 in the forward-rearward direction in which a relatively large resistance is encountered from the water.

[0080] According to an example embodiment, the rota-

tion actuator includes the hydraulic cylinder 4 to press the swivel bracket 2 by extending and retracting to rotate the swivel bracket 2 around the first rotation center axis C1, the first end 40a of the hydraulic cylinder 4 is attached to the clamp bracket 1, and the second end 41a of the hydraulic cylinder 4 is attached to the swivel bracket 2. Accordingly, the hydraulic cylinder 4 easily rotates the swivel bracket 2 around the first rotation center axis C1 relative to the clamp bracket 1. Furthermore, the hydraulic cylinder 4 is attached to the clamp bracket 1 and the swivel bracket 2, and thus attachment of the hydraulic cylinder 4 to the hull 101 is completed simply by attaching the clamp bracket 1 to the hull 101.

[0081] According to an example embodiment, the hydrofoil module 103 further includes the hydraulic oil feeder 5 including the pump 50 to supply hydraulic oil to the hydraulic cylinder 4 and the motor 51 to drive the pump 50, and attached to the clamp bracket 1. Accordingly, the hydraulic cylinder 4 is easily driven by the motor 51 that drives the pump 50. Furthermore, the hydraulic oil feeder 5 is attached to the clamp bracket 1, and thus attachment of the hydraulic oil feeder 5 to the hull 101 is completed simply by attaching the clamp bracket 1 to the hull 101.

[0082] According to an example embodiment, the hydraulic cylinder 4 and the hydraulic oil feeder 5 are located side by side in the right-left direction, and are located rearward of the first rotation shaft 11. Accordingly, the hydraulic cylinder 4 and the hydraulic oil feeder 5 are located side by side in the right-left direction, and thus an increase in the size of the device in the forward-rearward direction is reduced or prevented. In addition, the angle of attack is changed by the hydraulic cylinder 4 that presses the first rotation shaft 11 from the rear.

[0083] According to an example embodiment, the second end 41a of the hydraulic cylinder 4 is located forward of the first end 40a of the hydraulic cylinder 4 and above the first rotation shaft 11. The hydraulic cylinder 4 is configured to extend the rod 41 to rotate the wing 3 rearward and decrease the angle of attack, and to retract the rod 41 to rotate the wing 3 forward and increase the angle of attack. Accordingly, the second end 41a of the hydraulic cylinder 4 is located above the first rotation shaft 11, and thus an increase in the size of the device in the horizontal direction (forward-rearward direction) is reduced or prevented.

[0084] According to an example embodiment, in the reference state S1, the first rotation shaft 11 is located on the line of action L of the resultant force F3 of the lift force F1 and the drag force F2 acting on the hydrofoils 31 as viewed in the right-left direction. Accordingly, in the reference state S1, the line of action L of the resultant force F3 is located closer to the first rotation center axis C1, and thus in the reference state S1, the moment around the first rotation center axis C1 generated by the resultant force F3 of the hydrofoils 31 is extremely small.

[0085] According to an example embodiment, in the reference state S1, the first rotation center axis C1 of the first rotation shaft 11 is located forward of the line of action

L of the resultant force F3 of the lift force F1 and the drag force F2 acting on the hydrofoils 31. Accordingly, when the angle of attack of the wing 3 is no longer able to be maintained by the rotation actuator (hydraulic cylinder 4) due to a large resistance acting on the hydrofoils 31 from the water, for example, the wing 3 is rotated rearward such that the angle of attack becomes smaller, and thus the possibility that the wing 3 is rotated forward such that the stability of the hull 101 is impaired is reduced or prevented.

[0086] The example embodiments described above are illustrative for present teaching but the present teaching also relates to modifications of the example embodiments.

[0087] For example, while the hydrofoil is preferably switched from the underwater position to the above-water position by the user pulling (manually) the rope around the second rotation center axis in example embodiments described above, the present teaching is not restricted to this. In the present teaching, as in a hydrofoil module 203 shown in FIG. 10, a rotator 206 may alternatively be provided in the hydrofoil module 203. The rotator 206 mechanically rotates a wing 3 around a second rotation center axis C2. The rotator 206 includes a shaft 206a extending along the second rotation center axis C2, a rack 206b extending in an upward-downward direction, a pinion 206c provided at an end of the shaft 206a, and a drive source 206d. The shaft 206a is fixed to the wing 3 and rotates together with the wing 3. The rack 206b is moved in the upward-downward direction by the drive source 206d. As the rack 206b moves in the upward-downward direction, the pinion 206c rotates together with the wing 3 around the second rotation center axis C2, and hydrofoils 31 are switched between an underwater position and an above-water position. The drive source 206d includes a hydraulic pump driven by a motor. That is, oil chambers (not shown) are provided at both ends of the rack 206b to allow the rack 206b to be pressed and moved. The drive source may include a solenoid or a gear unit to transmit the torque of the motor to the rack.

[0088] While the outboard motor preferably propels the marine vessel in example embodiments described above, the present teaching is not restricted to this. In the present teaching, the marine vessel may alternatively be propelled by an inboard motor or an inboard-outboard motor, for example.

[0089] While the hull is preferably a monohull in example embodiments described above, the present teaching is not restricted to this. In the present teaching, the hull may alternatively be a catamaran.

[0090] While the reference angle of attack is preferably set to 6 degrees in example embodiments described above, the present teaching is not restricted to this. In the present teaching, the reference angle of attack may alternatively be set to an angle other than 6 degrees.

[0091] While the initial angle of attack is preferably set to 3 degrees in example embodiments described above,

the present teaching is not restricted to this. In the present teaching, the initial angle of attack may alternatively be set to an angle other than 3 degrees.

[0092] While the rotation actuator preferably includes a hydraulic cylinder in example embodiments described above, the present teaching is not restricted to this. In the present teaching, the rotation actuator may alternatively include a solenoid, for example.

[0093] While in the reference state, the first rotation shaft is preferably located rearward of the leading edges of the hydrofoils in example embodiments described above, the present teaching is not restricted to this. In the present teaching, in the reference state, the first rotation shaft may alternatively be located forward of the leading edges of the hydrofoils or may alternatively be located at the same position in the forward-rearward direction as the positions of the leading edges of the hydrofoils.

[0094] While the clamp bracket is preferably fixed to the hull by the bolts in example embodiments described above, the present teaching is not restricted to this. In the present teaching, the clamp bracket may alternatively be fixed to the hull by a member that clamps the clamp bracket and the hull, for example.

[0095] While the hydraulic oil feeder is preferably attached directly to the clamp bracket in example embodiments described above, the present teaching is not restricted to this. In the present teaching, the hydraulic oil feeder may alternatively be attached directly to the swivel bracket.

[0096] While in the reference state, the first rotation shaft is preferably located on the line of action of the resultant force of the lift force and the drag force acting on the hydrofoils as viewed in the right-left direction in example embodiments described above, the present teaching is not restricted to this. In the present teaching, in the reference state, the first rotation shaft may alternatively be deviated from the line of action of the resultant force of the lift force and the drag force acting on the hydrofoils as viewed in the right-left direction.

[0097] While the hydraulic cylinder and the hydraulic oil feeder are preferably located side by side in the right-left direction in example embodiments described above, the present teaching is not restricted to this. In the present teaching, the hydraulic cylinder and the hydraulic oil feeder may alternatively be located side by side in the forward-rearward direction.

[0098] While the hydraulic cylinder is preferably located rearward of the first rotation shaft in example embodiments described above, the present teaching is not restricted to this. In the present teaching, the hydraulic cylinder may alternatively be located forward of the first rotation shaft.

[0099] While the hydraulic oil feeder is preferably located rearward of the first rotation shaft in example embodiments described above, the present teaching is not restricted to this. In the present teaching, the hydraulic oil feeder may alternatively be located forward of the

first rotation shaft.

Claims

1. A hydrofoil module (103, 203) configured to be provided on a hull (101) of a marine vessel (100), the hydrofoil module (103, 203) comprising:

a pair of hydrofoil modular portions (103a) configured to be provided on both sides of the hull (101) in a right-left direction of the hull (101); wherein

the pair of hydrofoil modular portions (103a) are configured to provide the hull (101) with a lift force (F1) during sailing to raise the hull (101) out of the water; and

each of the pair of hydrofoil modular portions (103a) including:

a clamp bracket (1) including a first rotation shaft (11) having a first rotation center axis (C1) extending in a first direction (Y) that coincides with the right-left direction of the hull (101) and configured to be removably attached to the hull (101);

a swivel bracket (2) rotatably attached to the clamp bracket (1) via the first rotation shaft (11);

a wing (3) including a hydrofoil (31) configured to be located in water, and a strut (30) having a pillar shape and including a lower end (30a) on which the hydrofoil (31) is provided and an upper end (30b) attached to the swivel bracket (2);

a rotation actuator (4) configured to rotate the wing (3) together with the swivel bracket (2) in a second direction (X) that coincides with a forward-rearward direction of the hull (101) around the first rotation center axis (C1) to change an angle of attack of the hydrofoil (31); and

in a reference state (S1) in which angles of attack of hydrofoils (31) of the pair of hydrofoil modular portions (103a) are same as each other, the first rotation shaft (11) of each of the pair of hydrofoil modular portions (103a) is located forward of a center of area (P1) of the hydrofoil (31) with regard to the second direction (X) that coincides with the forward-rearward direction of the hull (101).

2. The hydrofoil module (103, 203) according to claim 1, wherein in the reference state, the first rotation shaft (11) is located forward of the center of area (P1) of the hydrofoil (31) and rearward of a leading edge (31a) of the hydrofoil (31) with regard to the second direction (X) that coincides with the forward-rear-

ward direction of the hull (101).

3. The hydrofoil module (103, 203) according to claim 1 or 2, wherein the clamp bracket (1) has a plate shape, includes a bolt hole (10) through which a bolt (B) passes to fix the clamp bracket (1) to the hull (101), and is removably fixed to the hull (101) by the bolt (B) passing through the bolt hole (10). 5
4. The hydrofoil module (103, 203) according to at least one of the claims 1 to 3, wherein a reference angle of attack (A1), which is the angle of attack of the hydrofoil (31) in the reference state, is set to a predetermined angle of 4 degrees or more and 8 degrees or less. 10
5. The hydrofoil module (103, 203) according to claim 4, wherein an initial angle of attack (A2), which is the angle of attack of the hydrofoil (31) in a state in which the strut (30) extends in a vertical direction that coincides with a vertical direction of the hull (101), is greater than 0 degrees and less than the reference angle of attack (A1). 15
6. The hydrofoil module (103, 203) according to at least one of the claims 1 to 5, wherein in the reference state, the strut (30) is inclined such that the lower end (30a) is located forward of the upper end (30b) with regard to the second direction (X) that coincides with the forward-rearward direction of the hull (101), and extends in a direction along a line of action (L) of a resultant force (F3) of a lift force (F1) and a drag force (F2) acting on the hydrofoil (31). 20
7. The hydrofoil module (103, 203) according to at least one of the claims 1 to 6, wherein the swivel bracket (2) includes a second rotation shaft (23) having a second rotation center axis (C2) extending in the second direction (X) that coincides with the forward-rearward direction of the hull (101), and is configured to support the wing (3) via the second rotation shaft (23) such that the wing (3) is rotatable; and 25
the wing (3) is configured to rotate around the second rotation center axis (C2) to switch between an underwater position at which the hydrofoil (31) is located underwater, and an above-water position at which the hydrofoil (31) is located above the water. 30
8. The hydrofoil module (103, 203) according to at least one of the claims 1 to 7, wherein the rotation actuator (4) includes a hydraulic cylinder (4) configured to press the swivel bracket (2) by extending and retracting to rotate the swivel bracket (2) around the first rotation center axis (C1); and 35
the hydraulic cylinder (4) includes a first end (40a) attached to the clamp bracket (1), and a second end (41a) attached to the swivel bracket (2). 40

9. The hydrofoil module (103, 203) according to claim 8, further comprising:
a hydraulic oil feeder (5) including a pump (50) configured to supply hydraulic oil to the hydraulic cylinder (4) and a motor (51) configured to drive the pump (50), and the hydraulic oil feeder (5) being attached to the clamp bracket (1). 45
10. The hydrofoil module (103, 203) according to claim 9, wherein the hydraulic cylinder (4) and the hydraulic oil feeder (5) are located side by side in the first direction (Y) that coincides with the right-left direction of the hull (101), and are located rearward of the first rotation shaft (11) in the second direction (X) that coincides with the forward-rearward direction of the hull (101). 50
11. The hydrofoil module (103, 203) according to claim 10, wherein the second end (41a) of the hydraulic cylinder (4) is located forward of the first end (40a) of the hydraulic cylinder (4) in the second direction (X) that coincides with the forward-rearward direction of the hull (101) and above the first rotation shaft (11); and
the hydraulic cylinder (4) is configured to extend a rod (41) to rotate the wing (3) rearward in the second direction (X) that coincides with the forward-rearward direction of the hull (101) and decrease the angle of attack, and to retract the rod (41) to rotate the wing (3) forward in the second direction (X) that coincides with the forward-rearward direction of the hull (101) and increase the angle of attack. 55
12. The hydrofoil module (103, 203) according to at least one of the claims 1 to 11, wherein in the reference state, the first rotation shaft (11) is located on a line of action (L) of a resultant force (F3) of a lift force (F1) and a drag force (F2) acting on the hydrofoil (31) as viewed in the first direction (Y) that coincides with the right-left direction of the hull (101). 60
13. The hydrofoil module (103, 203) according to at least one of the claims 1 to 12, wherein in the reference state, the first rotation center axis (C1) of the first rotation shaft (11) is located forward of a line of action (L) of a resultant force (F3) of a lift force (F1) and a drag force (F2) acting on the hydrofoil (31) in the second direction (X) that coincides with the forward-rearward direction of the hull (101). 65
14. A marine vessel (100) having a hull (101) provided with the hydrofoil module (103, 203) according to at least one of the claims 1 to 13. 70

FIG. 1

EXAMPLE EMBODIMENT

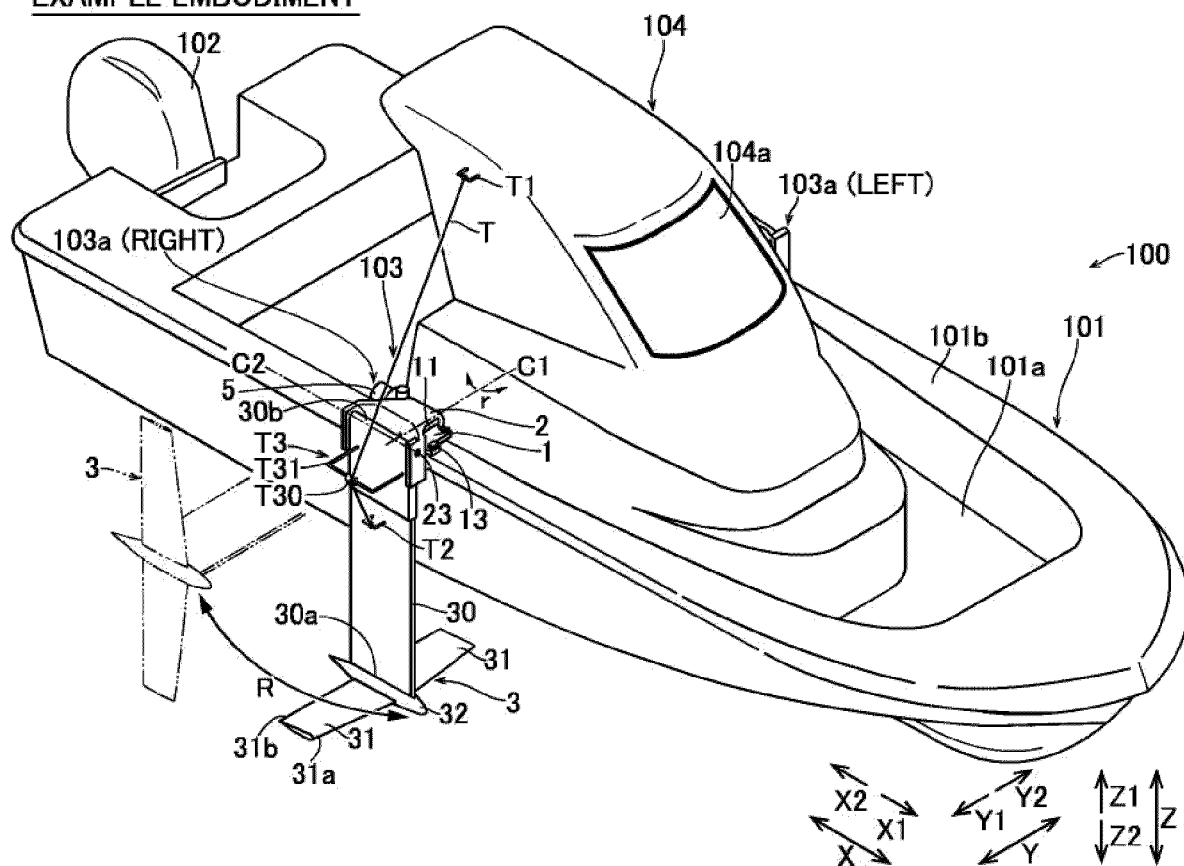


FIG. 2

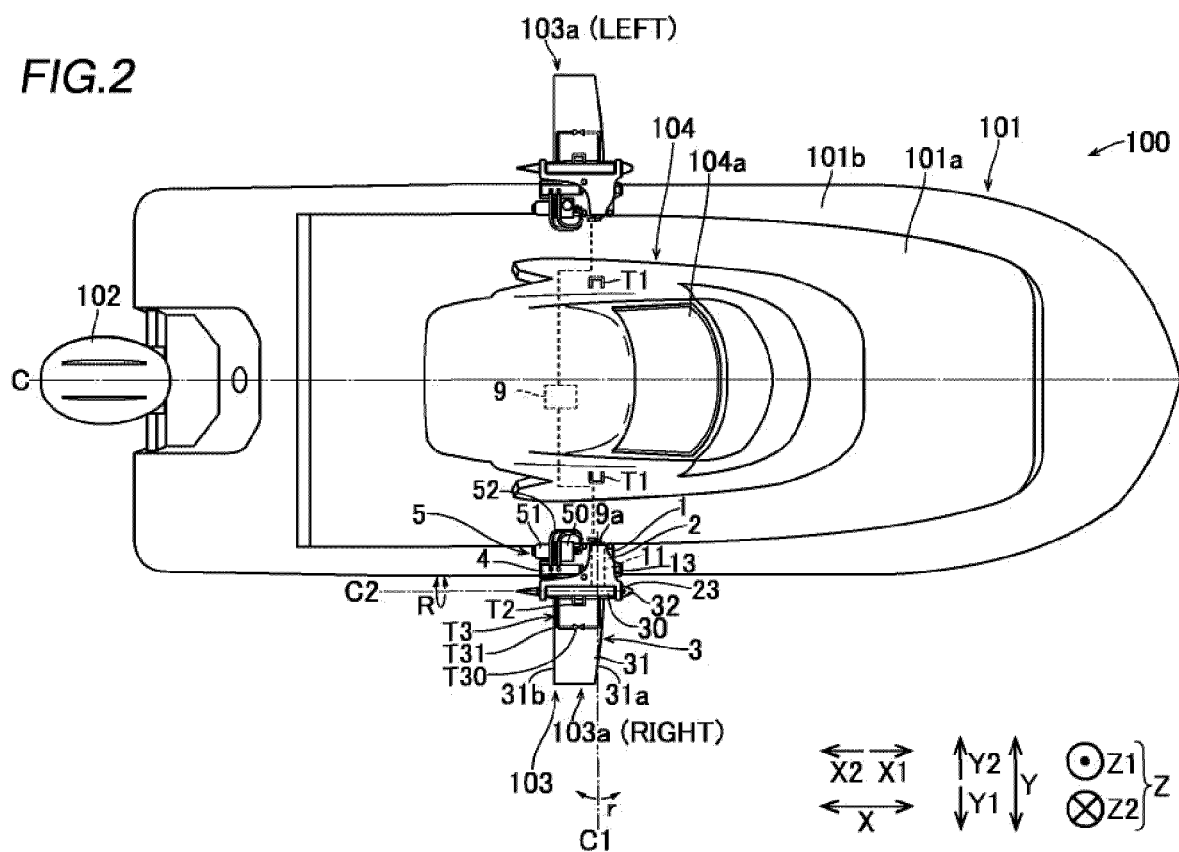


FIG.3

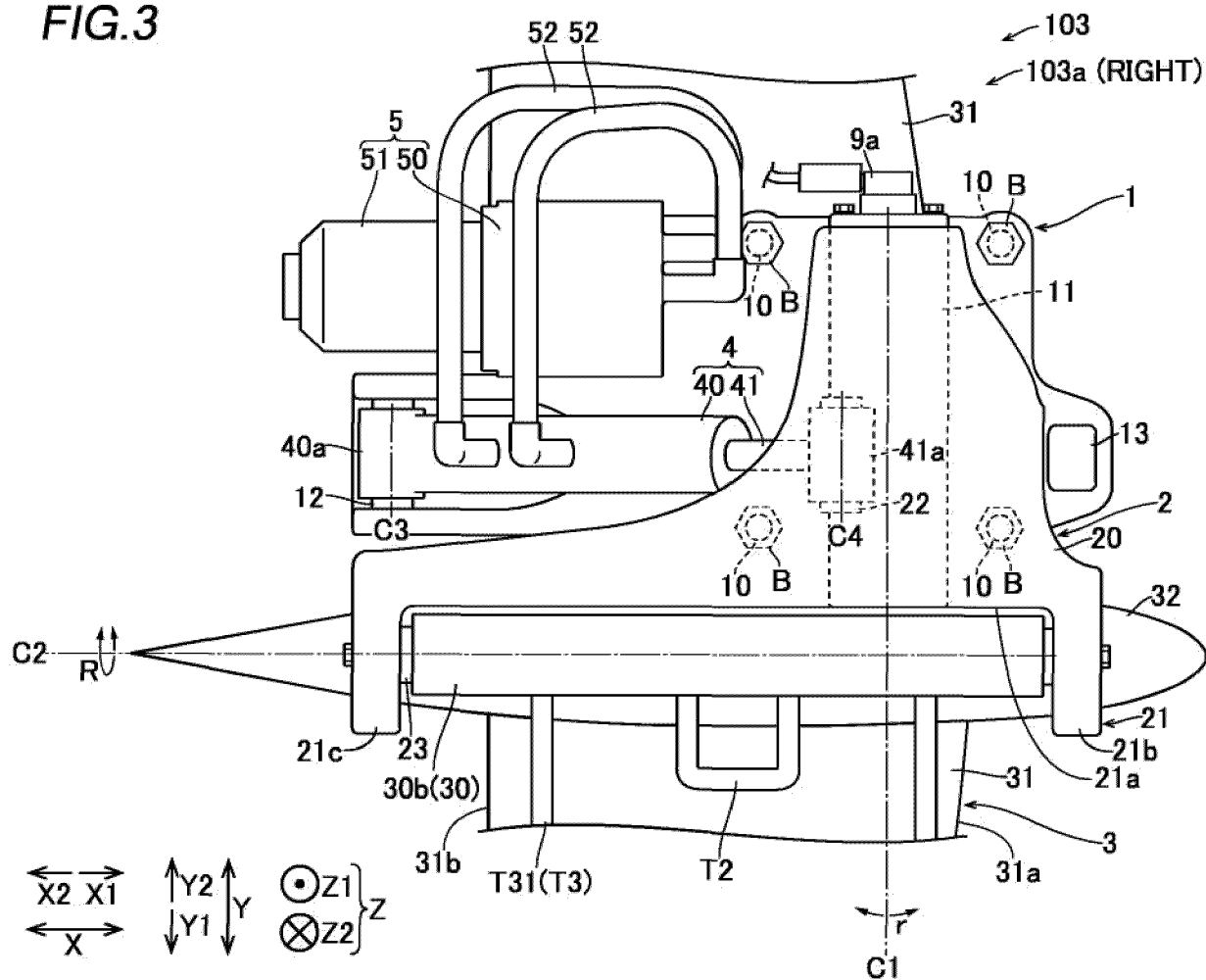


FIG.4

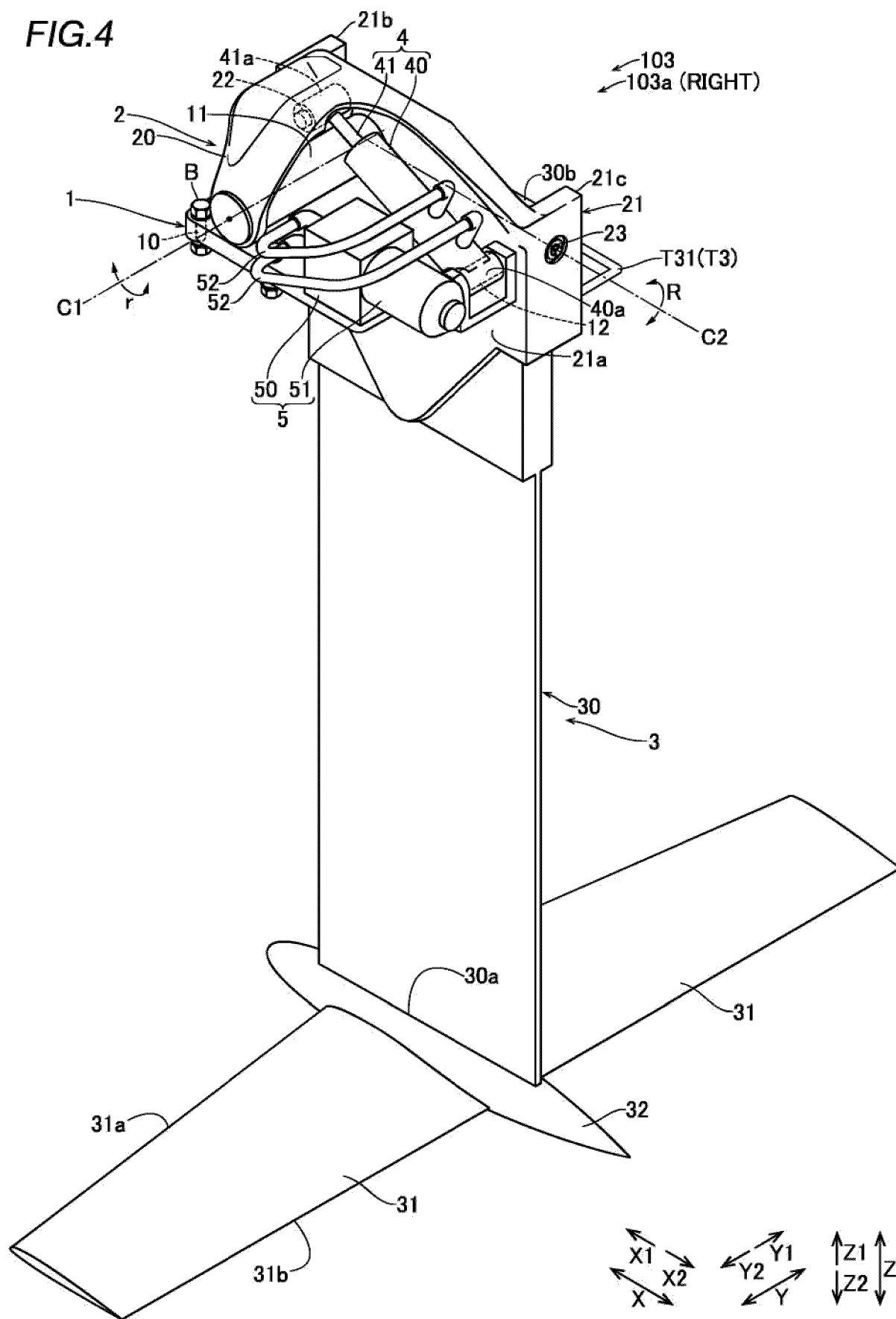


FIG.5

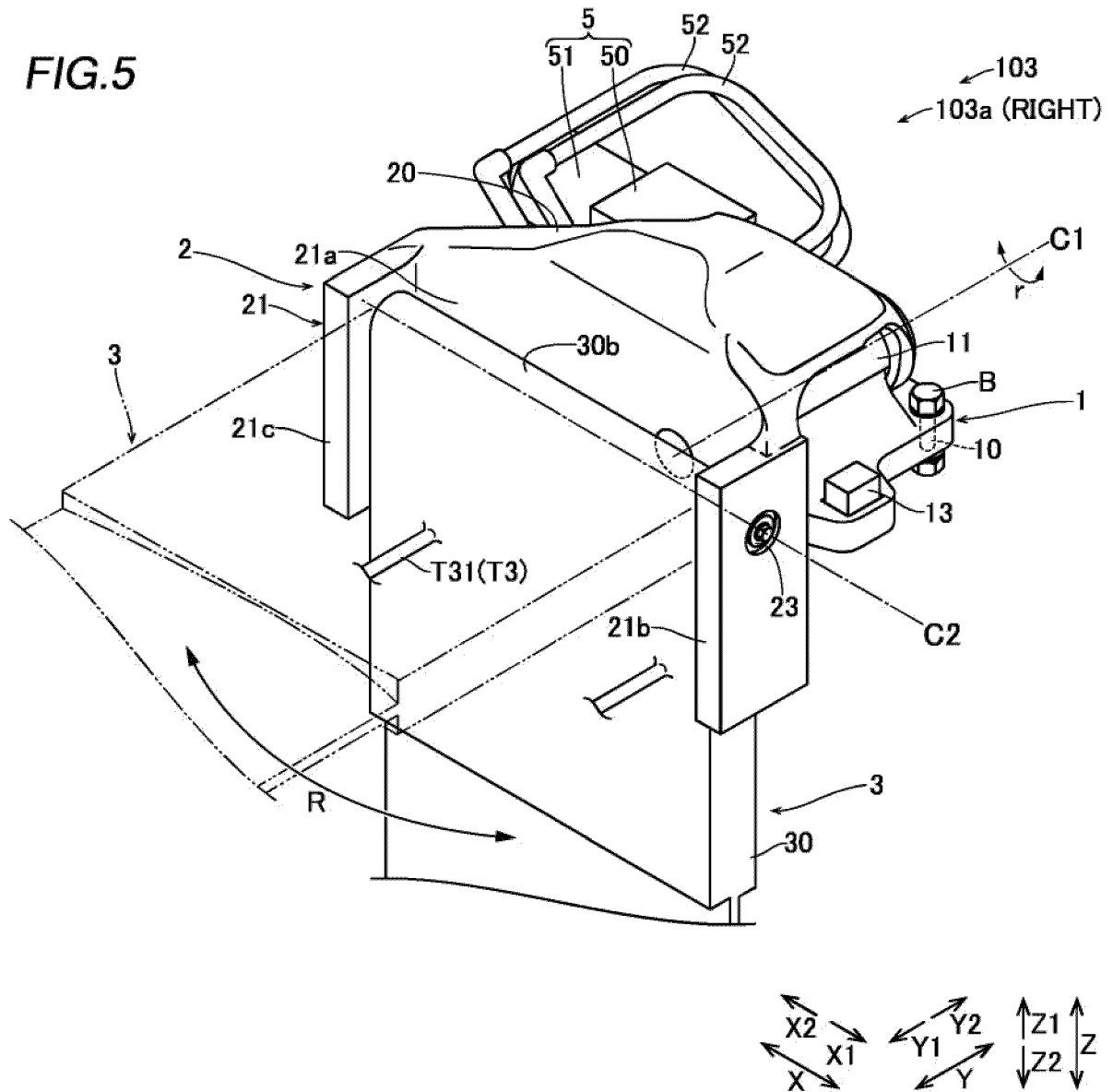


FIG.6

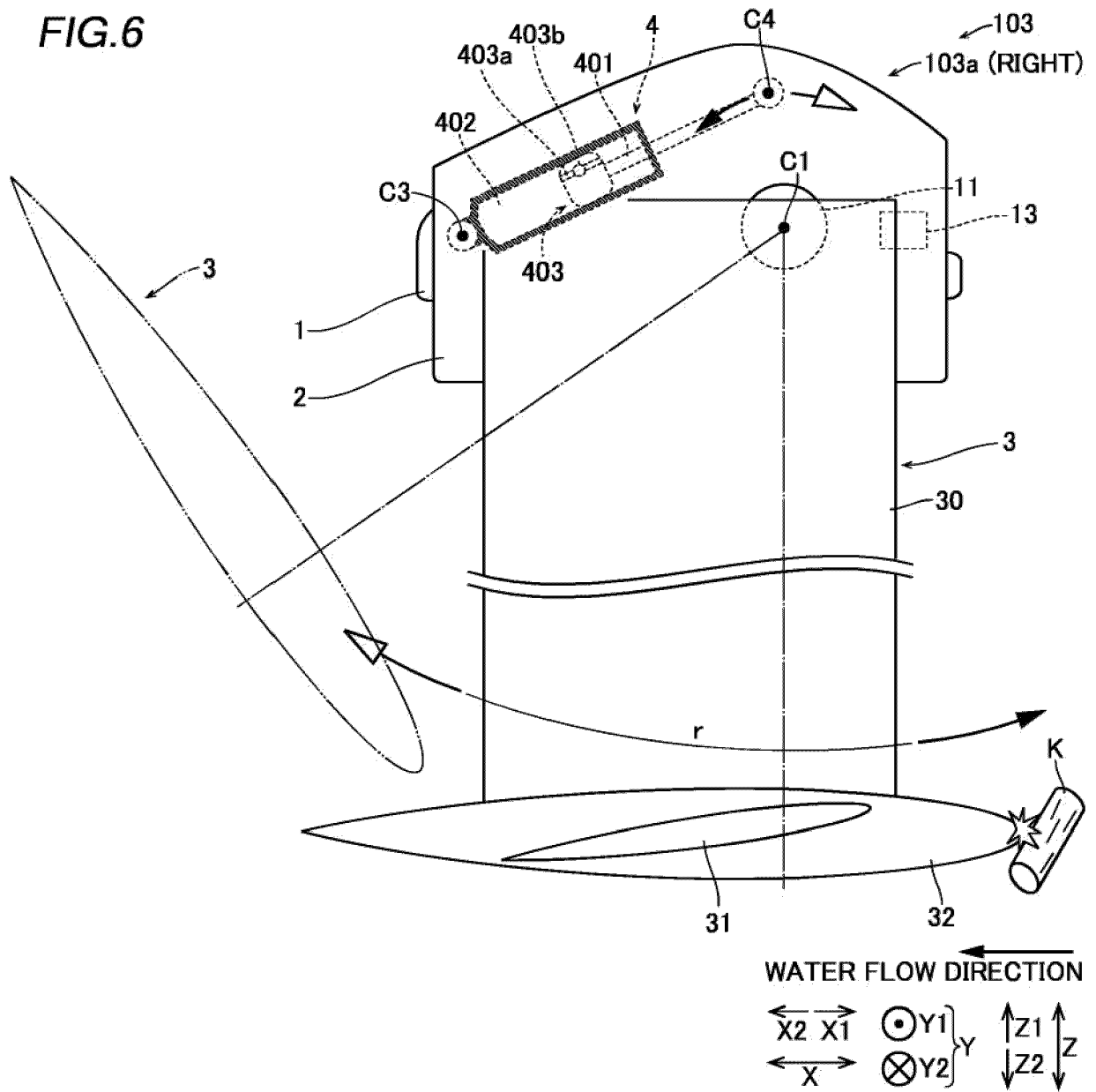


FIG. 7

REFERENCE STATE

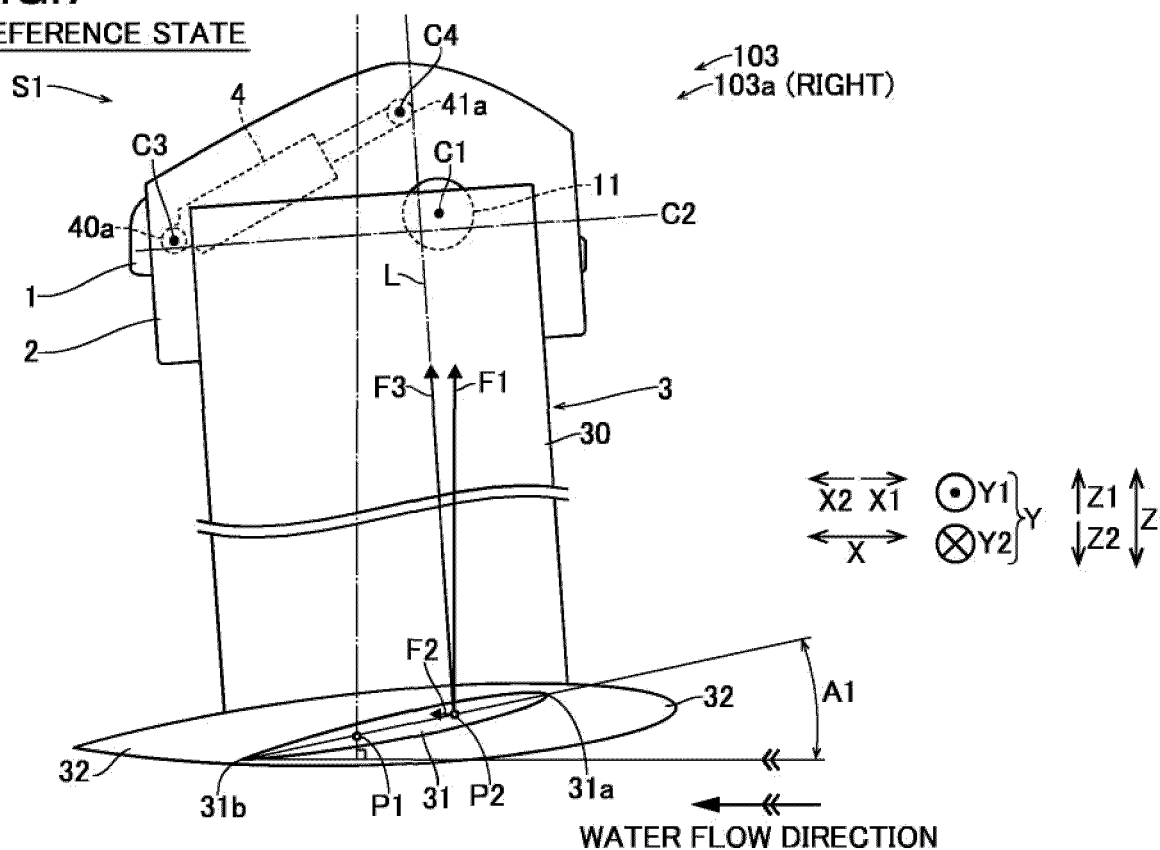


FIG. 8

INITIAL STATE

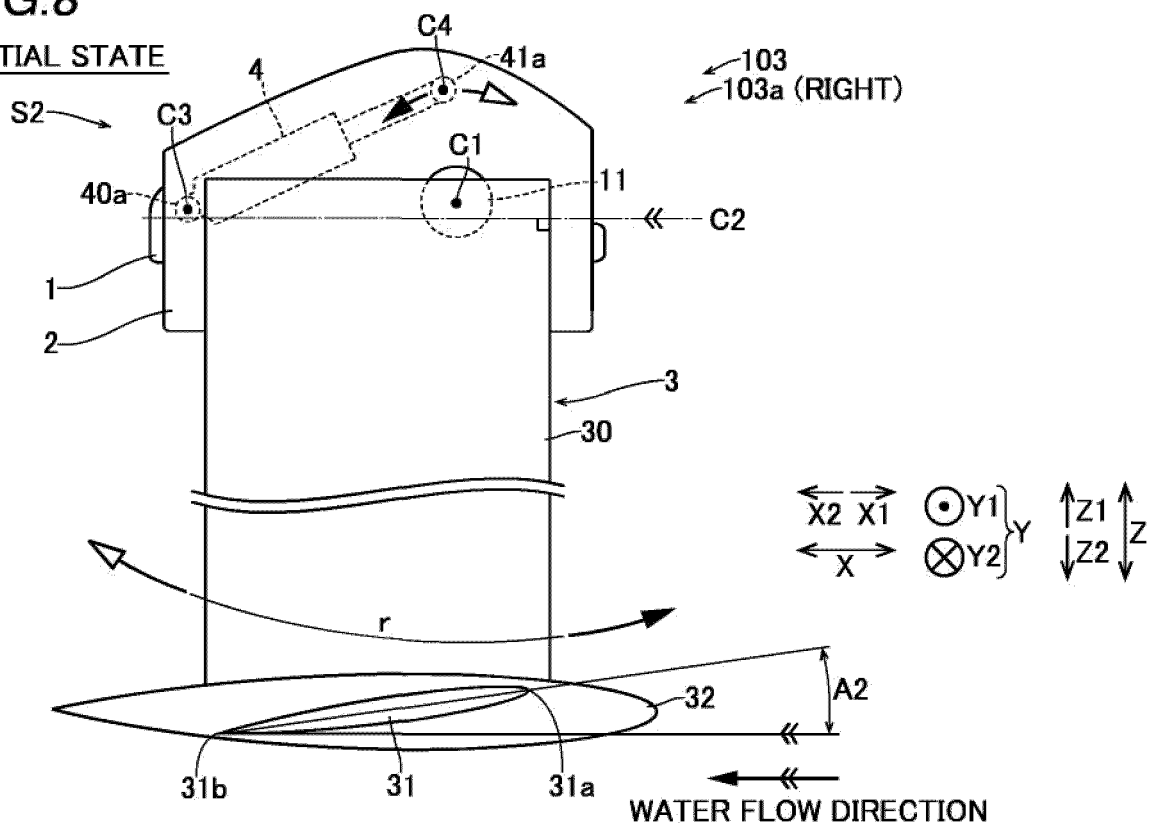


FIG. 9

REFERENCE STATE

S1 →

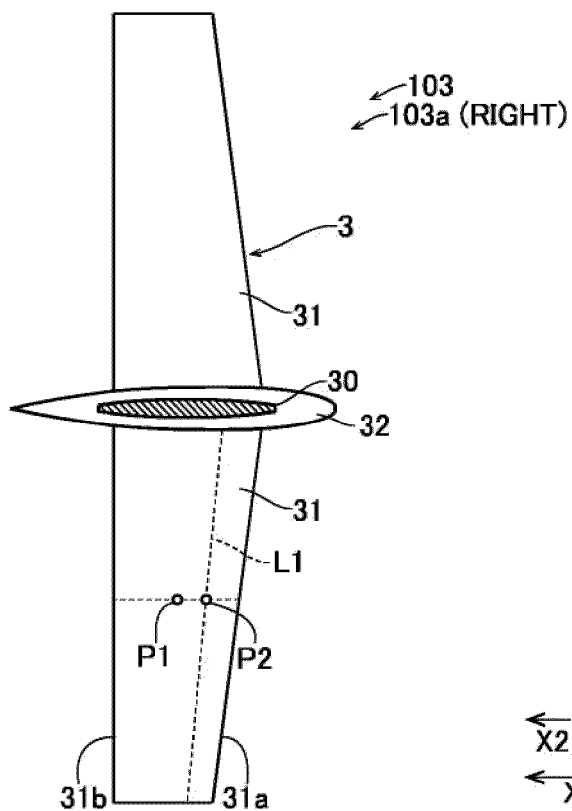
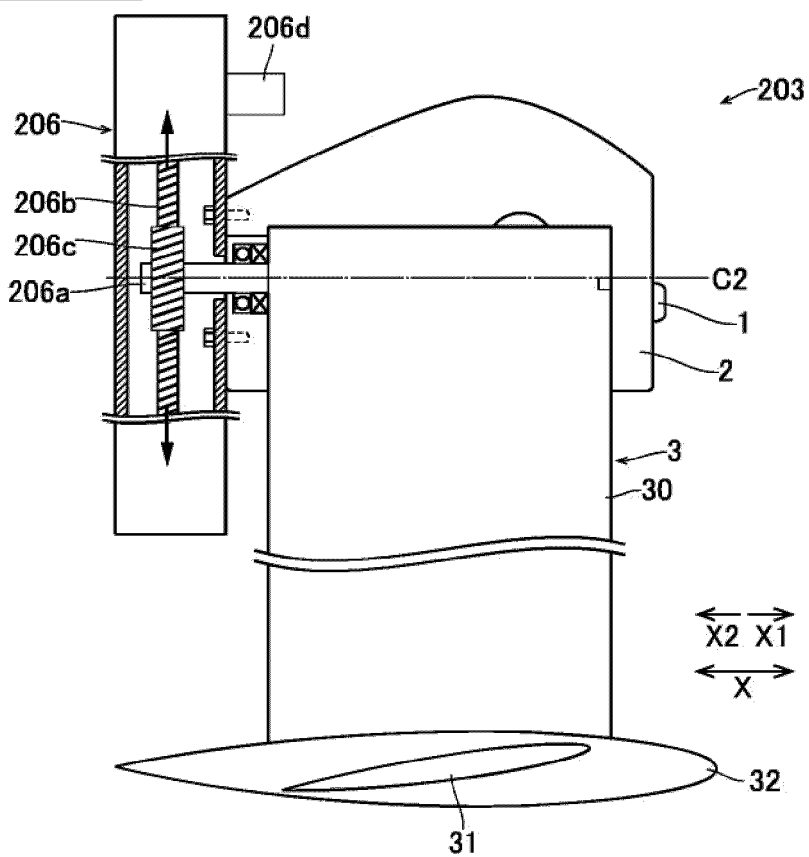


FIG. 10

MODIFIED EXAMPLE





EUROPEAN SEARCH REPORT

Application Number

EP 25 18 9879

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Place of search		Date of completion of the search	Examiner
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