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(54) **METHOD FOR CONTROLLING THE POSITION OF A HYDROFOIL, HYDROFOIL AND APPARATUS FOR CONTROLLING THE POSITION OF SAID HYDROFOIL**

(57) Method for controlling the position of a hydrofoil (1), such method providing for a detection step, in which at least one flow sensor (6) detects at least one speed measurement of a water flow movable along a transverse direction (F) and generates a corresponding flow signal (SF), a first calculation step, in which an electronic control unit (7) receives the flow signal (SF) and calculates a corresponding difference of lift (ΔP) between a first lift force (P1) of a port appendage (4') and the second lift force (P2) of a starboard appendage (4"), a second calculation step, in which the electronic control unit (7) calculates a movement position (PM) in which each appendage (4) is moved, in which the difference of lift (ΔP) is substantially zero, a driving step, in order to drive the actuator means (5) to move each appendage (4), a movement step in which the actuator means (5) move each appendage (4) in order to reach the corresponding movement position (PM) independently with respect to the other of the two appendages (4).

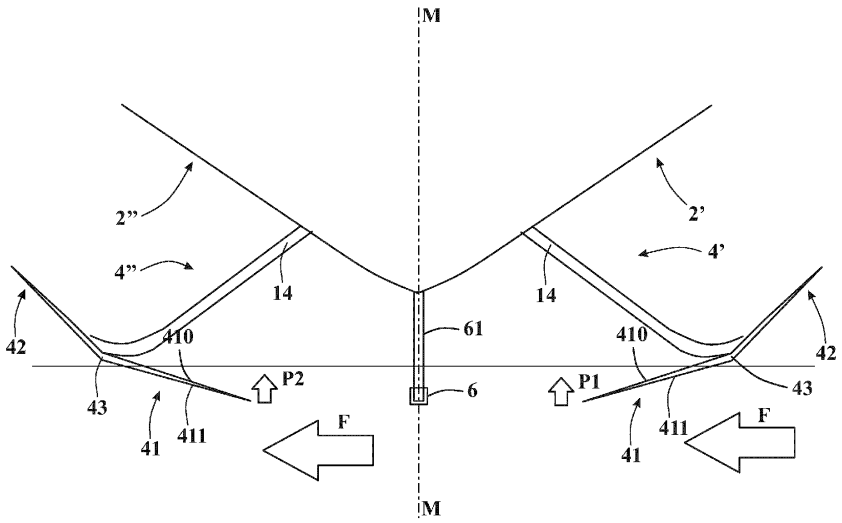

Fig. 5

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Description

Field of application

[0001] The present invention regards a method for controlling the position of a hydrofoil, a hydrofoil and an apparatus for controlling the position of said hydrofoil, according to the preamble of the respective independent claims.

[0002] The method, the hydrofoil and the control apparatus of the invention are intended to be advantageously employed in the nautical field for automatically controlling the position of a hydrofoil, i.e. the spatial position of the hydrofoil itself.

[0003] More particularly, the method that is the object of the present invention is advantageously employable in order to automatically drive appendages of the hydrofoil to move, so as to modify the position of the hydrofoil and in particular in order to maintain such position substantially horizontal.

[0004] The invention is therefore inserted in the context of the industrial field of the nautical industry, in the scope of production of hydrofoils and accessories thereof, and in the scope of use of such hydrofoils.

State of the art

[0005] Known on the market are new boats, also termed "hydrofoils", which are provided with appendages mounted on the hull of the boat and projecting below with respect to such hull for the purpose of being at least partially immersed in water.

[0006] During use, such appendages are capable of interacting with a water flow in which they advance, converting the pressure resulting from the relative speed between that of advancement of the hydrofoil and that of the water flow into a lift force directed upward. In particular, the greater the advancing speed of the hydrofoil on which such appendages are mounted, the greater the resulting lift force applied to the appendages, which lifts the hull from the free surface of the water.

[0007] More in detail, once a predetermined value of advancing speed has been exceeded, the generated lift force exceeds the weight force of the hydrofoil and the hull of the latter if lifted from the free surface of the water up to completely emerging and obtaining a navigation condition termed "foilborne".

[0008] Such foilborne navigation allows numerous advantages. In particular, during foilborne navigation, only the appendages are immersed in water and the hydrofoil navigates with a smaller surface area with respect to a "conventional" navigation, in which also the hull is at least partially immersed in water.

[0009] The aforesaid smaller immersed surface area involves a lower hydrodynamic resistance of the water on the hydrofoil and allows the hydrofoil to reach higher navigation speeds, given the same installed motor power.

[0010] Several examples of hydrofoils of known type are described in the documents US 3886884, US 2007/0157864 and US 3156209.

[0011] In particular, the hydrofoil described in US 3886884 is provided in a per se conventional manner with a hull intended to advance on the water in a first navigation condition of conventional type, i.e. with at least one portion of such hull immersed in water.

[0012] The aforesaid hydrofoil of known type also comprises two appendages, intended to be immersed in water in order to allow the hydrofoil to navigate also in a second condition, i.e. in foilborne condition.

[0013] More in detail, the hydrofoil of known type is provided with a bow appendage and with a stern appendage, which are mounted on the hull so as to project below the hull itself in order to be immersed in water and they are spaced from each other along a main extension direction of the hull itself.

[0014] In particular, the bow appendage is rigidly mounted on the rudder blade of the hydrofoil and it is intended to always be immersed.

[0015] Otherwise, the stern appendage is rotatably mounted on the hull in proximity to its stern and is susceptible of being moved with respect to the hull itself. More in detail, the stern appendage is extended transversely to the hull, from port to starboard, and is movable around a rotation axis orthogonal to the main extension axis of the hull itself and substantially horizontal.

[0016] In particular, the aforesaid stern appendage is movable between a lifted position, in which the appendage is substantially side-by-side the hull and the hydrofoil is susceptible of navigating in a conventional manner, and a lowered position, in which the appendage projects below with respect to the hull and the hydrofoil is susceptible of navigating, once the speed threshold value has been exceeded, in foilborne condition. More in detail, in the aforesaid lifted position, the stern appendage of the hydrofoil of known type is horizontal, side-by-side the hull and it completely emerges from the water so as to not interact with the water flow lines and not generate lift.

[0017] In this situation, the hull remains at least partially immersed, allowing the aforesaid navigation of conventional type.

[0018] Otherwise, in the lowered position, the stern appendage is vertical, projects below the bottom wall of the hull and is completely immersed in water so as to interact with the water flow lines and generate lift.

[0019] In order to allow a greater control of the position of the hydrofoil i.e. so as to maintain it substantially always horizontal during the entire navigation, the hydrofoil described in US 3886884 is also provided with movable terminations mounted on the bow and stern appendages.

[0020] More in detail, each bow and stern appendage has substantially flat shape, and is placed horizontal when the appendage is immersed in water. The aforesaid terminations are plates mounted on the appendages at a rear edge thereof, i.e. directed towards the stern, in opposite direction with respect to the advancement di-

rection. In addition, the aforesaid terminations are hinged to the corresponding appendage and are susceptible of being moved in order to vary an incidence profile (i.e. the substantially horizontal profile of the appendage which interacts with the water flow in order to convert the pressure of the water into the aforesaid lift force) of the appendage itself with the water flow lines.

[0021] In particular, the variation of the incidence profile involves a different interaction of the appendage with the water flow and then involves a different lift force developed by the appendage itself.

[0022] The hydrofoil described in US 3886884 is also provided with an electronic control apparatus programmed for automatically modifying the position of the aforesaid terminations of each appendage, in a manner such to control the position of the hydrofoil itself.

[0023] More in detail, such control apparatus of known type is provided with a plurality of sensors, in particular accelerometers and gyroscopes, which are adapted to detect the accelerations and tilts of the hull with respect to the three axes of rolling, pitch and yaw. In addition, on the basis of such detected information, the control apparatus is programmed for calculating the position in which the terminations of each appendage are placed so as to vary the lift generated by each appendage itself and hence maintain the hydrofoil substantially horizontal during navigation.

[0024] In addition, such control apparatus of known type is provided with a distance sensor, mounted on an external surface of the hull, in particular at the bottom of the hull, and adapted to detect the distance of the sensor itself (and hence of the hull) from the free surface of the water.

[0025] The control apparatus of known type is then programmed for comparing the distance detected by the aforesaid distance sensor with a desired distance and, in the event in which the two distances do not coincide, moving the terminations of the appendages until the detected distance coincides with the desired distance.

[0026] The hydrofoil of known type briefly described up to now and the control method of known type provided in such hydrofoil have in practice demonstrated that they do not lack drawbacks.

[0027] A first drawback of the aforesaid hydrofoil of known type lies in the fact that the distance sensor of the control apparatus of the aforesaid hydrofoil is only capable of detecting the distance of a point of the hull from a point of the free surface of the water (i.e. the distance of the point where the distance sensor is mounted on the hull from a point), which is not sufficient for knowing the actual position of the hull, and in particular the tilt of the hydrofoil with respect to the horizontal. Indeed, in the case of rolling or pitch, the distance sensor, which is centrally mounted on the bottom wall of the hull, does not detect any distance variation from the free surface of the water.

[0028] In such condition, in order to know, and thus control, the actual position of the hydrofoil, the control apparatus of known type must also know the measurements made by the accelerometers and by the gyroscopes. Therefore, the control apparatus of known type is rather complicated and hard to use, above all for non-expert pilots.

[0029] A further drawback of the hydrofoil of known type is tied to the fact that, in the case of the presence of waves transverse to the advancement direction, the appendages of such hydrofoil are susceptible of rotating the hull in an undesired manner.

[0030] More in detail, during navigation in the presence of transverse waves, such appendages are placed at different heights depending on whether the appendage is crossing the crest of a wave or a trough between two consecutive waves.

[0031] Therefore, different immersion levels of the different appendages correspond with such variable heights. As is known, different lift forces generated by the appendages correspond with different immersion levels.

[0032] In particular, in the presence of waves provided with heights greater than 10 cm, such as for example in the case of slightly rough sea, the lift variation generated by such waves is rather high and involves jolts of the hydrofoil, as well as oscillations of the hydrofoil itself with respect to the pitch and rolling axes thereof. It is clear that such navigation condition is rather unpleasant for people on board the hydrofoil, subjected to shakes, jolts and tilts.

[0033] In order to overcome the aforesaid drawback, such hydrofoil of known type provides for implementing a method for controlling the position of the hydrofoil itself, which provides for detecting the distance variation from the free surface of the water of the hull by means of the distance sensor. In particular, such distance of the hull from the free surface of the water corresponds with the immersion depth of the bow and stern appendages.

[0034] Subsequently, the control method of known type provides for moving the terminations of the appendages in a manner such to always maintain the hull at the same distance from the free surface of the water, i.e. in a manner such to maintain the appendages always immersed at the same level, so as to substantially always generate the same lift force.

[0035] Also such method for controlling the position of known type has however in practice demonstrated that it does not lack drawbacks.

[0036] The main drawback is tied to the fact that the aforesaid terminations are provided with dimensions much smaller than that of the appendages and that of the hull. Therefore, the movement of such terminations does not allow obtaining considerable generated lift variations and hence does not allow obtaining an optimal control of the position of the hydrofoil, especially in the presence of rather high waves or rather frequent waves.

[0037] A further drawback of the aforesaid hydrofoil and of the aforesaid control method lies in the fact that the distance sensor is unable to detect possible trans-

verse flows of the water in which the appendages are immersed.

[0038] In this situation, the hydrofoil and the method for controlling the position of known type hence are entirely useless in the case of sea that is flat on the surface but having underwater flows that tend to rotate the hydrofoil as if they were transverse waves.

Presentation of the invention

[0039] In this situation, the problem underlying the present invention is therefore that of overcoming the drawbacks manifested by the hydrofoils of known type, by providing a method for controlling the position of a hydrofoil, a hydrofoil and an apparatus for controlling the position of said hydrofoil which allow maintaining the hydrofoil itself in the desired position in any operating condition.

[0040] A further object of the present invention is to provide a method for controlling the position of a hydrofoil, a hydrofoil and an apparatus for controlling the position of said hydrofoil which allow limiting the jolts and the tilts to which the hydrofoil is subjected during the navigation thereof, also in case of high-speed transverse water flows.

[0041] A further object of the present invention is to provide a method for controlling the position of a hydrofoil, a hydrofoil and an apparatus for controlling the position of said hydrofoil which allow driving the hydrofoil itself in a simple and intuitive manner.

[0042] A further object of the present invention is to provide a hydrofoil and an apparatus for controlling the position of said hydrofoil that is entirely efficient and reliable in operation.

Brief description of the drawings

[0043] The technical characteristics of the invention, according to the aforesaid objects, can be clearly seen in the contents of the below-reported claims and the advantages thereof will be more evident in the following detailed description, made with reference to the enclosed drawings, which represent a merely exemplifying and non-limiting embodiment of the invention, in which:

- Fig. 1 shows a perspective view of a hydrofoil, object of the present invention, in which the hydrofoil is represented with the appendages placed in a lifted position in order to execute a conventional navigation, i.e. with the hull intended to be at least partially immersed in water;
- Fig. 2 shows a further perspective view of a hydrofoil, object of the present invention, in which the hydrofoil is represented with the appendages placed in a lowered position in order to execute a foilborne navigation;
- Figs. 3A and 3B respectively show a plan view and a side view of a hydrofoil and of a control apparatus thereof, both the object of the present invention, in which the position is visible at which several sensors of the present control apparatus are mounted;
- Fig. 4 shows a function block diagram of the apparatus and of the control method, object of the present invention;
- Fig. 5 shows a schematic front view of the hydrofoil, object of the present invention, during use in which a transverse water flow is identified.

Detailed description of a preferred embodiment

[0044] With reference to the enclosed drawings, reference number 1 overall indicates a hydrofoil, according to the present invention.

[0045] The hydrofoil 1, during use, is advantageously intended to float on a body of water, preferably with a substantially horizontal position, such position intended to be controlled by means of a method for controlling the position, object of the present invention.

[0046] In particular, in the following present description, with the term "position" it will be intended the spatial position of the hydrofoil 1 and more in detail the tilt of a lying plane of such hydrofoil 1 with respect to an ideal plane, preferably horizontal, as described more in detail hereinbelow.

[0047] Advantageously, the present control method is aimed to maintain the position of the hydrofoil 1 substantially horizontal during navigation of the hydrofoil 1 itself on the body of water, regardless of the surface conditions of the free surface of the water.

[0048] The hydrofoil comprises a hull 2 extended along a main extension axis X between a bow end 21 and a stern end 22.

[0049] Advantageously, the main extension axis X defines an advancement direction of the hydrofoil 1 itself along a navigation course thereof.

[0050] Preferably, in a manner per se known to the man skilled in the art, the hydrofoil 1 comprises at least one helm 3, mechanically mounted on the hull 2 and movable into a plurality of positions, each defining a corresponding turn angle α with respect to the main extension axis X.

[0051] In particular, with the term "helm" it must be intended hereinbelow a turn request member, preferably mounted at a driving zone of the hydrofoil 1, e.g. a driving cabin of the hydrofoil 1, and manipulatable by a pilot so as to drive a turning of the hydrofoil 1 with respect to the advancement direction.

[0052] The hydrofoil 1 also comprises at least two appendages 4, rotatably mounted on the hull 2 and projecting below with respect to the hull 2 itself.

[0053] In particular, such appendages 4 are during use intended to be at least partially immersed in water in order to generate a lift force and lift the hull 2 from the free surface of the water, allowing the hydrofoil 1 to navigate in foilborne condition.

[0054] With the term "lift", a lifting force must be intend-

ed in the present text, which is substantially directed upward, resulting from the fluid-dynamic forces that the water imparts on the aforesaid appendages 4.

[0055] The hull 2 is provided with a median plane M, comprising the aforesaid main extension axis X and defining a port half-hull 2' and a starboard half-hull 2".

[0056] Advantageously, with the hydrofoil 1 at rest, the median plane M is a substantially vertical plane which defines the aforesaid two half-hulls 2', 2" that are preferably mirrored and congruent with respect to each other.

[0057] The aforesaid at least two appendages 4 comprise at least one port appendage 4' mounted on the port half-hull 2' and susceptible of generating a first lift force P1 and at least one starboard appendage 4" mounted on the starboard half-hull 2" and susceptible of generating a second lift force P2.

[0058] The hydrofoil 1 also comprises actuator means 5 mechanically connected to the appendages 4 in order to move them with respect to said hull 2.

[0059] According to the idea underlying the present invention, the control method comprises a detection step, in which at least one flow sensor 6 mechanically fixed to the hull 2 detects at least one speed measurement of a water flow movable along a transverse direction F that is tilted with respect to the main extension axis X and generates a corresponding flow signal SF containing at least the aforesaid speed measurement. With the term "water flow" it must be intended a water current, provided with a progression along the aforesaid transverse direction F, provided with at least one component substantially orthogonal to the main extension axis X and, in particular, substantially orthogonal to the median plane M.

[0060] The method according to the invention also provides for a first calculation step, in which an electronic control unit 7 receives the flow signal SF and calculates, on the basis of the water flow speed, a corresponding difference of lift ΔP between the first lift force P1 of the port appendage 4' and the second lift force P2 of the starboard appendage 4".

[0061] The method according to the invention also comprises a second calculation step, in which the electronic control unit 7 calculates a movement position PM in which each appendage 4 is moved, in which the difference of lift ΔP is substantially zero.

[0062] In this manner, the canceling of the difference of lift ΔP exerted by the appendages 4 translates into an alignment of the lying plane of the hydrofoil 1 substantially horizontally, so as to control the position of the hydrofoil itself.

[0063] The method according to the invention also provides for a driving step, in which the electronic control unit 7 generates a driving signal SC in order to drive the actuator means 5 to move each appendage 4 around a corresponding first rotation axis Y orthogonal to the main extension axis X.

[0064] The present control method also provides for, according to the invention, a movement step in which the actuator means 5 move each appendage 4 in order to reach the corresponding movement position PM independently with respect to the other of the aforesaid at least two appendages 4.

[0065] In this manner, the method, object of the present invention, allows avoiding an undesired tilting of the hull 2 due to the aforesaid difference of lift ΔP, due to the action of the at least one water flow along a transverse direction F moving the appendages 4, canceling aforesaid difference of lift ΔP.

[0066] In operation, the aforesaid movement of the appendages 4 in the movement position PM modifies the lift force which each appendage 4 produces and consequently moves the appendages 4, which tend to be lifted due to an increase of the lift force or to sink due to a diminution of the lift force.

[0067] Consequently, the aforesaid movement of the appendages 4 involves a corresponding movement of the hull 2 with which appendages 4 are mounted, in order to vary the position of the hydrofoil 1.

[0068] Advantageously, therefore, the control method, object of the present invention, allows determining in a simple manner the position of the hydrofoil 1 and consequently moving the appendages 4 in order to control such position and in particular in order to maintain the position of the hydrofoil 1 substantially horizontal.

[0069] Advantageously, the flow sensor 6 is a magnetohydrodynamic sensor mounted below with respect to the hull 2.

[0070] More in detail, the magnetohydrodynamic sensor is mechanically fixed to a support bracket 61 fixed projectingly below the hull 2. Preferably, the support bracket 61 is the support bracket of a propeller of the hydrofoil 1.

[0071] In this manner, the flow sensor 6 remains constantly immersed in the water and therefore it is capable of carrying out the detection step according to the method in a continuous manner.

[0072] In accordance with the preferred embodiment illustrated in the enclosed figures, the appendages 4 are provided with an upper face 410 directed towards the hull 2 and a lower face 411 directed in the opposite direction with respect to the upper face 410. Advantageously, the detection step provides for detecting the direction of the course of the water flow movable along the aforesaid transverse direction F.

[0073] More in detail, the detection step provides for establishing if the direction of the water flow is from port to starboard or vice versa.

[0074] Advantageously, moreover, the first calculation step provides for associating a lower lift value with one between the port appendage 4' and the starboard appendage 4" which intercepts the water flow with the upper face 410.

[0075] Indeed, the pressure imparted by the water flow on the upper face 410 of the appendage 4 tends to lower the lift force, determining a lower lift between the two port and starboard appendages 4', 4".

[0076] Advantageously, the second calculation step

provides that the electronic control unit 7 defines, for the appendage 4', 4" associated with the lower lift value, a movement position PM with the lower face 411 at least partially directed towards the bow end 21 of the hull 2.

[0077] In this manner, directing the lower face 411 towards the bow end 21 increases the water flow intercepted by the lower face 411 itself, consequently increasing the lift force exerted on the hull 2 of the hydrofoil 1.

[0078] The method therefore provides that the increase of lift force is such to cancel the difference of lift, in order to bring the position of the hydrofoil 1 into substantially horizontal configuration.

[0079] Analogous to that described above, the first calculation step advantageously provides for associating a higher lift value with one between the port appendage 4' and the starboard appendage 4" which intercepts the water flow with the lower face 411. Advantageously, the second calculation step provides that the electronic control unit 7 defines, for the appendage 4', 4" associated with the higher lift value, a movement position PM with the upper face 410 at least partially directed towards the bow end of said hull 2.

[0080] In this manner, directing the upper face 410 towards the bow end 21 decreases the water flow intercepted by the lower face 411, consequently decreasing the lift force exerted on the hull 2 of the hydrofoil 1.

[0081] Advantageously, so as to prevent sudden lift variations generated by each appendage 4, the present control method provides that, during the movement step, each appendage 4 is continuously moved up to reaching the movement position PM.

[0082] In addition, in accordance with a preferred embodiment, the detection, calculation and driving steps are executed at a frequency comprised between 200 Hz and 6 kHz and still more preferably at a detection frequency of about 1000 Hz.

[0083] In this manner, in each time second, a number of movement positions PM are calculated comprised between 200 and 6000, which allow moving the appendages 4 substantially in a continuous manner between the plurality of calculated movement positions PM. Of course, it is possible to move the appendages 4 in a continuous manner also in the event in which the aforesaid steps of detection, calculation, processing and driving are executed at lower frequencies with respect to those indicated above, without departing from the protective scope of the present patent.

[0084] Preferably, the above-described signals, and in particular the flow signal SF and the driving signal SC, are signals of electrical type, susceptible of being processed both in reception and in emission by the electronic control unit 7.

[0085] As indicated above, also forming the object of the present invention is a hydrofoil 1, the position of which can be advantageously controlled by means of a method for controlling the position of the above-described type, regarding which the same nomenclature and the same alphanumeric references will be maintained for the sake of description simplicity.

[0086] The hydrofoil 1 according to the invention comprises a hull 2 extended along a main extension axis X between a bow end 21 and a stern end 22. In the following present description, reference will always be made to a hydrofoil 1 provided with only one hull 2, also an alternative embodiment of the hydrofoil 1 is nevertheless intended as possible, provided with two or more hulls 2, without departing from the protective scope of the present patent.

[0087] The hydrofoil also comprises at least two appendages 4, rotatably mounted on the hull 2 and projecting below with respect to the hull 2 itself.

[0088] The hull 2 is provided with a median plane M, comprising the main extension axis X, and defining a port half-hull 2' and a starboard half-hull 2".

[0089] The at least two appendages 4 comprising at least one port appendage 4' mounted on the port half-hull 2' and susceptible of generating a first lift force P1 and at least one starboard appendage 4" mounted on the starboard half-hull 2" and susceptible of generating a second lift force P2.

[0090] In accordance with the preferred embodiment illustrated in the enclosed figures, the hydrofoil 1 comprises four appendages 4, and in particular comprises two port appendages 4' mounted on the port half-hull 4' and two starboard appendages 4" mounted on the starboard half-hull 4".

[0091] All the above-described characteristics with reference to two appendages 4 must be intended as equally applicable, mutatis mutandis, to the embodiment which provides for four appendages 4.

[0092] The hydrofoil 1 also comprises actuator means 5 mechanically connected to the appendages 4 in order to move them with respect to the hull 2.

[0093] In particular, the aforesaid actuator means 5 preferably comprise at least one actuator for each appendage 4 so as to move each appendage 4 independent of the remaining appendages 4. Such actuators can for example be linear actuators and preferably hydraulic pistons.

[0094] The hydrofoil 1 according to the invention also comprises a control apparatus, which comprises at least one flow sensor 6 mechanically fixed to the hull 2 and configured for detecting at least one speed measurement of a water flow along a transverse direction F, tilted with respect to the main extension axis X, and for generating a corresponding flow signal SF containing at least the speed measurement.

[0095] In addition, the hydrofoil 1 comprises at least one electronic control unit 7, mounted on the hull 2 and placed in data communication with the flow sensor 6 and with the actuator means 5.

[0096] More in detail, the electronic control unit 7 is configured for receiving input signals from the flow sensor 6 and for calculating corresponding output signals to send to the actuator means 5 in order to move the appendages 4, as is better described hereinbelow. According to the idea underlying the present invention, the elec-

tronic control unit 7 is provided with a first calculation module 8, programmed for receiving the flow signal SF and for calculating, on the basis of the water flow speed, a corresponding difference of lift ΔP between the first lift force P1 of the port appendage 4' and the second lift force P2 of the starboard appendage 4".

[0097] In addition, the electronic control unit 7 is provided with a second calculation module 9, programmed for calculating a movement position PM in which each appendage 4 is moved, in which the difference of lift ΔP is substantially zero.

[0098] According to the invention, the electronic control unit 7 is also provided with a driving module 10, programmed for generating a driving signal SC and in order to drive the actuator means 5 to move each appendage 4 around a corresponding first rotation axis Y orthogonal to the main extension axis X, up to reaching preferably a desired tilt angle. The actuator means 5 are actuatable in order to move each appendage 4 at least in the movement position PM independently with respect to the other of the at least two appendages 4.

[0099] In accordance with a preferred embodiment of the present hydrofoil 1, illustrated in the enclosed figure 2, each appendage 4 comprises at least one first wing 41 that is substantially plate-like and mainly extended along a first lying plane.

[0100] More in detail, the aforesaid first wing 41 is shaped in a manner such to allow generating lift force, for example it is shaped with a NACA profile.

[0101] The aforesaid tilt angle is preferably comprised between 2° and 20°. The value of the tilt angle depends on the particular profile of the first wing 41, in particular depends on the type of NACA profile used, depends on the dimensions of the first wing 41. During use, moreover, the value of the maximum tilt angle advantageously depends on the maximum progression speed of the hydrofoil 1.

[0102] More precisely, the actuator means 5 are adapted to move each appendage 4 around the first rotation axis Y, in a plurality of positions with increasing lift between a position of minimum lift and a position of maximum lift.

[0103] In particular, in the position of minimum lift, the first wing 41 is placed with its first lying plane substantially parallel to the main extension axis X of the hull 2, and during use it is substantially parallel to the flow lines of the water in which the first wing 41 is immersed, so as to develop the least lift force possible.

[0104] Advantageously, in the position of maximum lift, the first wing 41 of the corresponding appendage 4 is placed with the first lying plane tilted by a maximum tilt angle with respect to the main extension axis X of the hull 2, and during use it is tilted with respect to the water flow lines in which the first wing 41 is immersed, by an angle such to develop the greatest lift force possible.

[0105] Each position of the appendages 4, comprised between the aforesaid positions of minimum lift and of maximum lift, corresponds with a different tilt angle of the first lying plane with respect to the main extension axis X comprised between 0 degrees (corresponding to the position of minimum lift) and the value of the maximum tilt angle, and in particular, increasing tilt angles correspond with increasing lift forces.

[0106] In accordance with the preferred embodiment illustrated in the enclosed figure 2, each appendage 4 also comprises a second wing 42, substantially plate-like and extended starting from the first wing 41 along a second lying plane tilted with respect to the first lying plane of the first wing 41. In other words, the first and the second wing 41, 42 of each appendage 4 are placed mechanically constrained to each other to form a substantially "C" shaped profile and joined together by an elbow 43, placed as a junction between the first and the second wing 41, 42, acting as a connector between the first and the second lying plane.

[0107] Preferably, each appendage 4 comprises at least one support leg 14 placed as a mechanical connection between the elbow 43 and the hull 2. More in detail, each support leg 14 is extended between a first end, fixed to the elbow 43, and a second end, rotatably mounted on the hull 2.

[0108] Advantageously, in order to move each appendage 4 towards a direction with higher lift, the first actuator means 5 are adapted to move the corresponding support leg 14 to rotate the first end thereof towards the bow of the hydrofoil 1. Likewise, in order to move each appendage 4 towards a direction with lower lift, the first actuator means 5 are adapted to move the corresponding support leg 14 to rotate the first end thereof towards the stern of the hydrofoil 1.

[0109] With particular reference to the enclosed figure 5, the water flow is movable along the transverse direction F substantially orthogonal to the median plane M of the hull 2, in particular according to a direction from port to starboard.

[0110] In this situation, the port appendage 4' exerts a first lift force P1 greater than the second lift force P2 exerted by the starboard appendage 4", since the port appendage intercepts the water flow with its lower surface 411.

[0111] Therefore, in order to cancel the difference of lift ΔP between the first lift force P1 and the second lift force P2, the electronic control unit 7 sends the driving signal SC in order to move the starboard appendage 4" in a higher lift configuration, i.e. rotating the starboard appendage 4" itself around the first rotation axis Y with the lower surface 411 at least partially directed towards the bow end 21.

[0112] In accordance with the preferred embodiment, the hydrofoil 1 comprises propulsor means adapted to move a water flow along a thrust direction, such propulsor means are of per se known type and therefore are not illustrated in detail and will not be described hereinbelow.

[0113] Advantageously, the flow sensor 6 is mechanically fixed to a support bracket 61 projecting below the hull 2 which carries, mounted thereon, at least one pro-

peller of the aforesaid propulsor means.

[0114] Also forming the object of the present invention is an apparatus for controlling the position of a hydrofoil preferably of the above-described type, regarding which the same nomenclature will be maintained for the sake of description simplicity.

[0115] The apparatus for controlling the position of a hydrofoil 1 according to the invention comprises at least one flow sensor 6 mechanically intended to be fixed to a hull 2 and configured for detecting at least one speed measurement of a water flow along a transverse direction F, tilted with respect to the main extension axis X, and for generating a corresponding flow signal SF containing at least the aforesaid speed measurement.

[0116] The apparatus according to the invention also comprises at least one electronic control unit 7, intended to be mounted on the hull 2 and placed in data communication with the flow sensor 6 and with the actuator means 5.

[0117] According to the idea underlying the present invention, the electronic control unit 7 of the control apparatus comprises a first calculation module 8, programmed for receiving the flow signal SF and for calculating, on the basis of the water flow speed, a corresponding difference of lift ΔP between a first lift force P1 of a port appendage 4' and a second lift force P2 of a starboard appendage 4".

[0118] The apparatus also comprises a second calculation module 9, programmed for calculating a movement position PM in which the appendages 4 is moved with the difference of lift ΔP that is substantially zero.

[0119] In addition, the apparatus according to the invention comprises a driving module 10, programmed for generating a driving signal SC and in order to drive actuator means 5 to move each appendage 4 around a corresponding first rotation axis Y orthogonal to a main extension axis X, in order to reach the movement position PM independently with respect to the other of the appendages 4.

[0120] In particular, the present control apparatus is of the above-described type in relation to the hydrofoil 1 and therefore all the characteristics reported with particular reference to the hydrofoil 1, object of the present invention, must also be completely intended as referred to the apparatus on its own described up to now, also the object of the present invention.

[0121] The method for controlling the position of a hydrofoil, the hydrofoil 1 and its control apparatus thus conceived therefore attain the pre-established objects.

Claims

1. Method for controlling the position of a hydrofoil (1), said hydrofoil (1) comprising:

- a hull (2) extended along a main extension axis (X) between a bow end and a stern end;
- at least two appendages (4), rotatably mounted on said hull (2) and projecting below with respect to said hull (2);

said hull (2) being provided with a median plane (M), comprising said main extension axis (X), and defining a port half-hull (2') and a starboard half-hull (2"); said at least two appendages (4) comprising at least one port appendage (4') mounted on said port half-hull (2') and susceptible of generating a first lift force (PI) and at least one starboard appendage (4") mounted on said starboard half-hull (2") and susceptible of generating a second lift force (P2);

- actuator means (5) mechanically connected to said appendages (4) in order to move them with respect to said hull (2);

said control method being **characterized in that** it provides for:

- a detection step, in which at least one flow sensor (6) mechanically fixed to said hull (2) detects at least one speed measurement of a water flow movable along a transverse direction (F) that is tilted with respect to said main extension axis (X) and generates a corresponding flow signal (SF) containing at least said speed measurement;
- a first calculation step, in which an electronic control unit (7) receives said flow signal (SF) and calculates, on the basis of the water flow speed, a corresponding difference of lift (ΔP) between the first lift force (PI) of said port appendage (4') and the second lift force (P2) of said starboard appendage (4");
- a second calculation step, in which said electronic control unit (7) calculates a movement position (PM) in which each said appendage (4) is intended to be moved, in which said difference of lift (ΔP) is substantially zero;
- a driving step, in which said electronic control unit (7) generates a driving signal (SC) in order to drive said actuator means (5) to move each said appendage (4) around a corresponding first rotation axis (Y) orthogonal to said main extension axis (X);
- a movement step in which said actuator means (5) move each said appendage (4) in order to reach the corresponding said movement position (PM) in an independent manner with respect to the other of said at least two appendages (4).

2. Control method according to claim 1, **characterized in that** said flow sensor (6) is a magnetohydrodynamic sensor mounted below with respect to said hull (2).

3. Control method according to claim 1 or 2, **charac-**

terized in that:

- said appendages (4) are provided with an upper face (410) directed towards said hull (2) and a lower face (411) directed in the opposite direction with respect to the upper face (410);
- said detection step provides for detecting the course direction of the water flow movable along said transverse direction (F);
- said first calculation step provides for associating a lower lift value with one from between said port appendage (4') and starboard appendage (4") which intercepts the water flow with said upper face (410).

4. Control method according to claim 3, **characterized in that** said second calculation step provides that said electronic control unit (7) defines, for said appendage (4', 4") associated with said lower lift value, a movement position (PM) with the lower face (411) at least partially directed towards the bow end of said hull (2).

5. Control method according to claim 3 or 4, **characterized in that** said first calculation step provides for associating a higher lift value with one from between said port appendage (4') and starboard appendage (4") which intercepts the water flow with said lower face (411).

6. Control method according to claim 5, **characterized in that** said second calculation step provides that said electronic control unit (7) defines, for said appendage (4', 4") associated with said higher lift value, a movement position (PM) with the upper face (410) at least partially directed towards the bow end of said hull (2).

7. Control method according to any one of the preceding claims, **characterized in that** in said movement step, each said appendage (4) is continuously moved up to reaching said movement position (PM).

8. Control method according to any one of the preceding claims, **characterized in that** said detection, calculation and driving steps are executed at a frequency comprised between 200 Hz and 6 kHz.

9. Hydrofoil (1) comprising:

- a hull (2) extended along a main extension axis (X) between a bow end and a stern end;
- at least two appendages (4), rotatably mounted on said hull (2) and projecting below with respect to said hull (2);

said hull (2) being provided with a median plane (M), comprising said main extension axis (X), and defining a port half-hull (2') and a starboard half-hull (2"); said at least two appendages (4) comprising at least one port appendage (4') mounted on said port half-hull (2') and susceptible of generating a first lift force (P1) and at least one starboard appendage (4") mounted on said starboard half-hull (2") and susceptible of generating a second lift force (P2);

- actuator means (5) mechanically connected to said appendages (4) in order to move them with respect to said hull (2);
- a control apparatus comprising:

  - at least one flow sensor (6) mechanically fixed to said hull (2) and configured for detecting at least one speed measurement of a water flow along a transverse direction (F), tilted with respect to said main extension axis, and for generating a corresponding flow signal (SF) containing at least said speed measurement;
  - at least one electronic control unit (7), mounted on said hull (2) and placed in data communication with said flow sensor (6) and with said actuator means (5);

said hydrofoil being **characterized in that** said electronic control unit (7) is provided with:

- a first calculation module (8), programmed for receiving said flow signal (SF) and for calculating, on the basis of the water flow speed, a corresponding difference of lift (ΔP) between the first lift force (PI) of said port appendage (4') and the second lift force (P2) of said starboard appendage (4");
- a second calculation module (9), programmed for calculating a movement position (PM) in which each said appendage (4) is intended to be moved, in which said difference of lift (ΔP) is substantially zero;
- a driving module (10), programmed for generating a driving signal (SC) and for driving said actuator means (5) to move each said appendage (4) around a corresponding first rotation axis (Y) orthogonal to said main extension axis (X);

said actuator means (5) being actuatable to move each said appendage (4) at least in said movement position (PM) independently with respect to the other of said at least two appendages (4).

10. Apparatus for controlling the position of a hydrofoil (1), said control apparatus comprising:

- at least one flow sensor (6) mechanically intended to be fixed to a hull (2) and configured for detecting at least one speed measurement of a water flow along a transverse direction (F),

tilted with respect to said main extension axis and for generating a corresponding flow signal (SF) containing at least said speed measurement;

- at least one electronic control unit (7), intended to be mounted on said hull (2) and placed in data communication with said flow sensor (6) and with said actuator means (5);

said apparatus being **characterized in that** said electronic control unit (7) comprises:

- a first calculation module (8), programmed for receiving said flow signal (SF) and for calculating, on the basis of the water flow speed, a corresponding difference of lift (ΔP) between a first lift force (P1) of a port appendage (4') and a second lift force (P2) of a starboard appendage (4");
- a second calculation module (9), programmed for calculating a movement position (PM) in which said appendages (4) are intended to be moved with said difference of lift (ΔP) substantially zero;
- a driving module (10), programmed for generating a driving signal (SC) and for driving actuator means (5) to move each said appendage (4) around a corresponding first rotation axis (Y) orthogonal to a main extension axis (X), in order to reach said movement position (PM) independently with respect to the other of said appendages (4).

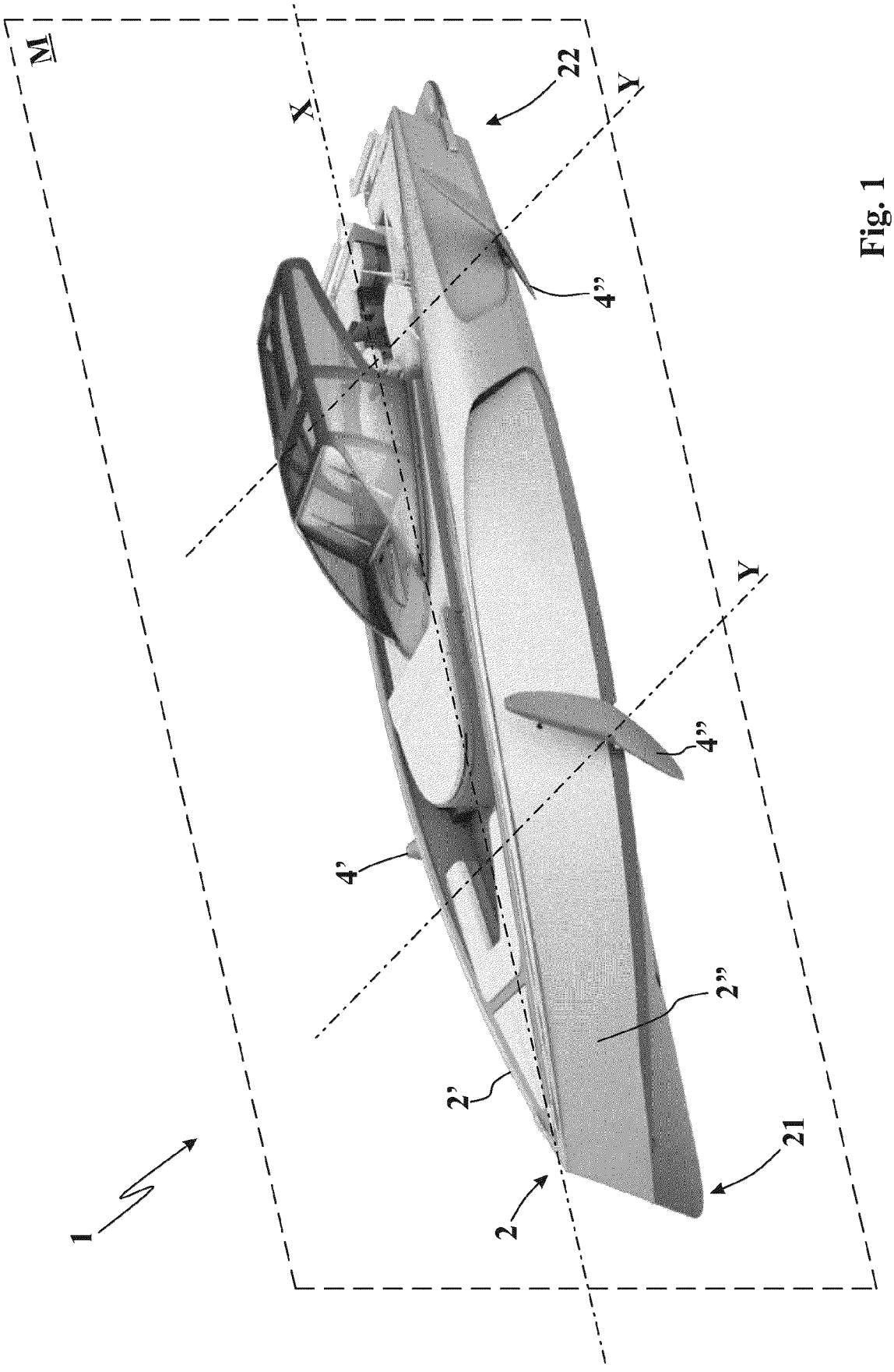


Fig. 1

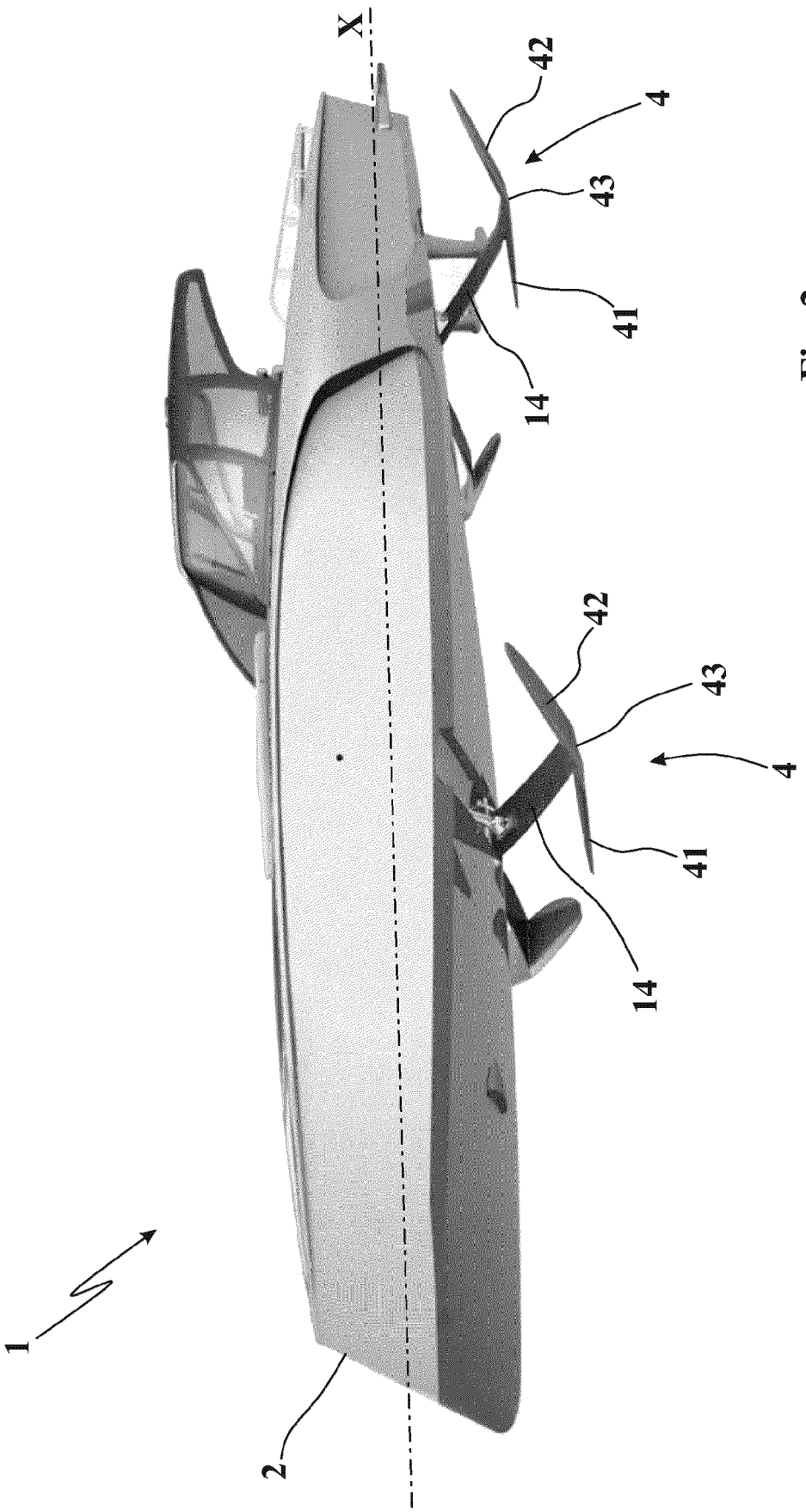
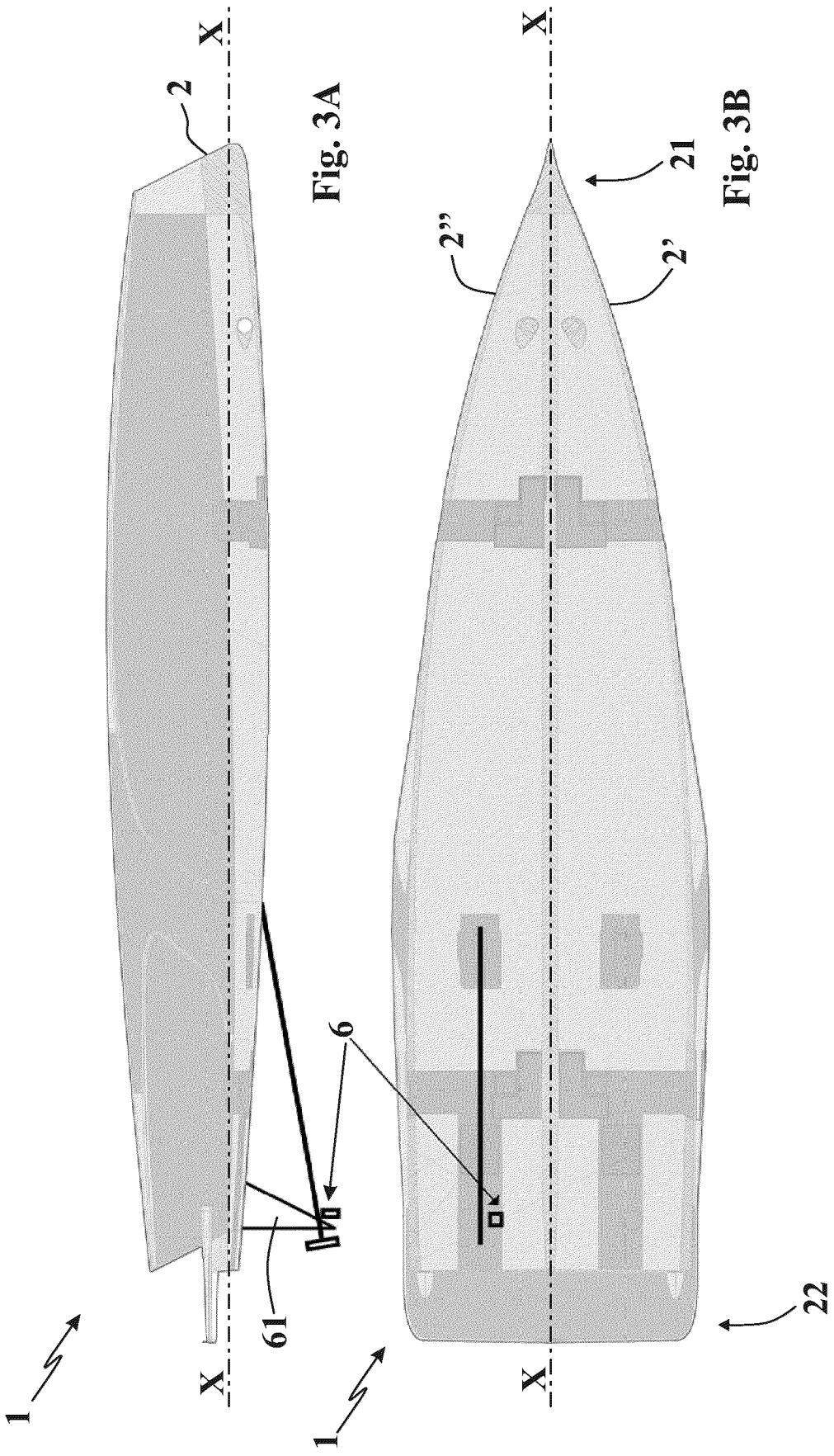


Fig. 2


X
2
Fig. 3A
X
21
2''
2'
Fig. 3B
6
61
1
1
X
X
22

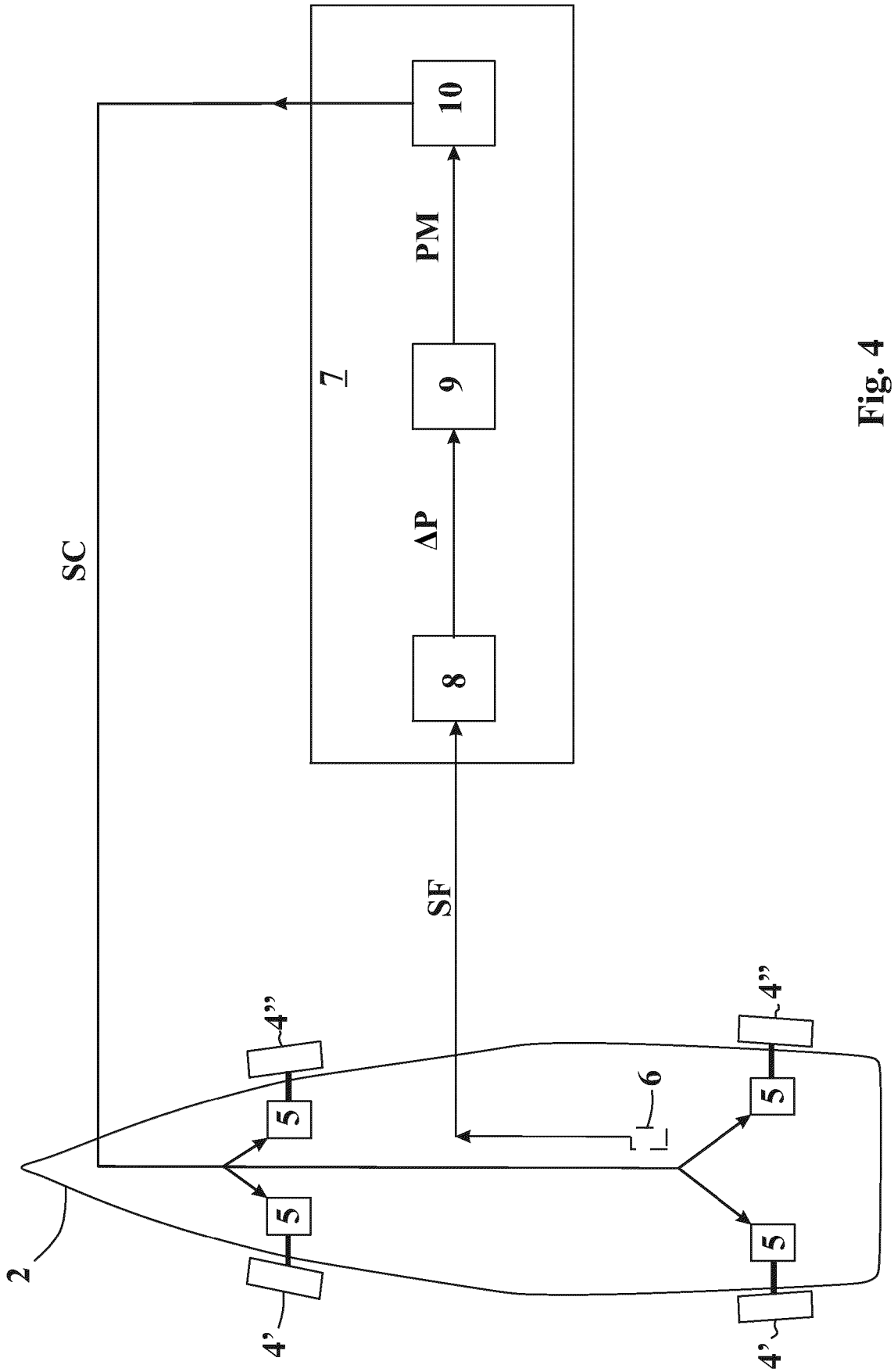


Fig. 4

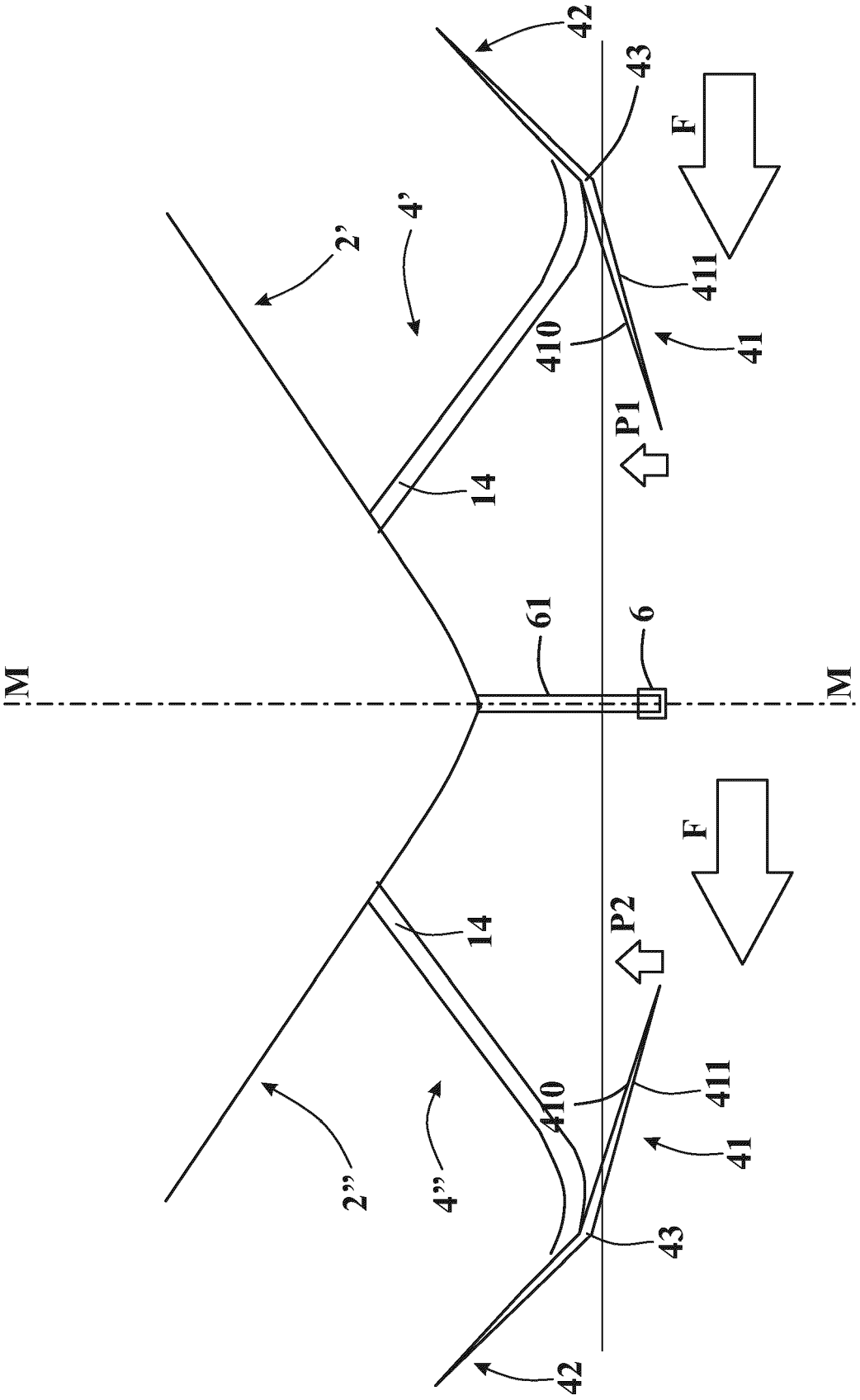


Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 21 16 4693

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,D	US 2007/157864 A1 (ALDIN GERARD [FR] ET AL) 12 July 2007 (2007-07-12) * paragraph [0066] - paragraph [0089]; figures 1-6 *	1-10	INV. B63B1/28
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TECHNICAL FIELDS SEARCHED (IPC)

B63B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	30 June 2021	Martínez, Felipe

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