

VEHICLE CAPABLE OF BEING SUBMERGED COMPRISING A MAST

The field of the invention is that of marine vehicles intended to move submerged in a liquid, notably underwater vehicles. It relates more particularly to underwater vehicles.

It relates notably to unmanned vehicles also referred to as UUVs (Unmanned Underwater Vehicles, which may autonomous vehicles also referred to as AUVs (Autonomous Underwater Vehicles) or non-autonomous vehicles also referred to as ROVs (Remotely Operated Vehicles).

Underwater vehicles have regularly to return to the surface for various reasons (to resupply with energy, to communicate with a high transmission bit rate, to be recovered, take measurements, etc.).

These underwater vehicles therefore comprise a payload comprising for example a telecommunications antenna or a camera intended to be used above the surface of the water. The underwater vehicle therefore needs to be capable of bringing this payload to a sufficient height above the surface of the water, often several meters above the surface of the water so as, so as to allow correct operation of the payload. It is desirable for example to emit and/or receive radioelectric waves with good performance or to acquire high-quality images of a landscape situated above the surface of the water. Furthermore, certain applications require a mast orientation that is as stable as possible along a vertical axis that is fixed with respect to the terrestrial frame of reference.

The payloads such as antennas are generally installed at the end of a deployable mast which is stowed when the underwater vehicle is traveling at depth and which is deployed when the vehicle rises back up toward the surface of the water, so as to bring the payload above the surface of the water to a sufficient height.

In large underwater vehicles, a mast extending along a radial axis of the body of the underwater vehicle is provided. The radial axis is defined with respect to a longitudinal axis of a body of the underwater vehicle. The body of the underwater vehicle is elongate along the longitudinal axis. In a retracted configuration, the mast is folded inside the body of the underwater vehicle. That makes it possible to limit the hydrodynamic drag of the underwater vehicle when it is traveling fully submerged. In order to place the payload above the surface of the water, the underwater vehicle surfaces and

the mast is translated along the radial axis so as to extend above the body of the underwater vehicle along a vertical axis. The stability of the mast is obtained by the inertia of the assembly and by virtue of a vehicle length that is greater than the length of the waves. Vehicles of a smaller size (of around
 5 one hundred kg, equipped with a payload weighing a few kg at the end of a mast of several meters) using this type of mast are highly unstable as soon as there is a little swell. This is because the vehicle floating on the surface of the sea follows the surface of the water and experiences a rolling and pitching movement. If use of the payload incorporated into the mast requires
 10 a certain stability of the mast then its performance is dependent on the sea state.

Solutions for improving the stability of the mast consist in providing means for varying the pitch (longitudinal attitude) of the body of the underwater vehicle so as to allow the longitudinal axis of the body of the
 15 underwater vehicle to be oriented in a substantially vertical direction when the underwater vehicle is floating on the surface of the water in a configuration. A first solution of this type is described in patent application GB 2 335 888 and depicted in figure 1. The mast 1 equipped with the payload extends vertically above the surface S of the water and is aligned with the
 20 longitudinal axis x_e of the body 3 of the underwater vehicle 4. In this solution, the mast 1 extends longitudinally substantially along the longitudinal axis x_e of the body 3 of the underwater vehicle 4 and is mobile in translation along this axis so as to be able to be retracted, inside the body 3 of the underwater vehicle 4 vehicle, or deployed outside the body of the underwater vehicle, as
 25 depicted in figure 1, toward the front of the body 3. The pitch of the body 3 of the underwater vehicle 4 is modified by the translational movement of a mass 5 internal to the body 3 of the underwater vehicle 4 along the longitudinal axis x_e or using control surfaces.

A second solution is described in patent application US 20080132130
 30 and is depicted in figure 2. In this solution, a first mast 100 equipped with the payload is connected to the body 102 of a floating vehicle by a first pivot connection 103 of axis perpendicular to the longitudinal axis x_l of the body of the floating vehicle and positioned near a first longitudinal end 104 of the body 102 of the floating vehicle. A second mast 105 is connected to the body
 35 102 of the floating vehicle by a second pivot connection 106 of axis parallel to that of the first pivot connection 103 and positioned close to the second

longitudinal end 107 of the body of the floating vehicle. This second mast 105 deploys in such a way as to alter the position of the center of gravity of the underwater vehicle along the longitudinal axis x_l of the body of the floating vehicle in order to vary the pitch of the body 102 so as to bring the vehicle into a stable position in which it floats at the surface of the water with the two masts 100, 105 and the body 102 of the underwater vehicle all vertical as depicted in figure 2. Control surfaces also allow the pitch of the body of the floating vehicle to be modified.

Certain applications defined in the context of the invention require the mast, stabilized in a substantially vertical direction, to be made to rotate on itself in the steady state, for example in order to acquire or transmit information in various directions that are radial with respect to a vertical axis. It may for example be necessary to make a radioelectric antenna rotate about a vertical axis that is fixed with respect to the terrestrial frame of reference in order to bring it to a correct orientation that allows it to communicate with another antenna or, when the antenna is a receive antenna, in order to determine a direction of a source about the vertical axis by determining the direction in which the received signal is strongest. It may also be necessary to capture images or acquisitions or emissions of radioelectric signals over 360° about a fixed vertical axis.

Now, the solutions depicted in figures 1 and 2 do not allow these functions to be performed.

It is an object of the invention to limit at least one of the aforementioned disadvantages.

To this end, one subject of the invention is a marine vehicle able to be submerged, comprising a body extending longitudinally along an axis x and a mast extending longitudinally along an axis x_m , the mast being equipped with a payload intended to be used above the surface of the water, the marine vehicle being capable of being in a panoramic configuration in which the mast extends at least partially above the surface of the water and extends longitudinally in a substantially vertical direction, the mast being in an operational configuration in which it extends beyond the body along the axis x , the marine vehicle comprising a thruster able to generate a torque about the axis x_m , when the marine vehicle is in the panoramic configuration, so as to cause the body and the mast to rotate about the axis x_m .

Advantageously, the thruster and the mast are arranged in such a way that when the axis x_m is inclined with respect to the axis x in the panoramic configuration, there is a non-zero lever arm between the axis x_m and the thruster.

5 Advantageously, the thruster comprises two contrarotating propellers each comprising blades of which the collective and cyclic pitch about a neutral position is variable, the propellers being mounted on the body in such a way as to have the same axis of rotation that is fixed with respect to the body, this axis of rotation being substantially parallel to the longitudinal axis
10 x .

Advantageously, the mast is connected to the body by a pivot connection allowing the mast to be pivoted with respect to the body between a stowed configuration in which the mast is folded down along the body and the operational configuration.

15 Advantageously, the mast is able to be immobilized in the operational configuration.

Advantageously, in the stowed configuration, the axis x_m extends substantially parallel to the axis x .

20 Advantageously, the marine vehicle is able to exhibit positive buoyancy in a panoramic configuration referred to as a stabilization configuration in which the body is fully submerged.

Advantageously, the marine vehicle is capable of exhibiting positive buoyancy in a panoramic configuration referred to as stabilization configuration in which the body is fully submerged, the mast breaking the
25 surface of the water.

Advantageously, the marine vehicle has a cross section that is smaller than a cross section of the body.

Advantageously, the mast is connected to the body by a pivot connection.

30 Advantageously, the pivot connection is positioned close to a first longitudinal end of the body.

Advantageously, the vehicle comprises rotation means configured to implement, on receipt of a rotation command, a rotation step during which the thruster generates a torque about the axis the axis x_m in order to cause the
35 body and the mast to rotate about the axis x_m , the marine vehicle being in a panoramic configuration.

Advantageously, the rotation means are configured to implement the rotation step when the axis x is inclined with respect to the axis xm.

The invention also relates to a method for controlling a marine vehicle as claimed in any one of the preceding claims, comprising a rotation step, during which the thruster generates a torque about the axis the axis xm in the panoramic configuration, so as to cause the body and the mast to rotate about the axis xm.

Advantageously, the method comprises a step of adjusting the buoyancy, prior to the rotation step, in order to bring the marine vehicle into a condition such that the vehicle exhibits positive buoyancy in the panoramic configuration.

Advantageously, the adjustment step is performed in such a way that the body is fully submerged in the panoramic configuration, with the mast breaking the surface of the water.

Advantageously, the method comprises a step of deploying the mast, prior to the rotation step, from a stowed configuration in which the mast is folded down along the body of the marine vehicle, into the operational configuration by pivoting the mast with respect to the body about a pivot connection connecting the mast to the body.

Advantageously, the method comprises a step of regulating the pitch of the body of the marine vehicle, prior to the rotation step, so that the axis xm is substantially vertical in the panoramic configuration.

The invention will be better understood with studying a number of embodiments described by way of nonlimiting examples and illustrated by attached drawings in which:

- figure 1, already described, schematically depicts one example of an underwater vehicle according to the prior art,
- figure 2, already described, schematically depicts one example of a floating vehicle according to the prior art,
- figure 3 schematically depicts a marine vehicle according to the invention in a panoramic configuration, the mast being in an operational configuration,
- figure 4 schematically depicts the marine vehicle of figure 3 in which the mast is in a stowed configuration,

- figure 5 schematically depicts the components of one example of a marine vehicle according to the invention.

From one figure to another, the same elements are denoted by the
5 same numerical references.

The invention notably relates to an underwater vehicle 10 as depicted in figure 3. An underwater vehicle is a submersible vehicle capable of moving under the water, namely when completely submerged. The invention also
10 applies to a surface vehicle, namely to a floating vehicle intended to float on the surface of the water and not intended to be fully submerged, namely exhibiting positive buoyancy.

The invention will be described hereinafter with reference to an underwater vehicle but applies to any marine vehicle.

15 The underwater vehicle 10 comprises a body 11 extending longitudinally along a longitudinal axis x and a mast 12 connected to the body 11 of the underwater vehicle. The mast 12 is equipped with a payload 13 intended to be used above the surface S of the water.

The payload 13 comprises at least one transmitter and/or at least one
20 receiver. The payload may comprise a transmitter able to transmit radioelectric waves or a radioelectric transmission antenna and/or receiver able to receive radioelectric waves or a radioelectric receive antenna and/or receiver able to receive light waves or an image sensor and/or an image or light-ray emitter.

25 Advantageously, the payload 13 or at least one transmitter and/or at least one receiver of the payload 13 is attached to the mast 12.

This rotation is achieved using the thruster.

The payload or at least one transmitter and/or at least one receiver of the payload 13 may be mounted with the ability to pivot with respect to the
30 mast about the axis of the mast. The underwater vehicle may comprise an actuator allowing the payload to be pivoted about the axis of the mast. At least one transmitter and/or at least one receiver of the payload 13 may be attached removably to the mast. It is contained for example in a reservoir able to be attached to the mast and able to be detached from the mast, for
35 example in order to raise communications equipment above the surface of the water.

In the nonlimiting example of the figures, the underwater vehicle comprises a reservoir 130 fixed, permanently or removably, to one end of the mast 12 in which the payload 13 is housed. As an alternative, the mast comprises the reservoir.

5 The underwater vehicle 10 comprises a body 11 of the underwater vehicle having a shape that is elongate along a longitudinal axis x of the underwater vehicle 10. The underwater vehicle is for example intended to move chiefly along the longitudinal axis x .

10 The mast 12 has a shape that is elongate along a longitudinal axis of the mast x_m .

 The mast is capable of being in at least one operational configuration in which the mast 12 projects with respect to the body 11 of the underwater vehicle 10 along the axis x . In other words, the mast 12 extends beyond the body 11 of the underwater vehicle 10 in the operational configuration. In
15 other words, the vehicle 10 has, in the operational configuration, a dimension, measured along the axis x , that is greater than the length of the body 11 of the underwater vehicle because the length of the projection formed by the mast 12, considered along the axis x , is added thereto. More specifically, in the operational configuration, the payload 13 or the end of the
20 mast closest to the payload 13, extends beyond the body 11 along the axis x .

 Advantageously, in the operational configuration, the mast 12 is secured to the body of the underwater vehicle 10 in terms of rotation about the axis x_m .

 The underwater vehicle 10 is able to be in a configuration referred to
25 as panoramic configuration, an example of which is depicted in figure 3, in which the mast 12 extends at least partially above the surface of the water and extends longitudinally in a substantially vertical direction z defined in a frame of reference connected with the earth so that the payload is positioned above the surface of the water, namely so that one end 12a of the mast
30 extends above the surface of the water. In other words, the longitudinal axis x_m of the mast 12 extends substantially vertically in the panoramic configuration.

 In the panoramic configuration, the mast is in an operational configuration.

35 If the mast 12 is able to be in several operational configurations, the vehicle is advantageously able to be in a configuration referred to as a

panoramic configuration for each operational configuration of the mast. As an alternative, the vehicle is able to be in a panoramic configuration for at least one operational configuration.

According to the invention, the underwater vehicle 10 comprises a thruster 14 able to generate a torque about the axis x_m so that the body 11 of the underwater vehicle and the mast 12 can be rotated about the axis x_m when the underwater vehicle 10 is in the panoramic configuration. Thus, the mast 12 and the body 11 of the marine vehicle 10 rotate about the axis x_m , which is fixed with reference to the terrestrial frame of reference, while remaining in the panoramic configuration. It is thus possible to perform the functions described earlier that entail rotating the mast about its axis x_m at a constant height. Furthermore, because the mast and the body 11 are secured in terms of rotation about the axis x_m , there is no need to provide a specific device to manage the twisting of the cables connecting the payload to the body 11 when the mast is rotating about its axis, unlike in a solution in which the mast 12 rotates about its axis x_m while the underwater vehicle is fixed with respect to the body of the underwater vehicle. This solution also makes it possible to avoid installing or using an actuator to cause the mast to pivot with respect to the body 11 of the underwater vehicle 10 or to cause the payload or a transmitter or receiver of the payload to pivot about the axis of the mast. If such an actuator is provided, the invention allows the panoramic rotation function to be achieved in the event of a failure of the actuator.

Advantageously, although not necessarily, the thruster 14 is a vectored-thrust thruster able to generate vectored thrust, namely thrust that is orientable with respect to the body 11 of the underwater vehicle 10.

In the remainder of the patent application, a thruster capable of generating an orientable thrust will be referred to as a vectored thrust thruster. Vectored-thrust propulsion differs from conventional propulsion in which the orientation of control surfaces leads to a change in the lift generated by the stream of fluid surrounding the control surfaces. The force generated by the fluid on the control surfaces orients the vehicle in the desired direction. One limitation of this form of propulsion is the need to generate a significant stream of fluid around the vehicle in order to bring about a change in lift of the control surfaces to allow a change in direction of the vehicle. In other words, it is not possible using conventional propulsion to

orient the vehicle in a desired direction without a significant movement of the vehicle when the fluid stream is zero.

5 Vectored thrust propulsion offers numerous advantages, notably increased maneuverability, simplification of the architecture (e.g. by eliminating the control surfaces). This capacity for orientation of the propulsion allows the vehicle to dispense with the conventional control surfaces used for steering, and therefore to significantly reduce the hydrodynamic drag of the vehicle thereby making it possible to increase the endurance of the vehicle.

10 Advantageously, the thruster 14 is able to generate a thrust directed along the axis x . This solution makes it possible to avoid installing a specific thruster for causing the mast 12 and the body 10 to rotate about the axis of the mast, the same thruster being able to cause the vehicle to advance along the axis x and being able to cause it to pivot about the axis x_m .

15 Advantageously, the thruster 14 is an omnidirectional vectored-thrust thruster. It is able to generate a thrust that can be oriented over 4π steradians.

In the embodiment of the figures, the thruster 14 is mounted on the body 11 of the underwater vehicle 10. In other words, the thruster 14 is connected to the mast 12 via the body 11 of the underwater vehicle 10.

20 In the nonlimiting example of figure 3, the thruster 14 comprises two propellers 15, 16. Advantageously, these propellers are contrarotating propellers each comprising blades 17 of which the collective and cyclic pitch about a neutral position is variable. In the embodiment of the figures, the propellers 15 and 16 are mounted on the body 11 in such a way as to exhibit the one same axis of rotation with respect to the body 11 of the underwater vehicle, this axis of rotation being parallel to the longitudinal axis x of the body 11 of the underwater vehicle 10.

25 As an alternative, the underwater vehicle 10 comprises a thruster 14 able to generate a thrust along the axis x and one or more lateral thrusters mounted on the body 11 and able to generate a thrust along two orthogonal radial axes. These lateral thrusters make it possible to generate the desired torque. The disadvantage with this type of thruster is that when the vehicle is advancing along the axis x , these lateral thrusters no longer achieve any effect because their thrust is "blown away" by the stream generated by the

forward movement of the vehicle. The vehicle therefore has to be equipped with control surfaces in order to maneuver it as it advances.

Advantageously, the underwater vehicle 10 is capable of floating, namely of exhibiting positive buoyancy, in a stable panoramic configuration like that depicted in figure 3, in which the mast 12 is in an operational configuration.

When, in the configuration referred to as panoramic configuration, the underwater vehicle exhibits positive buoyancy, no propulsion energy is therefore needed in order to keep the underwater vehicle 10 in this configuration, and this allows the durations of the missions of the underwater vehicle to be lengthened.

The underwater vehicle 10 may be made to float naturally in this configuration as a result of its positive buoyancy or may comprise means for regulating its buoyancy, which means will be described later.

As an alternative, the underwater vehicle 10 may be kept in a panoramic configuration by the thruster 14.

Advantageously, the thruster 14 (which makes it possible to generate the desired torque) and the mast 12 are arranged relative to one another in such a way that when the axis x_m is inclined with respect to the axis x in the operational configuration (non-zero angle α between x and x_m) there is a non-zero lever arm d , namely a non-zero distance, between the axis x_m and the thruster 14. For example, the mast 12 is connected to the body 11 on which the thruster 14 is mounted by a pivot connection 18 visible in figure 4 arranged some distance from the thruster 14 along the axis x so that the lever arm increases with the angle α , visible in figure 3, formed between the axis x and the axis x_m . In this way, when the thruster 14 is delivering thrust generating the torque about the axis x_m , there is a non-zero lever arm between the thrust delivered by the thruster and the axis x_m which is inclined with respect to the axis x . Specifically, this thrust is tangential to a circle orthogonal to the axis x_m and centered on the axis x_m . This configuration makes it possible to obtain better deployment of the energy of the thruster during rotation about the axis x_m and to generate the torque about x_m by simpler control of the thruster 14, notably in the case of a thruster 14 having two contrarotating propellers, than when α is zero, the lever arm between the thruster 14 and the axis x_m then being zero. Specifically, in instances in which the lever arm is zero, namely when the force of the thrust of the

thruster passes through the axis x_m , then the complex means used for producing rotation about the axis x_m is to use the difference in drag produced on each of the contrarotatory propellers. By increasing or decreasing one or other of these drags, the residual torque is no longer zero and allows rotation.

The mast 12 may be able to move with respect to the body 11. The mast 12 is, for example, connected to the body 11 by an articulation. This articulation is, for example, a pivot connection 18 with an axis of rotation substantially perpendicular to the axis x allowing the mast 12 to be made to pivot with respect to the body 11 between a stowed configuration, depicted in figure 4, in which the mast 12 is folded down along the body 11 of the underwater vehicle 10 (the hydrodynamic profile of the mast is thus affected only little when the mast 12 is in a stowed configuration) and a set of at least one operational configuration, of which one is depicted in figure 3. The mast 12 passes from the stowed configuration to the operational configuration by pivoting about the axis of rotation of the pivot connection 18.

Advantageously, in the stowed configuration depicted in figure 4, the mast 12 does not project from the body 11 along the axis x . The underwater vehicle unfolds between the stowed configuration and the operational configuration. The payload 13 moves away from the body 11 from the stowed configuration as far as the operational configuration.

Advantageously, like in the stowed configuration depicted in figure 3, the longitudinal axis x_m of the mast 12 (along which the mast 12 extends longitudinally) extends substantially parallel to the longitudinal axis x of the body 11 of the underwater vehicle. The hydrodynamic profile of the underwater vehicle is thus affected only little in the stowed configuration.

The end of the mast 12 which is furthest from the pivot connection 18 extends beyond the body 11, along the axis x , in the operational configuration.

The underwater vehicle 10 advantageously comprises an actuator, for example an actuating cylinder or a rotary motor, for example a stepping motor, allowing the mast to be pivoted between the stowed configuration and the operational configuration. The actuator is controlled by a control member.

The mast may for example be able to move between the stowed configuration in which the axis x_m forms a minimum angle α with the axis x ,

and at least one operational configuration in which the axis x_m forms a maximum angle α .

The minimum angle α is advantageously 0° and preferably comprised between 0° and 5° .

5 In the present invention, it is desirable to be able to make the mast rotate about its axis in a panoramic particular configuration in which the mast extends vertically and extends at least partially above the surface of the water and in which the mast is in an operational configuration in which the mast 12 projects with respect to the body 11 of the underwater vehicle 10
10 along the axis x . The angle α is greater than 90° in the operational configuration. Thus, the maximum angle α is greater than 90° and less than or equal to 180° .

 The mast 12 is advantageously able to be immobilized with respect to the body 11 of the vehicle 10 for a plurality of angles α in the range in which
15 it is variable. The mast immobilized at an angle α less than 90° allows the payload to be positioned above the surface when this vehicle is moving horizontally along its longitudinal axis. This allows the capabilities of the payload to be made available during transit.

 The mast 12 is advantageously able to be immobilized with respect to
20 the body 11 of the vehicle in at least one operational configuration.

 As an alternative, the mast 12 is fixed with respect to the body 11 of the underwater vehicle 10 and is in an operational configuration. As an alternative, the mast 12 is able to move in translation with respect to the body of the underwater vehicle, for example along the axis of the mast 12, as
25 described with reference to document GB 2 335 888, between a stowed configuration and an operational configuration.

 In the embodiment of figure 4, the mast 12 is housed, in the stowed configuration, on the outside of the body 11. As an alternative, the mast 12 is housed inside the body 11 in the stowed configuration. The hydrodynamic
30 profile of the underwater vehicle is then affected less.

 Advantageously, the underwater vehicle 10 is capable of floating, namely of exhibiting positive buoyancy in a panoramic configuration, referred to as stabilization configuration, as depicted in figure 3, in which the body 11 of the underwater vehicle 10 is fully submerged and in which the mast 12
35 breaks the surface of the water. Advantageously, a cross section of the mast is smaller than a cross section of the body 11.

Advantageously, a cross section, for example a mean cross section of the mast 12 (considered transversely to the axis x_m) between its connection (for example the articulation 18) to the body 11 and a longitudinal end of the mast 12 which end is intended to be out of the water in the operational configuration is less than a cross section, for example, a mean cross section, of the body 11 of the underwater vehicle (considered transversely to the axis x). This configuration promotes the stability of the mast 12 which stability is obtained because only a small cross section breaks the surface of the water. In effect, the instability of the mast stems from the variation in upthrust which is proportional to the variation in submerged volume resulting from the action of the waves. Because the cross section of the mast is small (in comparison with that of the body of the vehicle), the variation in submerged volume caused by the action of the waves is small and the disturbances experienced by the mast are small. This then results in far better stability of the mast when out of the water.

As an alternative or in addition, the underwater vehicle 10 may be capable of floating in a panoramic configuration in which the body 11 of the underwater vehicle 10 breaks the surface S of the water. This configuration is not as good for the stability of the mast.

In the embodiment of figures 3 and 4, the mast 12 is connected to the body 11 of the underwater vehicle 10 by a pivot connection 18 positioned near a first longitudinal end AV of the body 10 of the underwater vehicle and is further away from the second longitudinal end AR of the body 10 of the underwater vehicle 11. This makes it possible to provide a mast 12 of great length without affecting the hydrodynamic profile of the underwater vehicle in the stowed configuration and therefore makes it possible to bring the payload 13 to a great height above sea level. Furthermore, that makes it possible to limit the hydrodynamic drag of the underwater vehicle 10 during submerged transits by configuring the mast 12 into a stowed configuration with respect to the operational configuration.

The thruster 14 is mounted on the body 11 of the underwater vehicle 10, near the second end AR of the body 11 of the underwater vehicle 10.

For greater clarity, the first end AV is referred to as the front end of the vehicle and the second end AR is referred to as the rear end. The vehicle 11 is intended to move chiefly along the axis x , in the direction from the rear end AR toward the front end AV, or exhibits better efficiency in that direction. The

thruster 14 is therefore positioned near the rear end AR of the underwater vehicle.

As a variant, it is conceivable to reverse the layout of the mast 12 and of the thruster 14 along the axis x.

5 The underwater vehicle comprises panoramic configuration means able to implement a panoramic configuration step in which the vehicle is brought from a non-panoramic configuration into a panoramic configuration.

The panoramic configuration means comprise the means, where present, of deploying the mast allowing the mast to be brought into an
10 operation configuration from a stowed configuration.

The panoramic configuration means potentially comprise buoyancy regulating means allowing the buoyancy of the vehicle to be regulated, so as to allow the vehicle to be brought into a panoramic configuration of stabilization. In the case of an underwater vehicle, these buoyancy regulating
15 means are advantageously configured in such a way as to allow the underwater vehicle to pass from a fully submerged configuration into a panoramic configuration of stabilization, an example of which is depicted in figure 4.

In general, the buoyancy regulating means comprise means for
20 varying the density of the object or of the underwater vehicle.

The means for varying the density comprise at least one variable-density reservoir (two reservoirs, a rear reservoir 20 and a front reservoir 21 in the example of figures 3 and 4) the variation in density of which leads to a variation in the density of the vehicle. This reservoir has a variable mass and
25 a fixed volume (as in the example of figures 3 to 4) or a variable volume the variation volume of which leads to a variation in the volume of the vehicle, and a fixed mass. The buoyancy regulating means also comprise means making it possible to regulate the density of each reservoir. These means comprise means making it possible to vary the density of each reservoir (rear
30 valve 22 and front valve 23, pump 29 and actuator 30 in the nonlimiting example of the figures) and other means for controlling these means (control member 26).

In the example of figures 3 and 4, the reservoirs 20 and 21 are able to communicate with the environment in which the underwater vehicle is
35 immersed so that liquid in which the underwater vehicle is immersed can circulate between these reservoirs and the marine environment so as to fill

the reservoirs with or empty the reservoirs of this liquid in order to increase its mass. This environment is, for example, the marine environment but could be any other liquid. In the remainder of the text, reference will be made to the marine environment, but the invention is of course applicable to any other liquid.

The means for regulating the buoyancy of the underwater vehicle have been depicted schematically in figure 5. The reservoirs 20, 21 are able to communicate with the marine environment via respective hydraulic circuits 24, 25 that can be opened or closed by respective front valve 22 and rear valves 23, the circulation of the water from the marine environment toward the reservoirs 20, 21 (or vice versa) being brought about by a pump 29 actuated by an actuator 30, for example a motor. The actuator 30 and the front and rear valves are controlled by a control member 26 to regulate the masses of the reservoirs 20 and 21 by varying the volume of water contained in these reservoirs 20 and 21 (by discharging water contained in the reservoirs into the marine environment, or vice versa).

The means for varying the buoyancy of the vehicle are controlled by a control member 26 receiving a measurement of a parameter representative of the buoyancy of the vehicle and generated by a sensor 27, commanding these means on the basis of this measurement to vary the buoyancy of the vehicle in such a way that it exhibits a predetermined setpoint buoyancy.

The sensor 27 is, for example, an immersion sensor.

The control member 26 controls the valves and the pump to vary the masses of the reservoirs 20 and 21 by varying the volume of water contained in these reservoirs 20 and 21 (by discharging water contained in the reservoirs into the marine environment, or vice versa) so that the underwater vehicle exhibits a setpoint submersion received by the control member.

In the nonlimiting embodiment of the figures, the reservoirs 20 and 21 are spaced apart along the axis x. The two reservoirs 20, 21 are therefore each positioned near one of the ends of the underwater vehicle 1. The reservoir 21 is positioned near the rear end AR and the reservoir 20 near the front end AV of the underwater vehicle. As a variant, the buoyancy varying means comprise a single reservoir or more than two reservoirs.

As a variant, the means for regulating the density comprise at least one reservoir, referred to as external, of variable volume arranged in such a way that a variation in the volume of the reservoir leads to a variation in the

volume of the underwater vehicle. This reservoir communicates for example with an internal reservoir arranged inside the body of the underwater vehicle via a valve so as to allow a fluid to be passed from one of the reservoirs to the other or so as to block the passage of this fluid between the two reservoirs, a pump causing the fluid to circulate via the valve. An actuator, for example a motor, is provided to actuate the pump. This solution leads to fewer problems with corrosion and reliability than the previous solution at the expense of the mass and of the volume of the underwater vehicle. Two reservoirs may for example be provided, one at each longitudinal end of the underwater vehicle.

In the embodiment of the figures, the underwater vehicle 10 is intended to move chiefly along the axis x. As a result, as the mast 12 deploys, the mast 12 forms a projection on the front of the body 11 of the underwater vehicle 10 along the axis x thereby shifting the center of gravity of the underwater vehicle 10 in the direction of the axis x in figure 3. If the center of volume advances along the axis x by the same distance, the pitch of the vehicle does not vary. If the center of gravity advances by a longer distance than the center of volume, then the vehicle tips forward. The rear end of the vehicle tips down toward the bottom if the center of gravity moves back along the axis x by a greater distance than the center of volume. In order to alleviate this disadvantage, the underwater vehicle 10 advantageously comprises means for regulating the pitch of the body 11 of the underwater vehicle 10.

The panoramic configuration means potentially comprise pitch regulating means allowing the pitch of the body 11 of the underwater vehicle 10 to be regulated so that the mast can be vertical the panoramic configuration.

In the nonlimiting embodiment of figure 4, these means are arranged inside the body 11. This configuration allows the underwater vehicle to be used at greater depths than in the document US 20080132130.

These means comprise means making it possible to vary the pitch of the body 11 comprising, in the nonlimiting example of figure 5, the two reservoirs 20, 21 spaced apart along the longitudinal axis x and positioned respectively near the rear end AR and near the front end AV of the body 11. The means for varying the pitch of the body 11 comprise a hydraulic circuit via which the reservoirs 20, 21 communicate with one another so that a

fluid can pass from one to the other via a second valve 37 which is able to close the hydraulic circuit or open it in order to allow or disallow this fluidic communication. A second pump 38 allows the liquid to be circulated between the two reservoirs via the valve 37 and an associated actuator 39 for
5 actuating the pump 38.

As a variant, the one same pump can be used for varying the pitch and for varying the buoyancy. A directional-control valve or one or more additional valves are then provided to connect the pump to one of the two hydraulic circuits. The directional-control valve or each valve is controlled by
10 means of the control member.

The means for regulating the pitch also comprise a control member allowing control of the means allowing the pitch to be varied as a function of a setpoint pitch and of a measurement representative of a pitch of the body
11 of the vehicle coming from a measurement device. This control member is
15 the control member 26 of the buoyancy regulating means in figure 2 but may be another control member.

The measurement device comprises for example a pitch sensor 28 able to measure the pitch of the underwater vehicle, for example comprising immersion sensors positioned at the respective two longitudinal ends of the
20 underwater vehicle or a gravity sensor measuring the verticality of the mast
12 or of the body 11 or an inertial unit.

Regulating the buoyancy and the pitch using the same reservoirs as depicted in figure 5 means that these means can be shared thereby limiting the volume dedicated to these regulating operations and the number of
25 elements dedicated to this regulation.

Advantageously, the means for regulating the pitch are configured in such a way as to allow the underwater vehicle to be positioned in a panoramic configuration. Thus, these means comprise for example two reservoirs spaced apart along the axis x.

30 Other types of controllable internal means may be used to vary the pitch of the underwater vehicle, such as masses capable of translational movement along the axis x, an example of which is described in document GB 2 335 888. However, that system requires an additional and dedicated actuator.

35 In a variant, the reservoirs 20, 21 of the regulating means are replaced by variable-volume reservoirs as described earlier.

The use of a pivoting mast 105 to vary the pitch of the body of the underwater vehicle may also, as a variant, be envisioned like the one described in document US 20080132130, balancing thus occurring naturally upon deployment of the second mast.

5 The vehicle 10 comprises means of rotation R configured to cause the vehicle to rotate about the axis x_m on receipt of a rotation command when the vehicle is in the panoramic configuration. These means of rotation comprise the thruster and the panoramic configuration means as well as a control member configured to control the thruster 14, on receipt of a
10 command to rotate, so that it generates a torque about the axis the axis x_m in order to cause the body and the axis x_m to rotate about the underwater vehicle, the underwater vehicle being in a panoramic configuration. The panoramic configuration is preferably, although not necessarily, a panoramic configuration of stabilization.

15 In the nonlimiting example of the figures, this control member is the member 26.

Advantageously, the control member 26 is configured to implement the rotation step when the axis x is inclined (namely the axis x forms, with the axis x_m , an angle α different from 0° or 180°) with respect to the axis x_m . If
20 the axis x_m is initially aligned with the axis x (equal to 0° or 180°), the control member 26 is configured to vary the angle α before implementing the rotation step.

The panoramic position is advantageously a panoramic configuration of stabilization.

25 Advantageously, the means of rotation R are configured to position the underwater vehicle in a predetermined panoramic configuration before implementing the rotation step so that the vehicle is in this panoramic position during the rotation step. Thus, the control member 26 is configured to command the panoramic configuration means in such a way as to bring
30 the vehicle into this panoramic configuration. In a predetermined panoramic configuration, the operational configuration of the mast is predetermined and the height of the end 12a of the mast or of the payload 13 is predetermined.

The invention also relates to a method for controlling a marine vehicle comprising a rotation step, during which the thruster generates torque about
35 the axis the axis x_m when the vehicle is in the panoramic configuration, so as to cause the body and the axis x_m to rotate about the underwater vehicle.

Advantageously, the method comprises a panoramic configuration step to place the vehicle in the predetermined panoramic configuration. This step potentially comprises a step of deploying the mast 12 from a stowed configuration into the operational configuration by pivoting the mask with
5 respect to the body about a pivot connection connecting the mast to the body, prior to the rotation step, so as to bring the mast into the predetermined operational configuration of the panoramic configuration.

The panoramic configuration step may comprise a step of adjusting the buoyancy so that the panoramic configuration is a panoramic
10 configuration of stabilization.

The panoramic configuration step may comprise a step of regulating the pitch of the underwater vehicle.

Each control member may comprise one or more dedicated electronic circuits or a general purpose circuit. Each electronic circuit may comprise a
15 reprogrammable calculation engine (a processor or a microcontroller for example) and/or a computer executing a program comprising a sequence of instructions and/or a dedicated calculation engine (for example a collection of logic gates such as an FPGA, a DSP or an ASIC, or any other hardware module).

CLAIMS

1. A marine vehicle able to be submerged, comprising a body (11)
5 extending longitudinally along an axis x and a mast (12) extending
longitudinally along an axis x_m , the mast (12) being equipped with a payload
(13) intended to be used above the surface of the water, the marine vehicle
being capable of being in a panoramic configuration in which the mast (12)
10 extends at least partially above the surface of the water and extends
longitudinally in a substantially vertical direction (z), the axis x_m of the mast
being inclined with respect to the axis x , the mast (12) being in an operational
configuration in which it extends beyond the body (11) along the axis x , the
marine vehicle (10) comprising a thruster (14) able to generate a torque
15 about the axis x_m , when the marine vehicle (10) is in the panoramic
configuration, so as to cause the body (11) and the mast (12) to rotate about
the axis x_m , a lever arm between the axis x_m and the thruster (14) being
non-zero, the mast (12) being connected to the body (11) by a pivot
connection (18) allowing the mast (12) to be pivoted with respect to the body
20 (11) between a stowed configuration in which the mast (12) is folded down
along the body (11) and the operational configuration.

2. The marine vehicle as claimed in the preceding claim, wherein the
mast is able to be immobilized in the operational configuration.

25 3. The marine vehicle (10) as claimed in either one of the preceding
claims, in which the thruster (14) comprises two contrarotating propellers (15,
16) each comprising blades (17) of which the collective and cyclic pitch about
a neutral position is variable, the propellers being mounted on the body (11)
in such a way as to have the same axis of rotation that is fixed with respect to
30 the body (11), this axis of rotation being substantially parallel to the
longitudinal axis x .

4. The marine vehicle as claimed in any one of the preceding claims,
wherein, in the stowed configuration, the axis x_m extends substantially
35 parallel to the axis x .

5. The marine vehicle as claimed in any one of the preceding claims, wherein the marine vehicle is able to exhibit positive buoyancy in a panoramic configuration referred to as a stabilization configuration in which the body (11) is fully submerged.

5

6. The marine vehicle as claimed in any one of the preceding claims, wherein the marine vehicle is capable of exhibiting positive buoyancy in a panoramic configuration referred to as stabilization configuration in which the body (11) is fully submerged, the mast (12) breaking the surface of the water.

10

7. The marine vehicle as claimed in claim 6, wherein the marine vehicle has a cross section that is smaller than a cross section of the body (11).

8. The marine vehicle as claimed in any one of the preceding claims, wherein the mast (12) is connected to the body (11) by a pivot connection (18).

15

9. The marine vehicle as claimed in the preceding claim, wherein the pivot connection (18) is positioned close to a first longitudinal end of the body (11).

20

10. The marine vehicle as claimed in any one of the preceding claims, comprising rotation means configured to implement, on receipt of a rotation command, a rotation step during which the thruster (14) generates a torque about the axis the axis x_m in order to cause the body (11) and the mast (12) to rotate about the axis x_m , the marine vehicle being in a panoramic configuration.

25

11. The marine vehicle as claimed in the preceding claim, wherein the rotation means are configured to implement the rotation step when the axis x is inclined with respect to the axis x_m .

30

12. A method for controlling a marine vehicle as claimed in any one of the preceding claims, comprising a rotation step, during which the thruster (14) generates a torque about the axis the axis x_m in the panoramic configuration, so as to cause the body and the mast (12) to rotate about the axis x_m .

35

13. The method for controlling a marine vehicle as claimed in the preceding claim, comprising a step of adjusting the buoyancy, prior to the rotation step, in order to bring the marine vehicle into a condition such that the vehicle exhibits positive buoyancy in the panoramic configuration.

5

14. The method for controlling a marine vehicle as claimed in the preceding claim, wherein the adjustment step is performed in such a way that the body (11) is fully submerged in the panoramic configuration, with the mast (12) breaking the surface of the water.

10

15. The method for controlling a marine vehicle as claimed in any one of claims 12 to 14, comprising a step of deploying the mast (12), prior to the rotation step, from a stowed configuration in which the mast is folded down along the body of the marine vehicle, into the operational configuration by pivoting the mast (12) with respect to the body (11) about a pivot connection (18) connecting the mast (12) to the body (11).

15

16. The method for controlling a marine vehicle as claimed in the preceding claim, comprising a step of regulating the pitch of the body of the marine vehicle, prior to the rotation step, so that the axis x_m is substantially vertical in the panoramic configuration.

20