

Submersible having variable lift depending on the navigation mode

The present invention relates to an underwater vehicle. It applies in particular to remote operated underwater vehicles the propulsion of which is autonomous, referred to as self-propelled submersibles, of use in
5 detecting submerged bodies, such as underwater mines in particular.

The search for and detection of underwater mines is often performed using a submerged sonar, towed by means of a cable behind a surface vessel. In order to be effective, the sonar needs to be distant from
10 the surface vessel and to have a very long range, so as to be able to explore the marine environment sufficiently far ahead of the surface vessel. Such sonars are highly sophisticated and very expensive.

There are also underwater vehicles which are equipped with
15 video cameras and/or with a sonar for searching for and detecting submerged objects such as underwater mines. These vehicles can be launched into the water from a carrier ship or vessel. They are, depending on the circumstances, either independent of the carrier ship in the case of autonomous underwater vehicles, and have limited autonomy, or are
20 connected to the carrier ship by a connecting cable that supplies them with power and transmits the data necessary for maneuvering the underwater vehicle and for controlling the data means. The ship then has to constantly tow the cable as it moves around, to the detriment of the abilities both of the ship and of the underwater vehicle to move freely. There are various types of
25 autonomous underwater vehicle suited to mine detection: Unmanned Underwater Vehicles (UUVs), Autonomous Underwater Vehicles (AUVs) and Remotely Operated Vehicles (ROVs). The remainder of the document will use the expression "Autonomous Underwater Vehicle" to denote an underwater vehicle having the characteristics of being able to navigate

without a man on board and of not needing to have a physical connection (such as a data- or energy-transmitting cable for example) with a carrier ship.

Autonomous underwater vehicles or self-propelled underwater
5 vehicles can move around in two distinct ways: navigation may be underwater, if the entire underwater vehicle is submerged or alternatively at the surface, in the case in which part of the underwater vehicle is situated above the water surface. One example of such an autonomous underwater vehicle is given in patent US 2007125289.

10

There are various technical problems that are encountered when the vehicle is navigating on the surface:

- 15 - the vehicle has limited stability because it is subjected to the movements of the sea/air interface. This lack of stability may pose a problem when recovering the underwater vehicle.
- 20 - the immersed surface of the hull at the forward part of the vehicle is very limited for hydrodynamic reasons. However, this surface is of great usefulness for housing sensors intended to search for and detect submerged objects.
- 25 - the part of the surface of the underwater vehicle that is out of the water is also extremely limited, yet this surface is needed for using communications and/or location apparatus using the air as the medium. Autonomous underwater vehicles often need to stop in order, for example, to take a location fix using a GPS type system.
- 30 - the limitation of the part that is out of the water limits or prevents the supply of air as oxidant for the operation of the combustion engine or engines of the vehicle, thus reducing its autonomy.

- total submersion of the propulsion means is not assured. The turbine or turbines of the underwater vehicle propulsion means are therefore no longer suited to the properties of a medium made up of air or of a diphasic water/air medium which may give rise to rapid deterioration of the motor powering the underwater vehicle propulsion means.

One subject of the invention is an underwater vehicle designed for navigation at the surface or underwater having a hull and at least one normal-force generator of force normal to a longitudinal axis of said underwater vehicle, characterized in that:

- a forward part of said hull is asymmetric with respect to said longitudinal axis so as to generate lift as said underwater vehicle moves and
- said lift is in the opposite direction to the resultant of the normal forces of said normal-force generator or generators (6).

Advantageously, the underwater vehicle comprises at least one said normal-force generator arranged in such a way as to be out of the water during surface navigation.

Advantageously, the underwater vehicle comprises at least one motor powered autonomously and designed to actuate at least one propulsion means. The autonomously powered motor may notably be a combustion engine or, alternatively, an electric motor powered by a fuel cell or by an electricity generator set in turn driven by a combustion engine. Batteries may be provided to store the electrical energy that the fuel cell and/or the electricity generator set may produce.

Advantageously, the underwater vehicle comprises at least one said normal-force generator chosen from a fin borne by said hull, a vortex generator borne by said hull and a said propulsion means the thrust of which comprises a component along an axis normal to said longitudinal axis.

5

Advantageously, the underwater vehicle comprises at least one underwater measurement instrument situated on said forward part of said hull, said part being both submerged during surface navigation and asymmetric with respect to said longitudinal axis.

10

Advantageously, the normal at any point of said forward part of said hull of said vehicle comprises at least one component in the direction of said longitudinal axis and at least one component in the opposite direction to said lift.

15

Advantageously, the nose of said underwater vehicle comprises at least one ballasting system.

Advantageously, the underwater vehicle also comprises an air duct connecting at least one combustion engine to at least one said ballast.

20

Advantageously, the underwater vehicle comprises at least one duct equipped with a submersible air turbine connecting at least one said ballast to the external air.

25

Advantageously, the part that is out of the water in surface navigation of said underwater vehicle contains at least one instrument chosen from at least one aerial measurement instrument and at least one aerial communications instrument.

Another subject of the invention is a method of surface navigation of an underwater vehicle of which said pitch angle is comprised in a range from 5° to 20°.

5 Another subject of the invention is a method of surface navigation of an underwater vehicle, of which said pitch angle is sufficient to keep at least one said propulsion means beneath the water surface.

The invention will be better understood and further advantages,
10 details and features thereof will become apparent during the course of the explanatory description which follows, which is given by way of example with reference to the attached drawings in which:

- figure 1 is a schematic side view of the invention in underwater
15 navigation,

- figure 2 is a schematic side view of the invention in surface navigation,

20 - figure 3 is a cross section in profile through the forward part of the invention.

The description that follows gives a number of exemplary embodiments of the device of the invention; these examples are not intended
25 to limit the scope of the invention. These exemplary embodiments exhibit both the essential features of the invention and additional features connected with the embodiments concerned. For the sake of clarity, throughout the various figures the same elements will bear the same references.

30 In the remainder of the text, the terms forward, rear, in front of and behind are defined with respect to the longitudinal axis (4) of the

underwater vehicle, oriented from the rear of the vehicle forward, as illustrated in figure 1 from left to right.

In addition, the descriptor "nose" of the underwater vehicle can
5 be likened to the nose at the front of the underwater vehicle in the remainder of the text.

The term pitch angle is used here in its usual sense: the pitch angle is defined by the angle formed by the longitudinal axis 4 of the
10 underwater vehicle 1 and the horizontal.

The term normal-force generator always refers to force normal to the longitudinal axis 4 of the underwater vehicle 1.

15 Figure 1 illustrates the underwater vehicle 1 during underwater navigation: in one particular embodiment of the invention it is moving through the water 8, along the axis of travel 17 that coincides with its longitudinal axis 4. The underwater vehicle 1 has propulsion means 2, a nose 3 of which part 5 of the hull creates lift 10. In particular embodiments of the invention,
20 the propulsion means 2 may be a propeller or a turbine. A normal-force generator 6 generates a force 11 one component of which is normal to the axis 4, in the same direction as 10, but in the opposite sense. In the non-restrictive case of figure 1, the sum of the forces 10 and 11 cancel one another out. The thrust due to the propulsion means 2 allows the underwater
25 vehicle 1 to move in the direction of the longitudinal axis 4, at zero pitch angle. In one particular embodiment of the invention, the underwater vehicle 1 considered is an autonomous underwater vehicle, namely an underwater vehicle 1 that has no physical connection such as a cable with a carrier ship in order to supply it with power or to exchange data and which is able to
30 navigate without a man on board.

According to another particular embodiment of the invention, the normal-force generator 6 of figure 1 is a lift generator such as a fin or alternatively a vortex generator.

5 In one particular embodiment of the invention, the normal-force generator 6 may consist of inclining the trust of the propulsion means 2 with respect to the longitudinal axis 4 of the underwater vehicle 1, in combination with fins, vortex generators or alone.

10 Figure 2 illustrates the navigation of the underwater vehicle 1 at the surface 7, at a sufficient steady speed, namely for a speed comprised between 0.1 m.s^{-1} and 100 m.s^{-1} and preferably comprised between 1 m.s^{-1} and 20 m.s^{-1} . The interface between water 8 and air 9 is delimited by the surface 7. In the nonrestrictive case depicted in figure 2, the steady speed of
15 travel is enough to keep part of the nose of the underwater vehicle 1 out of the water. The movement of the underwater vehicle 1 is in the direction of the axis of movement 17.

The part out of the water comprises a normal-force generator 6,
20 which in this case is a vortex generator. Since the forces of drag in the air 9 are several orders of magnitude smaller than in the water 8, the force 11 is negligible in the case of figure 2. By contrast, the part 5 of the hull of the nose 3 is submerged. The speed of the underwater vehicle 1 gives rise to lift 10 which may for example be equal to that of the embodiment illustrated in
25 figure 1. The resultant of these two lifts allows the underwater vehicle 1 to have a pitch angle that is constant and which, in the nonrestrictive case of figure 2, is 10° . In one particular embodiment of the invention, the part 5 of the hull and the normal-force generator 6 are situated one on each side of the longitudinal axis 4 of the underwater vehicle 5 illustrated in figure 2.

The pitch angle obtained through the effect of the lift 10 advantageously allows the propulsion means 2 to be kept below the water surface. The turbine or turbines of the propulsion means 2 of the underwater vehicle 1 are not brought into contact with the air 9. This effect prevents deterioration of the motor operating the propulsion means 2: the partial or complete presence of air 9 in the turbines leads to an abrupt change in the hydraulic resistance imposed on a turbine of the underwater vehicle 1, and the motor that operates the singular or plural propulsion means 2 is not designed for such an abrupt change.

10

Figure 3 is a side view in cross section of the nose 3 of the underwater vehicle 1 when the underwater vehicle 1 is moving along in the same way as in figure 2, namely at the surface, at a steady speed that is sufficient to keep part of the nose 3 of the underwater vehicle 1 out of the water, namely at a speed of between 0.1 m.s^{-1} and 100 m.s^{-1} and preferably comprised between 1 m.s^{-1} and 20 m.s^{-1} . The nose 3 of the underwater vehicle 1 has both a submerged part and a part that is out of the water. In one particular embodiment of the invention depicted in figure 3, the nose 3 comprises a ballasting system 13 that facilitates the raising of the underwater vehicle 1 to the surface and the submerging thereof. The part 5 of the hull that creates the lift 10 comprises underwater measurement instruments 12, such as cameras or acoustic sensors. This location is advantageous for the use of the underwater measurement instruments 12 because it allows the underwater vehicle 1 to look downward and forward. This location of the ballasting system 13 is also advantageous for imposing a pitch angle of the underwater vehicle 1, as described in figure 2 but independently of the speed of the underwater vehicle 1. The ballasting system 13 in this case creates a thrust normal to the longitudinal axis 4, in the nose 3 of the underwater vehicle 1 whatever the speed thereof.

30

In particular embodiments of the invention, a combustion engine 18 may power the propulsion means 2 and/or the recharging of one or more batteries 20. Independently, in particular embodiments of the invention, the singular or plural propulsion means 2 may be actuated by a combustion engine 18 and/or an electric motor 19 powered for example by one or more batteries 20 or by a fuel cell.

The ballasting system 13 is attached, in a particular embodiment of the invention illustrated in figure 3, to:

- 10 - an air duct 14 which connects it to the combustion engine 18 or to a fuel cell,
- a duct provided with a submersible air turbine 16 which connects it to the air 9. This turbine allows the ballasting system to be subjected to a pressure made up of the maximum hydrostatic pressure imposed on the underwater vehicle 1 and of an overpressure of use in removing water. The maximum pressure imposed by the turbine may be comprised between 10 and 800 mbar, preferably between 50 and 500 mbar and preferably between 100 and 300 mbar.

20

This arrangement allows the combustion engine 18 or a fuel cell to be supplied with air 9 via a duct fitted with a submersible air turbine 16, the ballasting system 13 and the air duct 14. The duct 16 is submergible, which means to say is resistant, without being functional, to immersion in water. Its resistance may be in the form of mechanical strength: the turbine is then able to withstand the stresses associated with the hydrostatic or hydrodynamic pressure. The resistance may also be chemical: in which case the turbine is resistant to corrosion. Any air that may get in via the duct fitted with the submergible air turbine 16 flows under gravity to the bottom of the ballast 13 where it is discharged, for example by overpressure. This system prevents it from flowing into the air duct 14. The combustion engine 18 is designed to

procure air 9 as oxidant when the underwater vehicle 1 is navigating on the surface 7: the combustion engine 18 is then said to operate aerobically. This aerobic operation is highly advantageous for the underwater vehicle 1 because it allows the underwater vehicle 1 to have a great deal of autonomy
5 when navigating on the surface 7.

The part of the nose 3 of the underwater vehicle 1 that is out of the water during surface navigation 7, as illustrated in figure 3, comprises aerial communications and/or measurement instruments 15. Instruments are
10 qualified here as aerial when their use is facilitated by aerial carriage of electromagnetic waves. This is, for example, the case when using a GPS system. The use of these aerial communications and/or measurement instruments 15 is facilitated by the stability acquired by the underwater vehicle 1 navigating on the surface 7 with a pitch angle preferably of between
15 5° and 20°.

In all of the figures 1, 2 and 3, the part 5 of the hull that creates the lift 10 has one particular characteristic: at every point on this part, the normal to the hull has at least one component in the direction of the
20 longitudinal axis 4 and one component in the opposite direction to the lift 10. This characteristic makes it possible to create the lift 10 while at the same time limiting the force of drag relating to this part 5 of the hull. Limiting the drag force relating to this part 5 of the hull advantageously allows the self-propelled underwater vehicle to increase its autonomy in terms of energy
25 consumption.

CLAIMS

1. An underwater vehicle (1) designed for navigation at the surface (7) or underwater (8), having a hull, at least one propulsion means (2) and at least one normal-force generator (6) of force normal to a longitudinal axis (4) of said underwater vehicle (1), characterized in that:
 - a forward part (5) of said hull is asymmetric with respect to said longitudinal axis (4) so as to generate lift (10) as said underwater vehicle (1) moves;
 - 10 - said lift (10) is in the opposite direction to the resultant of the normal forces (11) of said normal-force generator or generators (6);
 - one said propulsion means (2) is designed to govern a pitch angle of said autonomous underwater vehicle (1) that is comprised in a range from to 5°
15 to 20° as said autonomous underwater vehicle (1) moves in said surface navigation (7).
2. The underwater vehicle (1) as claimed in the preceding claim, of which at least one said normal-force generator (6) is arranged in such a way
20 as to be out of the water during surface navigation (7).
3. The underwater vehicle (1) as claimed in one of the preceding claims, comprising at least one motor powered autonomously and designed to actuate at least one said propulsion means (2).
25
4. The underwater vehicle (1) as claimed in one of the preceding claims, of which at least one said normal-force generator (6) is borne by said hull and chosen from a fin and a vortex generator.

5. The underwater vehicle (1) as claimed in one of claims 1 and 3, of which at least one said normal-force generator (6) is chosen from a fin borne by said hull, a vortex generator borne by said hull, and a said propulsion means (2) the thrust of which comprises a component along an axis normal to said longitudinal axis (4).

6. The underwater vehicle as claimed in one of the preceding claims, comprising at least one underwater measurement instrument (12) situated on said forward part (5) of said hull, said part (5) being both submerged during surface navigation (7) and asymmetric with respect to said longitudinal axis (4).

7. The underwater vehicle (1) as claimed in one of the preceding claims, in which the normal at any point of said forward part (5) of said hull comprises at least one component in the direction of said longitudinal axis (4) and at least one component in the opposite direction to said lift (10).

8. The underwater vehicle (1) as claimed in one of the preceding claims, in which the nose (3) of said underwater vehicle (1) comprises at least one ballasting system (13).

9. The underwater vehicle (1) as claimed in claim 8 also comprising an air duct (14) connecting an element chosen from at least one combustion engine (18) and at least one fuel cell to at least one said ballast (13).

10. The underwater vehicle (1) as claimed in one of claims 8 and 9, comprising at least one duct equipped with a submersible air turbine (16) connecting at least one said ballast (13) to the external air (9).

11. The underwater vehicle (1) as claimed in one of the preceding claims, of which the part that is out of the water in surface navigation (7)

contains at least one instrument chosen from at least one aerial measurement instrument (15) and at least one aerial communications instrument (15).

- 5 12. A method of surface navigation (7) of an underwater vehicle (1) as claimed in one of the preceding claims, of which said pitch angle is comprised in a range from 5° to 20°.

- 10 13. A method of surface navigation (7) of an underwater vehicle (1) as claimed in one of the preceding claims, of which said pitch angle is sufficient to keep at least one said propulsion means (2) beneath the water surface (8).