

A BLADDER SYSTEM FOR A SUBMERSIBLE

Field of the Invention

[001] The present invention relates to a bladder system for a submersible and to a
5 particular submersible having a bladder system. It is particularly directed to small
submersibles which are remotely controlled or are autonomous.

[002] The invention has been developed primarily for use in submersible used in data
gathering for underwater topological review and mapping of natural growths and
formations and particularly Underwater Autonomous Mapping (UAM) and will be
10 described hereinafter with reference to this application. However, it will be appreciated
that the invention is not limited to this particular field of use.

Background of the Invention

[003] Submersibles need to be able to rise and lower in the water. This is made possible
15 by ballast and bladder systems that control ballast. Larger structures such as submarines
can devote various cavities in different locations of the submarine as ballast chambers
and elaborate control systems together with large pumps are required.

[004] However large submersibles are not able to undertake close proximity underwater
topological review as they are unable to be close to the surface being reviewed. This
20 closeness is needed for more accuracy and since the water in which the mapping is being
undertaken could be low visibility due to the sediments, salts or other particulates in the
water that causes light dispersion.

[005] Large submersibles also by their size are likely to stir up and create greater
particulates in the water or turbulent water which each provides further restrictions in
25 visibility.

[006] Overall the major problem with large submersibles is their lack of manoeuvrability
in tight areas.

[007] There is also a need in the field of Underwater Autonomous Mapping as well as in
many other uses for the submersible to take a slow methodical approach and defined
30 pathway so as to fulfil accurate travel. To do this accurate control is needed.

[008] It is therefore beneficial to have small, versatile and readily maneuverable
submersibles. To achieve this a different system of ballast and bladders is required.

[009] It can be seen that known prior art submersible have the problems of:

- a) Causes turbulence and therefore reduces optical effects
- b) Not usable in shallow water
- c) Requires large areas for manoeuvrability
- 5 d) Not versatile or adaptable.
- e) No known ability with speed and accuracy

[0010] The present invention seeks to provide submersible with a ballast and bladder system, which will overcome or substantially ameliorate at least one or more of the deficiencies of the prior art, or to at least provide an alternative.

- 10 [0011] It is to be understood that, if any prior art information is referred to herein, such reference does not constitute an admission that the information forms part of the common general knowledge in the art, in Australia or any other country.

Summary of the Invention

- 15 [0012] According to the present invention, there is provided a submersible and a bladder system for providing ballast for the submersible comprising: a submersible elongated body; a bladder mountable in the submersible body; venting pathway connecting between the bladder and external of the submersible body; a ballast control for controlling the venting in the venting pathway between the bladder and external of the submersible body; a power system for powering the ballast control; wherein the ballast control uses a one-way pump for high pressure use.
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[0013] Preferably the submersible elongated body is substantially 1 to 1.5 metres long.

- [0014] The ballast control can include at least one switching valve fluidly connected to the one-way pump for switching flow direction in the venting pathway. The ballast control can include a set of a plurality of switching valves wherein the set of switching valves work together to resist pressure equally on either side.
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- [0015] Preferably the ballast control includes a set of four switching valves fluidly connected to the one-way pump. The set of four of the at least one switching valves can be arranged to form two input switching valves on an input side of the one way pump and two output switching valves on an output side of the one way pump; wherein a first of the input switching valves fluidly connects to the venting pathway leading to external of the
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submersible body and a second of the input switching valves fluidly connects to the venting pathway leading to the bladder; and wherein a first of the output switching valves fluidly connects to the venting pathway leading to external of the submersible body and a second of the output switching valves fluidly connects to the venting pathway leading to the bladder; and whereby the control of input switching valves to have either the first or second input switching valve open and the other closed and thereby feed from either the bladder or external to the input of the one-way pump; to simultaneously control of input switching valves to have either the first or second output switching valve open and the other closed and thereby feed from the output of the one-way pump to the other of the bladder or external.

[0016] Preferably the pump is a diaphragm pump.

[0017] Preferably the switching valve is a ball valve.

[0018] The control of ballast uses a pressure sensing of the water in the bladder, whereby the actual flow of water in the venting between the bladder and external of the submersible body is precisely determined.

[0019] The ballast tank includes an inner expandable bladder.

[0020] The bladder operates in the range greater than 36 psi. but preferably the bladder operates substantially in the range from 36 psi. to 100 psi.

[0021] Preferably the ballast system is used in a submersible having an elongated body with the hydrodynamic effective shape is symmetrical for travel in at least two opposing longitudinal directions. It can include a hydrodynamic effective shape including a first and a second opposing substantially conical heads and a main cylindrical central part therebetween with each aligned along a common elongated axis to allow the hydrodynamic effective shape for travel in at least two opposing directions. That direction is along the longitudinal axis.

[0022] The submersible preferably has the main cylindrical central part or the differing length main cylindrical central part can include one or more of:

Batteries; Ballast; Motors; Electronics; Data and power connections; Other Payloads.

[0023] Preferably the main cylindrical central part and the first and the second opposing substantially conical heads are detachable and replaceable. The main cylindrical part can be replaced by a differing length of the main cylindrical part and with the first and the second opposing substantially conical heads attached to each end.

[0024] The elongated body of the submersible is substantially in the range of 1 to 5 metres long but preferably is substantially 1 to 1.5 metres long. The elongated body can

be substantially elliptical with a 1 to 1.5 metre major axis and a 0.3 to 0.5 metre minor axis.

[0025] The power system allows for the controllable driving of the submersible body is a 3 degree of freedom maneuvering system, where it can move in the at least two
5 opposing directions along the axis of the elongated shape, up and down, left and right. Preferably the power system includes two side thrusters on either side of the elongated body and a top thruster on a top surface wherein the top thrusters of the power system on the top side of the elongated body include 2 motors spinning in opposite directions to counter the angular momentum of each single motor. The two side thrusters of the power
10 system on either side of the elongated body are under the centre of gravity plane, wherein the probe is maintained stable during maneuvering.

[0026] Other aspects of the invention are also disclosed.

Brief Description of the Drawings

15 [0027] Notwithstanding any other forms which may fall within the scope of the present invention, preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a diagrammatic view of a submersible in accordance with a preferred embodiment of the present invention showing a submersible body, a power system
20 for allowing the controllable driving of the submersible body in the at least one longitudinal direction and a visual image capture system including a plurality of optical cameras locatable on or at the surface of the elongated body;

Fig. 2 is a diagrammatic view of a submersible of Fig. 1 showing the centre of gravity plane and the thruster force plane of the main motor of the power system;

25 Fig. 3 is a diagrammatic view of a submersible of Fig. 1 showing the plane of submersion when surfacing;

Fig. 4 is a diagrammatic view of a submersible of Fig. 1 showing the parts or sections of the submersible;

30 Figs. 5 is a diagrammatic view of a submersible of Fig. 1 showing the detachability of the parts or sections of the submersible and possible differing central part with two nose parts at either end;

Figs. 6 is a diagrammatic view of a submersible of Fig. 1 showing the payload use of the central part with two nose parts at either end;

5 Figs. 7 is a diagrammatic view of the ballast system of a submersible of Fig. 1 in accordance with an embodiment of the invention showing the valve and pump system and interconnecting venting system between ballast tank and external outlet;

Fig. 8 is a diagrammatic view of a one-way pump for use in the valve and pump system of an embodiment of the invention;

10 Figs. 9 and 10 are exploded diagrammatic views of a ballast tank and inner bladder for use in the valve and pump system and interconnecting venting system between ballast tank and external outlet of an embodiment of the invention;

Figs 11 and 12 are diagrammatic views of an external outlet for use in the valve and pump system and interconnecting venting system between ballast tank and external outlet of an embodiment of the invention;

15 Figs 13 and 14 are two operational modes of the valve and pump system and interconnecting venting system between ballast tank and external outlet of an embodiment of the invention;

Fig 15 is a valve and pump system and interconnecting venting system between two ballast tanks and external outlet of an embodiment of the invention;

20 Fig. 16 is a diagrammatic example of the resulting operational control of submerging and surfacing with use of the valve and pump system and interconnecting venting system between ballast tank and external outlet of an embodiment of the invention.

Description of Preferred Embodiments

25 [0028] It should be noted in the following description that like or the same reference numerals in different embodiments denote the same or similar features.

[0029] Referring to the drawings and particularly Figs. 1 to 5, there is shown a submersible 11 which comprises a submersible body having an elongated body with a hydrodynamic effective shape for travel in at least one longitudinal direction. There is a power system including two longitudinal side thrusters 21 for allowing the controllable driving of the submersible body in the at least one longitudinal direction and a top thruster 30 22 for allowing manoeuvring in a lateral plane to the longitudinal axis E-E.

[0030] The body structure is a combination of body size, body shape and body sections and body material. It is also relevant for motor location and ballast location. Although this body structure is a preferred embodiment of the submersible it is not the only form of submersible that can use the ballast system of the invention.

5 [0031] It is important to keep the body size of the submersible 11 with the submersible being substantially in the range of 1 to 5 metres long and more preferably substantially 1 to 1.5 metres long. In this way the buoyancy is readily maintained and can be powered with a battery power source 61 and allowing remote control or self-driving especially with the use of artificial intelligence of the visual capture system.

10 [0032] It is important to keep the body sections with the submersible being symmetrical so that there is clear bidirectional operation. This allows ready scanning of a section by forward and reverse motion, without any optical detriment. It also allows for ready reversing when encountering a solid material or an underwater hazard such as trees, plant growth, coral and other natural hazards. There can be a need for an
15 emergency evacuation manoeuvring due to fish or other aquatic animal dangers. Still further other waterway vehicle hazards might require detours or sudden stabilising action. Stabilisation generally occurs while in motion rather than while stationary.

[0033] As shown in Figs. 4 and 5 the elongated body of the submersible 11 includes a first and a second opposing substantially conical head 12 with a main cylindrical part
20 13 therebetween and aligned along a common elongated axis to allow the hydrodynamic effective shape for travel in at least two opposing directions.

[0034] A submersible can have the main cylindrical central part 13 and the first and the second opposing substantially conical nose heads 12 being detachable and replaceable. Therefore, any nose head 12 that has faulty camera or connections can be
25 readily replaced and repaired while the submersible is able to continue operation with a new nose part 12.

[0035] Also as shown in Fig. 5 the main cylindrical part 13 can be replaced by a differing length main cylindrical part and attached to the first and the second opposing substantially conical heads. A submersible with the main cylindrical part having a differing
30 length main cylindrical part can include the payload.

[0036] Ballast Structure

[0037] Referring to Fig. 6 the payload is generally locatable in the central part 13 of the body of the submersible and can be categorised into batteries 61, ballast 65, electronics 69 and other payload. The size of the central part can be varied to allow different payloads and to allow replaceability.

5 [0038] Referring to Figs. 6 and 9, the ballast 65 is a ballast tank with a one-way pump with two-way switching valve for allowing water in and water out of the central payload part 13. Ballast is required as the submersible floats due to the weight of water that it displaces being equal to the weight of the submersible. This displacement of water creates an upward force or buoyant force. The submersible, with ballast, can control its
10 buoyancy, thus allowing control of the sinking and surfacing of the submersible.

[0039] Generally, the submersible has ballast tanks, that can be alternately filled with water or air. When the submersible is on the surface, the ballast tanks are filled with air and the submersible's submerged density is less than that of the surrounding water. To submerge, the ballast tanks are flooded with water and the air in the ballast tanks is
15 vented or pressurised to alter density until its overall density is greater than the surrounding water and the submersible begins to sink due to negative buoyancy.

[0040] A supply of compressed air can be maintained aboard the submersible in air tanks for use with the ballast tanks. However, there can merely be a pumping out of water and decrease in pressure and density. To keep the submersible level at any set depth,
20 the submersible maintains a balance of air and water and pressure and thereby density in the ballast tanks so that its overall density is equal to the surrounding water which is its neutral buoyancy. When wishing to bring the submersible to the surface, compressed air flows from the air tanks into the ballast tanks and/or the water is forced out of the submersible until its overall density is less than the surrounding water and forms positive
25 buoyancy and thereby the submersible surfaces.

[0041] The level of surfacing affects the requirements of the ballast, the compressed air and the balancing effect. However, the submersible of the invention is only required to surface sufficiently for access to the power and data access ports 41. These are located on a top surface of the submersible and above a surfacing line S-S of Fig. 2 that
30 is above the centre of gravity of the submersible. In this way the submersible stays in a settled balanced upright orientation and avoids tendency to roll. Preferably the surfacing line S-S is in the top quartile of the submersible body.

[0042] The ballast structure comprises five main parts:

- a) Ballast tank - 65
- b) Venting pathway – 66, 67, 68, 70
- c) One-way pump 71
- d) Switching valves - A, B, C, D of 66
- 5 e) Control system

[0043] a) ballast tank

[0044] Referring to Figs 6 and 9 the ballast tank 65 is a cylindrical pressure chamber 86 with an end cap 81 that has a central opening for receiving and connecting to the venting input 67 from the pump system 66 and the venting path 68 to the outlet 70 that
10 vents with the outside environment to the submersible.

[0045] The ballast tank includes a rubber bladder 85 within the solid pressure chamber 86 that is fed by a manifold 83 leading from the end cap 81 opening and feeds through spaced holes into the bladder at spaced distances. This ensures a constant pressure buildup or release of the whole bladder rather than distorted expansion or
15 reduction.

[0046] In order to control the ballast tank pressure, it is a more accurate approach to include a relief valve that engages with a compressed gas source. In this way the exact pressure can be determined rather than relying on flow meters that are less accurate.

[0047] b) Venting pathway

[0048] Referring to Figs 6, and 7 the venting pathway leads directly from external opening 70 to the ballast tank 65 through the directional pumping system 66. As shown in Figs 11 and 12 the external opening 70 includes piping 91 that feeds to piping 68 leading to the directional pumping system 66. However, the external opening 70 does not include a pressure control system but leaves that to be taken care of downstream at
20 the directional pumping system 66. Instead the opening includes a porous body 92 with porous holes 93 for controlling sedimentary intake but not preventing water intake or outtake.

[0049] c) One-way pump

[0050] Referring to Figs 6, 7 and 8 the pressure must be maintained on one side from the direct venting from the external opening 70 to the external pressure and also the
30 pressure must be maintained on the other side from the pressure in the ballast tank.

[0051] A submersible must change its pressure to submerge as against reversing pressure to surface the pumping system must be operative in two directions. The ballast pump must operate to take in water and pressure into the ballast as well as releasing water and pressure from the ballast pump while countering the effects of the external pressure.

[0052] Generally, pumps are notorious for being strong in one direction but not in the other. Further there is substantial weight and size limitation in submersibles of the size of less than 3 metres and preferably about 1 metre.

[0053] A novel solution to this problem is to use a one-way pump with a switching valve system. More particularly it is to use a diaphragm pump 71 in a one-way operation with a switching flow operation system. In this way the pump 71 provides pressure control on both sides of the pump and valve system 66 and operates as strongly with flow in one direction as with flow in the opposite direction.

[0054] The diaphragm pump can be a 12-volt system so easily charged from the batteries 61 of the submersible. The weight to power ratio provided can be 1.8 kilograms providing greater than 100 psi. The rate of flow can be about 3 to 6 litres per minute. This allows the system to operate as a self-priming pump and to be corrosion resistant and have smooth operation over long continuous operation. the pump can include a rubber bracket to absorb the vibration from the working pump under pressure of greater than 100psi.

[0055] d) Switching valve

[0056] For the switching valves to be able to take the pressure on both sides of the valve but to still allow switching and flow in opposite directions the valves of the system are ball valves. These type of valves do not have a weakness of operation from one way to the other.

[0057] Referring to Figures 13 and 14 the switching valves 79 and identified as A, B, C, D. The four valves operate together with the one-way pump 71 with the connected piping to form the pump and valve system 66. This has two primary modes of Mode A of figure 13 where water and pressure are being vented out the outlet 70 and Mode B of figure 14 where water and pressure are being vented inwardly from the outlet 70.

[0058] In mode A and mode B the one-way pump 71 always forces the flow from left to right.

[0059] The four valves operate as a unified set of four of the switching valves 79 arranged to form two input switching valves A and C on an input side of the one way pump 71 and two output switching valves B and D on an output side of the one way pump 71. A first of the input switching valves C fluidly connects to the venting pathway 68 leading to external outlet 70 of the submersible body and a second of the input switching valves A fluidly connects to the venting pathway 67 leading to the bladder 65. A first of the output switching valves D fluidly connects to the venting pathway 68 leading to external outlet 70 of the submersible body and a second of the output switching valves B fluidly connects to the venting pathway 67 leading to the bladder 65.

10 [0060] The control of input switching valves A, B, C, D is to have either the first or second input A or C switching valve open and the other closed and thereby feed from either the bladder or external to the input of the one-way pump and to simultaneously control of output switching valves to have either the first or second output switching valves B or D open and the other closed and thereby feed from the output of the one-way pump
15 to the other of the bladder or external.

[0061] In mode A of Fig. 13 it can be seen that valve C is closed and thereby not providing a source of water or pressure. However, because of the strength of the valve it prevents leakage of pressure from valve D or from the external pressure from outlet 70. Instead in this mode valve A is open and allows input of water and pressure from the bladder into the input pathway of one-way pump 71. To ensure this operation of input flow the valve B is closed and thereby provides a strong barrier to the water and pressure from the bladder. The outlet bladder D is open and thereby the pump 71 is able to ensure pumping of water and pressure from the bladder 65 to the outlet 70.

25 [0062] In mode B of Fig 14 it can be seen that valve D is closed and thereby not providing a source of water or pressure. However, because of the strength of the valve it prevents leakage of pressure from valve C or from the external pressure from outlet 70. Instead in this mode valve C is open and allows input of water and pressure from the external outlet 70 into the input pathway of one-way pump 71. To ensure this operation of input flow the valve A is closed and thereby provides a strong barrier to the water and pressure from the bladder. The outlet bladder B is open and thereby the pump 71 is able
30 to ensure pumping of water and pressure from the outlet 70 to the bladder 65.

[0063] Referring to Fig 15 there is the ability to use the valve array and pump to distribute water across multiple bladders and not be restricted to just one bladder. I.e. if

we use two bladders, one at head and one at tail, control is achieved of the attitude (pitch), as well as our overall buoyancy. This operation method gives us another degree of freedom for control of submersible pitch and overall weight that is generally not possible with small submersibles.

5 [0064] This could be extended to any number of valves, and any number of bladders.

[0065] The combination of diaphragm (or high pressure) pump and valve array allows for a compact solution that allows the dynamic movement of water through the sub body, to adjust for buoyancy and pitch offset. The compactness and extensibility of the system is what makes it ideal for the small form submersibles. In larger vessels, where you have
10 space and greater weight freedoms, you could also use this system - however you may be better suited to using more common forms of ballast system, such as gas/water ballast systems, or piston pumps (with large motors to drive the units. Hence, it is more a case that this system has been developed for the small form factor, for submersibles less than 5m.

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[0066] e) Control system

[0067] The control system needs to undertake a number of controls including control of location, control of depth, control of system allowing position and/or depth. Further the control system must control the electronics, motors, and batteries.

20 [0068] In operation of the depth system it is necessary to control the flow and pressure through control of the valves 79 and pump 71 of the pump and valve system 66 and with feedback of the pressure sensor on the ballast take interconnected to a pressure source for calibration and accurate volume and density calculation of water in the ballast tank and ready calculation of required pressure for required alteration of density and thereby
25 alteration of buoyancy between the surface pressure and the neutral buoyancy pressure.

[0069] The electronics includes electronics to run the motors 21, 22 as well as to provide guidance through use of the stereoscopic cameras 35 as well as controlling the operation of the monoscopic wide angled cameras 31 for performing visual capture. The electronics collects the data from the visual image capture and is connectable by
30 connector 41 when the submersible surfaces so as to transfer the data and obtain controlling instructions from a mother ship or other central bank.

[0070] Motor location

[0071] As shown in Figs 1 and 2, the power system for allowing the controllable driving of the submersible body is a 3 degree of freedom manoeuvring system, where it can move in the at least two opposing directions along the axis of the elongated shape, up and down, left and right. This is provided by two side thrusters 21 on either side of the elongated body and a top thruster 22 on a top surface.

[0072] The top thrusters 22 of the power system on the top side of the elongated body include 2 motors spinning in opposite directions to counter the angular momentum of each single motor. The top thruster is placed in the middle of the AUV therefore the force generated from the thruster is very close to the centre of mass point, this helps with the control system and reduce complication in the maneuvering control.

[0073] The side thruster 21 has a tube-like configuration to decrease the amount of turbulent generate from the thruster. This helps with the ability to take high quality pictures from the camera that are behind the thruster stream.

[0074] The two side thrusters of the power system on either side of the elongated body are under the centre of gravity plane, wherein the submersible is maintained stable during maneuvering. More preferably it is in the lower 25 percentile. The thruster force plane is parallel to the centre of gravity plane which extends longitudinally down the submersible. With the thruster force being operative longitudinally it provides the primary main bidirectional movement in opposing directions along the elongated axis.

[0075] A beneficial element is that the power system can be totally on the central part 12 with the payload of the batteries 61 and controlling electronics 69 also in the central part. In this way the motor is spaced from the primary ring 411 of cameras 31 on the axis A-A or B-B on the nose parts 12 of the submersible.

[0076] Apart from normal movement of the submersible an important element is that there are top thrusters 22 that allow movement of the submersible around a 3 to 5 metre range around the neutral buoyancy. In this way there is ready fine tuning of operation without use of the ballast system. This is a substantial advantage over submersibles that only include ballast systems.

[0077] The combination of bladder system and top mounted thrusters are important. The bladder system can be used for neutral buoyancy trim, with the top thrusters used for ascent and descent (precise depth control). The combination of top thrusters and ballast system is also important for the purposes of energy efficiency, and optimisation of motion. E.g. If we intend to descend the submersible to a greater depth, then we can

adjust to be heavier than water so that we descend - without any further actuation from the top thrusters, thus saving energy. We can then re-trim to neutral once we achieve our desired depth. In this case, top thrusters could act as trimming tools, whilst the bladder system could be the primary driver of vertical motion.

- 5 [0078] Conversely, if we want to resurface, the submersible could simply evacuate the bladder completely, and rise to the surface in a highly efficient manner (without any further control input from thrusters), except if one wanted to control the rate of ascent/descent.

[0079] Our mode of operation - using bladder as primary driver of motion, with
10 thrusters as trim; or thrusters as primary driver, with bladder as trim (to trim to neutral) - could be switched depending on the types of applications that the submersible is undertaking.

[0080] By tying in the use of the horizontal thrusters, we are able to control our surge and yaw as we descend under the effort of the bladder system. If desired, we can adjust
15 our attitude using the bladder system to point the nose of the submersible in a specific direction, and use the horizontal thrusters to thrust in that direction

[0081] I.e. We use the bladder system to point the submersible and its actuators in a desired direction, and run horizontal thrusters to actuate in that direction. This, again, would give us a more efficient form of motion in some situations. The bladder system acts
20 as an attitude actuation method, whilst the thrusters act as a linear actuation method.

[0082] This mode of operation could also be extended to be used to align cameras in a particular direction (e.g. dimming the nose to get a better view of a particular underwater object).

[0083] Our system (bladder + thrusters) is designed for both trimming to neutral, as
25 well being the primary driver of vertical actuation. The total volume of the bladder used should be calculated as a percentage of the weight and total density (weight and volume factors) of the submersible, so that it can be used to trim in all kinds of water conditions. As an example, if the submersible has a density of 990kg/m^3 and weight of 100kg , and we aim to have a bladder volume of 5% (of total weight), this will allow us to adjust our
30 total weight (and hence density) from 100kg - 105kg . This would allow us to adjust our density to be from 990kg/m^3 - 1039kg/m^3 . Hence, we could aim for neutral buoyancy in both fresh water (1000kg/m^3) and salt water (1035kg/m^3).

[0084] Overall, the combination of thrusters and bladder system is essential for generating the types of actuation (mode of operation)

[0085] Example

[0086] With a submersible designed to operate at maximum depth the current bladder system is 88 metres which is roughly 142.991 psi (pounds per square inch).

Referring to Fig 16 an example of pressure characteristic of the submersible as we are
5 sinking:

- a) Submersible is on top of the surface. Internal pressure 14.69 psi and External pressure 14.69 psi. The submersible current density is less than the sea water density
- b) As we want to sink, the bladder will then take in the water. The water that we take
10 in replace the available air space inside the submersible, in other words it is compressing the internal air space. The internal pressure now increased to 15.69 psi. We then lock our valve and stop the pump (the internal pressure has increase by 1 psi due to the positive displacement of the water that we take in). This process takes around 6 seconds. We are pumping at the rate of 8L/Min which result in a
15 total take in of 0.78L of sea water (0.7995kg)
- c) At this point our density is higher than the water density so the submersible start to sink. As soon as we reach the depth that is desire (overshoot). We start to open the valve and pumping out the water. At this point out internal pressure is 15.69psi and External pressure (depends on depth ideal situation is 88meter (142.991 psi))
- d) The pressure different from internal vs external is: $142.991 - 15.69 = 127.301$ psi.
20 This pressure different is what the pump needs to be working against to pump the water from inside the submersible to outside environment. Because the pump is working against it ideal situation which is on the surface the pump rate is dropped from 8L/min down to 1L/min due to strong pressure is pushing back in the system
25 from outside environment when we open the valve.
- e) In order to achieve neutral buoyancy, we have to pump out the amount of water until the internal pressure is down to 14.909 psi (currently 15.69 psi). At this point it would take us roughly 36.7 seconds.
- f) After this the submersible is running on engines
- g) To pump out the 0.78L at this point it would take the sub around 10.2 seconds to
30 be positive in buoyance force. This will bring us up to surface. And the process repeats

Interpretation

Embodiments:

[0087] Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to one of ordinary skill in the art from this disclosure, in one or more embodiments.

[0088] Similarly it should be appreciated that in the above description of example embodiments of the invention, various features of the invention are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of one or more of the various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the claims following the Detailed Description of Specific Embodiments are hereby expressly incorporated into this Detailed Description of Specific Embodiments, with each claim standing on its own as a separate embodiment of this invention.

[0089] Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

Different Instances of Objects

[0090] As used herein, unless otherwise specified the use of the ordinal adjectives “first”, “second”, “third”, etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

Specific Details

[0091] In the description provided herein, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known methods, structures and techniques
5 have not been shown in detail in order not to obscure an understanding of this description.

Terminology

[0092] In describing the preferred embodiment of the invention illustrated in the drawings, specific terminology will be resorted to for the sake of clarity. However, the invention is not intended to be limited to the specific terms so selected, and it is to be
10 understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar technical purpose. Terms such as "forward", "rearward", "radially", "peripherally", "upwardly", "downwardly", and the like are used as words of convenience to provide reference points and are not to be construed as limiting terms.

15 Comprising and Including

[0093] In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" are used in an inclusive sense, i.e. to specify the presence of the stated features but not to
20 preclude the presence or addition of further features in various embodiments of the invention.

[0094] Any one of the terms: including or which includes or that includes as used herein is also an open term that also means including at least the elements/features that follow the term, but not excluding others. Thus, including is synonymous with and means
25 comprising.

Scope of Invention

[0095] Thus, while there has been described what are believed to be the preferred embodiments of the invention, those skilled in the art will recognize that other and further modifications may be made thereto without departing from the spirit of the invention, and
30 it is intended to claim all such changes and modifications as fall within the scope of the invention. For example, any formulas given above are merely representative of procedures that may be used. Functionality may be added or deleted from the block

diagrams and operations may be interchanged among functional blocks. Steps may be added or deleted to methods described within the scope of the present invention.

[0096] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Industrial Applicability

[0097] It is apparent from the above, that the arrangements described are applicable to the submersible industries.

Claims

The claims defining the invention are as follows:

1. A bladder system for a submersible having an elongated body substantially 1 to 5 metres long, the bladder system for providing ballast for the submersible comprising:
 - 5 a. a bladder mountable in the body of the submersible;
 - b. a venting pathway connecting between the bladder and external of the submersible body;
 - c. a ballast control for controlling the venting in the venting pathway between the bladder and external of the submersible body;
 - 10 d. a power system for powering the ballast control;wherein the ballast control uses at least one controllable directional one-way pump.
 2. A bladder system for a submersible according to claim 1 wherein the ballast control includes at least one switching valve fluidly connected to the one-way pump for switching flow direction in the venting pathway.
 - 15 3. A bladder system for a submersible according to claim 2 wherein the ballast control includes a set of a plurality of switching valves wherein the set of switching valves work together to resist pressure equally on either side.
 4. A bladder system for a submersible according to claim 3 wherein the ballast control includes a set of four switching valves fluidly connected to the one-way pump.
 - 20 5. A bladder system for a submersible according to claim 1 wherein the set of four of the at least one switching valves is arranged to form two input switching valves on an input side of the one way pump and two output switching valves on an output side of the one way pump;
- wherein a first of the input switching valves fluidly connects to the venting pathway leading to external of the submersible body and a second of the input switching valves fluidly connects to the venting pathway leading to the bladder; and
- wherein a first of the output switching valves fluidly connects to the venting pathway leading to external of the submersible body and a second of the output switching valves fluidly connects to the venting pathway leading to the bladder; and

whereby the control of input switching valves to have either the first or second input switching valve open and the other closed and thereby feed from either the bladder or external to the input of the one-way pump;

5 to simultaneously control of input switching valves to have either the first or second output switching valve open and the other closed and thereby feed from the output of the one-way pump to the other of the bladder or external.

6. A bladder system for a submersible according to claim 1 wherein the pump is a diaphragm pump.

7. A bladder system for a submersible according to claim 1 wherein the switching valve
10 is a ball valve.

8. A bladder system for a submersible according to claim 1 wherein the control of ballast uses a pressure sensing of the water in the bladder, whereby the actual flow of water in the venting between the bladder and external of the submersible body is precisely determined.

9. A bladder system according to claim 1 wherein the bladder includes an inner expandable bladder.
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10. A bladder system for a submersible according to claim 1 wherein the bladder operates in the range greater than 36 psi.

11. A bladder system for a submersible according to claim 1 wherein the bladder
20 operates substantially in the range from 36 psi. to 100 psi.

12. A bladder system for a submersible according to claim 1 wherein elongated body with a hydrodynamic effective shape includes a first and a second opposing substantially conical head and a main cylindrical central part therebetween and aligned along a common elongated axis to allow the hydrodynamic effective shape for travel in at least
25 two opposing directions.

13. A bladder system for a submersible according to claim 1 wherein the main cylindrical central part and the first and the second opposing substantially conical heads are detachable and replaceable.

14. A bladder system for a submersible according to claim 1 wherein the main cylindrical
30 part can be replaced by a differing length main cylindrical part and attached to the first and the second opposing substantially conical heads.

15. A submersible having an elongated body substantially 1 to 5 metres long, the submersible including a bladder system of any one of claims 1 to 14 for providing ballast for the submersible comprising:

- a. a bladder mountable in the body of the submersible;
- 5 b. a venting pathway connecting between the bladder and external of the submersible body;
- c. a ballast control for controlling the venting in the venting pathway between the bladder and external of the submersible body;
- d. a power system for powering the ballast control;

10 16. A submersible according to claim 15 wherein the ballast control uses at least one controllable directional one-way pump.

17. A submersible according to claim 16 wherein the main cylindrical central part or the differing length main cylindrical central part can include one or more of:

- a. Batteries;
- 15 b. Ballast;
- c. Motors;
- d. Electronics
- e. Data and power connections;
- f. Other Payloads.

20 18. A submersible according to claim 15 wherein the elongated body is substantially elliptical with a 1 to 1.5 metre major axis and a 0.3 to 0.5 metre minor axis.

19. A submersible according to any one of claims 15 to 18 wherein the power system for allowing the controllable driving of the submersible body is a 3 degree of freedom maneuvering system, where it can move in the at least two opposing directions along the
25 axis of the elongated shape, up and down, left and right.

20. A submersible according to any one of claims 15 to 19 wherein the power system includes two side thrusters on either side of the elongated body and a top thruster on a top surface.

21. A submersible according to claim 20 wherein the top thrusters of the power system on the top side of the elongated body include 2 motors spinning in opposite directions to counter the angular momentum of each single motor.
22. A submersible according to claim 21 wherein the two side thrusters of the power system on either side of the elongated body are under the centre of gravity plane, wherein the probe is maintained stable during maneuvering.