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A battery pack

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Field

The present invention relates to a battery pack particularly though not solely to an underwater propulsion device for attachment to a scuba diver.

Background

US patent number 6823813 ("Mazin") discloses a leg mounted propulsion device for swimmers and divers as shown in Figure 1. Propulsion units 14 are attached to the diver's legs. A battery pack is either attached as a weight belt 16 or as a cylinder beside the air tank 13. A controller is attached to the belt 16 beside the buckle on the stomach of the diver.

Mazin may suffer from a number of disadvantages including lack of adequate sealing for the battery pack, lack of modularity, difficultly of access to the controller (especially when the diver's hands are already holding other equipment), lack of flexibility in control, and/or lack of user friendliness and difficulty of user servicing.

It would be desirable to provide a battery pack or underwater propulsion device which overcomes one or more of these disadvantages or which at least provides the public with a useful choice.

Summary

In general terms the invention proposes that a micro-controller is housed inside the battery pack and/or the battery pack is double sealed. This may have the advantage that sealing of the battery pack may be improved even if the outer casing is opened while the diver is still wet, additional modules may be easily added, a much wider range of control options and user interactivity may be possible, user friendliness may be improved and/or users may easily service or upgrade the device anywhere.

In a first particular expression of the invention there is provided an underwater propulsion device as claimed in claim 1 or 2.

Example implementations of the invention are provided in any one of claims 3 to 19.

In a second particular expression of the invention there is provided a battery pack as claimed in claim 20 or 21.

Brief Description of Drawings

One or more example embodiments of the invention will now be described, with reference to the following figures, in which:

Figure 1 is a plan view of a diver equipped with a prior art propulsion device;

Figure 2 is a schematic view of a propulsion device according to an example embodiment;

Figure 3a and 3b are transparent view of the electronics battery pack in Figure 2;

Figure 4 is a perspective view of the hand controller in Figure 2;

Figure 5 is a perspective view of the thruster in Figure 2;

Figure 6 is a perspective view of the battery pack in Figure 2; and

Figure 7 is a flow diagram of the control strategy.

Detailed Description

An underwater propulsion device 200 according to the example embodiment is shown in Figure 2. There are two thrusters 202, each with straps 204 to attach to the calf of a diver. The thrusters 202 are electrically connected to an electronics battery pack 206 via cables 208. A further cable 210 electrically connects the electronics battery pack 206 to a hand controller 212.

Electronics Battery Pack

The electronics battery pack 206 is shown in more detail in Figure 3. An outer casing 300 is in the shape or an open ended cylinder. The open end 302 is sealed with a cover 304. The cover 304 has two quick release clips 308 to lock it in place. The outer casing 300 has a D-Ring 310 located about half way down its length to attach via stainless steel clips to the diver's buoyancy compensator device (BCD).

The outer casing 300 is made of clear Polyoxymethylene thermoplastic (marketed by Dupont™ under the name Delrin®) or Polyethylene (also known as Polythene or PE) thermoplastic to withstand 30 bar (300m). Alternatively ultra high molecular weight polyethylene (marketed by Royal DSM under the name Dyneema®) can be used if up to Level 3, 7.62 balls is required.

The cover 304 is sealed to withstand up to 100m of water. There are two O-rings sealing the top cover. The upper O-ring 312 is to withstand impact on the top cover during dive, including shear force. The lower O-ring 314 is to withstand water pressure of up to 10 bar.

The cover 304 includes Underwater Sea-Con connectors 316, 318 for both the thruster cables 208 and an Underwater Sea-Con connector 320 the controller cable 210. The male connectors 316, 318, 320 in turn are connected via female connectors 324, 326, 328 into an internal compartment 330. The Underwater Sea-Con connectors 316, 318, 320 are an underwater & pressure-proof connection, can be disconnected & connected in the water.

The internal compartment 330 houses the battery pack 332 and the electronics 334. The battery pack 332 and the electronics pack 334 are further sealed within the internal compartment 330 by a secondary sealing cover 335. This provides additional sealing, and provides protection if diver should accidentally unclip the top cover during a dive. A holder 336 holds the electronics pack 334 from rising up (as air expands when ascending). The secondary sealing cover 335 includes two O-rings 338, 340 at the top of the electronics pack 334 to seal against the inner wall of the outer casing 300.

When deliberately opening the top cover 304, a diver hands can be dripping wet. The secondary sealing 338, 340, prevents water from entering into the electronics pack 334.

Several water detectors are installed in the battery pack on several levels in the unit, to detect any presence of water. The hand controller 212 may light up and/or emit sound, should there be any water detected. Lights and/or sound within the outer casing 300 may also give indication thru the transparent casing if water is detected.

The secondary sealing cover 335 also includes cable glands 342 to connect the thruster cables 208, and the controller cable 210, into the electronics pack 334. The cable gland 342 may be brass made nickel plated and/or plastic, to withstand water pressure up to 5 bars (50m). Alternatively they may be glass-reinforced cable glands, able to withstand 30 bars pressure (300m) or wet connectors.

When inserting or removing the battery pack 332 into the outer casing 300, air must be able to escape/enter. A port plug 348 is installed on the secondary sealing cover 335, serving two functions.

1) To remove excessive hydrogen gas build up from the batteries, if left over long period of time in an enclosed compartment. The port plug 348 enables the releasing hydrogen gas by controlling the gas release, a special thread enables the gas to be released without any damage to the battery pack or user.

2) To allow excessive air flow - at times when diver seals the compartment too tight or dives too deep, air contracts more than it expands after the diver ascend to the surface, so it may be hard to pull out the battery pack. By

removing the port plug 348, this allows outside air to fill up the battery compartment for easy removal.

When removing the battery pack 332 a pulling ring 350 is located at the centre of the entire electronics & battery pack. The concentrated and focus the force to pull out the battery pack, on the middle. Any excess force will be spread out, reducing any wear & tear.

The electronics battery pack 206 may have independent application from the rest of the equipment. For example the battery pack may be used to extend power tools in hazardous areas on land.

Electronics Pack

The electronics pack 334 includes a micro-controller, motor drive circuits, a battery power supply for the electronics, and water detectors. The input from the hand controller 212 is provided as an input to the micro-controller. The micro-controller includes a stored algorithm or program which determines an appropriate control signal to send to the motor drive circuits. In turn depending on the control signal the motor drive circuits provide drive signals to the thruster cables 208 to energise the thrusters 202.

The circuitry is water-proof and splash-proof. Critical components will be resin-flooded (adding a thick layer of plastic composite to withstand water pressure – the plastic composite will combine chemically, forming a thick non-penetrating layer on the electronics, apart from withstanding water pressure, it also prevents

oxidising and condensation of the electronics metallic connection, further enhancing stability in transmission).

The electronics pack 334 includes a plastic housing 352 to reduce any condensation formed. Heat dissipated by circuitry will be spread out in the casing 352 to heat up water vapour through the vent holes 354. The vent holes 354 allow air within the internal compartment 330 to enter/exit for easier removal or insertion of the battery pack 332 and the electronics pack 334.

The plastic housing 352 is attached at the top to the secondary sealing cover 335. At the bottom is it attached to a stainless steel base 356. The base 356 is used to transfer heat and spread the temperature downwards.

The electronics pack 334 is electrically connected with the battery pack 332 by electrical splash-proof connectors. The physical connection is via 2 fasteners. Independent power isolators are provided for individual battery or power source. As the battery is capable of highly discharge electric current at very fast rate, individual power switch within the Electronics Battery Pack, provides additional safety in addition to having a safety switch on the hand controller. When the isolator is turned on this will provide power to the Microcontroller. However, only when the safety switch 406 is turned on, will the micro-controller activate the thrusters 202. This provides further safety against accidental powering the device by children or dropping from heights, and to reduce the risks of having electric shock.

The control strategy 700 is shown in Figure 7. In a conventional device a short-circuit or leakage, could cause the motors to malfunction and going into uncontrollable. The Micro-Controller 702 in the example embodiment provides

digital control, intelligence, and enhance safety. If the Micro-Controller 702 is damaged, the system will shut down. For example the motor driver 704 will only proceed on receipt of a valid signal from the Micro-Controller.

The micro-controller 702 is powered from a voltage regulator 706 connected to the battery pack 332.. The voltage regulator 706 also prevents any over voltage damaging the micro-controller 702.

The use of a micro-controller allows much greater control over the speed of the thrusters and management of the battery charge. Also water detector(s) are connected to the micro-controller as sensor(s). When water is detected, LED and/or buzzer will activate and micro-controller will deactivate the propulsion unit 202 until the water is clear or the system is reset. As well the micro-controller can be connected to additional modules and the firmware can be upgraded to offer further functionality. For example location or GPS functionality, communications or GSM functionality and interacting with other wireless devices. For example a cellular telephone module can be installed in the Electronics Battery Pack compartment. The diver can then speak though a full face mask to connect to the above water telephone network via a surface buoy. Voice commands may be used to call preset numbers, or if the device detects an emergency condition an emergency number might be called with a pre-recorded emergency message. Also since the motor control is done in the electronics pack 334, only one cable is required to go to the hand controller 212, making it lighter and easy to manipulate.

The firmware or algorithm may include digital control over the speed of the thrusters. In the event the safety switch is activated, or any errors conditions occur (eg: cable unplugged, short circuit, over temperature, water detected etc) the thrusters are immediately deactivated. A different type of power switch can

be used to detect diver awareness, by means of hand or jaws depression. A diver can press on a spring loaded hand switch or a force sensor installed in the diver regulator's mouth piece, which senses the amount of force the diver's jaws holds the mouth piece. Through these two methods, any sudden reduction in forces will trigger the micro-controller to deactivate the thrusters 202 immediately.

Hand Controller

The hand controller 212 is shown in more detail in Figure 4. The switch comprises 3 sections, 400, 402, 404 which are modular and can be upgraded, changed or easily serviced. The switches 406,407 in section 404 are US Military approved, grade MIL-25224-3 (switch) and MIL-B-5423 (switch boot).

The controller 212 is universal and can be used on left or right hand. The first section 400 is curved 408 to follow the shape of the diver's wrist and includes a strap to attach firmly around the diver's wrist. Alternatively it may have a hand strap to dangle loosely around the palm.

The third section 406 is the bottom plate which attaches the first and section sections 400, 402 together.

All connections within the controller 212 will be pressure sealed by resin to 5 bar (50m). The sections 400,402,404 are made from plastic and are not watertight. No sealing is required between sections 400,402,404.

The switches 406,407 include an on-off switch 406 used to turn the thrusters 202 on and off. A second switch 407 is used to adjust the speed. Depending on the user's requirement (whether to be hands-free or hands-on) the user can choose the hand controller switch to be hands-free design or hands-on design.

The hands-free design, which uses on-off-on switch, will have the speed preset in "low speed – off – high speed". The hands-on design, which uses mom-off-mom switch, will have the speed preset and an additional safety feature which allows the switch to spring back to off mode when user releases the finger/ thumb off from the switch. However, user must constantly put the thumb or finger on the switch to energise the thrusters 202.

The speed can be Preset or Variable. For variable the user will either depress the switch by adding additional force or turning a knob to adjust the speed. Because the speed of the BLDC motor can be controlled exactly, synchronising of the two motors and speed adjustment can be achieved easily.

The on/off switch 406 is designed to be hands-free but can be operated with just a flick from the finger or thumb. The control signal from the on/off switch 406 to the micro-controller will sent via wired connection 210 or alternatively maybe wireless eg. radio frequency, infra-red, etc.

Because the hand controller 212 straps onto the hand wrist of the diver, the diver's hand is still free. Two hand straps may also be used to secure the cable 210 firmly to the diver's hand length towards the wrist. Thus the diver can still hold a torchlight or other dive equipment in that hand. The location of the on/off switch 406 is based on the ergonomics of average adult hand wrist, including the angle of wrist to hand and thickness of the hands & thumb. The on/off

switch 406 is turned on in a backward position (towards the diver), which is slightly more difficult than the turn off forward position (away from the diver). This allows the diver the more natural actuation of pushing forward, for an immediate stop or emergency brake.

The device 200 may include sensors, for example water speed sensors or depth sensors. The hand controller 212 may include an LCD panel with GUI (Graphic User Interface) and/or touch interactivity. Information can then be packaged and transmit through the micro-controller via wireless transmission (Radio-Frequency) and decoded by another micro-controller at the diver's wrist. The system can also relay a power signal (RF may be limited in water up to 1m) by transmitting information from the battery pack to the diver's wrist and display information on a diver's mask (like head-up display). Depending on the application eg: sports, technical, commercial, military, different information may be gathered and/or displayed.

Thrusters

The thrusters 202 are shown in more detail in Figure 5. Each thruster 202 is rated over 1 HP to provide 7kg of thrust. Higher power ratings can be provided depending on the application. Thrust is provided by a brass propeller 500 or turbine/jet system. A shaft 502 connected to the propeller 500 is stainless steel or titanium. An internal SKF bearing is used to absorb vibration. With oil filled sealing it is rated to 100m depth rating, or with metal sealing rated from 300m - 1000m. The casing 506 is aluminium. A motor 508 connected to the shaft 502 may be a brushless DC (BLDC) motor for high efficiency and precise control. The motor 508 is electrically connected to the thruster cable 508 via bushing 510 and connector 512.

The Calf straps 202 are made of Kelvar, Nylon and/or Neoprene. They are an ergonomic design to support the thrusters on the calf muscles. A thigh strap is used to secure the cable 208 to the diver's thigh with a quick release, allowing diver to release the strap in an emergency. The straps are wear and tear, heat and corrosion resistant.

Battery

The battery pack 332 is shown in more detail in Figure 6. It includes 2 vertical Lithium Polymer batteries 600,602. Each battery is used separately for each thruster, but the micro-controller may control battery usage depending on the application. More batteries can be used for different applications.

A stainless steel top plate 604 is attached to the base 356 to transfer heat and to provide structural support to the electronics compartment 334. A plastic middle 606 and base plate 608 reduce condensation and help guide the electronics and battery pack 206 into the internal compartment 330. A stainless steel casing 610 is to transfer heat and provide shock-resistance, with vent holes 612 to allow air to flow in and out easily when the electronics and battery pack 206 is being pulled out of the internal compartment 330.

The batteries 600,602 are mounted with rubber to provide protection against shock damage.

The base 356 is fastened to the top plate 604. The secondary sealing cover 335 can thus be easily fastened and separated from the electronics pack 334, and the battery pack 334. This allows easy access to the electronics pack 334 and the power switch(s).

Usage

A typical dive will involve the diver attaching the electronics battery pack 206 to the BCD or weight belt, and when ready to enter the water, the thrusters 202 are attached to the legs and the hand controller 212 to the wrist. Once in the water, when the diver is oriented in the desired direction, the on/off switch 406 is actuated to energise the thrusters and speed is controlled with switch 407. Any further control(s) (non-critical) can communicated wirelessly between the Hand Controller 212 and the Electronics Battery Pack 206 and other devices such as a heads up display in the diver's mask. An acoustic modem with a hydrophone, can be installed in the Electronics Battery Pack 206 to exchange information with other diver teams in the water. Information received by other divers, can in turn be displayed on their mask, allowing networking in the water.

The battery pack 332 may be charged by undoing the cover 304, removing the housing 352, undoing the port plug 348 and then withdrawing the Electronics Battery Pack 206 using the pulling ring 350. An electronic controlled charger is then connected to the batteries and ensures all the cells within the battery are charged evenly. There should be enough slack in the cables 208,210 between the cover 304 and the gland 342 for unrestricted access to the internal compartment 330 when the cover 304 is removed.

The user may add modules to the electronics pack 334 by connecting to any spare connectors on the microcontroller. Additionally a micro-controller with upgraded firmware may be used to replace the existing microcontroller in a plug and play manner.

Whilst exemplary embodiments of the invention have been described in detail, many variations are possible within the scope of the invention as will be clear to a skilled reader.

CLAIMS

1. An underwater propulsion device comprising:

at least one propulsion unit configured for attachment to a user,

a controller configured for attachment to the user and to receive the user's input, and

a battery compartment configured for attachment to the user and including a battery substantially water sealed in a first enclosure, and the first enclosure substantially water sealed in a second enclosure.

2. An underwater propulsion device comprising:

at least one propulsion unit configured for attachment to a user,

a controller configured for attachment to the user and to receive the user's input, and

a battery compartment configured for attachment to the user including a battery and a micro-controller configured to energise the propulsion unit according to the user's input.

3. The device in claim 1 or 2 wherein the battery compartment comprises a cylinder with a removable cover, a first O-ring configured to seal between the removable cover and an end wall of the cylinder and a second O-ring configured to seal between the removable cover and an inner wall of the cylinder.

4. The device in claim 3 further comprising an electronics battery pack configured to locate inside the cylinder and two spaced O-rings, the two spaced O-rings configured to seal between the inner wall and a sealing cover at an end of the electronics battery pack.

5. The device in claim 4 further comprising a wet connector in the removable cover for an electrical cable between the electronics battery pack, the propulsion unit and/or the controller.

6. The device in claim 5 further comprising a substantially water tight cable gland in the sealing cover for the electrical cable.

7. The device in any one of claims 4 to 6 further comprising a pull ring located at the centre of the sealing cover.

8. The device in any one of claims 4 to 7 further comprising a removable one way vent in the sealing cover.

9. The device in any one of the preceding claims wherein the controller is configured to strap to either of the user's wrists.

10. The device in any one of the preceding claims wherein the controller includes a switch configured to deenergise the propulsion unit with an actuation away from the user and to energise the propulsion unit with an actuation toward the user.

11. The device in claim 11 wherein the controller further includes a second switch configured to increase the speed of the propulsion unit with an actuation away from the user and to lower the speed of the propulsion unit with an actuation toward the user.

12. The device in any one of the preceding claims wherein a battery is removable from the battery compartment.

13. The device in claim 12 further comprising a plurality of removable batteries, a metal casing around the batteries, and a plurality of plates configured to locate the batteries within the battery compartment.

14. The device in claim 13 wherein the plurality of plates comprises a top metal plate, a middle plastic plate and a bottom plastic plate.

15. The device in claim 2 wherein the micro-controller includes a motor controller for the propulsion unit.

16. The device in claim 2 where the battery compartment includes an electronic compartment including the micro-controller.

17. The device in claim 12 when dependant on claim 2 where the battery compartment includes a power switch between the battery and the micro-controller.

18. The device in any one of the preceding claims wherein the propulsion unit includes a brushless DC motor.

19. The device in claim 16 further comprising water detectors in the electronic compartment and the battery compartment.

20. A battery pack comprising a removable battery substantially water sealed in a first enclosure, and the first enclosure substantially water sealed in a second enclosure, the second enclosure configured for attachment to a user.

21. A battery pack comprising a removable battery and a micro-controller inside a substantially water sealed battery compartment configured for attachment to a user, the micro-controller configured to energise an electrical load electrically connected to the battery according to the user's input.