

7000M Lander Design for Hadal Research

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Abstract—Biology and ecology research in hadal zone (6000-
11000 m) has been a renewed interest recently. With advances in
engineering technology, breaking the knowledge gap of hadal
science becomes reality. Free-fall vehicle also known as “Lander”
has been widely applied in marine investigation for decades.
Achievements made in hadal field with landers have vastly
couraged scientists to implement further progress. This paper
describes the design of a 7000-meter lander, which mainly
focused on hadal biology and ecology research. Effort for oil-
filled compensation approach of powering and control subsystem
has been conducted, which increases the reliability of pressure
resistance and seal while reducing the size and weight of the
sealed housing. Results of the high pressure test demonstrate the
proposed approach is practical and reliable.

Keywords—free-fall vehicle; lander design; oil-filled compensation;
high pressure test

I. INTRODUCTION

Depth rating from 6000 to 11000 meters of the ocean which
known as the hadal zone is still one of the least understood
habitats on Earth [1]. High hydrostatic pressure, darkness, and
low temperature are typical environmental characteristics of
hadal zone. Far from the initial thought of forbidden life, the
hadal zone is rich in species diversity and abundance [2-6].
However, existing knowledge about hadal ecosystem is still
rare and sporadic due to technological limitations in such
extreme conditions. Recent advances in marine engineering
technology provide us opportunities to discover the hadal
mystery, such as remotely operated vehicles (ROV, the Kaiko
7000[7]), Hybrid ROV (the Nereus[8]), human occupied
vehicles (HOV, the DEEPSEA CHALLENGER[9], the
JiaoLong[10]), and free-fall bottom landers (the Hadal
Landers[11], the Alpha Lander[12]) et al.

Lander is an untethered platform which could free-fall to
the sea floor under self-gravity and float back up to the surface
by releasing ballast. After landing on the sea floor, corresponding
tasks are performed until a pre-programmed
time or an acoustic recovery command is received. It has
advantages in flexible configuration, easy to use, long term
duration working time, and low cost, and has been widely
applied in benthic bottom exploration and research since early
in last century [13-16]. The lander is generally used as an
observing or sampling platform for various purposes depending
on scientific payloads its equipped, such as deep-sea imaging,
environment measuring, oceanic noise recording, organisms or
sediments sampling.

The use of landers makes a new approach to investigate the
hadal zone, especially in understanding the biology and
ecology in the deepest area on the earth. An important progress
has been made during the “HADEEP” project cooperated by
University of Aberdeen (U.K.) and University of Tokyo
(Japan), where two hadal landers are employed[11]. However,
long-duration and large-scale surveys are still urgent demand
for hadal research.

A 7000 meters rated lander with the capacity of 30-day’s
endurance is presented in this paper, which mainly focused on
the research of hadal biology and ecology. The organization of
the paper is as follows. The design of the lander system is
described in section 2. Related high pressure tests are presented
in section 3. In section 4, conclusion is presented.

II. SYSTEM DESIGN

A. System Overview

The lander system is divided into delivery subsystem,
powering and control subsystem, and scientific payload
subsystem, as shown in Fig. 1. The delivery subsystem consists
of a main frame, a buoyance package, basic equipment
(acoustic release, altimeter, pressure sensor, electronic compass,
Iridium beacon, Xenon flasher, and hydraulic compensator), a
timing-release mechanism and ballasts. The powering and
control subsystem consists of two lithium batteries, a main
controller, a power managing modular, and a video
recording/processing modular. The powering and control
subsystem is arranged in three sealed housing (two for the
lithium batteries, one for the rests) filled with oil, which linked
to the hydraulic compensator. While the scientific payload
subsystem consists of a CTD, a digital stills camera, a flashgun,
a video camera, two LED lights, a Niskin bottle, a sediment
sampler and a funnel trap.

B. Delivery Subsystem

1) Main Frame and Buoyance Package

The tripod shaped main frame of the lander is 2.3 meters in
tall, 3 meters in maximum outside diameter. The frame is made
of aluminum, and is wrapped with anticorrosive materials. A
total of 28 13-inch Vitrovex® glass spheres fixed to an
aluminum frame are used to provide system buoyance during

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ascent, and have a net buoyance of 240 kg in water. The lander system is designed as a split structure for transport considering, and could be easily hooked together through a high strength nylon rope before deployment with buoyance high and weight low, leading to a large metacentric and maintaining a vertical attitude in water.

2) Basic Equipment

The lander is equipped with sensors to determine the real-time system state, including an altimeter, a pressure sensor and an electronic compass. Two acoustic release units and a related Deck Unit (Teledyne Benthos Inc., USA) are selected to retrieve the system when needed, the maximum slant range of the acoustic release is 10 km. Iridium beacon and Xenon flasher (MetOcean Inc., Canada) are devices to locate the lander when it surfaces. Another component of basic equipment is the hydraulic compensator, which compensates the inner pressure of oil-filled housing, such as electronic housing and battery housing. A clump of ballast weights made of 10 cast iron blocks (5 kg each) is suspended on each of the three legs and tied to the release mechanism. The number of iron blocks can be flexible arranged according to desired descent speed.

3) Release Mechanism

Release mechanism is a key component of the lander system, comprising three independent ballasts release approaches: acoustic release, actively controlled release and timing release. Acoustic release mechanism is the principal approach, through which the lander would release ballasts as long as one acoustic release receiving the acoustic command. Active releasing mechanism controlled by the mainboard would trigger the actuator to release the ballasts when the lander occurring an emergency during the descent. In case of bad environment conditions or unexpected reasons, acoustic release may be failed, which is not willing to be happened, thus a timing release mechanism is proposed. Every time before deployment, a predefined countdown is set to the timing release mechanism. Whenever the predefined time is up, it will trigger the actuator to release the ballasts, so it’s important to make a detailed schedule to determine the predefined time.

C. Powering and Control Subsystem

The whole system is powered by two same Lithium batteries, one of which specially supplying the video recorder system (including a video camera, two LED lights and a video recording/processing modular). The lander is mainly controlled by a low power consumption mainboard integrated with a multiport serial module due to serial communication mode used by most sensors. To monitor power state and switch on/off the devices under control of the mainboard is achieved by a power managing modular.

Since limited capacity of image processing of the main controller, a special video recording/processing modular is proposed to record video data, and extracts single-frame image every few minutes to decide whether moving objects are in the field of view. The analysis result is then transferred to the main controller to trigger corresponding actions. To conserve energy, the video recording/processing modular goes into sleep mode if no moving objects observed, and will wake up in a predefined cycle time.

Considering long duration deploying requirements, the maximum designed working time on sea floor is up to 30 days, which requiring a large power supply unit and a high reliable pressure resistance and seal solution. Oil-filled compensation housing (shown in Fig. 2) is proposed to hold powering and control subsystem. This design increases the reliability of pressure resistance and seal while reducing the size and weight.
of the sealed housing. As a result, high pressure would act directly on the battery and electronic components inside, which may lead to a fatal damage, thus related high pressure tests are carried out in section 3.

D. Scientific Payload Subsystem

Proposed lander is mainly focused on biology and ecology research in hadal zone. Based on requirement analyses, missions to achieve corresponding goals are imaging, environment measuring and hadal sampling, thus scientific payloads equipped in this lander consist of a video camera, a high resolution still camera and supporting flash gun, two LED lights, an CTD profiler integrated with a dissolved oxygen sensor, and a Niskin bottle, a sediment sampler and a funnel trap.

III. Pressure Test

The sealed housing are linked to hydraulic compensator through oil hose, causing the internal pressure equals to external environment pressure. It brings the problem that units inside must be strong enough to resist the high pressure (reaching up to 70 MPa).

We carefully design the pressure test process, battery was tested firstly. As shown in Fig. 3, two different kind of lithium battery are tested in oil pressure tank under 70 MPa, left is a disposable lithium battery with high energy density, right is a rechargeable lithium battery. Results is clear, the rechargeable battery doesn’t appear any distortion, while the disposable lithium battery is broken. Then, we retest the battery with wires draw forth through the tank to measure the battery voltage. After a whole day testing, it maintains a stable state.

Unit of the control system is tested separately in a water pressure tank under 80 MPa with oil-filled in a ziplock bag, Fig. 4 shows the pressure test of the mainboard. Unfortunately, the mainboard damaged because of some electronic components crushed, and so do other units. Thus, essential protection for the special electronic components is needed. We wrap the components in a small pressure resistance hull, as shown in Fig. 5, then following pressure tests are carried out. The result is encouraging, and we also run the mainboard for a long time in air after pressure test.

At last, the whole powering and control subsystem is tested on-line, shown in Fig. 6. Wires are drawn forth through the tank to check the real-time status of the system. More than 100 hours on-line test had been carried out, the system still present in good conditions.
IV. CONCLUSION

The design of a 7000-meter lander for hadal biology and ecology research is presented in this paper. The system has the abilities of taking photos, recording videos, measuring environment parameters and sampling in pre-programmed mode. To increase the reliability of pressure resistance and seal while reducing the size and weight of the sealed housing under great hydrostatic pressure in hadal environment, oil-filled pressure compensation approach is proposed, and corresponding pressure test are carried out. The test result indicates the powering and control subsystem could resist the high pressure and maintaining a stable work status. Release function test and other experiments are also conducted in water pool, and all represent in desired conditions. Sea trial experiments will be performed subsequently.

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REFERENCES

[8] Bowen, A.D., et al., The Nereus hybrid underwater robotic vehicle for global ocean science operations to 11,000 m depth. 2008: IEEE.