Fuel Cell AUV "URASHIMA"

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1. Introduction

It is considered that acquisition and analysis of Arctic Ocean marine data is indispensable to the clarification of global warming. As an effective means of investigating the Arctic Ocean, access to which is difficult, there has been a demand for development of an autonomous underwater vehicle (AUV) capable of cruising long distances.

The AUV URASHIMA is regarded as a test vehicle in the development of an AUV capable of autonomous navigation under the ice of the Arctic Ocean. The Japan Agency for Marine-Earth Science and Technology started this development, and the vehicle powered by lithium-ion rechargeable battery was delivered in March 2000. In order to extend its cruising range, replacing its power source to fuel cells was completed in March 2003, and the new URASHIMA successfully recorded the world's longest continuous cruising of 317 km in February 2005.

This paper gives a general description and reports on the sea trial results of URASHIMA, the world's first fuel cell-powered deep sea cruising explorer.

2. System composition of URASHIMA

URASHIMA is an AUV, and basically does not require any support from the mother ship during navigation. However, this vehicle is designed to be able to be monitored by the accompanying mother ship. The URASHIMA system is composed of the vehicle and the on-board facilities.

The on-board facilities include the control container housing control and monitor panels, the power source container and the fuel cell on-board equipment. Communication between the vehicle and the mother ship is made possible by optical fiber cable (disconnected while cruising) or acoustic means under water, long distance radio at the surface and radio wave LAN on board.

Table 1 shows the principal specifications of the vehicle, and **Fig. 1** shows its configuration.

3. Fuel cell system

3.1 Fuel cell

URASHIMA uses polymer electrolyte fuel cell (PEFC) as a power source. As compared with other fuel cells, the PEFC is characterized by a low operating temperature of about 60ºC to 80ºC, so it is easy to facilitate heat insulation measures and to control the temperature at starting and stopping operation.

Table 1 Principal Specifications of the vehicle

Item	Specifications
Type	Autonomous underwater vehicle (AUV)
Dimensions (m)	10.7 (L) × 1.3 (W) × 1.5 (H) (approximate)
Weight in air (t)	approx. 10
Max. operating depth (m)	3 500
Max. cruising range (km)	300
Cruising speed (kt)	approx. 3

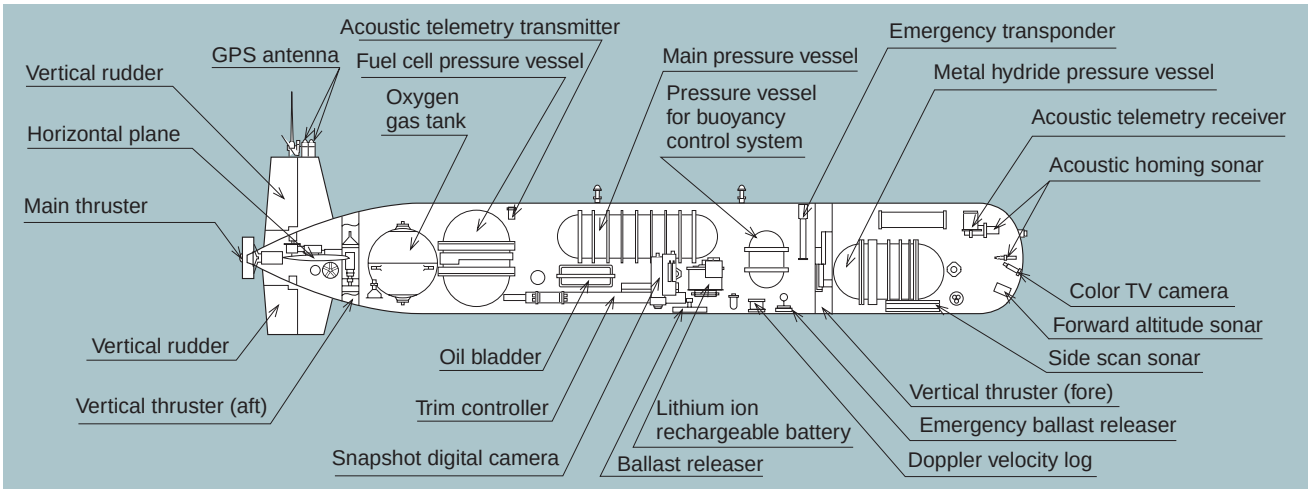

Fig. 1 General arrangement of vehicle Configuration and layout of the vehicle (side view)

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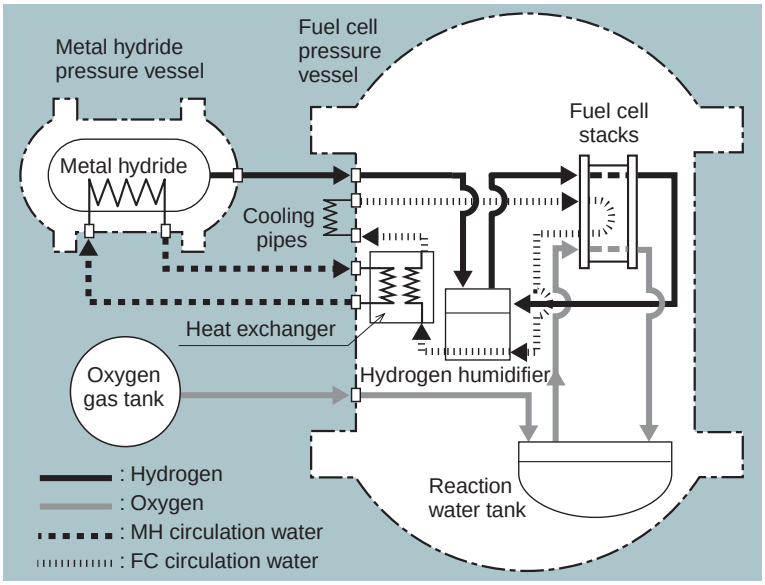

Fig. 2 Block diagram of fuel cell system
This figure shows the outline and configuration of the gas and circulation water systems for the fuel cell system of URASHIMA.

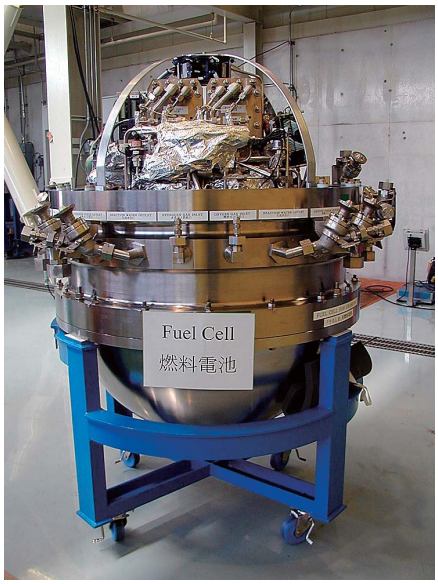

Fig. 3 Fuel cell
This photo shows the fuel cell main body housed in the vehicle's fuel cell pressure vessel.

And it can be assembled in a compact and light-weight system. In the present case, two fuel cell stacks are connected in series for a rated output of 120 V, 4 kW. **Fig. 2** shows the configuration of the fuel cell system for the AUV URASHIMA, and the photograph in **Fig. 3** shows its appearance.

Differing from the land-use system, the fuel cell system mounted on URASHIMA is a completely closed cycle fuel cell system. The fuel cell is housed in a pressure vessel made of titanium alloy. Oxygen gas is supplied from a high-pressure (14.7 MPa) oxygen gas tank, and the hydrogen gas is supplied as fuel from the metal hydride contained in a pressure vessel. One of the characteristics of the closed cycle system is that pure oxygen, not air, is used as oxidizer. The unreacted gas passing through the fuel cell stacks is recirculated in the system, and reacted water is collected in a reaction water tank in the fuel cell pressure vessel.

Temperature and humidity control is very important for PEFC. In the fuel cell stack, water at a constant temperature is circulating to maintain the operating temperature, and temperature and humidity of the gas line are controlled by heat insulation and heating.

3.2 Metal hydride

Storage of hydrogen gas by metal hydride (MH) was adopted in consideration of safety. As the metal hydride, AB5 type rare-earth-based alloy is used on account of its excellent absorbing efficiency, and its capability of absorbing and desorbing in the normal temperature range (20 – 60°C). Desorbing discharge of hydrogen from the metal hydride is a heat absorbing endothermic reaction, and the desorption is controlled by using the waste heat from the fuel cell as the heat source.

4. Sea trials

A long distance cruising test was performed from Feb. 26 to Feb. 28, 2005 by repeated two-way autonomous cruising between two points 25 km apart north-to-south in Suruga Bay. The autonomous cruise was continued non-stop for 56 hours at a depth of 800 m at an average speed of approx. 3 knots to record the world's longest continuous AUV cruising of 317 km.

During the cruise, the fuel cell smoothly followed fluctuating loads such as vehicle speed changes, etc. and operated stably. The hydrogen supply from the metal hydride was smooth, and good overall performance as a fuel cell system was confirmed.

5. Conclusion

The successful 317 km long-distance continuous non-stop cruise of the fuel cell AUV URASHIMA has proved that the fuel cell is useful as an underwater power source.

In concluding this paper, we express our deep gratitude to the members of the Japan Agency for Marine-Earth Science and Technology for their kind support and advice from the initial stage of development of URASHIMA and the fuel cell system for the underwater vehicle.


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