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Advanced Technologies for Cruising AUV *URASHIMA*

Taro Aoki, Satoshi Tsukioka, Hiroshi Yoshida, Tadahiro Hyakudome, Shojiro Ishibashi,
Takao Sawa, Akihisa Ishikawa, Junichiro Tahara, Ikuo Yamamoto and Makoto Ohkusu
Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Kanagawa, Japan

There are concerns about the impact that global warming will have on our environment, which will inevitably result in expanding deserts and rising water levels. Autonomous Underwater Vehicles (AUV) were considered and chosen as the most suitable tool for conducting surveys concerning these global environmental problems. JAMSTEC has started building a long-range cruising AUV. The plan for its development is in several steps. As the first step, the AUV *Urashima* was built in 1999, and sea trials have been held since 2000. The *Urashima* dived to a 3,518-m depth in 2001. At the end of February 2005, the *Urashima* was able to cruise autonomously and continuously for 317 km, beyond its target range of 300 km; this record is the longest one in the world. The PEFC (Polymer Electrolyte Fuel Cell) power system with metal hydrogen storage has been developed for expanding its cruising range. As the second step, the AUV *Urashima-2*, which will cruise more than 3,000 km, started development in 2007. The development plan of the next AUV was selected as one of the official, nationally important technologies in Japan. The deep-ocean areas we know of constitute only a small fraction of the entire deep ocean. The information that can be obtained by man-made satellites is limited to that pertaining to the surface or subsurface portions of the sea. Today, man does not have the means to canvass the entire deep ocean at one time. If a number of AUV like the *Urashima* autonomously cruise in various deep-ocean areas of the world, man will then, for the first time, be able to get that entire picture.

INTRODUCTION

JAMSTEC has developed several deep-sea exploration vehicles: manned submersibles *Shinkai 2000* and *Shinkai 6500*, deep ROV (Remotely Operated Vehicle) 3000-m-class *Dolphin 3K*, 7000-m-class *Urov 7K*, and 11000-m-class (full depth) *Kaiko*. These vehicles have had many brilliant achievements. However, the utility of cable-less unmanned vehicles has not yet been recognized, because they have not been equipped with real-time investigation devices such as TV cameras, or did not work well with a manipulator, and the operation times are limited because of battery life. So, manned vehicles and ROV have been developed with a higher priority than cable-less unmanned vehicles or autonomous underwater vehicles (AUV). Breaking through these engineering walls, we have continued to develop important elements of AUV engineering, high-speed acoustic telemetry systems, highly efficient power sources, and so on.

On the other hand, there have recently been many discussions on the expansion of deserts and warming of the Earth, which may be caused by the current trend towards destruction of the global environment. JAMSTEC has continued to conduct research to clarify the mechanisms involved in the circulation and perturbation of the oceans. AUV can collect large amounts of ocean data efficiently. Many AUV, such as the *Autosub* (Collar et al., 1995), *Hugin* (Kristensen et al., 1998), *Theseus* (Ferguson, 1998), *Odyssey* (Mellingham et al., 1993), *ABE* (Bradley et al., 2000) and *Remus* (Stokey et al,, 2005) are being developed in European countries and America. These AUV carry their power sources within their bodies, so operating times and cruising ranges are limited by the amount of energy they carry. In addition, highly accurate position sensing is needed for AUV to cruise over long ranges alone. Because of these 2 factors, the development of power sources (Scamans et al., 1994; Aoki et al., 1997) and navigation systems are very important key technologies for AUV development (Zerr, 2005).

The *Urashima* has been in development since 1997. The vehicle adopts a closed cycle fuel cell system as its power source to enable long-range cruising. The vehicle also has a highly precise inertial navigation system to enable precise cruising over long ranges. This paper introduces several key technologies and the results of sea trials of the *Urashima*. The sea trials have been held since 2000, and the tests have continued for several years. The equipment, hardware, software and autonomous functions have been improved gradually. The test goals of *Urashima*—3,500 m in depth, and 300 km in cruising range—have been reached and even surpassed. Recently *Urashima* has begun to undertake cruises for scientific applications.

CONSTRUCTION OF AUV *URASHIMA*

Fig. 1 shows the *Urashima*, and Table 1 lists the specifications. The vehicle consists of titanium frames, with some pressure vessels made of titanium alloy for protecting control systems and other electrical devices from the 3,500-m-depth's water pressure, and buoyancy materials used for additional buoyancy. We use syntactic foam as the main buoyancy material. The specific gravity is 0.5. The body is covered with FRP (fiberglass reinforced plastics) faring covers. The vehicle has a cylindrical shape for reducing hydrodynamic drag in order for it to cruise long distances using limited energy. The vehicle has the following actuators: a main thruster (D.C. brush-less motor, 1.5 kW) for cruising, vertical rudders for heading control, and horizontal rudders for depth control. The vehicle also has posture control systems such as a level adjuster and buoyancy control system. The buoyancy control system is like the bladder of a fish. This system consists of an oil tank contained in a pressure vessel (VBT: variable ballast

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