

## Development of an Underwater Glider with Independently Controllable Main Wings

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### ABSTRACT

The purpose of this research is to develop an 'underwater glider with independently controllable main wings' for the use of oceanographic survey and worldwide-scale monitoring of marine environment by using a number of swarm-intelligent underwater gliders. The experimental underwater glider 'ALEX' was designed for much of a high performance of motion. The CFD technique was applied to estimating hydrodynamic forces in different conditions of glider's attitude and environmental flow. Various kinds of experiments lead to the conclusion that the 'underwater glider with independently controllable main wings' had an admirable motion capability as compared with conventional 'underwater gliders with fixed main wings'.

### KEY WORDS:

Underwater glider; independently controllable main wings; buoyancy engine; movable mass system; gliding angle; ALEX.

### INTRODUCTION

It has become possible to conduct ocean exploration or underwater operation using a variety of underwater robots in recent years. They are roughly categorised into 'Human Occupied Vehicles (HOV)' and 'unmanned underwater robots' (Ura and Takagawa, 1994). Manned research submersible 'SHINKAI 6500' of Japan Agency for Marine-Earth Science and Technology (JAMSTEC) is very famous as the deepest manned underwater vehicle in the world. Deep-sea cruising Autonomous Underwater Vehicle (AUV) 'URASHIMA' and 10,000 m class deep-sea Remotely Operated Vehicle (ROV) 'KAIKO' of JAMSTEC are masterworks of Japanese underwater robotics. However, the vehicle of 'KAIKO' was regrettably lost in 2003, and 7,000m class ROV 'KAIKO 7000 II' is now in operation. Several different types of AUV and ROV also have been developed for small-scale investigation or personal use.

Underwater glider is one of manageable underwater vehicles for its simple mechanics; accordingly manufacture and operation cost will be relatively low. Underwater glider has no propulsive machinery, so that this silent and safe underwater vehicle can be maintained with ease and is easy on ocean environment and many forms of life in the sea.

The gliding submersibles of 'PTEROA' series were first proposed by Ura and Otsubo (1985) and the shuttle type AUV 'ALBAC' was developed by Kawaguchi, Ura, Oride and Sakamaki (1995) at the University of Tokyo, Japan. And then, four types of unmanned underwater glider named 'Seaglider', 'Slocum Glider', 'Spray Glider', 'Slocum Thermal Glider' have been developed one after another for environmental measurement in the United States of America (Rudnick, Eriksen, Fratantoni and Perry, 2004), and some of them can certainly be purchased here in Japan. Yamaguchi, Sakai and Yamashita (2004) and Yamaguchi, Naito, Kugimiya, Akahoshi and Fujimoto (2007) of Kyushu University, Japan have also developed a glider-type underwater vehicle. And recently, Seo, Jo and Choi of Seoul National University, the Republic of Korea (2008) and Lien, Chiu, Guo, Lee of National Taiwan University, Taiwan and Kim, Bae and Lee of Pusan National University, the Republic of Korea (2008), and Guo and Kato of Osaka University, Japan (2008) have started in developing underwater gliders.

The authors are planning to develop an 'underwater glider with independently controllable main wings' for the application to oceanographic survey, wide-range monitoring of marine environment, fisheries, ocean exploration, marine sports and leisure activities. The end of this research is to offer manned or unmanned underwater gliders with a high performance of motion. This paper deals with development of an experimental underwater glider named 'ALEX' as a test-bed of the 'underwater glider with independently controllable main wings'.

The ALEX was designed for much of a high performance of motion. Main wings, upper rudder, diving rudder, movable balance weight, and combination valve for vent / blow can be independently controlled by on-board microcomputer system or by radio-control system. Linear acceleration, angular velocity, depth, position by GPS and direction by magnetic compass can be measured, and these sensor data in storage will be transmitted to PC station by wireless modem system at the surface. Motion performance of the glider was observed in a towing tank and a swimming pool. The computational fluid dynamics (CFD) technique was also introduced for estimating hydrodynamic forces such as lift and drag in various conditions of glider's attitude and environmental flow. The CFD result was compared with the 3-component-force test, and it was verified that the experimental underwater glider has hydrodynamic characteristics as expected at the stage of design.