Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference
Vancouver, BC, Canada, July 6-11, 2008

ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

Maneuverability Experiments of AUV

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ABSTRACT

There are concerns about the impact that global warming will have on our environment, and which will inevitably result in expanding deserts and rising water levels. AUVs (Autonomous Underwater Vehicle) were considered and chosen, as the most suitable tool for conducting surveys concerning these global environmental problems. JAMSTEC has started to build a long range cruising AUV. The plan for its development is in several steps. As the first step an AUV, named “URASHIMA”, was built in 1999, and sea trials have been held since 2000. URASHIMA dived to 3,518m depth in 2001. At the end of February 2005, the vehicle was able to cruise autonomously and continuously for 317km, beyond its target range of 300 km.

Recently the AUV “URASHIMA” has begun to undertake cruises for scientific applications. These applications require precise maneuvering of the vehicle for detailed investigations. For high performance maneuvering of the vehicle, it is necessary to design a control system based on a mathematical model for the vehicle. To construct an accurate mathematical model, experiments on the maneuverability of the vehicle were done during sea trials. The experimental results were used in system identification for the mathematical model.

This paper describes vehicle dynamics, presents experimental results of maneuverability obtained with the AUV “URASHIMA” during the sea trials, and presents calculated results after the system identified a mathematical model.

KEY WORDS: Autonomous Underwater Vehicle, Sea Trial, Vehicle dynamics, System Identification

INTRODUCTION

Autonomous underwater vehicles can move freely, because they do not need cable for power supply and communications. So, the vehicles are able to maneuver precisely by a high-performance controller (Silvestre & Pascoal, 2006). AUVs can be used for scientific applications requiring detailed investigations. An accurate mathematical model based on vehicle dynamics is needed for design of the high-performance controller. It is necessary for the mathematical model to express the actual motions of the vehicle precisely.

The AUV “URASHIMA” is shown in figure 1. The vehicle is 10.6m long, 1.3m wide and 1.5m high. It is equipped with one main thruster for cruising, and horizontal rudders (right and left) and vertical rudders (upper part and lower part) for vehicle steering and diving in the vertical and horizontal planes respectively. The maximum speed of the vehicle is 2.0m/s. The vehicle consists of titanium frames and some pressure vessels made of titanium alloy for protection of the control systems and other electrical devices from water pressure at 3,500m depth. Buoyancy material is used for additional buoyancy. The buoyancy material consists of syntactic foam and epoxy resin. The specific gravity is 0.5. The body is covered with FRP (Fiberglass Reinforced Plastic) faring covers. The vehicle has a cylindrical shape for reducing hydrodynamic drag in order to cruise long distances using limited energy. The vehicle also has posture control systems like 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 Tank) and an oil bladder. The system is able to change buoyancy from 0kg to 60kg according to water depth.

Fig.1 Deep & Long range Cruising AUV “URASHIMA”

MATHEMATICAL MODEL

The dynamic model of the AUV “URASHIMA” in 6 degrees of freedom is described by two coordinate frames as indicated in figure 2 (Fossen, 1994). The notation for the motion of the vehicle are described by the following vectors:

$$\begin{aligned} \eta &= [x,\ y,\ z,\ \phi,\ \theta,\ \psi]^T \\ \nu &= [u,\ v,\ w,\ p,\ q,\ r]^T \\ \tau &= [F_x,\ F_y,\ F_z,\ M_x,\ M_y,\ M_z]^T \end{aligned} \tag{1}$$

Here η denotes the position and orientation vector with coordinates