Simulation of a Two-Part Underwater Maneuverable Towed System

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ABSTRACT

A hydrodynamic model of a two-part underwater maneuverable towed system is proposed in which a depressor is equipped with active horizontal and vertical control surfaces, and a towed vehicle is attached to the lower end of a primary cable. In such a system the towed vehicle can be maneuvered in both vertical and horizontal planes when it is towed at a certain velocity and the coupling effect of excitations at the upper end of the primary cable and disturbances of control manipulations to the towed vehicle can be reduced. In the model the hydrodynamic behavior of an underwater vehicle is described by the six-degree-of-freedom equations of motion for submarine simulations. The added masses of an underwater vehicle are obtained from the three-dimensional potential theory. The control surface forces of the vehicle are determined by the wing theory. The results indicate that with relative simple control measures a two-part underwater maneuverable towed system enables the towed vehicle to travel in a wide range with a stable attitude. The method in this model gives an effective numerical approach for determining hydrodynamic characteristics of underwater vehicles especially when little or no experimental data are available or when costs prohibit do experiments for determining these data.

KEY WORDS: finite difference, control surface, maneuverable, towed system, two-part tow, underwater, underwater vehicle

1. INTRODUCTION

As an effective tool for many marine applications the underwater towed system plays an important role in naval defense, ocean exploitation and ocean research. In recent years, several hydrodynamic models of underwater towed systems have been proposed by various authors (Chapman 1984, Koterayama et al. 1988, and Kato 1991). But the research on the hydrodynamic behavior of an underwater towed system at present is mainly concentrated on a single cable or passive towed method. Due to the demand of ocean research, there is a need for the system to have the capability of moving in a wide range with a stable attitude under ocean environments. One of the easy methods to achieve this objective is to use a two-part underwater towed system (Ranmuthugala and Gottschalk 1993, Wu and Chwang 1997).

In this paper, a new type of a two-part underwater maneuverable towed system is proposed in which a depressor is equipped with active horizontal and vertical control surfaces, and a towed vehicle is attached to the lower end of a primary cable. In such a system, the towed vehicle can be maneuvered in both vertical and horizontal planes when it is towed at a certain velocity and the coupling effect of the excitation at the upper end of the primary cable and the disturbance of control manipulations to the towed vehicle can be reduced. In the model the hydrodynamic behavior of an underwater vehicle (a towed vehicle or a depressor) is described by the six-degree-of-freedom equations of motion for submarine simulations. The added masses of an underwater vehicle are obtained from the three-dimensional potential theory, and the control surface forces of the vehicle are determined by the wing theory.

The results indicate that with relative simple control measures a two-part underwater maneuverable towed system enables the towed vehicle to travel in a wide range with a stable attitude. The method in this model gives an effective numerical approach for determining hydrodynamic characteristics of underwater vehicles especially when little or no experimental data are available or when costs prohibit do experiments for determining these data.

2. MATHEMATICAL FORMULATION

The system described in this paper consists of primary, secondary and depressor cables, the towed vehicle and the depressor are attached to the end of the secondary and depressor cables respectively (Fig. 1). The primary cable and the depressor cable are negatively buoyant, while the towed vehicle and the secondary cable are neutrally buoyant.

Three different coordinate systems are used in the derivation of equations, i.e. the fixed inertial coordinate system (X,Y,Z) and local coordinate systems for the cables (t,n,b) and for the underwater vehicles (x,y,z) as shown in Fig. 1 and Fig. 2. The governing equations for cables are given first, then three cables are modeled separately and interfaced dynamically at the conjunction. The speed of the tow ship at water surface and dynamic equations for the towed