ABSTRACT

A mathematical model in cylindrical coordinate system for researching on the configuration of underwater towed cable during ship turning maneuvers is presented in this paper. The configuration of towed cable is obtained by numerical integration of motion equations for towed cable, using MATLAB program and fourth-order Runge-Kutta method. Different situations are discussed by changing the major influencing parameters. A lumped parameter model for towed array system is presented. The results of our MATLAB program are successful compared to OrcaFlex data, to the results of full-scale experiments and to those calculated from finite difference schemes.

KEY WORDS: Towed cables; Hydrodynamics; Lumped mass.

INTRODUCTION

Underwater towed cable system has been widely used in marine seismic exploration and military tasks, which consist of towed cable, vehicle and sonar array and is towed by ship or submarine. With the influence of ambient conditions, such as wave or current, and the movement of relative structures, towed cable has a significant dynamic response. Therefore, the study on mechanical phenomena, towing performance, motion and its associated problems of towed cable have a essential meanings for the field of marine engineering. While, the functions of towed cable are connecting ship and vehicle, transmitting remote signal, providing power to the underwater equipments, which make the study on towed cable much more important in the underwater towed cable system research.

Choo and Casarella (1972), Chapman (1984) did research on steady-state analyses of the configuration of underwater towed cable during ship turning maneuvers, which contributed to the research of underwater towed cable system significantly. Chapman’s study was more comprehensive. He defined a critical ship turning radius, above which the cable vehicle system maintains an equilibrium shape that is nearly equal to the planar configuration associated with straight towing ship trajectory. In this case, the turning radius and velocity of the vehicle are nearly equal to that of the ship. Below the critical turning radius, the vehicle depth is large increase and the vehicle turning radius is large decrease.

Extensive model scale tests have been carried out by Nakamura and Koterayama (1991). The tests were focused on frequency domain quasi-linearized numerical solutions for the slow drift case. A study of the 360° turning behavior of towed arrays as a function of turn radius, cable length, and tow speed was proposed by Kishore and Ganapathy (1996). They found that during the turning maneuver, a towed array formed a closed loop if the ship turning radius was less than a specific value that depended on array length and ship speed, which is similar to Chapman’s critical radius.

Grosenbaugh (2007) extended the work of Chapman by performing a detailed analysis of the transient behavior that occurs in going from a straight-tow, planar configuration to a three-dimensional steady-state turning configuration, and developed an alternate definition for the transition point between large radius and small radius turning behavior. He proposed that towed vehicle systems rarely reach steady state during typical ship turning maneuvers, especially for small radius turning. Finally, Mark performed the behavior of towed cable systems during ship turning maneuvers in currents.


In this paper, a three dimensional steady-state model for towed cable during ship turning maneuvers is presented. Different situations are discussed by changing the major influencing parameters. The dynamic analysis during ship turning maneuvers can be made on the basis of the steady-state analysis. Lumped parameter model for towed array system is presented. The results are compared to OrcaFlex (OrcaFlex is the world’s leading package for the dynamic analysis of offshore marine systems) data, to the results of full-scale experiments and to those calculated from finite difference schemes. The presented results can be referred to the further research on the forecasting of configuration of underwater towed cable during ship turning maneuvers.

STEADY-STATE MODEL

A three dimensional mathematical model in cylindrical coordinate system is more simple and convenient than any other model in rectangular coordinate system when ship turning maneuvers. Fig.1 shows a tow ship turning maneuvers in cylindrical coordinate OPRZ.