

Lateral Motion Control of an Underwater Thruster System Suspended to a Ship by a Slender Marine Structure

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ABSTRACT

This paper describes the control of a system consisting of a thrust unit connected to a surface vessel by means of a marine cable, riser or other similar slender marine structure. Motion only in the lateral direction has been considered. Position and velocity control of the thruster system results in vibration suppression in the system. The stability of the system is analyzed using Lyapunov theory, and the system is shown to be globally asymptotically stable and thereby robust to environmental disturbance.

INTRODUCTION

Underwater cables, risers and other similar slender marine structures connected to surface vessels undergo deformations due to fluid forces and vessel motions, hence vibrations and swinging motions (oscillations) are induced in the system. The main aim of the present work is to demonstrate that by controlling the bottom-end point of the structure, vibrations and oscillations in the system are suppressed.

The system considered in this paper consists of a cable/riser connected to a surface vessel at the top end and to a thrust unit at the bottom end. A control system is proposed for position and velocity control of the thrust unit through which the cable/riser bottom-end point can be kept at a desired position. The thruster control system receives position reference signals from underwater transponder systems.

In this paper motion in the lateral direction only has been considered. The mathematical model describing the lateral motion of the cable/riser system and vessel motion is based on the work of Triantafyllou (1990), Blevins (1990), Chakrabarti and Frampton (1982) and Weaver, Timoshenko and Young (1990). These equations are combined with the equations of motion of an underwater thrust unit, taking into account the reaction forces between the two systems. The closed loop system is shown to be globally asymptotically stable using Lyapunov theory.

Future work will include motion in three directions. The 3-D dynamic behavior of a pipe system is given by Chung, Huttelmaier and Cheng (1994) and references therein.

This paper is outlined as follows: The mathematical model of the total system is presented first, then the controller design and stability analysis is presented; simulation results and conclusions follow.

MATHEMATICAL MODELING

Fig. 1 illustrates the system to be investigated. It consists of a surface vessel and a cable/riser system connecting an underwater thrust unit. In the present approach motion in the lateral direction only has been considered; however, a similar approach could be

Received March 18, 1996; revised manuscript received by the editors July 22, 1996. The original version (prior to the final revised manuscript) was submitted directly to the Journal.

KEY WORDS: Vibration damping, thruster control, cable, riser.

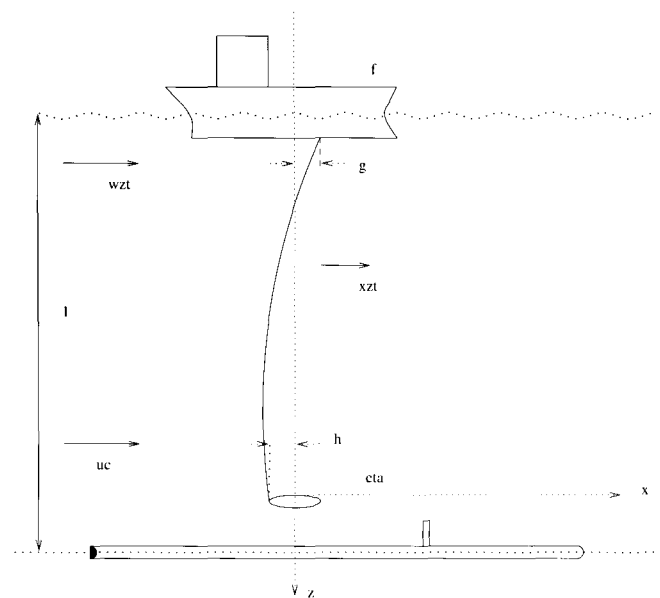


Fig. 1 Slender marine structure connecting thrust unit to ship

taken for damping of the modes in the longitudinal direction. The equation of motion of the cable/riser system is similar to that of a slender beam under the influence of external forces. It is assumed that the cable/riser is connected to the vessel and to the thruster system by means of ball-joints, and that this results in small derivatives of the angles of deflection and zero bending moment. Further, it is assumed that the mass of the vessel is much greater than the mass of the cable/riser system, which implies that the vessel is not affected by the cable/riser motion.

Equation of Motion of Thrust Unit

The equation of motion of the thrust unit in the lateral direction at depth ($z = l$) is given by:

$$m_t \ddot{\eta}_x(t) + d_1 \dot{\eta}_x(t) + f_{d_2}(\dot{\eta}_x) = u_x + f_c(z, t) \quad (1)$$

where:

$$f_{d_2}(\dot{\eta}_x) = d_2(\dot{\eta}_x - U_{c_i}) \left| \dot{\eta}_x - U_{c_i} \right| \quad (2)$$