The Interaction Dynamics of a Semi-Submersible Towing a Large Towfish

Mae L. Seto
International Submarine Engineering Research Ltd.
Port Coquitlam, Canada

George D. Watt
Defence Research Establishment Atlantic
Dartmouth, Canada

ABSTRACT
The interactions between a semi-submersible drone and its large towfish, where the tension in the tow cable joining them is about 20% of the weight of the drone, are investigated. Since standard cable dynamics modelling computer programs do not model tow-vehicle/tow-body interactions, an iterative approach to calculating these interactions is developed. Drone motions are modelled with a non-linear, six degree-of-freedom, underwater vehicle simulation incorporating pre-defined, three component, time dependent tow cable tensions applied at the tow point. Cable dynamics are modelled with the nonlinear, finite element, cable/towfish dynamic simulator DYNTOCABS, which accepts pre-defined tow-point accelerations as time varying boundary conditions. The interactions are calculated by iterating between these two programs. The method is applied to simple turning maneuvers important to minehunting operations.

KEY WORDS: Cable Dynamics, Towfish, Semi-Submersible, Coupled Motions, Interactions

NOMENCLATURE

\( D \) \hspace{1cm} \text{diameter of turn.}
\( i \) \hspace{1cm} \text{iteration index.}
\( \ell \) \hspace{1cm} \text{drone length.}
\( m, m' \) \hspace{1cm} \text{drone mass; } m' = m/(\frac{1}{2} \rho \ell^2).
\( N_r \) \hspace{1cm} \text{yaw moment due to yaw rate.}
\( N_y \) \hspace{1cm} \text{yaw moment due to lateral velocity.}
\( N_{\Delta r} \) \hspace{1cm} \text{yaw moment due to rudder deflection.}
\( \tau, \tau' \) \hspace{1cm} \text{yaw rate; } \tau' = \tau \ell/U.
\( \text{rpm} \) \hspace{1cm} \text{revolutions per minute.}
\( t_s \) \hspace{1cm} \text{time, in a U-turn, at which the rudder is re-zeroed.}
\( T_s \) \hspace{1cm} \text{lateral body reference frame tension.}
\( U \) \hspace{1cm} \text{drone speed.}
\( x_G, x_G' \) \hspace{1cm} \text{drone longitudinal center of gravity; } x_G' = x_G/\ell.
\( x_t, x_t' \) \hspace{1cm} \text{longitudinal location of cable towpoint on drone.}
\( X, Y, Z \) \hspace{1cm} \text{inertial reference frame displacement coordinates.}
\( Y_r \) \hspace{1cm} \text{lateral force due to yaw rate.}
\( Y_v \) \hspace{1cm} \text{lateral force due to lateral velocity.}
\( Y_{\Delta r} \) \hspace{1cm} \text{lateral force due to rudder deflection.}
\( b_{\Delta r} \) \hspace{1cm} \text{\( \Delta \)th iteration rudder deflection.}
\( \psi \) \hspace{1cm} \text{drone heading.}
\( \psi_f \) \hspace{1cm} \text{final drone heading after a manoeuvre.}
\( \theta \) \hspace{1cm} \text{drone pitch.}
\( \phi \) \hspace{1cm} \text{drone roll.}

Primed quantities are dimensionless. Forces are nondimensionalized with \( \rho U^2 \ell^2/2 \), and moments with \( \rho U^2 \ell^2/2 \), where \( \rho \) is the density of sea water.

1. INTRODUCTION
DREA and ISER are evaluating issues facing the development of a Canadian Remote Minehunting System (CRMS) for the Canadian Navy. The CRMS is an autonomous, snorkelling drone towing a deployable, active towfish which houses a side scan sonar for route surveying and mine location on the sea floor. With route surveying, sonar images are obtained from an area where mine hunting is anticipated, in order to provide a reference against which future mine hunting images can be compared. A high degree of towfish stability is required to get good images, and the absolute location of the towfish must be known for differencing images with those from subsequent mine hunting surveys. Drone motions, whether from waves or necessary maneuvers, cause towfish (sonar) disturbances. These disturbances degrade the sonar image and make mine detection and classification difficult.

The requirement for high towfish stability leads to a need for a stable towing platform. The semi-submersible DOLPHIN (Deep Ocean Logging Platform for Hydrographic Instrumentation and Navigation) Mk1 vehicle developed by ISE Research Ltd. is a proven stable remote platform for hydrographic instrumentation. It can operate in up to sea state 5 and has successfully demonstrated its towing capability (Preston and Shupe, 1993). DOLPHIN Mk2 (Figure 1) is currently a candidate drone for the CRMS. It is 8.5 m long with a 1 m hull diameter, has a