International Journal of Offshore and Polar Engineering (ISSN 1053-5381)
Copyright © by The International Society of Offshore and Polar Engineers
Vol. 19, No. 3, September 2009, pp. 214–223

Ship and Winch Regulation for Remotely Operated Vehicle's Waypoint Navigation

Jonathan D. M. Zand, Bradley J. Buckham* and Daniela Constantinescu
Department of Mechanical Engineering, University of Victoria
Victoria, British Columbia, Canada

Sairam Prabhakar
Department of Mechanical Engineering, McGill University, Montréal, Québec, Canada

When working at significant depths, small inspection class ROV can suffer from restricted maneuverability due to accumulated drag over the tether. In this work, the surface vessel and winch motions are coordinated in a position regulation system that assists the maneuvering of the small ROV. The methodology is developed within a simulation that incorporates a simplified ship dynamic model, a complete tether dynamics model, and an ROV with idealized thrusters. A lumped mass representation of the tether is used that incorporates low-tension effects along with a fundamentally correct formulation of the tether payout/retrieval dynamics that is valid for both taut and low-tension circumstances. A 2-D transit maneuver is considered in this study. The position regulator uses a depressor mass to provide some control over the deployed tether profile, and the tether disturbance is reduced by making the depressor follow the ROV according to a schedule established by a series of a priori equilibrium studies. The optimal relative depressor locations are defined in terms of the ROV surge speed, subject to constraints stemming from starting and stopping considerations. A revised transit procedure is given that is shown to reduce the time of a 600-m transit at the 200-m depth by 44% over the current accepted practice.

INTRODUCTION

Submerged remotely operated vehicles (ROV) are the safest means to deliver human sentience to the deep sea. Generally, ROV have an open frame design that allows the installation of a variety of sensors, manipulators and scientific payloads. However, to acquire visual feedback for the pilot and deliver pilot intent to the vehicle, a tether with electrical and/or optical conductors must connect the vehicle to the pilot's surface station. Unfortunately, combinations of even moderate ocean current, ROV depth and deployed tether length can cause the tether to billow out behind the vehicle; this is referred to here as blow back. Blow back of the tether produces disturbances on the ROV that inhibit desired ROV motions and prevent the vehicle from holding depth. The tether disturbance problem is exacerbated for small inspection class ROV which typically employ a neutrally buoyant tether.

In this work, a tether position regulation strategy for transit maneuvers of small ROV systems with neutrally buoyant tethers is developed. The strategy includes active ship positioning and winch control that significantly reduce the tether disturbance on the ROV during the transit, thus liberating the ROV to hold depth and maximize forward speed. The use of active ship and winch control has been previously addressed in the context of towed vehicle operations through simulation studies. Williams (2006) employed a model-based approach to determine the ship motion and winch activity necessary to produce smooth towfish maneuvers. Chauvier (1998) minimized towfish repositioning time with a ship motion and winch activity optimization scheme, but noted that abrupt towfish trajectory changes can't be achieved through ship and winch actions. Chauvier's conclusion was consistent with the idea of the "Bowden-cable" (Chapman, 1982) or the "water-pulley" (Delmer et al., 1988) phenomenon: Drag forces act as a sheath that retards changes in the profile of a submerged cable. As such, sudden lateral or surge motions of the surface vessel do not translate immediately to the towed vehicle. Rather, surface vessel motion manifests in movement of the towfish along the tangent direction of the cable at the towfish termination.

Very few simulation studies of tether regulation in the ROV paradigm have been conducted. Triantafyllou and Grosenbaugh (1991) illustrated the lateral positioning of a massive intermediate cage for a large ROV system using a Smith controller to compensate deadtime in the feedback loop. Prabhakar (2005) examined station-keeping of a large ROV employing a liveboating tether configuration in which the only gravitational restoring forces were due to tether self-weight. Prabhakar used discrete acoustic feedback of a control node on the cable to drive ship and winch motions to station-keep the control node and reduce tether disturbances. This work investigates the potential for a simple PID strategy to regulate the tether profile, through coordinated ship and winch activity, in order to assist the ROV pilot during high-speed ROV transit maneuvers. While similar to the station-keeping task, the transit maneuver has the added complications of the depressor lagging and overshooting the ROV during the starting and stopping phases, respectively.

The tether position regulator is developed within a dynamics simulation package that includes a simplified surface vessel dynamic model, a conventional ROV dynamics model, and a low-tension, fixed-length lumped mass tether model connecting the 2 vehicles that was derived and implemented in Buckham et al. (2004a and b). However, to accurately capture the winch activity, a variable-cable length capacity must complement the existing model. In this work, 2 shortcomings of existing variable-length tether models are addressed:

*ISOPE Member.

Received November 11, 2008; revised manuscript received by the editors June 3, 2009. The original version (prior to the final revised manuscript) was presented at the 18th International Offshore and Polar Engineering Conference (ISOPE-2008), Vancouver, July 6–11, 2008.

KEY WORDS: Remotely Operated Vehicles (ROV), cable dynamics, variable length cables, dynamics modeling; tether management.