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Ship and Winch Regulation for Remotely Operated Vehicle Waypoint Navigation

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ABSTRACT

When working at significant depths, small inspection class ROVs 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 such an inspection class 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 tether is used that incorporates a formulation of bending and torsional effects along with payout and retrieval effects induced by the winch activity. A two-dimensional 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. The optimal depressor locations are defined in terms of the ROV surge speed subject to constraints stemming from starting and stopping considerations. The method is shown to reduce the time of a 600 m transit at 200 m depth by 41%.

KEY WORDS: remotely operated vehicles; cable dynamics; variable length cables; dynamics modeling; tether management.

INTRODUCTION

Submerged remotely operated vehicles (ROVs) are the safest means to deliver human sentience to the deep sea. Generally, ROVs have an open frame design that allows a variety of sensors, manipulators and scientific payloads to be installed. However, to acquire visual feedback for the pilot and deliver pilot intent to the vehicle, a tether with electrical and optical conductors must connect the vehicle to the pilot's surface station. Unfortunately, even a moderate combination of ocean current, ROV depth and deployed tether length can cause the tether to billow out behind the vehicle, referred to here as blow back. Blow back of the tether can produce a tether disturbance on the ROV that inhibits forward motion and prevents the vehicle from holding depth.

Gravity is the prevalent means to combat drag accumulation and regulate the tether profile: negatively buoyant armoured cables, and dense depressor masses can be used to create downforce and prevent blow back. However, the tether disturbance problem is exacerbated for small inspection class ROVs 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 reduces the tether disturbance on the ROV during the transit, thereby 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. Williams (2006) employed a model based approach to determine ship motion and winch activity necessary to produce smooth towfish manoeuvres. Chauvier (1998) minimized towfish repositioning time with a ship motion and winch activity optimization scheme, but also 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 "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 cable tangent.

In the ROV paradigm, 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. Station-keeping of a large ROV employing a liveboating tether configuration was examined by Prabhakar (2005) 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 stationkeep the control node such that the tether disturbance was drastically reduced. The current work adds to these previous contributions by addressing the tether positioning during high speed ROV transit maneuvers. While similar to the stationkeeping 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 finite element tether model that connects the two vehicles. The following section presents an overview of the dynamics modeling with an emphasis on the variable tether length terms that model the winch effects. The physical properties of the small ROV system are then provided, followed by an overview of the selected transit maneuver and initial simulations that demonstrate current transit procedures. Finally, position regulation of the simulated tether is accomplished via feedback of the ROV and depressor states. To evaluate the feasibility of the regulation scheme, simple PID controllers are used to drive the ship and winch activity.