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Validation of a numerical model of a ship and cable-towed body system

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Abstract: Underwater towing of cables is critical for a wide variety of maritime operations, including resource exploration, search and rescue, underwater archaeology and military applications. The Defence Science and Technology Group (DSTG) are developing a capability for examining the operability of underwater cable-towed body systems. The main objective is to develop a high-fidelity simulation capability for predicting the real time configuration of underwater towed systems. This study presents an overview of recent numerical simulation validation activities using data from full-scale sea-trials. The simulations predict the ship and towed body motion, the cable's shape, tension in the cable and ship towing loads. Experimental measurements of cable shape and tension from the literature were compared with simulation results for a towed body sea-trial, demonstrating reasonable agreement across different tow speeds. These findings confirm the model's fitness-for-purpose and will improve the reliability of the operational decision support systems.

Keywords: *Towed cable array, simulation, experimental validation, sea-trials, hydrodynamics*

1. INTRODUCTION

Underwater cables and towed bodies play a critical role in a wide range of maritime operations, especially in defence applications such as towed-array sonar and variable depth sonar. These systems are essential for underwater surveillance, anti-submarine warfare and environmental monitoring. Modern naval operations are increasingly required to operate in challenging ocean conditions - including high sea states, elevated speeds and during rapid or complex manoeuvres - whilst towing long, flexible cable systems with high-precision sensing equipment. Understanding the dynamic behaviour of these systems is therefore vital for mission success and operational safety. This variability in depth, stability and positioning of the towed body ultimately impacts the effectiveness of the deployed sensors. In naval applications, deviations from the intended array geometry can degrade sonar performance, while excessive tension or entanglement risks damaging expensive and sensitive equipment. These operational challenges have long motivated the development of numerical simulation tools to model the physics of cable dynamics in marine environments. Several approaches have been proposed and applied across different domains, including offshore engineering, oceanography and defence. Notably, lumped-mass methods and finite-element models have been used to capture the elastic and inertial properties of cables subjected to hydrodynamic loading. Early work by Delmer *et al.*(1988) demonstrated a lumped-element simulation framework for modelling acoustic towed arrays, validated through both laboratory and field tests.

In response to these numerical simulation needs, the Defence Science and Technology Group (DSTG) has developed a physics-based simulation capability using Fredyn software (Quadvlieg *et al*. 2024). This high-fidelity tool is capable of modelling the full dynamic coupling between ship motion, underwater cable behaviour and the hydrodynamic response of towed bodies. In the long term, this capability contributes to DSTG's broader mission of delivering technological edge and operational advantage to the Australian Defence Force through advanced scientific research and engineering. The findings of this study can be used to support the continued development of simulation-informed operational guidance tools. Fredyn's validated accuracy can enhance pre-mission planning by identifying potential risks and informing operator decisions on tow speed, heading and payload deployment.

The objective of this study is to validate the Fredyn simulation tool using empirical data from full-scale sea-trials. Particular attention is given to the agreement between simulated and measured values of cable shape, cable vertical and lateral angles at ship and towed body, tension in cable and towed body position.

2. METHODOLOGY AND RESULTS

The report of an ONR sea-trial (Rispin and Diggs, 1981) involves towing a depressor body at high speeds with a faired cable. The arrangement and Fredyn simulation are shown in Figure 1, where a ship on constant heading and speed tows a cable attached a depressor body and with a rope drogue attached to the depressor. Some of the critical parameters which affect the depressor manoeuvring and body motion, depth and tension in the cable for the depressor are not specified. Therefore these parameters were estimated or varied to tune the simulations. The Fredyn simulation approach retains the full two-way hydrodynamic and mechanical interaction between the towing vessel and the cable-towed body system. Fredyn solves ordinary differential equations governing six-degrees-of-freedom motion for vessel and towed bodies while integrating the cable as a discretized elastic line. This modelling framework enables Fredyn to predict key performance variables such as the shape and orientation of the cable, tension along its length, the position and attitude of towed bodies and the forces exerted on the towing vessel. Such predictions are essential for both design evaluation and real-time operational decision-making

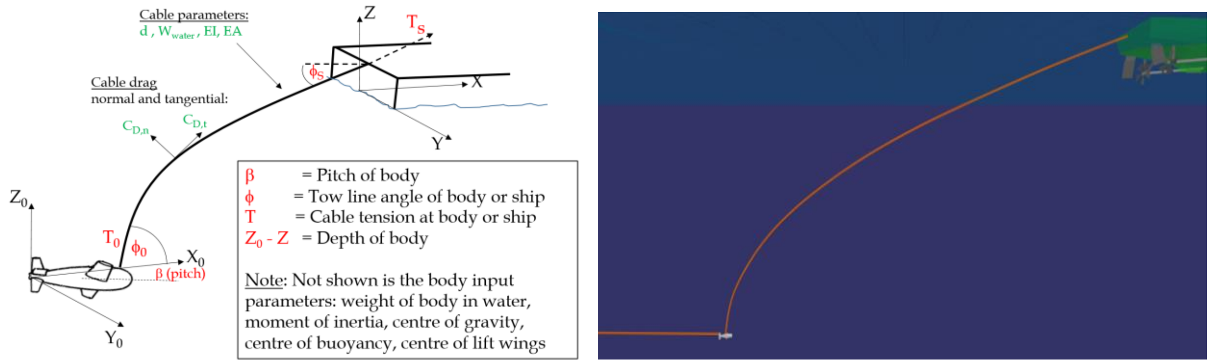

Figure 1 Fredyn simulation of ship, cables and depressor body (top).

Plots of the Fredyn simulated cable shape (depth of depressor body, towline angle) and tension at different tow speeds are shown in Figure 2 (bottom), indicating the Fredyn model can predict the absolute and relative trend changes of different variables over a wide range of tow speeds.

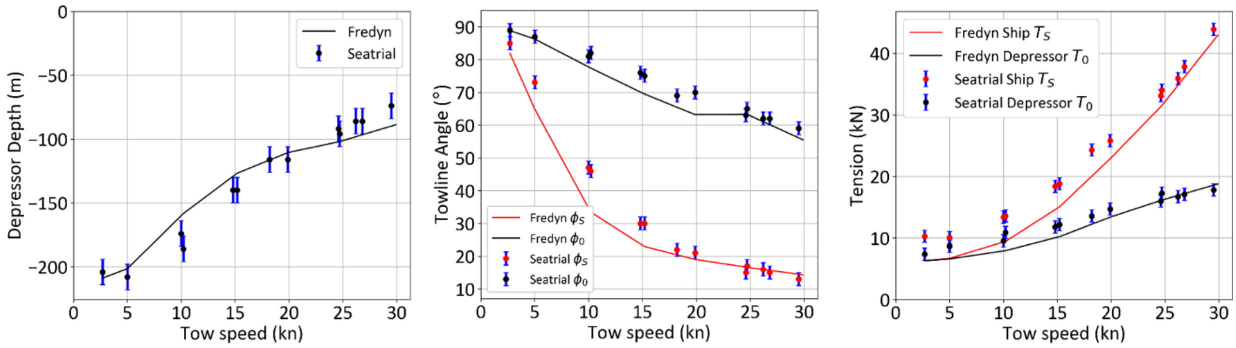

Figure 2 Plots of Fredyn versus sea-trial data over different tow speeds: plots of depressor depth, tension in cable at ship/depressor, tow angle and depressor pitch angle.

3. CONCLUSIONS

The model and simulation of ship and towed array systems has been validated with sea-trial data of a towed body. The results show the model is capable of accurately predicting towed cable and body depth profiles, angle of cable and tension in the cable. The scalability of the physics-based model provides assurance that the use of this experimental data is suitable for validation of the general ship and cable systems. In the future, it is suggested to further validate the model with additional sea-trial data of the towed array without a body.

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