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Editorial

Models and Simulations of Ship Manoeuvring

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Models and simulations of ship manoeuvring are fundamental tools for predicting and controlling vessel motion under real operational conditions [1–3]. Bridging hydrodynamic theory and practice, they support critical applications ranging from ship design and performance assessment to navigation safety, pilot training, and autonomous operations [4,5]. Recent advances in modelling techniques, numerical methods, and system identification have enabled more accurate representations of nonlinear hydrodynamics, propulsion–steering interactions, and environmental effects, particularly in shallow and restricted waters [2,6,7]. At the same time, growing demands for safety, energy efficiency, and decarbonisation place increased emphasis on model fidelity, robustness, and computational efficiency, especially for real-time and control-oriented applications [5,8]. As manoeuvring models evolve from off-line analysis tools to components of real-time decision-support systems and digital twins, their validation, transparency, and applicability become increasingly important [1,9].

This Special Issue presents recent advances and emerging trends in ship manoeuvring modelling and simulation, addressing both methodological developments and practical applications. The papers published in this Special Issue illustrate the diversity and maturity of contemporary ship manoeuvring research, covering advances in modelling, simulation, validation, and application. Improved estimation of manoeuvring derivatives and hydrodynamic interactions for modern hull forms is addressed through novel modelling and numerical approaches (Chame et al.; Lee and Kim) (Contributions 1 and 2). The role of controllability, model formulation, and experimental verification is highlighted in studies combining theory with dedicated testing (Lee and Kim) (Contribution 3). Shallow-water effects, increasingly relevant for ports and coastal operations, are examined using both numerical simulations and data-driven techniques, demonstrating complementary strengths and limitations (Moreira et al.; Li et al.) (Contributions 4 and 5). Finally, a broader perspective is provided on the evolution of manoeuvring research towards integrated frameworks incorporating digital twins, artificial intelligence, and Maritime Autonomous Surface Ship (MASS) (Tadros et al.) (Contribution 6). Together, these contributions define a coherent framework that reflects current challenges and points to emerging directions in ship manoeuvring models and simulations.

Chame et al., Lee and Kim, and Lee and Kim (Contributions 1, 2, and 3) address core methodological challenges in ship manoeuvring modelling, with particular emphasis on the accurate formulation, identification, and validation of dynamic models. In Chame et al. (Contribution 1), a novel approach is proposed for predicting linear velocity derivatives in modern ship hulls, combining theoretical consistency with validation through low-speed manoeuvring simulations, thereby strengthening the link between hydrodynamic parameter estimation and practical simulation frameworks. The work in Lee and Kim (Contribution 2) extends this perspective by numerically investigating hydrodynamic interaction effects across different ship types, highlighting how hull geometry and configuration

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influence manoeuvring forces and moments and underlining the limitations of generic coefficient sets. Complementing these modelling-oriented contributions, Lee and Kim (Contribution 3) focus on controllability and attitude dynamics, deriving the controllable region for a towed underwater system and validating the theoretical results through dedicated water-tank experiments. Together, these studies emphasise the importance of physically grounded model formulations, ship-type-dependent hydrodynamic characterisation, and rigorous validation, providing a solid methodological foundation for reliable manoeuvring simulations and control-oriented applications.

Moreira and Guedes Soares, Li et al., and Tadros et al. (Contributions 4, 5, and 6) capture the ongoing expansion of ship manoeuvring research beyond classical formulations towards data-driven methods, complex operating environments, and system-level integration. In Moreira and Guedes Soares, neural networks are employed to investigate vessel manoeuvring behaviour in shallow and restricted waters, demonstrating how machine learning approaches can effectively capture nonlinear hydrodynamic effects that are difficult to represent using conventional models. Complementing this perspective, Li et al. (Contribution 5) presents high-fidelity numerical simulations of ship manoeuvrability in shallow water, providing physically interpretable insights into depth-related hydrodynamic changes and offering valuable benchmarks for both empirical and data-driven models. A broader synthesis is offered in Tadros et al. (Contribution 6), who review the evolution of ship manoeuvring research over the last decade and a half, highlighting the convergence of hydrodynamics, control, digital twins, artificial intelligence, and MASS concepts. Together, these contributions emphasise the growing need to combine physics-based understanding with data-centric techniques and integrated simulation frameworks, reflecting the transition of manoeuvring models from stand-alone analysis tools to key components of modern, real-time decision-support and autonomous systems.

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