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Editorial

Verification and Validation Analysis on Marine Applications

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1. Introduction

Both users and developers of computational simulations are facing a crucial dilemma—how can confidence in modelling and simulation be properly evaluated? The predominant measures used to establish and quantify this confidence are verification and validation. Specifically, verification involves evaluating the precision of a computational model's solution through comparison with established solutions. Conversely, validation involves assessing the accuracy of a computational simulation by comparing it with experimental data. While verification does not concern itself with correspondence between simulation and reality, validation is centred around comparison with the physical world. In simpler terms, verification is mainly a mathematical matter, while validation pertains primarily to physics. This concept was first established by influential philosophers of science in the twentieth century, such as Popper [1] and Carnap [2].

The quantification of verification and validation with uncertainty estimation traces its origin to the seminar work of Richardson [3], who described an approach to obtaining a solution of higher order than what is available through a numerical solution.

In recent decades, verification and validation have assumed central importance in all work involving numerical modelling, as depicted in several contributions, e.g., those by Coleman and Stern [4], Roache [5], Oberkampf and Blottner [6], and Oberkampf and Trucano [7]. Through the reporting of confidence intervals in the form of a symmetrical band around the solution, uncertainty has become standardized in the engineering field, as well as marine hydrodynamics. In the last two decades, many studies have analyzed and investigated the procedure used to quantify uncertainties, with some primarily focused on marine hydrodynamic applications, such as those by Stern et al. [8,9] and Eça et al. [10,11].

The significance of applying verification and validation procedures to computational fluid dynamics simulations is also recognized by the widely known organization in the field of naval architecture, the ITTC (International Towing Tank Conference). The ITTC provides guidelines for the quantitative assessment of uncertainties in verification and validation studies [12].

There are several examples of recent studies that assess uncertainties (numerical and experimental) in different areas of marine hydrodynamics applications, for instance, those by Wilson et al. [13], De Luca et al. [14], Terziev et al. [15], and Bilandi et al. [16].

In this context, the present Special Issue collected five contributions demonstrating the breadth of cases in which verification and validation analysis can be applied. The collected articles include numerical modelling cases that are particularly difficult to measure experimentally and where verification analysis is of value, including high-speed craft hydrodynamics (Contributions 1 and 5), added resistance in waves (Contribution 2), cavity formation during water exit (Contribution 3), and super-cavitating flow modelling (Contribution 4).

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2. Overview of Published Articles

Contribution 1: Sulman et al. used unsteady Reynolds averaged Navier–Stokes modelling with the volume of fluid method to model the free surface and an overset mesh approach to account for motions to study varying shapes and positions of steps on high-speed planing craft. Despite the complexity of the numerical model used, Sulman et al. achieved a discretization uncertainty of 0.56% and a low comparison error across three cases spanning beam-based Froude numbers from 1.13 to 2.59. Their findings highlight the importance of considering the full operational envelope of a hull when incorporating a stepped hull arrangement, since some designs can be highly beneficial at some, but not all speeds.

Contribution 2: Chirosca et al. made use of a time domain potential flow solver to predict the added resistance of the Duisburg Test Case. The discretization uncertainty of the model was predicted to be approximately 2% for calm water resistance and 3.16% for added resistance, while both metrics showed good agreement with experimental data. Although Chirosca et al. did not carry out a full validation study, they predicted experimental uncertainties between 0.41% and 2.68%. Based on the proximity of the calculated data and the experimental results, it is likely that a full validation would be successful should the validation uncertainty be lower than the comparison error.

Contribution 3: Zan et al. modelled the water exit process of a steel frame structure using unsteady Reynolds averaged Navier–Stokes modelling to predict the force and entailed water mass. Their model, which modelled the free surface using the volume of fluid method, showed low levels of uncertainty between 1.39% and 0.70%. In addition, Zan et al. compared the time history of the force acting on the steel frame structure using three systematically refined meshes showing close agreement across the so-called grid triplet. Among their main findings, Zan et al. reported that the water exit force first increased with velocity, and then decreased after a critical point. However, the maximum water exit force increased with speed.

Contribution 4: Arad Ludar and Gany developed an analytical approach to model axisymmetric super-cavitation bubbles around slender bodies accounting for the presence of viscosity at low Reynolds numbers. The development of analytical models can be used to verify the correct asymptotic behaviour of the numerical solution and is frequently used for code verification. Such analytical models with derivation that contains viscous terms are of greater value when testing numerical solvers, particularly in cases that are experimentally challenging or where experimental data are unavailable.

Contribution 5: Pacuraru et al. modelled planing hull performance with various geometrical features using an unsteady Reynolds averaged Navier–Stokes solver. They conducted separate grid and time step convergence studies, finding negligible uncertainty of less than 0.3% due to temporal discretization and up to 8.91% uncertainty in low-speed cases due to spatial discretization. Pacuraru et al. achieved a low error compared to experimental data, which was also characterized by low uncertainty, meaning that the validation uncertainty was dominated by the spatial discretization error.

Conflicts of Interest: The author declares no conflicts of interest.

List of Contributions:

1. Sulman, M.; Mancini, S.; Bilandi, R.N. Numerical Investigation of Single and Double Steps in Planing Hull. *J. Mar. Sci. Eng.* **2024**, *12*, 614. https://doi.org/10.3390/jmse12040614.
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