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Predicting the Hydrodynamic Performance of Inland Waterway Ships in Extreme Shallow Waters Using State-of-the-Art CFD

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ABSTRACT

Inland waterway navigation faces significant challenges due to the increasing impact of climate change, particularly extreme weather events such as prolonged periods of low water levels. During these events, the hydrodynamic behavior of inland waterway ships is severely affected by complex ship-waterway interactions. The confinement of the waterway critically impacts steering and propulsion performance, resulting in significant operational risks and design constraints.

Accurately predicting the hydrodynamic performance of inland waterway ships under such extreme conditions is crucial for optimizing ship designs, supporting policy development, and enabling safe and efficient maneuvering with minimal under-keel clearance.

Our paper explores the application of state-of-the-art computational fluid dynamics (CFD) techniques to accurately predict the hydrodynamic performance of inland vessels maneuvering in extreme shallow water. We present high-fidelity simulations based on the numerical solution of the Reynolds-Averaged Navier-Stokes (RANSE) equations coupled with the Reynolds stress model for turbulence closure, but also using scale resolving techniques. The simulations are thoroughly validated on various representative ship types operating on German inland waterways, including multi-body configurations such as pusher-barge systems. In addition, we demonstrate how systematic CFD simulations can be leveraged to develop novel mathematical models for the maneuvering behavior of inland waterway ships in extreme shallow water scenarios.

Our paper highlights the novel integration of advanced CFD techniques with practical applications in ship performance prediction in extreme shallow waters to address critical challenges in the future of inland waterway transportation.