Marine propellers operate in turbulent flows, presenting a significant challenge for numerical analysis and design. Conventional linear and potential flow theories have limitations in predicting turbulent flows. Viscous methods, though capable of handling turbulence by incorporating a turbulence model, are often computationally intensive. This study addresses these issues by developing an efficient numerical solver for simulating turbulent flows around propellers. Building upon the Viscous Vorticity Equation (VISVE) solver, originally designed for laminar flows by the Ocean Engineering Group at UT, this research extends its capabilities to tackle complex topics like turbulence modeling. The focus is on implementing the $k-\omega$ SST turbulence model in both 2-D and 3-D versions of the VISVE solver. Discretized using the Finite Volume Method, the turbulence model employs a hybrid parallelization strategy with OpenMP/MPI for efficient utilization of High-Performance Computing resources. The developed numerical model is validated and subjected to convergence tests across various applications, including hydrofoil and cylinder analyses, ultimately turbulent propeller flows. The VISVE method offers advantages such as a reduced computational domain and postprocessing pressure calculations, significantly improving computational efficiency. In summary, this research contributes to the development of a robust and efficient numerical solver for simulating turbulent flows around hydrofoils and propellers, with potential applications in marine propulsion design and performance analysis.

Investigating Calcium and Organic Fouling Interactions in Complex Water Systems and their Effect on Reverse Osmosis Membranes

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Currently, reverse osmosis membranes are used to treat seawater/brackish water in multiple parts of the world. These technologies provide an energy-efficient solution to desalinate waters. However, these technologies are inappropriate to treat highly contaminated waters due to fouling-foulant and foulant-membrane interactions that deteriorate membrane performance. The complex interactions of organic foulants and inorganic scalants require a deeper understanding to help guide the design of technologies that can effectively treat these highly contaminated waters. Previous research has shown that in feedwaters containing calcium, sulfate, and organic macromolecules, calcium interacts with the carboxylic acid groups of the organic molecules and can bridge these organic molecules together and to the membrane’s surface. This interaction leads to thicker, less dense organic fouling layers. These organic macromolecules inhibit gypsum nucleation on the membrane and adhere to gypsum crystals which impedes gypsum precipitation and forces the crystals to form flat sheets instead of the typical rosette shape. By including more complex waters that vary in pH and contain various organic species that can compete for calcium interactions, we can develop a more holistic understanding of how calcium and organic foulants interact with each other and the membrane’s surface. By using Near-Edge X-Ray Absorption Fine Structure at the carbon K-edge and calcium L-edge, we reveal that at lower pH conditions the protonated carboxyl groups interact less with calcium leading to a thinner, more compact organic fouling layer, and we witness less inhibition of gypsum nucleation. Through Wide Angle X-Ray Scattering and X-ray Diffraction we can see that even though the macrostructure of gypsum is influenced heavily by the organic macromolecules, regardless of pH, the internal crystal structure of the gypsum scalant is unchanged.

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