UNSTRUCTURED RANS SIMULATIONS FOR OPEN-CHANNEL FLOW

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High-fidelity Reynolds-averaged Navier-Stokes simulations for complicated geometries including the free surface represent many challenges, including gridding around complicated geometries and accurate, robust, and efficient simulation of the interaction between the free surface and the underlying flow. A new nonlinear free surface RANS solver [1] has recently been developed by researchers at Mississippi State University for simulation of flow past surface ships, using as naval destroyers and other novel hullforms. This unstructured flow solver uses grids that have mixed-element types which are used within the boundary layer, so that the boundary layer can be fully-resolved, if needed. Furthermore, because of the use of unstructured grids, complicated geometries, such as propellers, rudders, shafts and struts for surface ships, and bridge-piers and energy dissipators for open-channel flows, can be readily gridded, and the flow field simulated.

The flow solver U^{2}NCLE [2] solves the incompressible Reynolds-averaged Navier-Stokes equations via the artificial incompressibility formulation, using an implicit Roe-averaged finite volume methodology and has been parallelized and ported to many different computer architectures. Several turbulence models are available as well as access to grid regeneration and subgrid rotation via the unstructured grid generator AFLR3. The free surface is obtained by solving the kinematic free surface equation and using the resulting wave elevations as a pressure boundary condition. The grid is moved to match the free surface via a three-dimensional extension of Farhat's torsional spring analogy [3], while conforming to any geometry within the flow. Due to the computational cost of moving the grid, the grid is moved once every 100 iterations, which is acceptable for steady-state flow simulations.

In this current research effort, the unstructured flow solver is applied to several geometries of interest to open-channel flow simulations, including channel contraction, flood plan flows, flow around bridge piers and around submerged bridge piers, and flow over a spillway. Current efforts focus on analyzing the code's ability to simulate open-channel flow with the long-term goal of simulating contaminant transport and bed erosion for highly complicated flow regimes. Coupled with the simulation efforts, another primary long-term goal is the inclusion of gradient-based optimization methods for flow field optimization and prediction of contaminant transport.

References

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