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Computations of Compressible Cavitating Flows: Numerical Methods and Engineering Applications

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Abstract:
Multiphase flow analyses using computational fluid dynamics (CFD) have been playing a key role in research and development fields, in favor of the advancement of computing power and numerical methods. This research group lists several issues arising from computations of cavitating flows, and the efforts to resolve each issue as well as our various computational experiences will be shared.

Firstly, the computational framework is introduced. Among many mathematical models that describe cavitating flows, we have selected a suitable model for our research aim, i.e., computations of large-scale cavitating flows in a wide range of engineering applications. Numerical methods that cope with the listed issues will be covered in this section. Especially, we developed multiphase flux schemes for steady/unsteady all-speed flows with robust shock-capturing properties. A new cavitation model with physics-based thermodynamic corrections will be also introduced.

In the second part, validation results by well-known benchmark problems will be provided. Each test case demonstrates core numerical/physical features of our computational framework, which shows that our efforts effectively deal with the issues we pointed out.

For the last part, the computational results of representative engineering application problems from disparate disciplines will be presented. Turbopump inducer is a key component of a fuel supply system in launch vehicles. The proposed cavitation model with thermodynamic corrections will be employed for the cryogenic cavitation around the turbopump inducer, which will be compared with the conventional modeling approach. Supercavitation is in the limelight for its remarkable drag-reduction capability for underwater vehicles. The vehicle's hydrodynamic behaviors under different supercavitation conditions will be examined by steady/unsteady simulations.

Keywords: Compressible cavitating flows, Numerical methods for multiphase flows, Physics-based cavitation model, Computational Fluid Dynamics (CFD), Engineering applications