DOUBLE-SIDED IMMERSED BOUNDARY METHOD WITH THIN-SHELL STRUCTURES FOR FAST BLAST SIMULATION

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Key words : fast CFD – immersed boundary method – urban blast – numerical – simulation

An efficient double-sided immersed boundary method (IBM) approach has been developed for thin-shell geometries and implemented in the next-generation fast CFD solver, used by the Rapid City Planner tool for explosive threats. The primary advantage over the traditional IBM approach is that airtight surface models or closed convex hulls are not required, since boundary detection is independent of a ray-tracing-type intersection test. This novel approach is also independent of inside and outside definitions, which facilitates seamless fusion of interior and exterior environments for blast ingress or egress calculations in Rapid City Planner. The kernel of the approach incorporates a bounding-box immersion-based detection scheme with a multi-ghost cell approach to enforce boundary conditions in multiple directions simultaneously.

This double-sided approach allows IBM 'ghost' and 'fluid' cells to exist in the same physical space, which results in boundary feature detection that is nearly independent of Cartesian grid resolution and structural position relative to CFD grid. The approach handles thin shell structures and convex corners, and is well-suited for CAD-based or architectural models, or for meshes generated from point clouds, which may have multiple intersections, overlapping, or incomplete mesh regions. Dynamic structural changes, such as removal of elements due to a failure condition, are supported and require no modifications to geometric topology. The approach is demonstrated for urban blast scenarios including external blast with ingress, internal blast with venting, and urban blast with frangible structural failure. Select comparisons to small-scale experiments from the literature are made. The approach is evaluated for accuracy, efficiency, and applicability for fast urban blast calculation in the Rapid City Planner tool.