The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5 – 9 June 2022, Oslo, Norway

The Conforming Transient h-r Unstructured Adaptive Mesh Refinement (cThruAMR) Method for Multiphysics Simulations of Manufacturing Processes

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Key Words: *Moving interfaces, image-based simulation, enriched finite elements*

Manufacturing processes including casting, welding, brazing, soldering, and most additive manufacturing methods involve multiphase flow and solidification. Simulations of these processes must address evolving interfaces between multiple materials and phases. The physics and physical quantities are discontinuous across these moving interfaces. Discretization methods for moving interface problems with interfacial discontinuities are thus required to address these problems accurately.

Enriched finite element methods, including the Conforming Decomposition Finite Element Methods (CDFEM) are powerful tools for coupled multiphase and multimaterial problems with moving interfaces. To capture the discontinuities across interfaces, these methods introduce some form of enrichment of the degrees of freedom. Additional unknowns are assigned to the mesh entities (elements, nodes, sides, or edges) that are associated with these interfacial elements, and additional equations are formulated. In CDFEM, level sets are used to describe the domain of each material or phase. Nodes are added at the intersection of each level set surface with the edges of the input mesh, and a conforming mesh is generated automatically. This allows the weak and strong discontinuities across the interfaces to be captured using standard finite element methods.

In the current work, a new strategy is developed for automated interface conforming tetrahedral mesh generation, which produces higher quality meshes than standard CDFEM. The Conforming Transient h-r Unstructured Adaptive Mesh Refinement (cThruAMR) method uses a combination of h-adaptivity and r-adaptivity to generate high quality meshes that conform to a moving interface. The term h-adaptivity is used for refining or cutting the mesh. Conforming h-adaptivity is used in CDFEM to capture dynamic topology problems. The term r-adaptivity is used for moving the nodes of the mesh to capture a desired feature. By combining h and r adaptivity, cThruAMR is able to produce high quality meshes even for dynamic topology problems. The method is closely related to the Conforming to Interface Structured Adaptive Mesh Refinement (CISAMR) method, but employs a general unstructured mesh and is developed for transient moving interface problems.

This talk will describe cThruAMR including the strategies employed for r-adaptivity, level set advection, and dynamic DOF handling. The method is verified using multiple benchmark problem, yielding optimal rates of convergence. The resulting discretizations are shown to have better conditioning and improved mesh quality compared to standard CDFEM discretizations.

*Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.