Multi-Material Reconnection-based Arbitrary Lagrangian Eulerian (ReALE) Method

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Abstract. We present a complete reconnection-based multi-material arbitrary-Lagrangian-Eulerian (Re-ALE) strategy devoted to the computation of multi-material compressible fluid flows using the moment of fluid (MOF) interface reconstruction. In ReALE we replace the rezoning phase of classical ALE method by a rezone where we allow the connectivity between cells of the mesh to change. This leads to a polygonal mesh that recover the Lagrangian features of following the material that we loose using standard ALE methods with fixed connectivity. In this work we have implemented MOF interface reconstruction on polygonal mesh in ReALE framework to deal with multi-material problems.

Numerical schemes in compressible fluid dynamics make use of two classical kinematic descriptions: the Lagrangian description and the Eulerian description. First one is characterized by computational cells that move with fluid velocity, the second one uses a fixed computational grid through which fluid moves. In this context, Arbitrary Lagrangian-Eulerian (ALE) methods were introduced in [4] to exploit advantages of two previous frameworks. The main elements in ALE simulation are an explicit Lagrangian phase [6] in which the solution and grid are updated, a rezoning phase in which nodes of Lagrangian grid are moved to improve geometric quality of the grid, and a remapping phase in which the Lagrangian solution is conservatively interpolated from the Lagrangian grid onto the rezoned one.

In standard ALE methods [1] the new mesh from the rezone phase is obtained by moving grid nodes without changing connectivity of the mesh. With the new ReALE method [3] presented here, connectivity of the mesh is allowed to change during the rezone phase renamed as the reconnection phase. The main idea is to define a new grid using specific movement of generators and formalism of Voronoi diagrams. The updated position of the generator \(G^{\text{new}}\) is defined by mean of a convex combination between the new Lagrangian-like position \(G^{n+1,\text{lag}}\) and the centroid \(X^{n+1}_c\) of the Lagrangian cell such that \(G^{\text{new}} = G^{n+1,\text{lag}} + \omega_c (X^{n+1}_c - G^{n+1,\text{lag}})\) where \(\omega_c \in [0;1]\) is constructed using invariants of the right Cauchy-Green strain tensor associated to the Lagrangian cell \(\Omega_c\) between times \(t^n\) and \(t^{n+1}\). With such a formula, generator movement is chosen in the way that cell movement is close to Lagrangian and cell shape is close to regular hexagon. This new method leads to general polygonal mesh and allows to follow Lagrangian features of the mesh much better than for standard ALE methods. Furthermore, in the context of multi-material computations using ReALE method (as for standard ALE method), grid and
fluid move separately, and mixed cells containing two or more materials could appear. These mixed cells contain material interfaces, which need special treatment to be taken into account. This is done using the Moment of Fluid (MOF) method [3, 2].

Numerical tests, like the Kelvin-Helmholtz instability (see Figure 1) representative of our multi-material ReALE simulations, will be presented using animated video to demonstrate the robustness and the accuracy of this method.

References