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A Multi-Material CCALE-MOF Approach in Cylindrical Geometry

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Abstract. In this paper we present recent developments concerning a Cell-Centered Arbitrary Lagrangian Eulerian (CCALE) strategy using the Moment Of Fluid (MOF) interface reconstruction for the numerical simulation of multi-material compressible fluid flows on unstructured grids in cylindrical geometries. Especially, our attention is focused here on the following points. First, we propose a new formulation of the scheme used during the Lagrangian phase in the particular case of axisymmetric geometries. Then, the MOF method is considered for multi-interface reconstruction in cylindrical geometry. Subsequently, a method devoted to the rezoning of polar meshes is detailed. Finally, a generalization of the hybrid remapping to cylindrical geometries is presented. These explorations are validated by mean of several test cases using unstructured grid that clearly illustrate the robustness and accuracy of the new method.

AMS subject classifications: 76M10, 76N15, 65K10

Key words: Cell-centered scheme, Lagrangian hydrodynamics, ALE, MOF interface reconstruction, Rezoning algorithm, polar meshes, hybrid remapping, axisymmetric geometries.

1 Introduction

In this work, we consider the simulation of multi-material compressible flows on unstructured meshes in cylindrical geometry. For this, we adopt an Arbitrary Lagrangian-Eulerian (ALE) description [19] that has the great advantage to combine the best features of both Eulerian and Lagrangian approaches. Indeed, this choice is not only well

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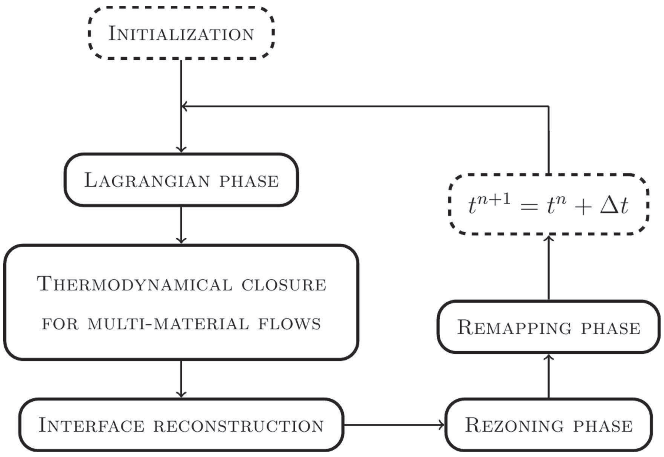

Figure 1: Multi-material CCALE algorithm flowchart.

adapted to naturally track free surfaces and interfaces between different fluids as purely Lagrangian methods, but also to handle flow distortion as Eulerian methods [3,6]. Here, a Cell-Centered Arbitrary Lagrangian Eulerian (CCALE) [15,16] approach is particularly considered whose main elements are as follow.

As depicted on Fig. 1, the first step of the algorithm relies on an explicit Lagrangian phase in which the physical variables and grid are updated thanks to a slightly modified version of the Explicit Unstructured Cell-Centered Lagrangian HYDrodynamics (EUCCLHYD) scheme [25–27] in cylindrical coordinates. Recently, new investigations have been made about cell-centered Lagrangian schemes [4,12]. The scheme presented in this paper is a modified version of the area weighted finite volume scheme of [25]. Then, multi-material flows treatment is done thanks to specific interface capturing method. This choice allows to track the volume fraction of each material used for the thermodynamical closure relying on the equal strain rates assumption. This approach is quite simple to implement and remains sufficient in most of the cases [16,32]. This, leads to constant evolution of the volume fraction during the Lagrangian phase. Such an approach allows to reconstruct with accuracy the interface between each material. In this context, many developments have been done for 2D Cartesian geometries. First, a previous version of the CCALE algorithm solving two-material compressible flows using a Volume Of Fluid (VOF) method [36] have been proposed in [10,16]. Then an extension to Moment Of Fluid (MOF) approach has been considered to enhance multi-material (more than two components) flows in [13,15]. Subsequently, a rezoning phase is realized. It consists in moving the Lagrangian nodes to improve the geometric quality of the grid [21]. Finally, the physical variables are conservatively interpolated from the Lagrangian grid onto the new rezoned one during the remapping phase. Here an extension of the hybrid remapping [7] to cylindrical geometries is introduced. We want to notice that in ALE framework using cell-centered formulation, this phase is straightforward. In the lines of these works, the main goal of this paper is to extend the CCALE-MOF algorithm to treat