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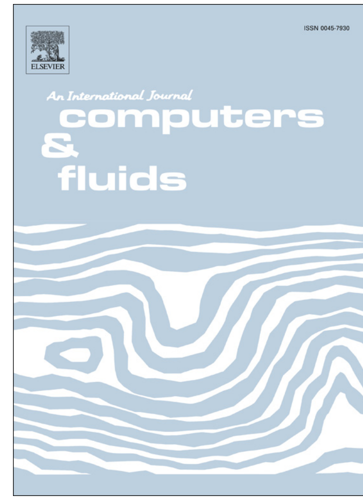

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A Naturally Anti-Diffusive Compressible Two Phases Kapila Model with Boundedness Preservation Coupled to a High Order Finite Volume Solver

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Abstract

This paper presents a two phases flow model combined with a high order finite volume solver on unstructured mesh. The solver is highly conservative and preserves the sharpness of the interface without any reconstruction. Special care has been taken for boundedness preservation, as a high order scheme does not guaranty the boundedness of the volume fraction.

The efficiency of the method is demonstrated with two numerical experiments: the simple advection test and the interaction between the shock and the helium bubble. Although experiments have been carried out with fine mesh, it is also demonstrated that the method allows satisfactory results to be obtained with coarse mesh.

Keywords: Kapila model, two phases flow, finite volume, moving least square, boundedness preservation

1. Introduction

Multiphase flows intervene in a wide range of industrial problems, including aerospace, atmospheric, biological, chemical, civil, mechanical, and nuclear systems. Currently, these type of flows are not mastered and form the topic of much challenging research.

We discuss in this study the methods of the resolved surface type for two immiscible fluids. This family of methods is able to capture coherent interfaces, in contrary to dispersed multi-phase flow methods. A widely used resolved surface approach is the volume of fluid (VOF) method [1], where a marker is transported. This marker, defined as the volume fraction (between 0 and 1) represents each fluid's parts in the control volumes. For the VOF method, the conservation feature is not hard to obtain. However, the main weakness of this kind of method is the numerical diffusion and the interface smoothing, especially for low order schemes. To avoid these problems, several methods of interface reconstruction have been proposed. These algorithms are nevertheless usually implemented for cartesian or structured meshes (SLIC Noh and Woodward [2], PLIC Youngs [3]) and with a first order accuracy. Heavier and more sophisticated methods have been proposed with a second order accuracy [4], still with cartesian meshes. Another possibility to avoid smoothing problems lies in the interface sharpening, for example by adding a compressive term as a source term in the fluid governing equations [5]. Finally, models avoiding explicit geometrical reconstruction have been proposed, as for example the CICSAM method [6] or the approach developed by Chen et al [7], where the numerical diffusion is reduced thanks to a combination of high order accurate schemes near the interface. Local mesh refinement could also handle low diffusion [8].

Another type of resolved surface approaches are the front tracking methods, represented by the level set method [9]. The latter method is based on the transport of a distance function. Because of the smooth property of this function, the level set method is very slightly diffusive. On the other hand, the mass conservation is difficult to obtain with such a method for complex flows. To obtain the benefits of both types of resolved surface approach, coupled level set and VOF methods have already been developed, for structured meshes [10], and for unstructured ones [11],[12].

Different models are avalaible in the litterature for multiphase flow, for instance: the Baer–Nunziato model [13], the Kapila model [14] and the Saurel–Abgrall model [15]. While, some of them have 7 equations [16], other reduce to 6 [17] or even 5 equations [18]. In this paper, a two-phase Kapila model is proposed based on a high order finite volume solver using moving least square reconstruction (MLS) [19]. The MLS approach allows a high spatial order

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