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ORIGINAL PAPER

On the analysis of heterogeneous fluids with jumps in the viscosity using a discontinuous pressure field

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Abstract Heterogeneous incompressible fluid flows with jumps in the viscous properties are solved with the particle finite element method using continuous and discontinuous pressure fields. We show the importance of using discontinuous pressure fields to avoid errors in the incompressibility condition near the interface.

Keywords Heterogeneous fluids · Multi-fluids · Multiphase flows · Incompressible Navier–Stokes equations · Free-surfaces · Interfaces

1 Introduction

The simultaneous presence of multiple fluids with varying properties in external or internal flows is found in daily life, in marine environmental problems, and numerous industrial processes, among many other practical situations. These types of flow are labeled "multi-fluid" or simply "heterogeneous fluids" and they typically exist in different forms depending on their phase distribution. Examples are gas-liquid transport, magma chambers, fluid–fuel interactions, crude oil recovery, spray cans, sediment transport in rivers and floods, pollutant transport in the atmosphere, cloud formation, fuel injection in engines, bubble column reactors and spray dryers for food processing, to name only a few. This demonstrates the large incidence and also importance of multi-fluid flows, which probably occur even more frequently than single phase flows [1].

As a result of the interaction between the different fluid components, multi-fluid flows are rather complex and very difficult to describe theoretically. Despite the practical importance of the problem and the intensive work carried out in the last decade for the development of suitable mathematical and computational models, it is widely accepted that the numerical study of heterogeneous flows is still a major challenge [1].

Computing the interface between two immiscible fluids or the free-surfaces is difficult because neither the shape nor the positions of the domains between the fluids are a priori known. In this kind of flows there are basically two approaches for computing interfaces, which are, using the terminology in [2], interface-tracking and interface capturing. The former computes the motion of the flow via a mixed Lagrangian–Eulerian approach [3] or a space-time approach [4,5], where the numerical domain adapts itself to the shape and position of the interfaces. Standard interface-capturing methods consider both fluids as a single effective fluid with variable properties [6–8]. The interfaces are considered as a region of sudden change in the fluid properties. This approach requires an accurate modeling of the jump in the properties of the two fluids taking into account that the interfaces can move, bend and reconnect in arbitrary ways. Furthermore, prescribing exact boundary conditions in the interface is usually approximated. Non-standard interface-capturing methods have been developed to increase the accuracy in representing the interface, such as the Enhanced-Discretization Interface-Capturing Technique (EDICT) [9,10]. There

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