A generalized multi-field two-fluid concept for numerical simulation of two-phase flows

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Multiphase flows occur in a variety of industrial applications, e.g. in chemical engineering or in nuclear safety research. An important feature of these flows is the formation of different flow patterns depending on the relative flow rates of the phases. These patterns are not explicitly defined by the conduit and have different characteristics. Past research on the simulation of multiphase flows mainly focused on establishing methods that are appropriate within a well-defined flow regime. The present contribution aims at the development of a generalized framework in OpenFOAM for the simulation of industrial scale multiphase flows with largely varying interfacial length scales, which has the capability to reproduce the mechanisms of flow pattern transitions. For the simulation of disperse flows, the two-fluid approach, where each phase is represented by its own phase-averaged velocity field, is widely accepted. This concept serves as a basis and is extended to allow interface-resolving simulations for large gas structures, while disperse phase elements are still represented in terms of a number density function.

The present contribution focuses on two parts. Firstly, one feature of multiphase flow pattern transitions is the inherent polydispersity of the occurring gas structures. The difference in diameter between the smallest and the largest elements spans over at least one order of magnitude. In general, this aspect is taken into account by population balance modeling. A successful and stable method for this purpose is the method of classes which will be utilized here, following the ideas of the GENTOP-approach of Hänsch et al. (2012). Since lift-force induced separation of bubbles according to their size is considered as an important mechanism for the transition from bubbly to slug flow, particular emphasis is put on employing a class method which also takes different velocity fields for the disperse phase into account.

The second part focuses on the handling of interface-resolving gas structures within the two-fluid model. Beside the aspect of interface sharpening to counteract the numerical diffusion, the momentum exchange between the separate velocity fields is important. In reality, the phases share a single velocity field and a no-slip condition is present at the interface. This condition can also be met in a two-fluid model by forcing the velocity of the two phases to be equal at interface. However, as such a method requires a high grid resolution, we introduce a direction depended model for the momentum exchange at the interface, that accounts separately for pressure and friction induced drag. Finally, the presented framework allows the simulation of multiphase flow problems close to an industrial scale and gives realistic predictions, even on a coarse grid.

Haensch, S.; Lucas, D.; Krepper, E. & Hoehne, T. A multi-field two-fluid concept for transitions between different scales of interfacial structures, International Journal of Multiphase Flow, 2012, 47, 171-182