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AN ALE-PFEM METHOD FOR COMPUTATIONAL SIMULATIONS OF TWO-PHASE FLOW PROBLEMS

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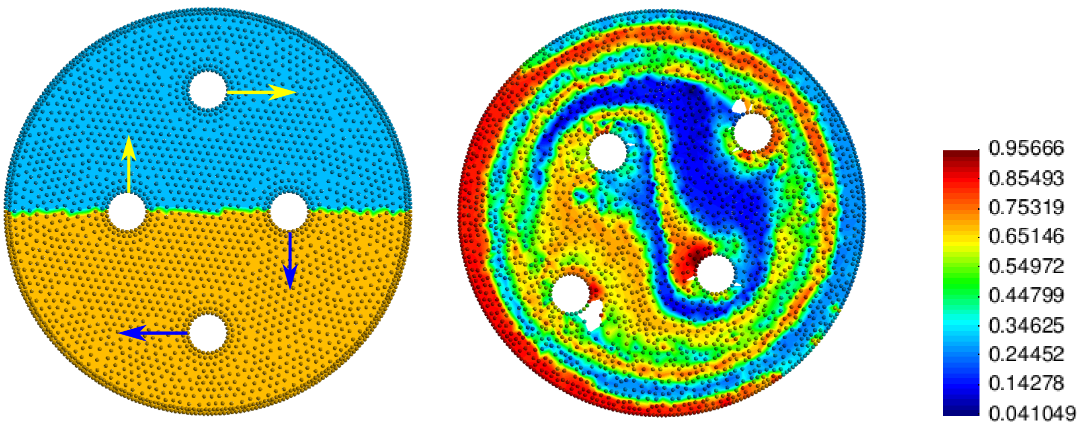
In the two-fluid mixture model [1], which belongs to the class of interpenatring continua models, two fluid phases are assumed to co-exist everywhere in the domain, with the flow of each phase governed by its own set of continuity and momentum balance equations. The interaction with the other phase is described by the interaction terms present in the momentum balance equations.
In the proposed numerical method for computational analyses of two-phase flow processes, the two-fluid model is adopted. However, the governing equations of the two phases are not written in the standard Eulerian-Eulerian description. Instead, the equations of one phase (called liquid phase l) are formulated in the Lagrangian description and the ones of the other phase (called gas phase g) are formulated in the Arbitrary Lagrangian-Eulerian (ALE) description:

$$
\begin{aligned}
&\frac{D_l\phi_l}{\partial t} + \phi_l \nabla \cdot (\boldsymbol{u}_l) = 0\\
&\frac{D_l\boldsymbol{u}_l}{\partial t} = -\frac{1}{\rho_l}\nabla p + \frac{1}{\phi_l\rho_l}\nabla \cdot (\phi_l \boldsymbol{\tau}_l) + \boldsymbol{g}_l + \boldsymbol{f}_{lg}\\
&\frac{D_l\phi_g}{\partial t} + (\boldsymbol{u}_g - \boldsymbol{u}_l)\cdot\nabla\phi_g + \phi_g \nabla \cdot (\boldsymbol{u}_g) = 0\\
&\frac{D_l\boldsymbol{u}_g}{\partial t} + (\boldsymbol{u}_g - \boldsymbol{u}_l)\cdot\nabla\boldsymbol{u}_g = -\frac{1}{\rho_g}\nabla p + \frac{1}{\phi_g\rho_g}\nabla \cdot (\phi_g \boldsymbol{\tau}_g) + \boldsymbol{g}_g + \boldsymbol{f}_{gl}
\end{aligned}
$$

The Finite Element Method together with the stabilization techniques, the Characteristic-Based Split [4] and the Algebraic-Flux Correction [3], are employed to solve numerically the governing equations. The Lagrangian description of phase l is empowered by the Particle Finite Element Method [2]. As the flow of the phase l is described in the Lagrangian description, the nodes of the computational mesh are updated in accordance with the particles of phase l. The mesh elements are frequently globally regenerated to avoid severe distortion and the material boundary is identified by the α-shape technique.

The proposed ALE-PFEM method is well suited for two-phase flow problems characterized by free surfaces and large moving boundaries. It should be noted that the proposed Lagrangean-ALE two-fluid model can be extended to multiphase flow problems characterized by more than two phases without any conceptual changes.



a) b)

Figure 1: Application of the ALE-PFEM for two-phase flows with large moving boundaries: Distribution of volume fraction of one fluid phase during mixing of two fluid phases due to the stirring by means of four rotating mixing bars at a) t=0, b) after 20 s.

REFERENCES

[1] Kai Hiltunen, Ari Jäsberg, Sirpa Kallio, Hannu Karema, Markku Kataja, Antti Koponen, Mikko Manninen, and Veikko Taivassalo. Multiphase flow dynamics - theory and numerics. *VTT Publication*, 2009.

[2] S.R. Idelsohn, E. Oñate, and F. Del Pin. The particle finite element method: a powerful tool to solve incompressible flows with free-surfaces and breaking waves. *International Journal for Numerical Methods in Engineering*, 61(7):964–989, 2004.

[3] Dmitri Kuzmin and Matthias Möller. Algebraic flux correction i. scalar conservation laws. In Dmitri Kuzmin, Rainald Löhner, and Stefan Turek, editors, *Flux-Corrected Transport*, Scientific Computation, pages 155–206. Springer Berlin Heidelberg, 2005.

[4] O.C. Zienkiewicz, P. Nithiarasu, R. Codina, M. Vázquez, and P. Ortiz. The characteristic-based-split procedure: an efficient and accurate algorithm for fluid problems. *International Journal for Numerical Methods in Fluids*, 31(1):359–392, 1999.