The Numerical Coupling of a Two-Fluid Model with an Homogeneous Relaxation Model

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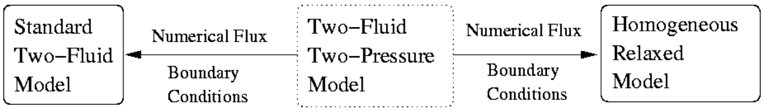
We examine here a numerical method in order to deal with the unsteady interfacial coupling of two distinct two-phase flow codes relying on the two-fluid approach (TFM) on the one hand, and on the homogeneous relaxation model (HRM) on the other hand. This work has been motivated by industrial needs in the NEPTUNE project [8]. The basic idea of the coupling approach is to introduce a father model, which corresponds to the two-fluid two-pressure model ([6, 11]). The latter model enables to recover both models on each side of the coupling interface through some relaxation process, and also to calculate convective fluxes through the interface, providing some suitable initialization of states on both sides of the latter interface. This unsteady coupling method has been proved to be rather stable in many cases, and it does not hide structural deficiencies or incoherencies of models to be coupled. It may be easily implemented when both codes rely on the Finite Volume approach. Current investigations concern the coupling of codes through some sharp porous interface (see [5]). This strategy slightly differs from those investigated by the working group (see [3, 7]). The reader is also referred to [1] for an alternative way of coupling TFM and HRM.



Governing equations of the two-fluid model TFM [10]

$$
\begin{cases}
\partial_t(\alpha_l\rho_l) + \partial_x(\alpha_l\rho_l U_l) = 0\\
\partial_t(\alpha_l\rho_l U_l) + \partial_x(\alpha_l\rho_l U_l^2 + \alpha_l P) - P\partial_x(\alpha_l) = S_{3,l}\\
\partial_t(\alpha_l E_l) + \partial_x(\alpha_l U_l(E_l + P)) + P\partial_t(\alpha_l) = S_{4,l}\\
\partial_t(\alpha_v\rho_v) + \partial_x(\alpha_v\rho_v U_v) = 0\\
\partial_t(\alpha_v\rho_v U_v) + \partial_x(\alpha_v\rho_v U_v^2 + \alpha_v P) - P\partial_x(\alpha_v) = S_{3,v}\\
\partial_t(\alpha_v E_v) + \partial_x(\alpha_v U_v(E_v + P)) + P\partial_t(\alpha_v) = S_{4,v}
\end{cases}
$$

Governing equations of HRM [2, 4]

$$
\begin{cases}
\partial_t(\rho C) + \partial_x(\rho C U) = 0\\
\partial_t(\rho) + \partial_x(\rho U) = 0\\
\partial_t(\rho U) + \partial_x(\rho U^2 + P) = 0\\
\partial_t(E) + \partial_x(U(E + P)) = 0
\end{cases}
$$

The father two-fluid two-pressure model [6, 11]

$$
\begin{cases}
\partial_t(\alpha_l) + V_I\partial_x(\alpha_l) = S_{1,l}\\
\partial_t(\alpha_l\rho_l) + \partial_x(\alpha_l\rho_l U_l) = 0\\
\partial_t(\alpha_l\rho_l U_l) + \partial_x(\alpha_l\rho_l U_l^2 + \alpha_l P_l) - P_I\partial_x(\alpha_l) = S_{3,l}\\
\partial_t(\alpha_l E_l) + \partial_x(\alpha_l U_l(E_l + P_l)) + P_I\partial_t(\alpha_l) = S_{4,l}\\
\partial_t(\alpha_v\rho_v) + \partial_x(\alpha_v\rho_v U_v) = 0\\
\partial_t(\alpha_v\rho_v U_v) + \partial_x(\alpha_v\rho_v U_v^2 + \alpha_v P_v) - P_I\partial_x(\alpha_v) = S_{3,v}\\
\partial_t(\alpha_v E_v) + \partial_x(\alpha_v U_v(E_v + P_v)) + P_I\partial_t(\alpha_v) = S_{4,v}
\end{cases}
$$

Source terms :

$$S_{1,l} = \frac{A}{\tau_p}(P_l - P_v) \qquad S_{3,l} = \frac{B}{\tau_u}(U_v - U_l) \qquad S_{4,l} = V_I S_{3,l}$$

$$S_{1,l} + S_{1,v} = 0 \qquad S_{3,l} + S_{3,v} = 0 \qquad S_{4,l} + S_{4,v} = 0$$

Numerical results [9, 10]

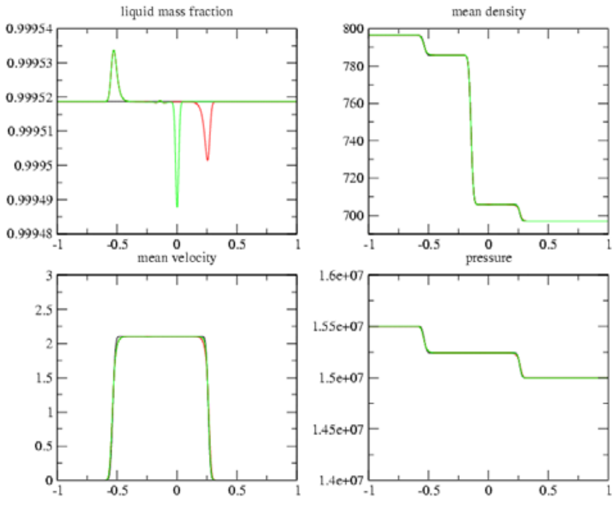


Fig 1: The domain contains 10000 cells. The coupling interface is located at x=0, the HRM domain corresponds to x>0 and the TFM domain to x<0. Green lines: coupled simulation, black lines : HRM simulation, red lines : TFM simulation. The initial discontinuity is located in the TFM domain, at x=-0.25. A pressure wave (a shock wave in HRM simulation) travels towards the HRM domain through the coupling interface.

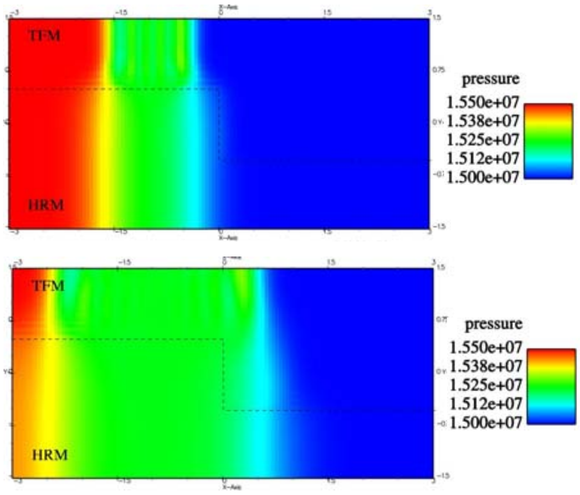


Fig 2: The dashed line represents the coupling interface.The TFM domain is on the top and the HRM domain is on the bottom. An initial discontinuity is located at x=-1 In the HRM domain, a shock wave travels towards the right side and a rarefaction wave travels to the left. The figures show the approximate coupled solution computed at two different instants.

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