# Development of the Multi-Phase/Multi-Dimensional Code BUBBLEX

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## 1. Introduction

A test version of the two-fluid program has been developed by extending the PISO algorithm [1]. Unlike the conventional industry two-fluid codes, such as, RELAP5 [2] and TRAC [3], this scheme does not need to develop a pressure matrix. Instead, it adopts the iterative procedure to implement the implicitness of the pressure. In this paper, a brief introduction to the numerical scheme will be presented. Then, its application to bubble column simulation will be described. Some concluding remarks will be followed.

## 2. Numerical Scheme

PISO loop starts with expanded momentum equation. The Phase Intensive Momentum Equation (PIME) is introduced in the separate paper [4,5]. The momentum equation is written as follows;

$$\frac{\partial\left[U_\varphi^{n+I}\right]}{\partial t}+\left[U_\varphi^{n+I}\right]g\nabla U_\varphi=-\frac{\nabla p^{n+I-1}}{\rho_\varphi}+S_\varphi$$

$$U_\varphi^{n+I}=U_\varphi^{*(n+I)}-\frac{\nabla p_\varphi^{n+I}}{\rho_\varphi A_\varphi}$$

$U_\varphi^{n+I}$ : velocity vector at time step $n$, PISO iteration step I for phase $\varphi$. [x] means the implicit terms.

Then, pressure estimator solves, which is derived from the expanded mass conservation equations:

$$\nabla g\left(\left(\alpha_a\left(\frac{1}{\rho_a \mathrm{A}_a}\right)+\alpha_b\left(\frac{1}{\rho_b \mathrm{A}_b}\right)\right)\nabla\right)\left[p^{n+I}\right]=$$

$$\nabla g\left(\alpha_a \mathrm{U}_a^*+\alpha_b \mathrm{U}_b^*\right)$$

$$+\frac{\alpha_a}{\rho_a}\left(\frac{\partial\psi_a^n}{\partial t}\left[p^{n+I}\right]+\psi_a^n\frac{\partial\left[p^{n+I}\right]}{\partial t}+U\nabla g\rho_a\right)$$

$$+\frac{\alpha_b}{\rho_b}\left(\frac{\partial\psi_b^n}{\partial t}\left[p^{n+I}\right]+\psi_b^n\frac{\partial\left[p^{n+I}\right]}{\partial t}+U\nabla g\rho_b\right)$$

Mass and energy conservation equations are in conservative forms.

$$\frac{\partial\left[\alpha_\varphi\rho_\varphi\right]}{\partial t}+\nabla g\left(\left[\alpha_\varphi\rho_\varphi\right]U_\varphi^{n+I}\right)=0 \quad (1)$$

$$\frac{\partial\left[\alpha_\varphi\rho_\varphi e_\varphi\right]}{\partial t}+\nabla g\left(\left[\alpha_\varphi\rho_\varphi e_\varphi\right]U_\varphi^{n+I}\right)=0 \quad (2)$$

At the present moment, the size of the dispersed phase is fixed to be 3mm. Some detailed descriptions for models are found in [4].

## 3. Applications

As a first trial, a conceptual bubble column is simulated to show the capability of the scheme to cope with the phase separation problem.

A bubble column is a box with width of 0.15m and height of 1.0m. Depth is tentatively assumed to be 0.01m. Two-dimensional calculation is performed for this case. 25 and 75 uniform cells are given to its width and height respectively. Pressure boundary condition is given to the top boundary face. Flow boundary condition is specified at the bottom face. Air is blown into the bottom of the column with the velocity of 0.1m/s. It lasts until a equilibrium condition is reached. Figure-1A shows the phase fraction distribution at the time.

Problem restarts from this time by resetting the starting time to zero. Inlet velocity is set to zero to simulate the settling bubble column. Figure-1 shows the flow pattern in the course of settling. Settling is almost finished at 2 second as presented in figure-1E. Unlike RELAP5 case [6] the level stays flat without any oscillation. This can be seen by figure-1F through H.

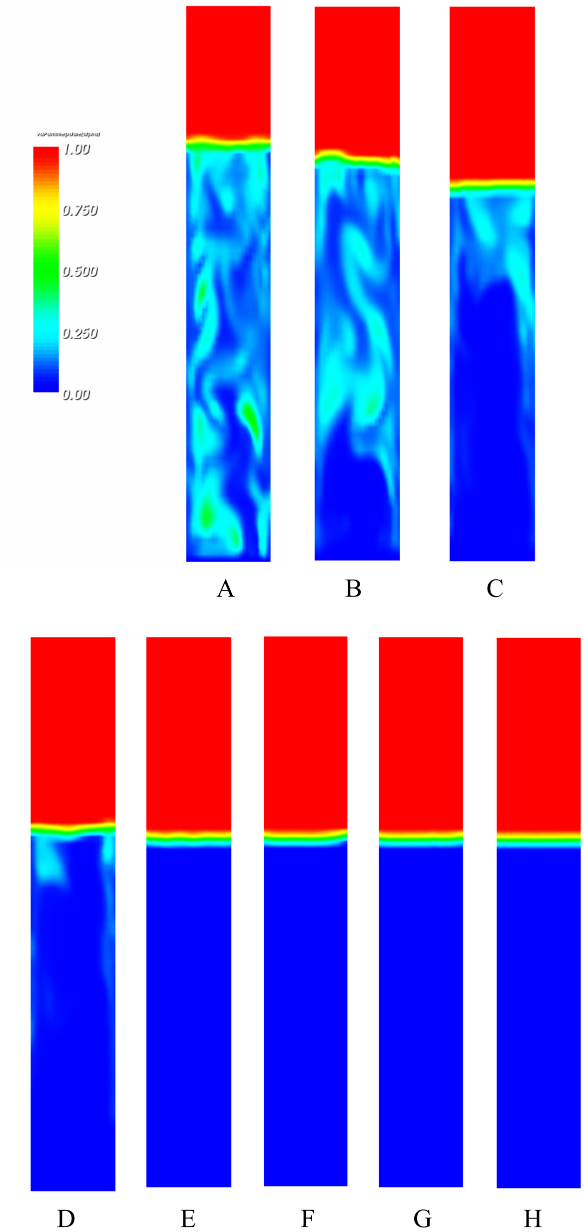


Figure-1. Phase Fraction Distribution. 0.0sec(A), 0.5sec(B), 1.0sec(C), 1.5sec(D) 2.0sec(D), 2.5sec(E), 3.0sec(F), 3.5sec(G) 20.0sec(H)

## 4. Conclusions

PISO algorithm with phase intensive momentum equation formulation is shown to be an efficient way to treat the phase separation problem. But, further study should be devoted to extend the formulation to areas, such as, phase change. Interfacial mass and/or momentum transfer is also open area to study. Hopefully, this approach may be applied to investigate the global flow behavior in the downcomer during the reflood period in the near future.

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## NOMENCLATURE

$\alpha$ phase volume fraction
$U$ velocity.
$\rho$ density.
$\tau$ shear force.
$M$ inter-phase friction.
$R$ Reynold stress.
$g$ body force.

Subscript:
$\varphi$ phase indication.

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