Numerical Fluid Mechanics II

Summer Semester 2018

DELIVERABLE TASK III:
Implementation of Continuous Species Transfer

Given: Friday, 22/06/2018
Deadline: 20/07/2018

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Implementation of Continuous Species Transfer (CST) in interFoam

The Navier-stokes equation for two-phase flow with volume of fluid (VOF) approach implemented in interFoam reads :

$$\nabla.u = 0 \tag{1}$$

$$\rho\left[\frac{\partial u}{\partial t} + \nabla(uu)\right] = -\nabla p + \nabla\mu\left(\nabla u + (\nabla u)^T\right) + f_b + f_{sf} \tag{2}$$

Here,
$f_b = \rho g$ and $f_s = \sigma\kappa\nabla\alpha$ are body force term and surface tension force term respectively.

- $\rho = \alpha_1\rho_l + (1-\alpha_1)\rho_g$ mixture density
- $\mu = \alpha_1\mu_l + (1-\alpha_1)\mu_g$ mixture viscosity

$$\alpha = \begin{cases} 1 & \text{in fluid 1} \\ 0 & \text{in fluid 2} \\ 0 < \alpha < 1 & \text{interphase} \end{cases}$$

and the VOF equation reads:

$$\frac{\partial\alpha_1}{\partial t} + \nabla\left[\alpha_1 u\right] + \nabla\left[\alpha_1(1-\alpha_1)u_r\right] = 0 \tag{3}$$

The objective of the third deliverable task is to implement continuous species transfer(CST) equation in openFoam solver interFoam. The CST equation reads as:

$$\begin{aligned} \frac{\partial C}{\partial t} + \nabla.(CU) = \nabla.(< D >_a \nabla C) \\ + \nabla.\left[(D_1 - D_2)\alpha_1\left(\frac{1}{\alpha_1 + \frac{1-\alpha_1}{H}} - 1\right)\nabla C\right] \\ + \nabla.\left[\frac{C}{\alpha_1 + \frac{1-\alpha_1}{H}}\left(\frac{1}{H}\frac{D_1 - D_2}{\alpha_1 + \frac{1-\alpha_1}{H}} - \left(D_1 - \frac{D_2}{H}\right)\right)\nabla\alpha_1\right] \end{aligned} \tag{4}$$

- Henry constant $H = C_g/C_l$.
- Concentration $C = \alpha_1 C_l + \alpha_2 C_g = C_l\left(\alpha_1 + \frac{1-\alpha_1}{H}\right)$
- $< D >_a = D_1\alpha_1 + D_2\alpha_2$ is the arithmetic mean mixture diffusivity. D_1 and D_2 are the diffusion coefficient of the species in the gas phase and liquid phase respectively

A group of 4 students will complete the task and submit a combined report.

Tasks

The Deliverable Task I should contain the case folder with modified solver myInterFoamCST of OpenFOAM (60p) and a written report (40p) describing the following results:

- (30p) Run simulation in a domain of height $h = 10$ cm and width 5 cm. Insert a bubble of 5 mm at 1 cm above the bottom surface with following fluid properties:

Fluid	ρ [kgm^{-3}]	μ [kgm^{-1}s^{-1}]	[ν m^{2}s^{-1}]	D cm^{2}s^{-1}	H=C_g/C_l
Water-glycerol	1205	9.45×10^{-3}	6.2241×10^{-5}	2.13×10^{-6}	33
O_2	1.122	1.824×10^{-5}	1.6257×10^{-5}	0.2085	—

  Initial $C_g = 8$ molm^{-3}
  Note: **a minimum of** 20 **grid point is necessary per bubble diameter. The CFL number should be** ≤ 0.5

- plot a contour of the concentration field of the final time. (5p)
- check boundedness of the solution. (15p)
- explain your results and make your final conclusions about the Deliverable Task.

Bonus task (10p)
Calculate the mass transfer coefficient from the simulation.
Deadline: 19th July,2018 23:59 email: md.ashfaqul.bari@fau.de