CFD-DEM Modeling of Bubble Movement in a Rectangular Fluidized Bed

F. Mostafaei, S. Golshan, R. Zarghami , R. Sotudeh Gharebagh, N. Mostoufi

Process Design and Simulation Research Center, School of Chemical Engineering, College of Engineering, University of Tehran

FLUIDIZATION XVI
May 26 - 31, 2019, Guilin Shangri-La Hotel, Guilin, China

Outlines

- Introduction
- Experiments
- Modeling
- Results and Discussion
- Conclusion

Introduction

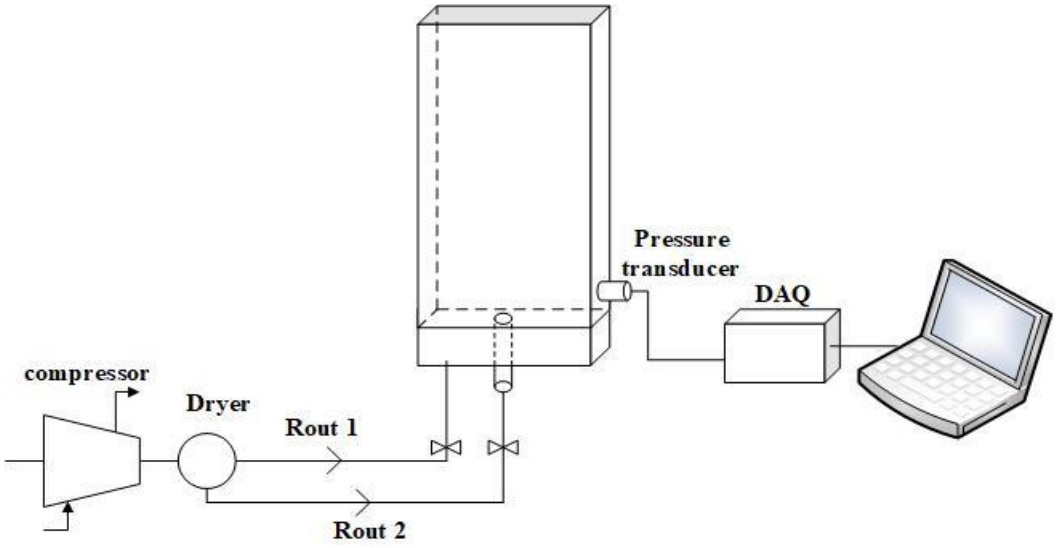
- Bubbles have a significant effect on the hydrodynamics of fluidized beds, therefore, study of bubble dynamics is of great importance
- Pressure signals and direct visualization provide useful information about bubbles in fluidized beds
- CFD-DEM is a powerful tool by which a broader vision of a fluidized bed behavior can be achieved
- In this work, single bubble was studied by CFD-DEM simulations
- Pressure signal and particle and gas velocity profiles are important properties inspected in this work in different stages of bubble formation, elevation, and eruption

Introduction

Experimental studies	
Van der Schaaf et al. [1]	Investigated pressure waves produced due to injection of a single bubble into a fluidized bed
Nosrati et al. [2]	Investigated attenuation of the pressure wave produced by injecting a single bubble in a 2D fluidized bed

Simulation studies	
Zhang et al. [3]	Used TFM to study the pressure signal produced by injection of a single bubble
Olaof et al. [4]	Compared size of a single bubble using TFM and DEM
Gera et al. [5]	Investigated particles motion near the bubble formation zone

Experimental Set-up



Specifications	
Bed diameter (cm)	20(w)×2(d)×100(l)
Static bed height (cm)	20 and 30 in separate runs
Glass beads	
Density (kg/m^3)	2500
Dimeter (mm)	1.3

Experiments were performed for validation

Operating condition:

Minimum fluidization velocity	0.129 m/s
Injection velocity	0.85 m/s
Injection time	0.24 s

Modeling equations and specification

$$\frac{\partial}{\partial t}(\varepsilon\rho_g) + \nabla.(\varepsilon\rho_g u_g) = 0$$

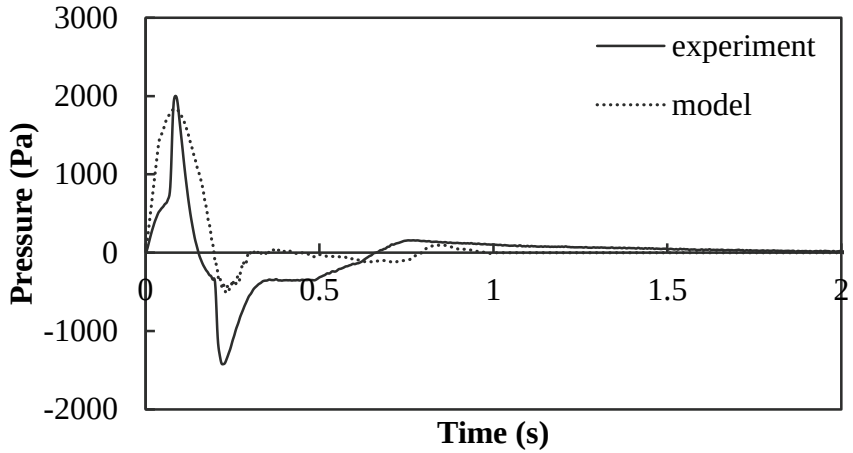
$$\frac{\partial}{\partial t}(\varepsilon\rho_g u_g) + \nabla.(\varepsilon\rho_g u_g u_g) = -\varepsilon\nabla P_g - \nabla.(\varepsilon\tau_g) + \varepsilon\rho_g g$$

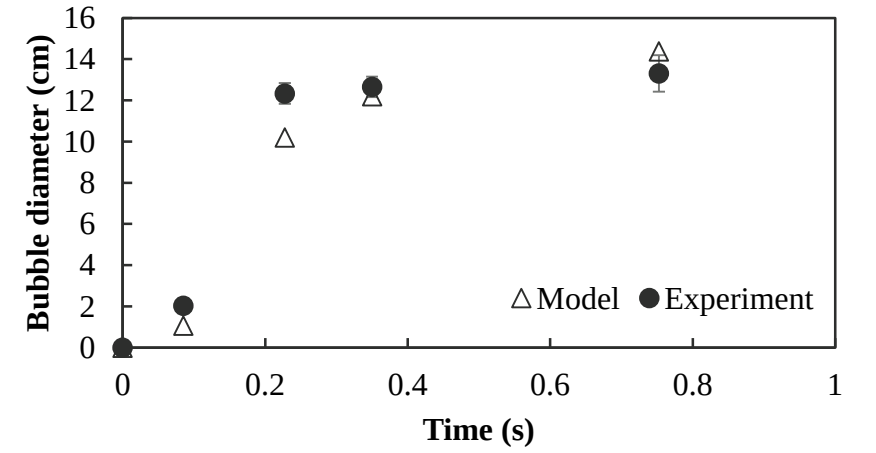
$$m_i \frac{d\vec{V_i}}{dt} = \sum_{j\in contact} \left(\vec{F}_{ij}^{n} + \vec{F}_{ij}^{t}\right) + \vec{F}_i^{drag} + \vec{F}_i^{g} + \vec{F}_i^{\nabla p}$$

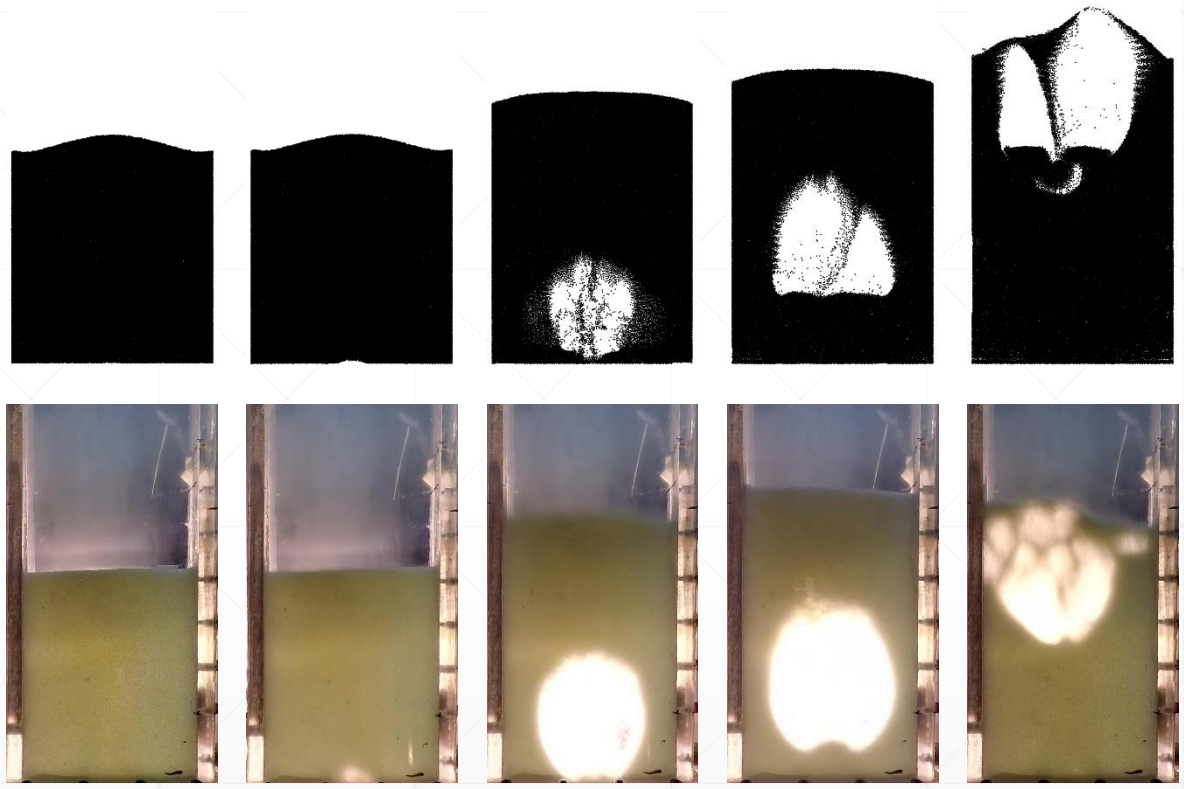
Drag force: Koch-Hill model
Contact forces: Hertzian contact model

- Geometry was generated by GAMBIT
- LIGGGHTS and OpenFoam were utilized to run the simulation
- 463000 particles were simulated in this work

Validation

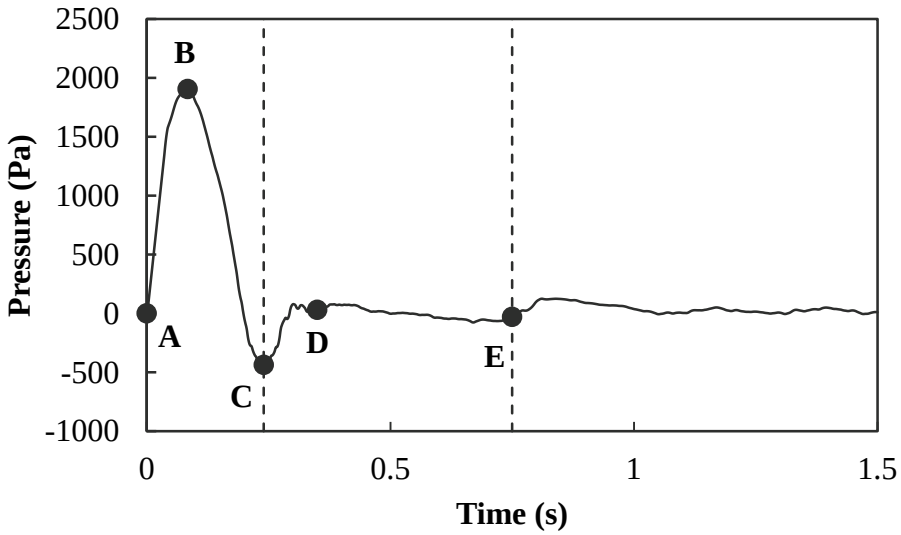


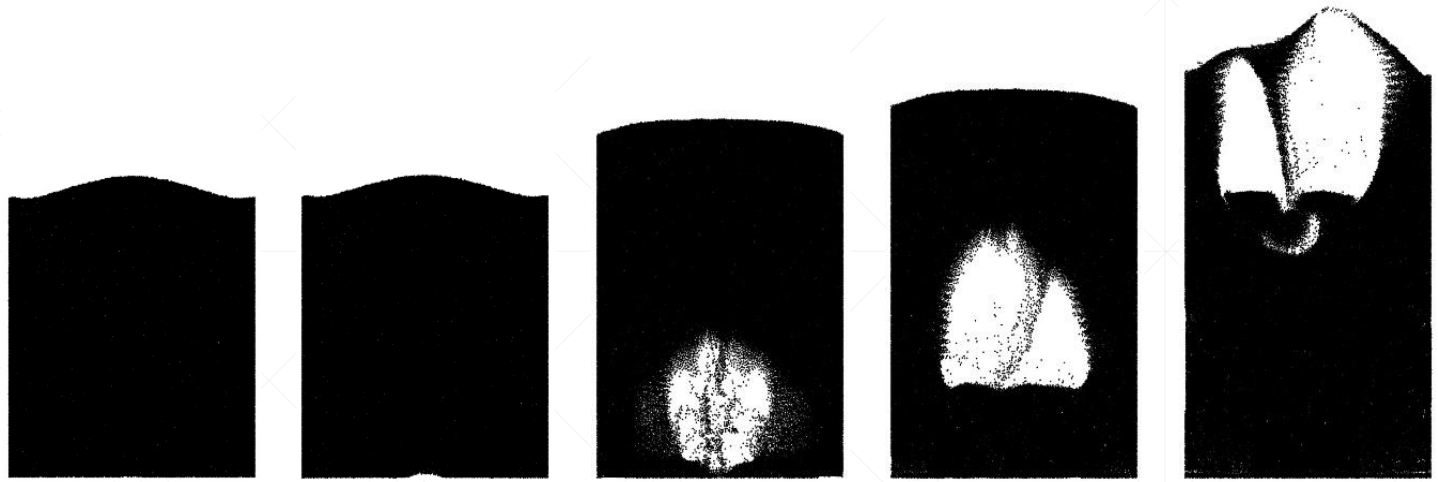




t = 0 s Point A | t = 0.085 s Point B | t = 0.23 s Point C | t = 0.35 s Point D | t = 0.75 s Point E

Pressure signal





t = 0 s — Point A

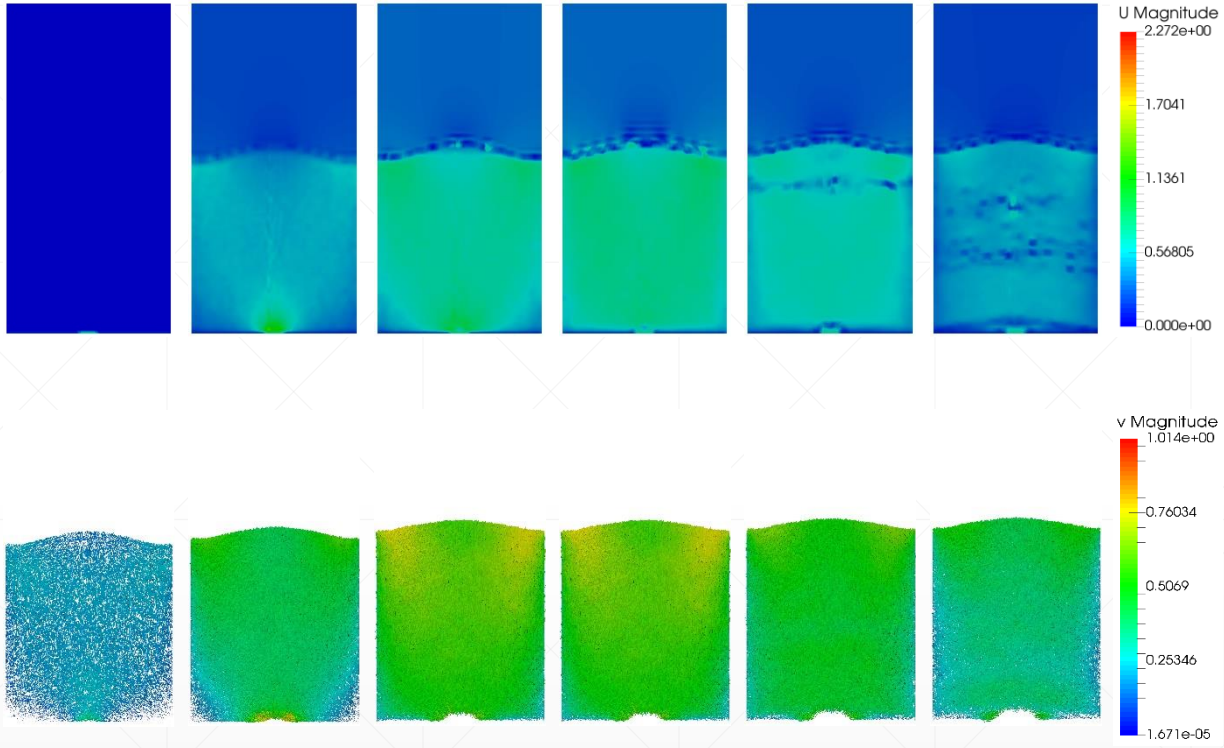
t = 0.085 s — Point B

t = 0.23 s — Point C

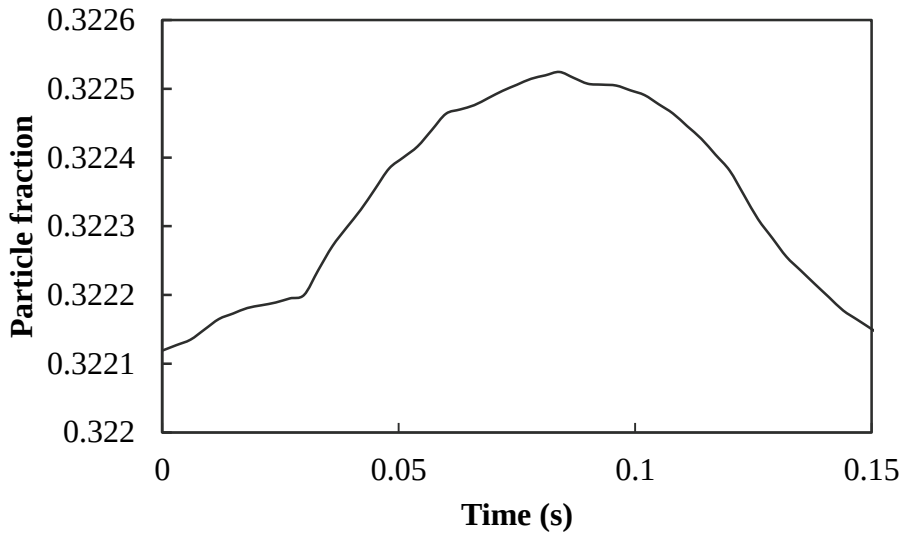
t = 0.35 s — Point D

t = 0.75 s — Point E

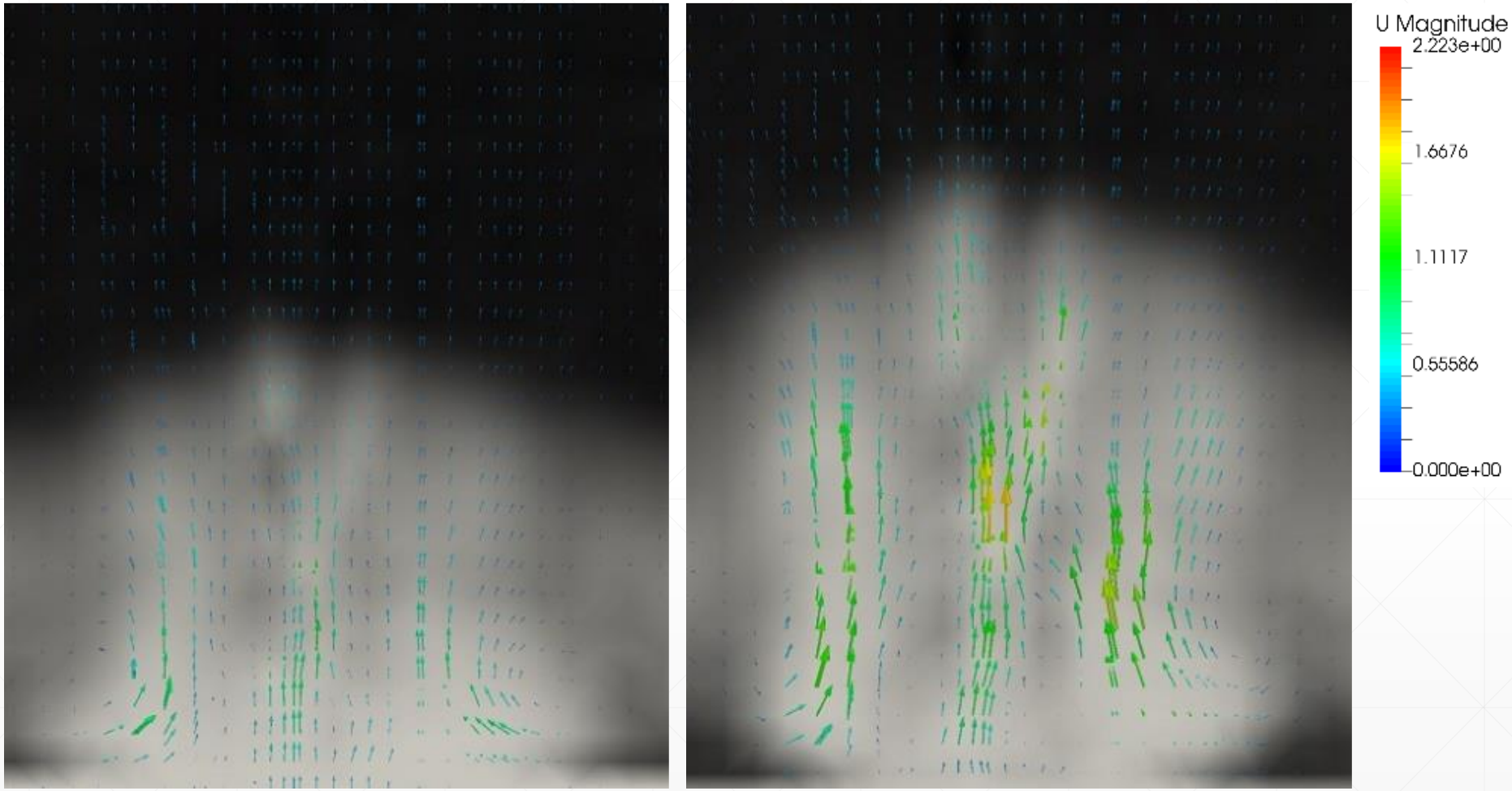
Formation stage



t=0 s t=0.03 s t=0.0575 s t=0.085 s t=0.1125 s t=0.14 s

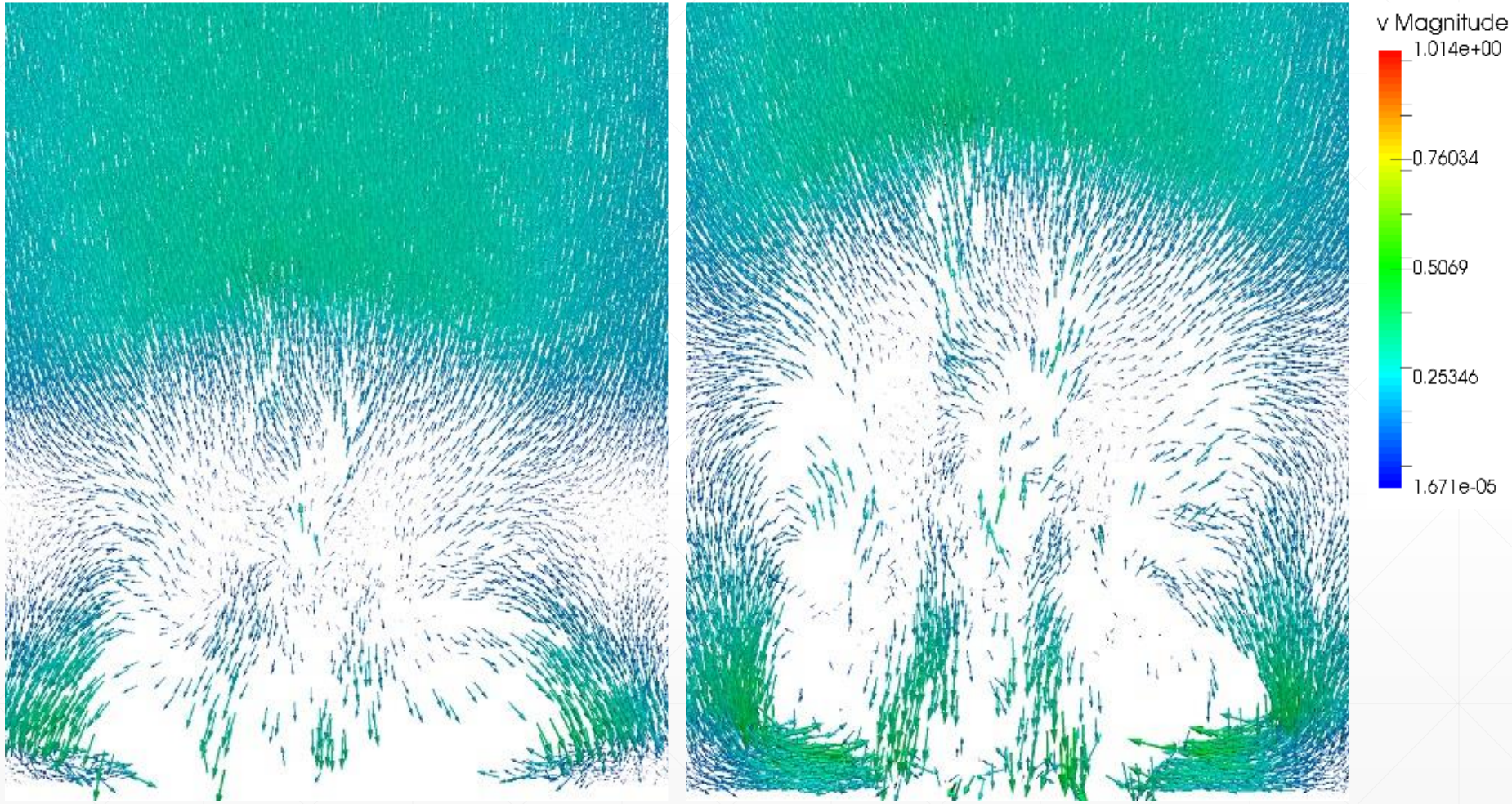


Gas velocity profile inside the bubble, formation stage



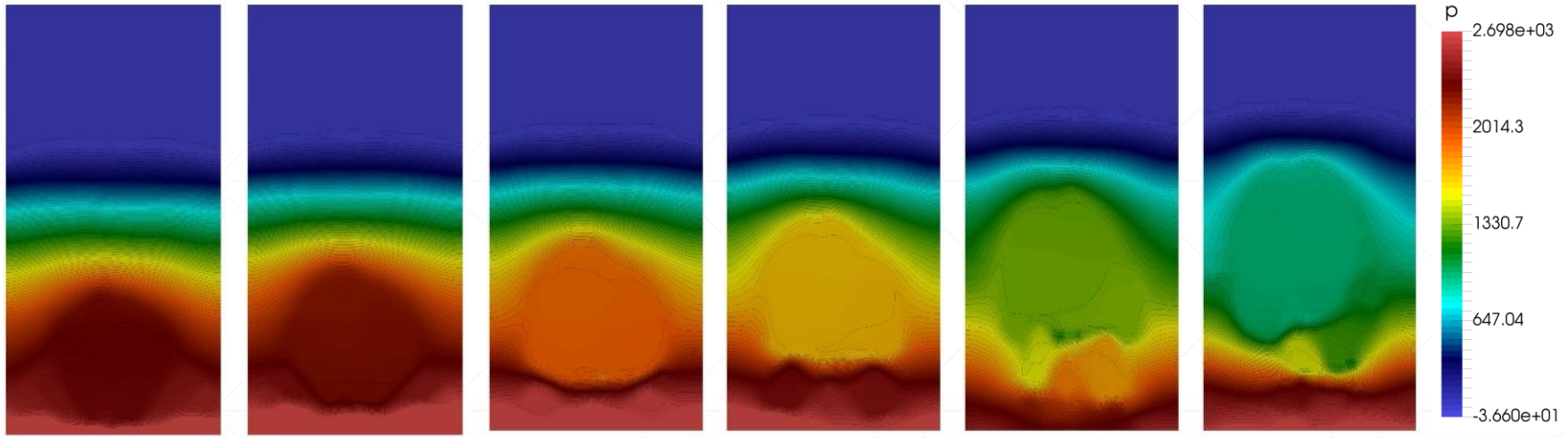
(a) t=0.15 s **(b) t=0.19 s**

Particle velocity profile inside the bubble, formation stage



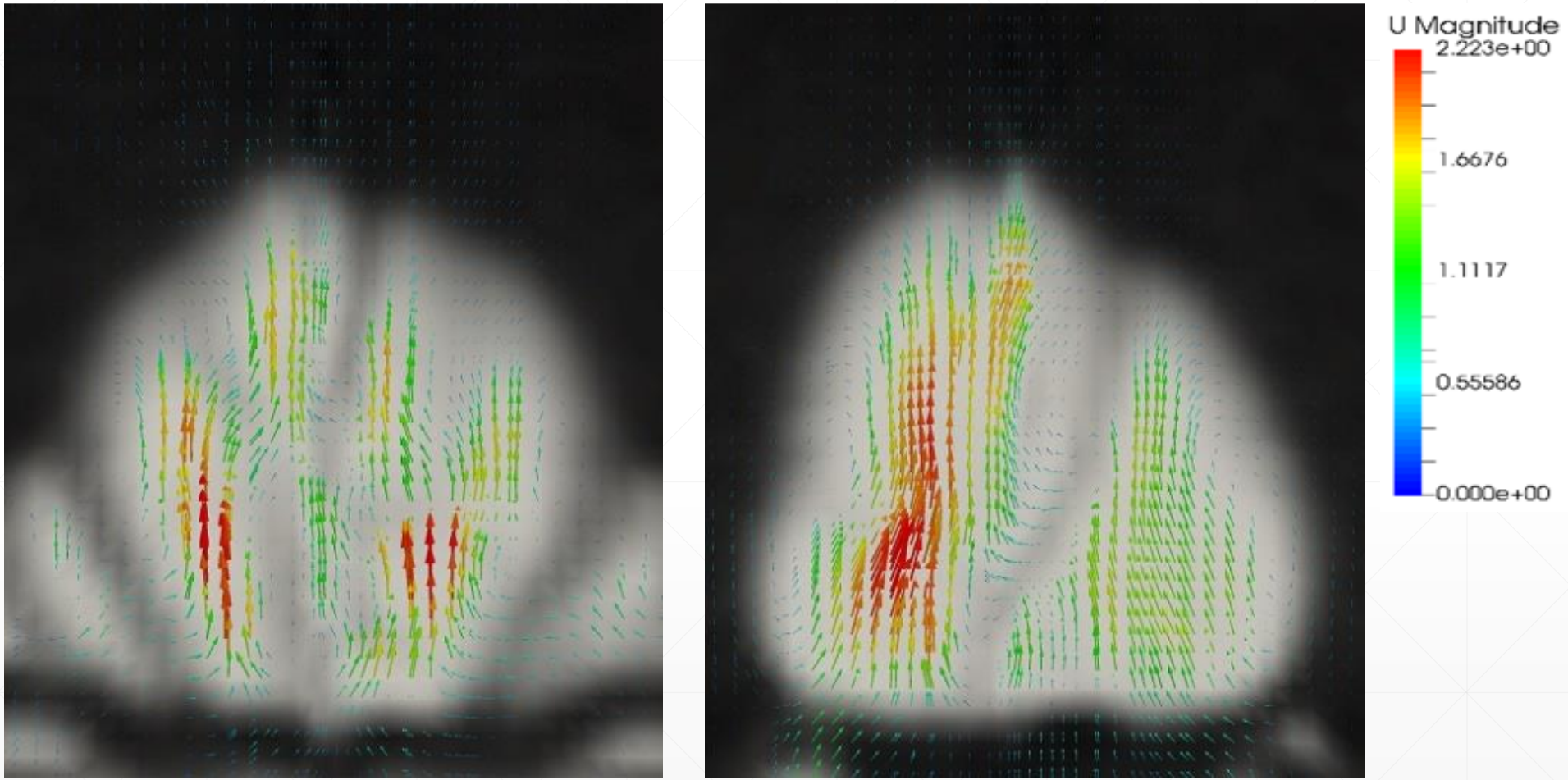
(a) t=0.15 s **(b) t=0.19 s**

Rising stage



t = 0.2425 s t = 0.2716 s t = 0.3175 s t = 0.355 s t = 0.3925 s t = 0.43 s

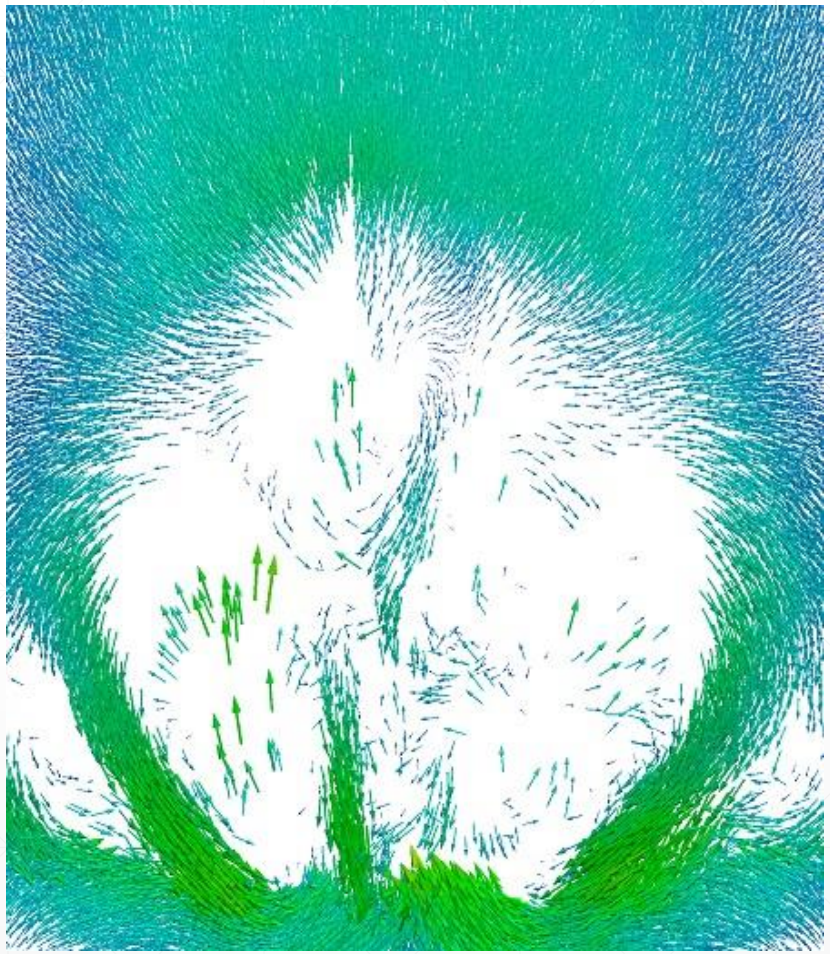
Gas velocity profile inside the bubble, rising stage



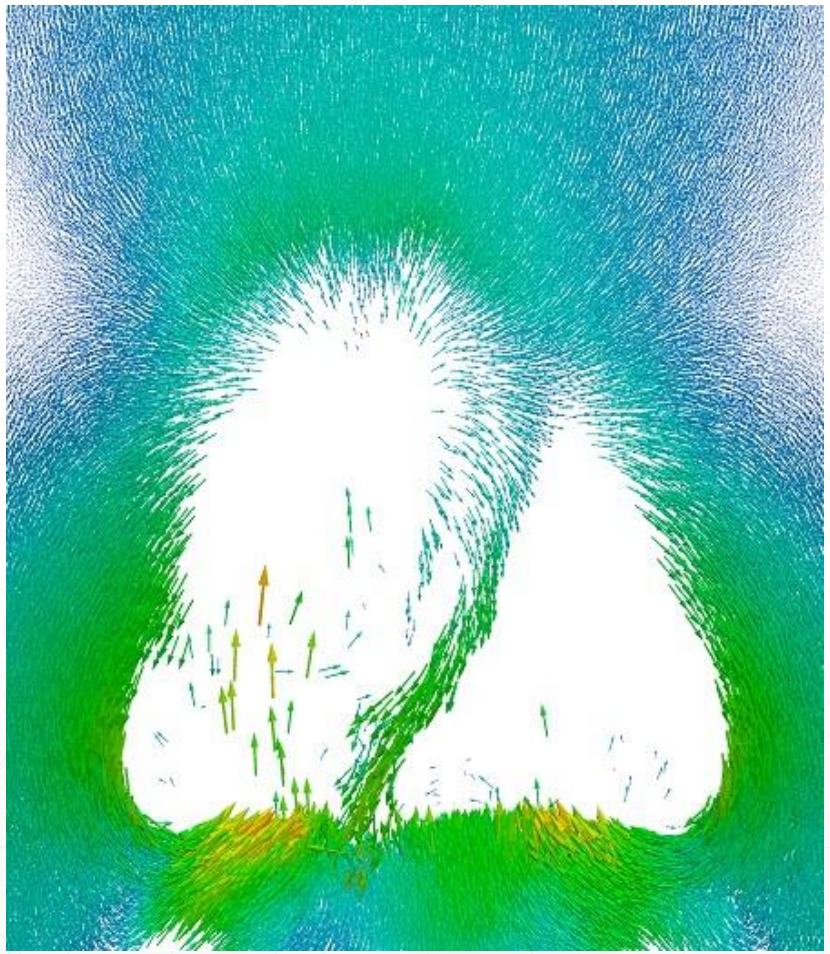
(c) t=0.28 s

(d) t=0.38

Particle velocity profile inside the bubble, rising stage

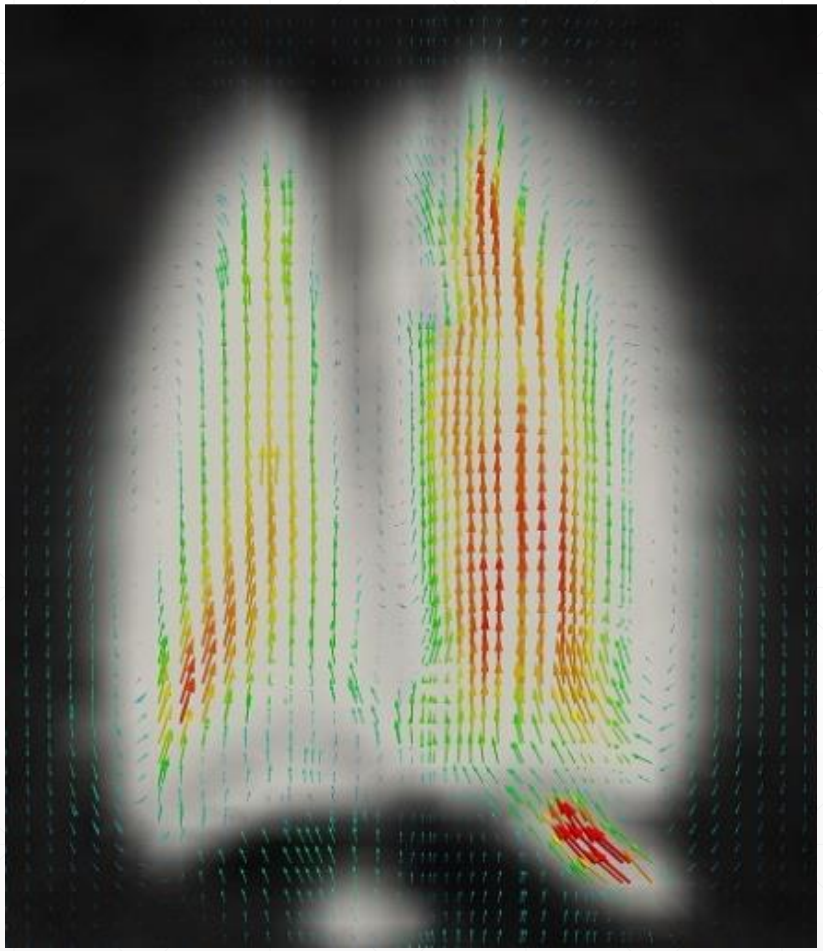


(c) t=0.28 s

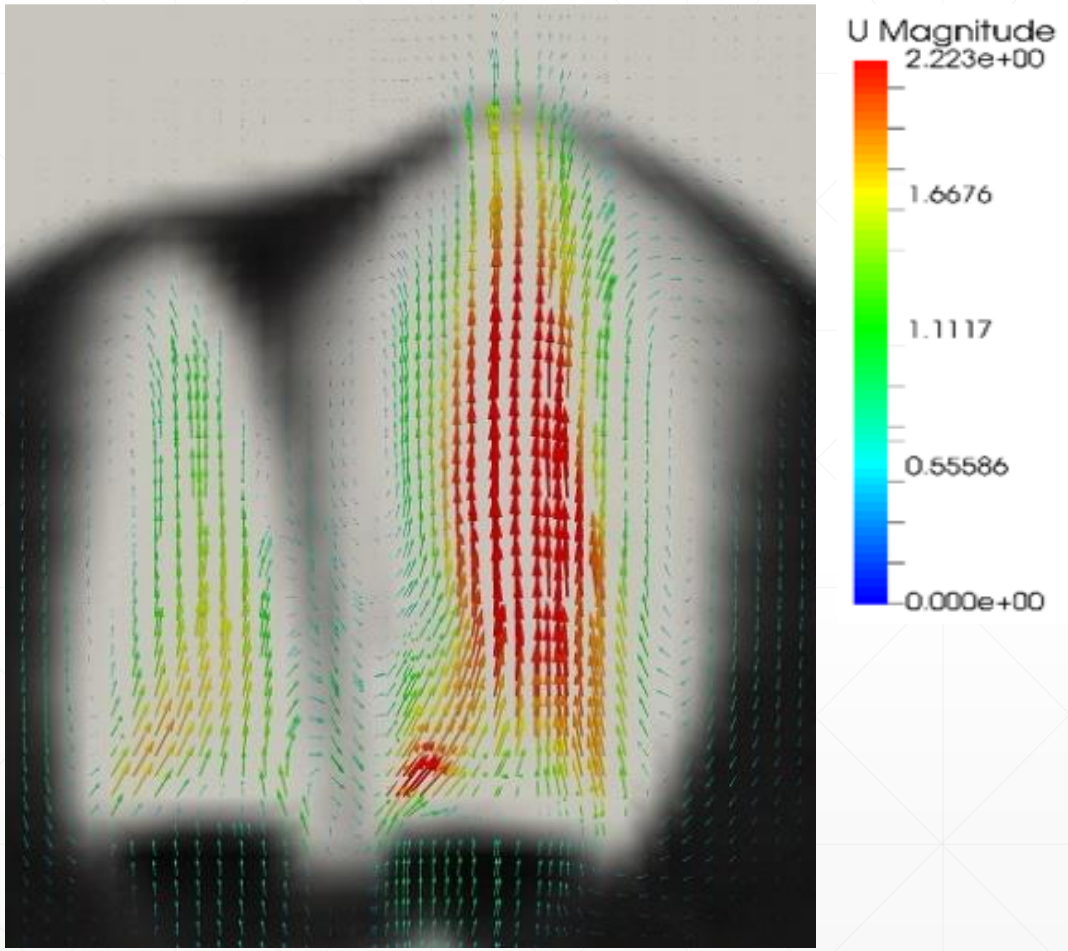


(d) t=0.38 s

Gas velocity profile inside the bubble, eruption stage

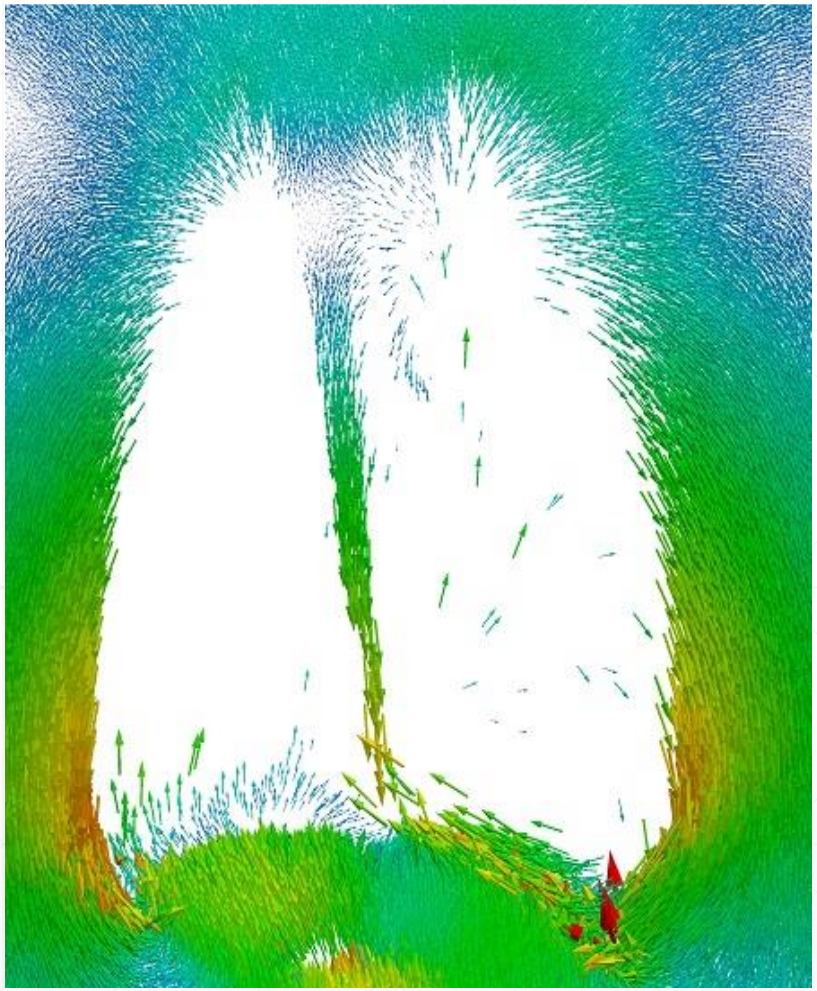


(e) t=0.59 s

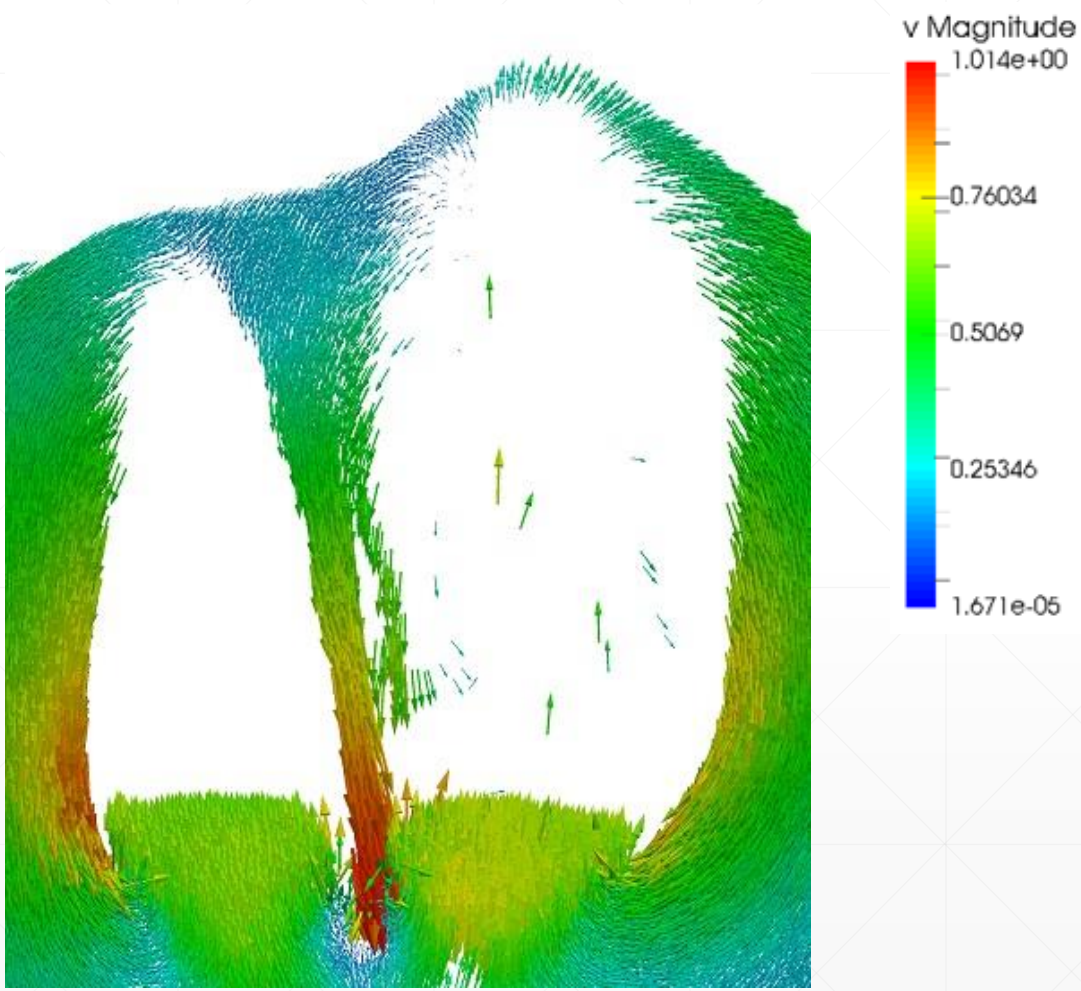


(f) t=0.72 s

Particle velocity profile inside the bubble, eruption stage



(e) t=0.59 s



(f) t=0.72 s

Conclusions

- Different stages of life of a single bubble, from formation to eruption, was simulated by CFD-DEM
- Model was validated with experimental results
- Pressure signal was obtained and discussed in three different stages
- Particle and gas velocity profile inside and outside of a single bubble in different stages was studied

Any question?

Thanks for your attention