THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Micro-Scale Simulation of Bubble-Water Flow in Coal Seam Gas Reservoirs by Lattice Boltzmann Method

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1. Background and research objectives

➢ Background

The gas/water two-phase flow in cleat networks has been a critical issue in coal seam gas (CSG) reservoirs. A key parameter affecting the flow of gas in coal cleats is the wetting potential of gas/water (Li et al., 2012; Zhang et al., 2015). However, our understanding of wettability effects on gas flow still needs further research.

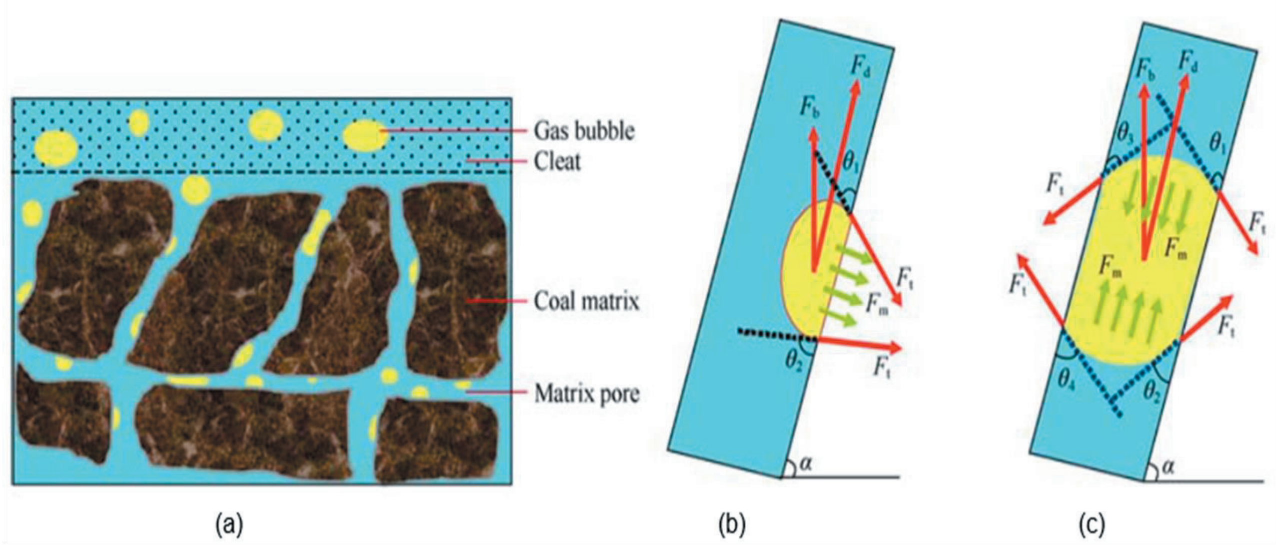


Fig. 1 Schematic diagram of the distribution and force analysis of gas bubble and gas column in capillary tubes (Xiangfang Li et al., 2012).

➢ Main objectives

This research seeks to understand the gas flow behaviours in cleats, and the main objectives are:

- To build a LBM model to simulate bubble-water dynamics at pore scale;
- To analyse the effects of wettability and capillary pressure on gas-water flow capacity.

2. Wettability

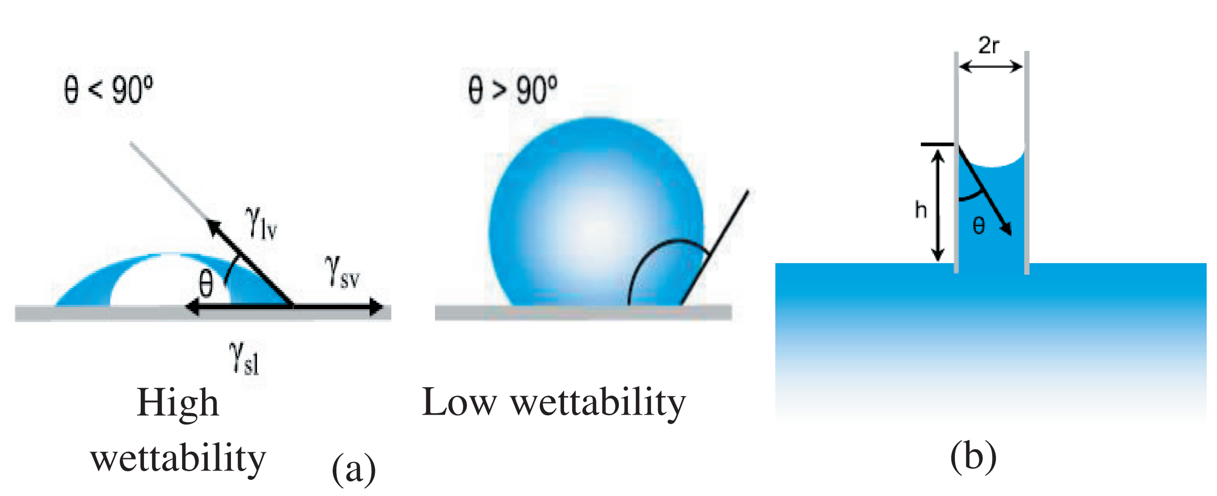


Fig. 2 Schematic diagram of (a) contact angle and (b)capillary imbibition phenomenon (http://www.reservoirengineering.org.uk)

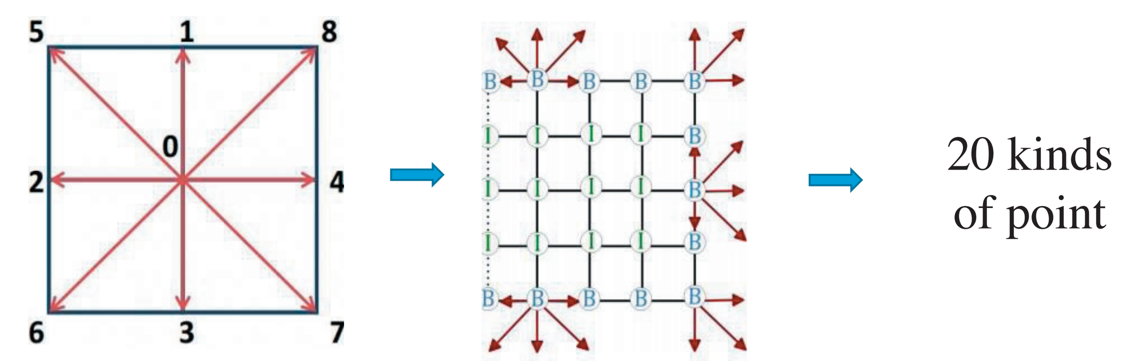
3. Methodology

➢ Lattice Boltzmann equations

$$g_i(\boldsymbol{x}+\boldsymbol{e}_i\delta t, t+\delta t) = g_i(\boldsymbol{x},t) + (1-q)[g_i(\boldsymbol{x}+\boldsymbol{e}_i\delta t, t) - g_i(\boldsymbol{x},t)] + \frac{g_i^{eq}(\boldsymbol{x},t) - g_i(\boldsymbol{x},t)}{\tau_\phi}$$

$$f_i(\boldsymbol{x}+\boldsymbol{e}_i\delta t, t+\delta t) = f_i(\boldsymbol{x},t) + \frac{f_i^{eq}(\boldsymbol{x},t) - f_i(\boldsymbol{x},t)}{\tau_n} + \left(1-\frac{1}{2\tau_n}\right)\frac{w_i}{c_s^2}\left[\boldsymbol{e}_i - \boldsymbol{u} + \frac{(\boldsymbol{e}_i\cdot\boldsymbol{u})}{c_s^2}\boldsymbol{e}_i\right]\cdot(\mu_\phi\nabla\phi + \boldsymbol{F}_b)\delta t$$

➢ To distinguish different points on the fluid/solid interaction



4. Benchmark

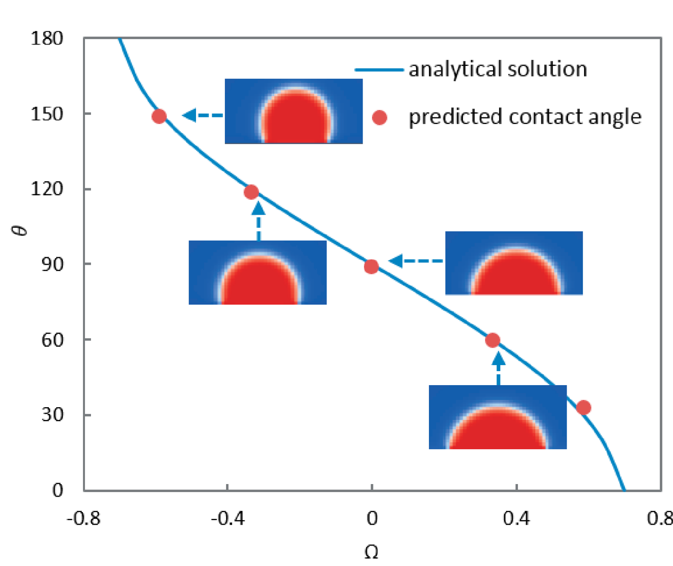


Fig. 3 The verification of the wetting boundary condition

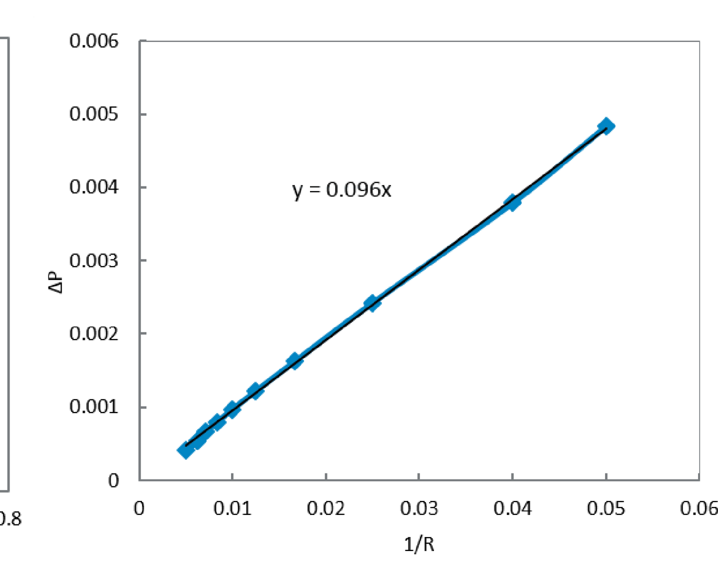


Fig. 4 The verification of the Laplace law

$(a)\ E_o = 5, M = 0.2267$ $(b)\ E_o = 10, M = 0.453$ $(c)\ E_o = 20, M = 0.907$

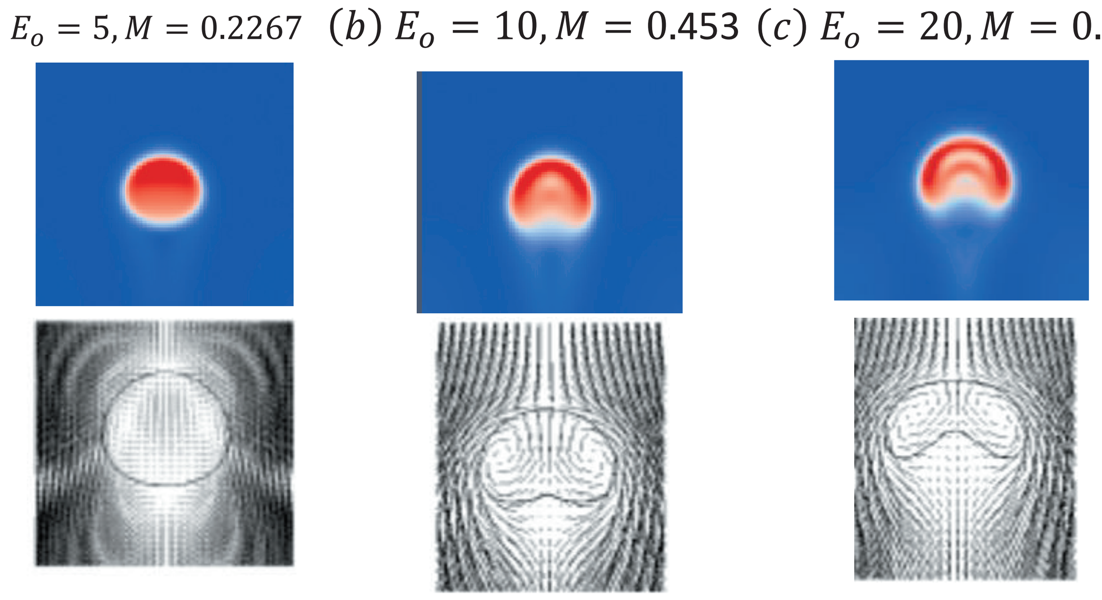


Fig. 5 Bubble shapes under different buoyancy force. This model (top) Naoki Takada model (bottom).

5. Simulation results and conclusions

➢ Simulation results

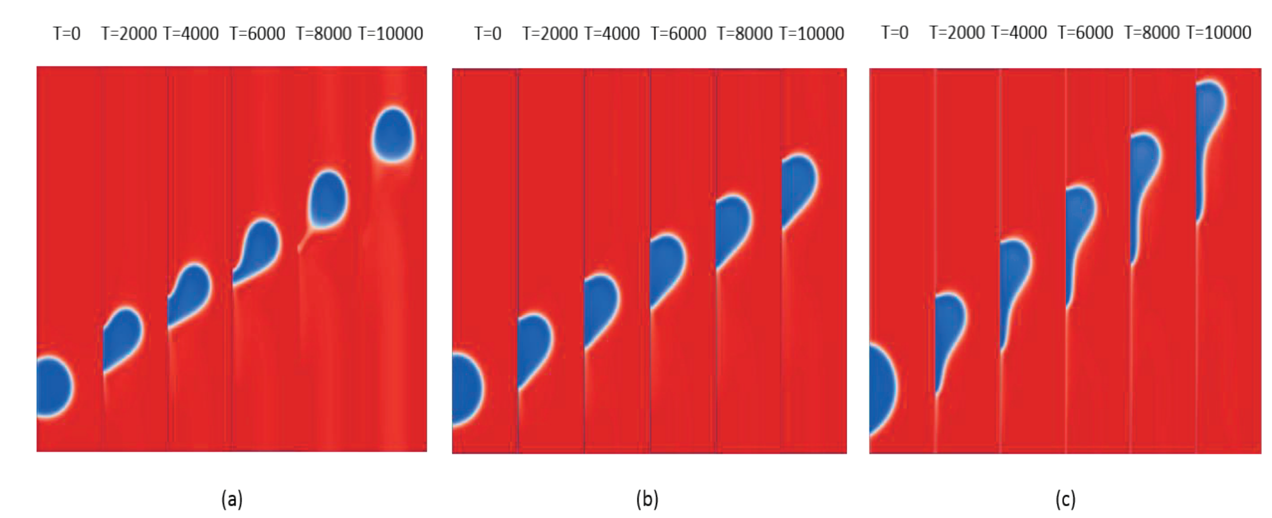


Fig. 6 Dynamic behaviour of bubble-water flow in a single cleat with different contact angles: (a) 68°, (b) 90°, (c) 112°

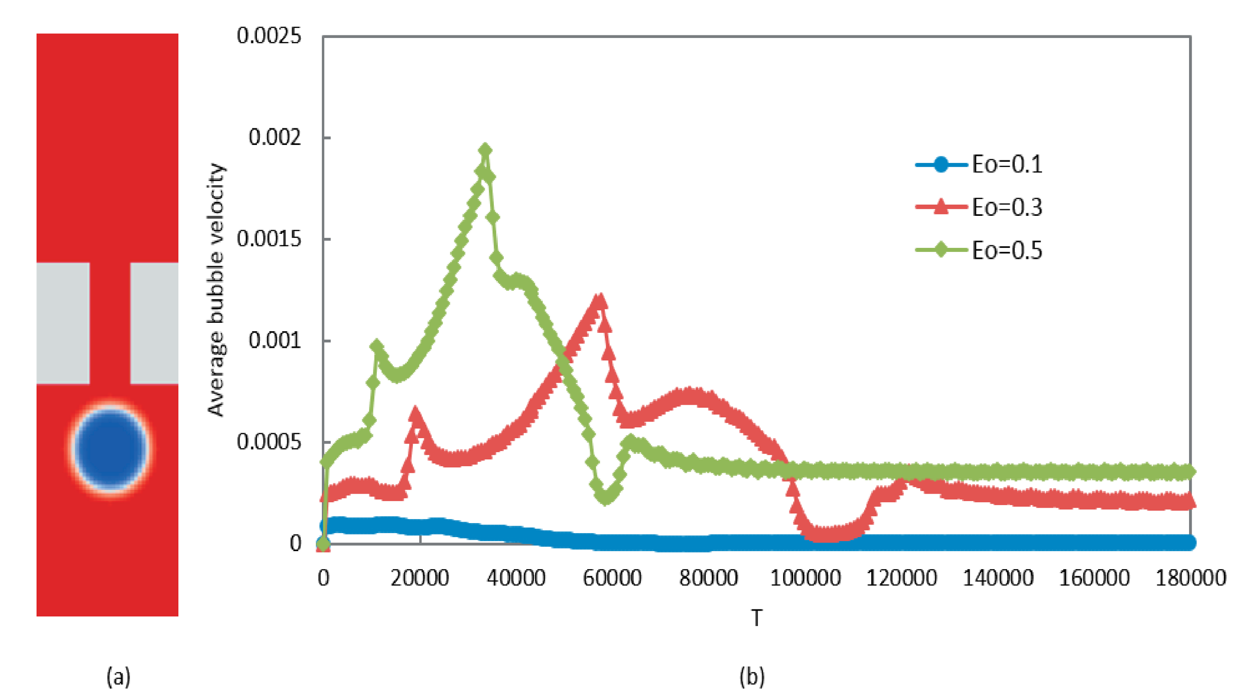


Fig. 7 (a) Schematic illustration of simulation geometry (the red, blue and white are water, gas and solid, respectively); (b) Evolution of average velocity of bubble with different drag forces

➢ Conclusions

- For different contact angles, the gas bubble shape and movement are significantly different, which means the relative permeability highly depends on wettability of coal.
- For bubble-water flowing in a cleat with a narrow throat, the capillary pressure plays an important role in determining the fluid flow capacity.
- These phenomena are likely to have significant impacts on drainage rates and relative permeability within a coal seam.

Acknowledgements

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