# Pore-Scale Simulations of Bubble-Water Flow in Coal Seams by Lattice Boltzmann Method

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## BACKGROUND AND RESEARCH OBJECTIVES

### Background

A key parameter affecting the flow of gas in coal cleats is the wetting potential of gas/water. However, how wettability affects gas flow still needs further research.

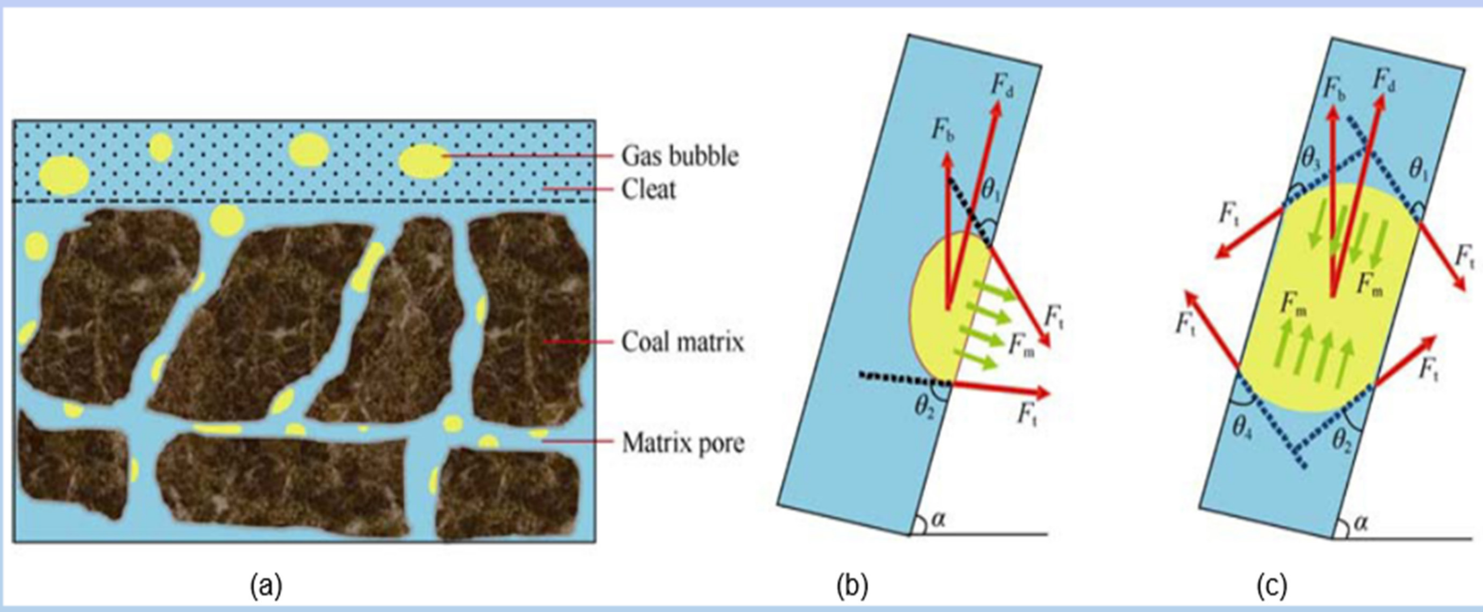



**Fig. 1** Schematic diagram of the distribution and force analysis of gas bubble and gas column in capillary tubes (Xiangfang et al., 2012).

### Main objectives

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

## METHODS

The model is based on a free energy model proposed by Swift et al. in 1996.

### Main components of the model

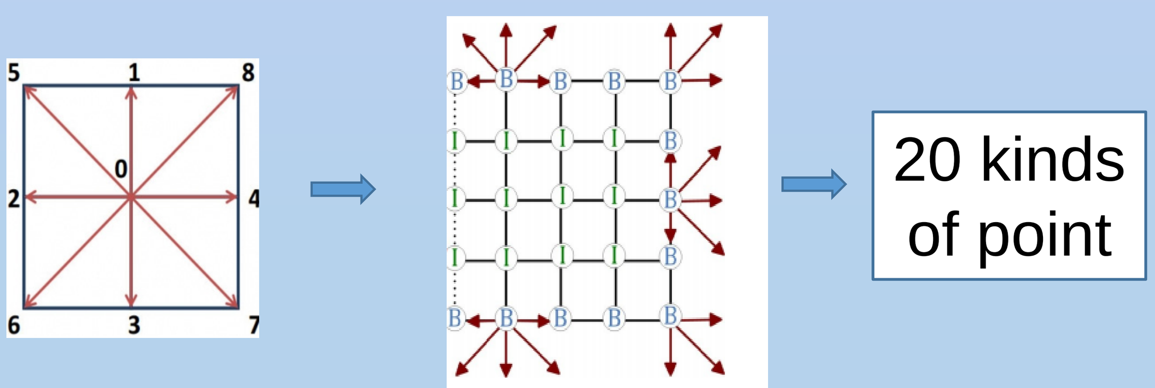
The interface capturing equation:

$$g_i(\boldsymbol{x}+\boldsymbol{e}_i\delta t, t+\delta t) = g_i(\boldsymbol{x}, t) + (1-q)[g_i(\boldsymbol{x}+\boldsymbol{e}_i\delta t, t) - g_i(\boldsymbol{x}, t)] + \Omega_i$$

The momentum equation:

$$f_i(\boldsymbol{x}+\boldsymbol{e}_i\delta t, t+\delta t) = f_i(\boldsymbol{x}, t) + \Omega_i$$

### To distinguish different points on the fluid/solid interaction




### To deal with the corner points

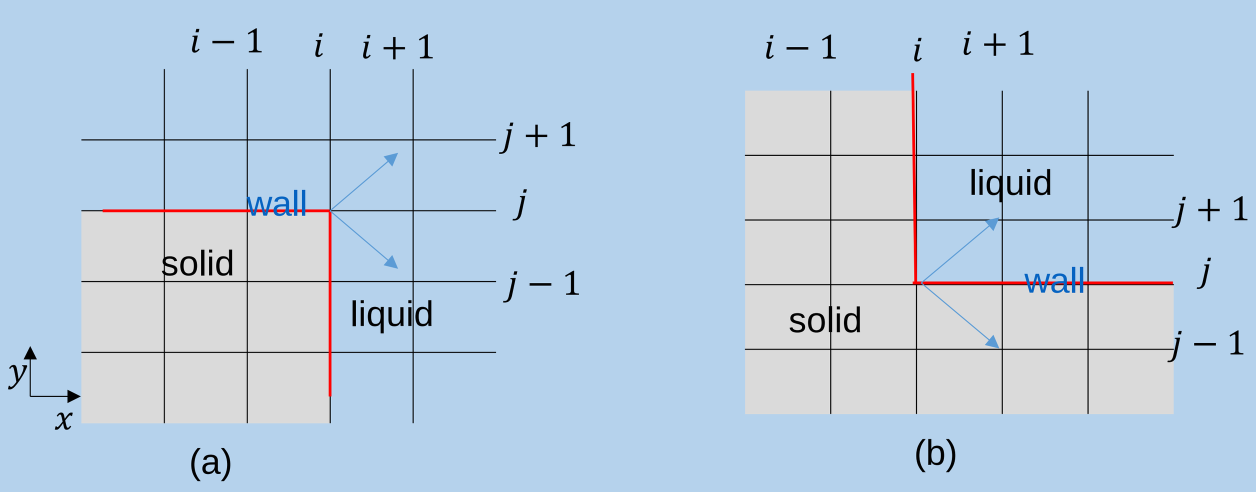



**Fig. 2** Transition nodes at the intersections of two orthogonal walls: (a) convex (b) concave

## BENCHMARK

### Single bubble rising under buoyancy

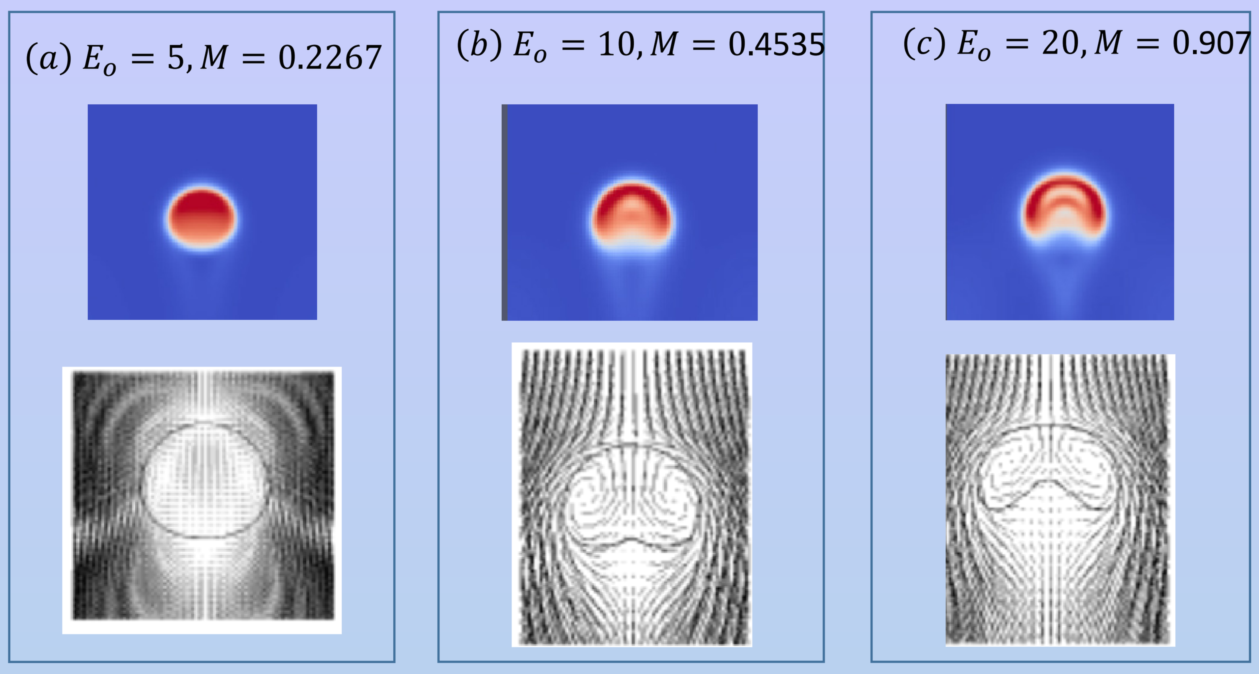
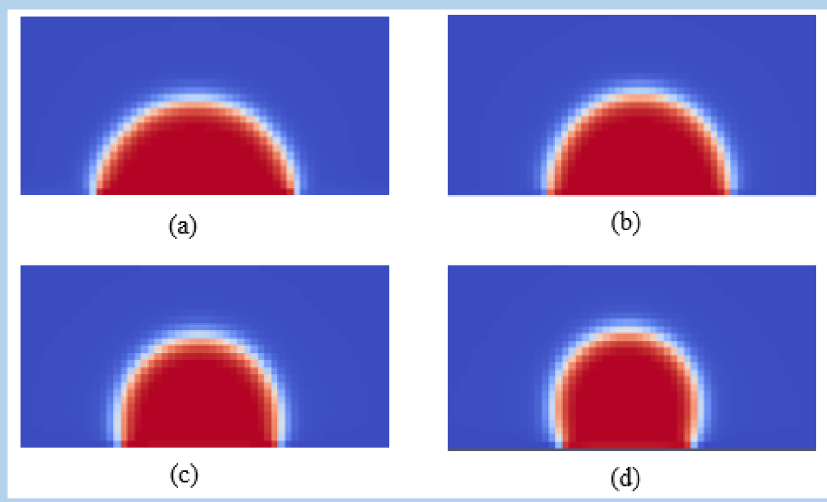



**Fig. 3** Bubble shapes under different buoyancy force. This model (top) Naoki Takada model (bottom)

### Wetting contact angle




The calculated $\theta$ and the simulated $\theta^\alpha$ are:

$(a)\ \theta = 60^\circ, \theta^\alpha = 62.1^\circ$;
$(b)\ \theta = 90^\circ, \theta^\alpha = 91.7^\circ$;
$(c)\ \theta = 120^\circ, \theta^\alpha = 121.3^\circ$;
$(d)\ \theta = 150^\circ, \theta^\alpha = 148.6^\circ$

**Fig. 4** Different contact angle obtained through numerical simulations. The red and blue are water and gas respectively.

## SIMULATION AND RESULTS

### Simulation

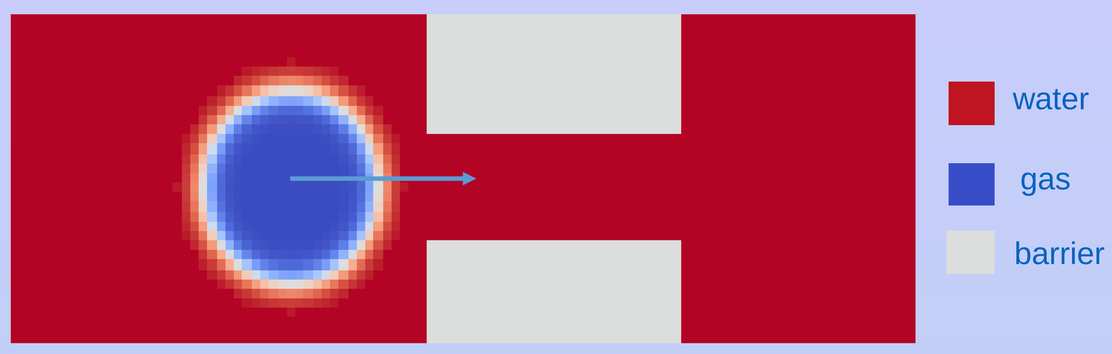



**Fig. 5** Gas bubble flow through a narrow channel

The drag force $F$ is fixed.
The contact angle is changed from $45^\circ$ to $120^\circ$.

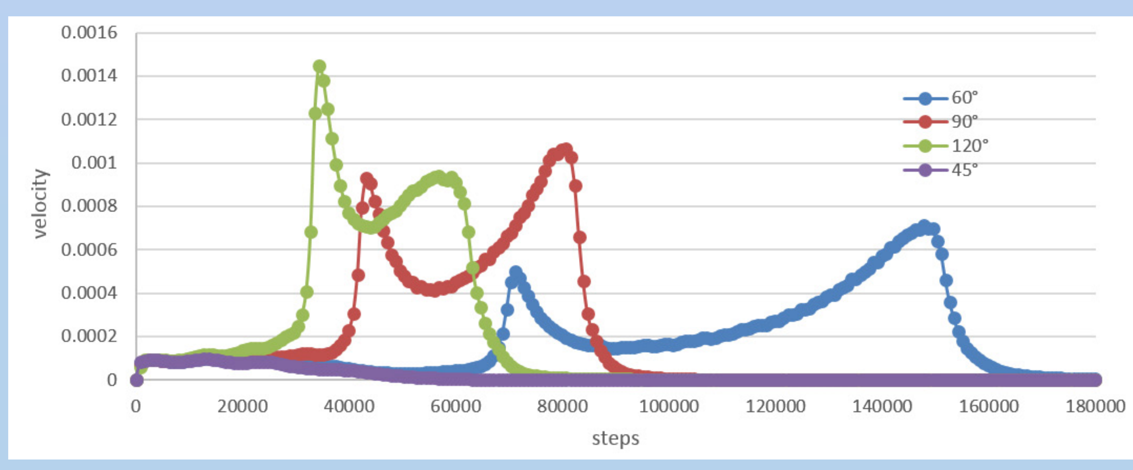



**Fig. 6** The gas flow velocity under different contact angle

### Results

The simulation results indicate that the wettability of water has significant impacts on the flow capacity of gas bubble. An increase of bubble velocity is observed when the surface changes from water wet to gas wet. The bubble flow process significantly influences the drainage of water and the further gas production.

ACKNOWLEDGEMENT

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