Appendix A

We simulated the fluid flow between two parallel plates filled with a porous medium which is a homogeneous material with a uniform porosity ε and permeability K. In the simulation, the computational grid is 100×100, the relaxation time τ is 0.8, and the viscosity ratio J is assumed to be unity. The flow is driven by a pressure difference, and a nonslip boundary condition is applied to both the top and bottom walls. Firstly, we suppose there was only one single component fluid flow in the media, then the nonlinear resistance forces (the second term in Eq.3 of the paper) can be ignored due to the fluid flow is weak and the inertial is disappeared. Consequently, the flow at steady state can be described by the Brinkman- extended Darcy equation

$$\frac{\nu_e}{\varepsilon}\frac{\partial^2 u}{\partial y^2}-\frac{\nu}{K}u+G=0$$

with u(x, 0)= 0 and u(x, H)= 0; the analytical solution can be given by

$$u=\frac{GK}{\nu}\left(1-\frac{\cosh[r(y-H/2)]}{\cosh(rH/2)}\right),\quad r=\sqrt{\nu\varepsilon/K\nu_e}$$

where H is the width of the field, and cosh is the hyperbolic function with

$\cosh(x)=(e^x+e^{-x})/2$.

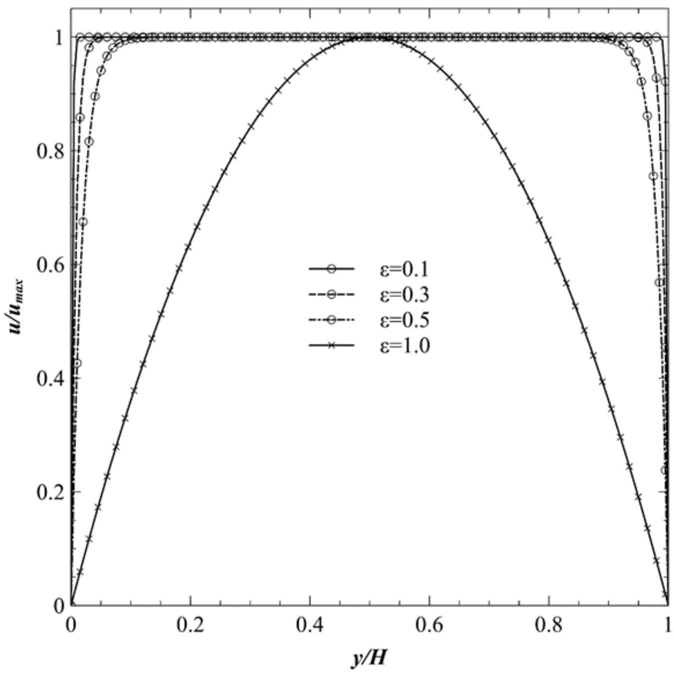


Figure 1 Simulation results of porous flow between plates. The velocity profiles of a single-component fluid flow without mass transfer, ignoring the nonlinear drag force term. Note that velocity u was normalized by the maximum velocity at the centerline of the channel u_{max}.

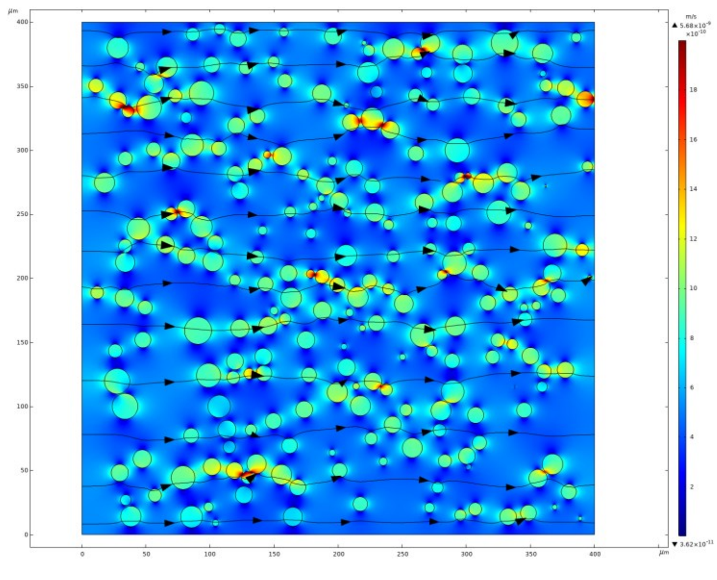
The velocity profiles are detailed in Figure 1(a). When the porosity is 1.0, the fluid flow between the two plates is the free flow due to the porous material being absent. The results are consistent with the analytical solution of the typical plane Poiseuille flow. Owing to the existence of porous media, with the reduction in porosity, the velocity profiles will be more flattened, which is in good agreement with the solution of the Brinkman-extended Darcy equation.

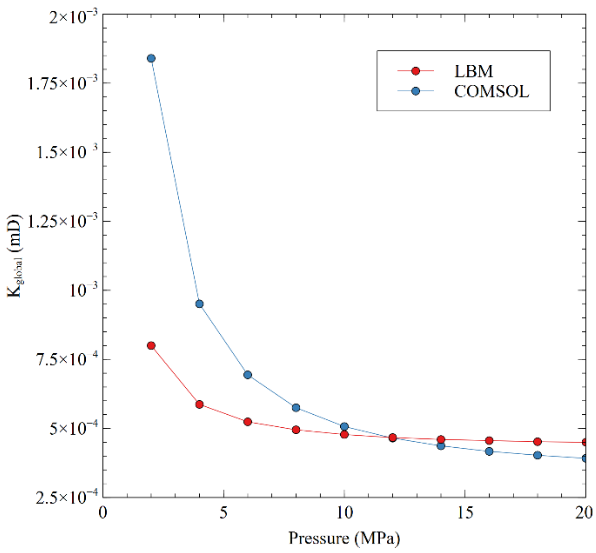
Then, the diffusion field with adsorption effect is added for the validation of the coupling system. In this case, the diffusion coefficient is 1/3, and a constant concentration C_0=1 is set at the inlet; the initial concentration of the rest of the field is 0, the saturation adsorption capacity is 3, the desorption rate constants are set to 0.005, 0.01, 0.015, and 0.02, and the adsorption rate constant is fixed at 0.05. It is worthwhile mentioning that the nonlinear resistance forces should be included due to the system involving mass transfer through the fluid-solid interface.

Figure 1(b) displays the relationship between the concentration and the adsorbed amount of the coupled flow with both fluid flow and gas diffusion. At a fixed value of concentration, the higher the Langmuir pressure, the lower the adsorbed amount, which can be supported by the solution of a typical Langmuir adsorption isothermal equation. All the simulation results are in good agreement with the analytical solution in Figure 5, which ensures the validation of the present model.

Appendix B

We used the Finite Element software COMSOL Multiphysics to simulate the methane flow in the coal matrix. The “Darcy’s Law” module is employed in the simulation. The coal matrix contains OM and IOM, the IOM contents were consistent with the paper (34%), which are randomly generated by “COMSOL with MATLAB” module base on a random reconstruction algorithm for porous media. The permeability of OM and IOM were calculated according to the apparent permeability model in the paper, which considers the non-Darcy effect. The other parameters were shown in Tab.1, and the results were shown in Fig.2.





(a) (b)

Figure 2 Comparison of the results of LBM and COMSOL

Fig.2(a) shows the velocity distribution under pressure at 6MPa. Fig.2(b) shows the variation of global permeability under different pressure. Due to the governing equation employed in LBM and COMSOL were different, these two sets of results show a slight difference. Due to the COMSOL simulation of methane flow in three-component porous media involves the coupling of multiple physical fields and complex boundary conditions, it is remained unresolved and has to left for further study.