A packed bed methodology to study the effect of coal surface wettability on relative permeability using a steady-state core flooding apparatus

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Abstract

The relative permeability behaviours of gas and water in coal are primary factors in the productivity of a coal seam gas reservoir. To observe the effect of a range of surface wettability cases on relative permeability we prepared the following packed cores from Dawson Mine coal powders:

a) untreated coal

b) hydrogen peroxide treated coal powder (hydrophilic)

c) silane treated coal powder (hydrophobic).

Wettability was characterised using a falling particle method to determine the distributions of contact angles in each sample (63°, 56° and 89°, respectively - Figure 1). Homogeneous artificial coal cores were produced by pressing coal powders (particle size range of 53 - 212 µm) into 25 mm diameter and 25 mm long cylinders in a 10 tonne hydraulic press.

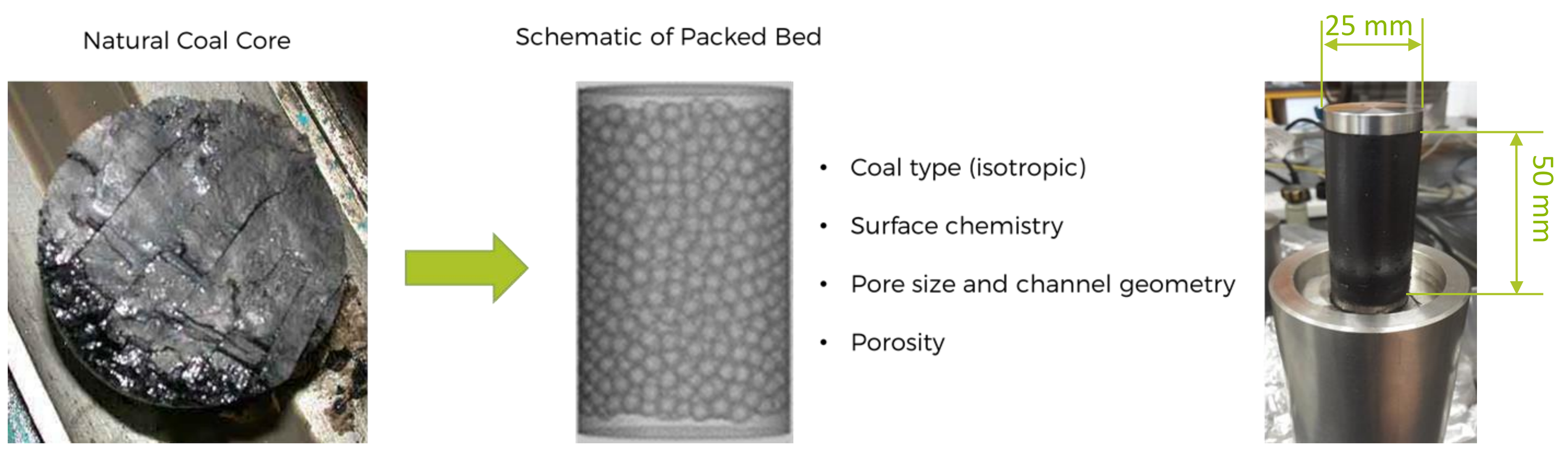
The porosities of the packed coal cores were 21.7 % in the untreated coal, 26.8 % in the coal oxidized in hydrogen peroxide and 26.3 % in the silane treated coal (determined from helium pycnometry and mercury porosimetry measurements). The absolute permeabilities measured in a Hassler type cell with a 4 %wt KCl brine at a confining stress of 70 bar were 0.93 ± 0.15 mD in the untreated coal, 1.24 ± 0.21 mD in the oxidized coal, and 0.98 ± 0.11 mD in the silane treated coal.

Research Aims

1. To improve predictions of effective permeability of gas and water in CSG reservoirs.

2. Study the effect of coal surface wettability on relative permeability by using packed beds that provide homogeneous, isotropic pore structure with controllable pore size and channel geometry.

3. Develop new laboratory measurement techniques to measure relative permeability in coal to allow systematic investigation of the effect of coal surface wettability, cleat geometry, cleat network and pressure.



Contact Angle Measurement

The wettability of these powders was characterised using a falling particle method (Fuerstenau and Diao, 1991) to determine the distributions of contact angles in each sample.

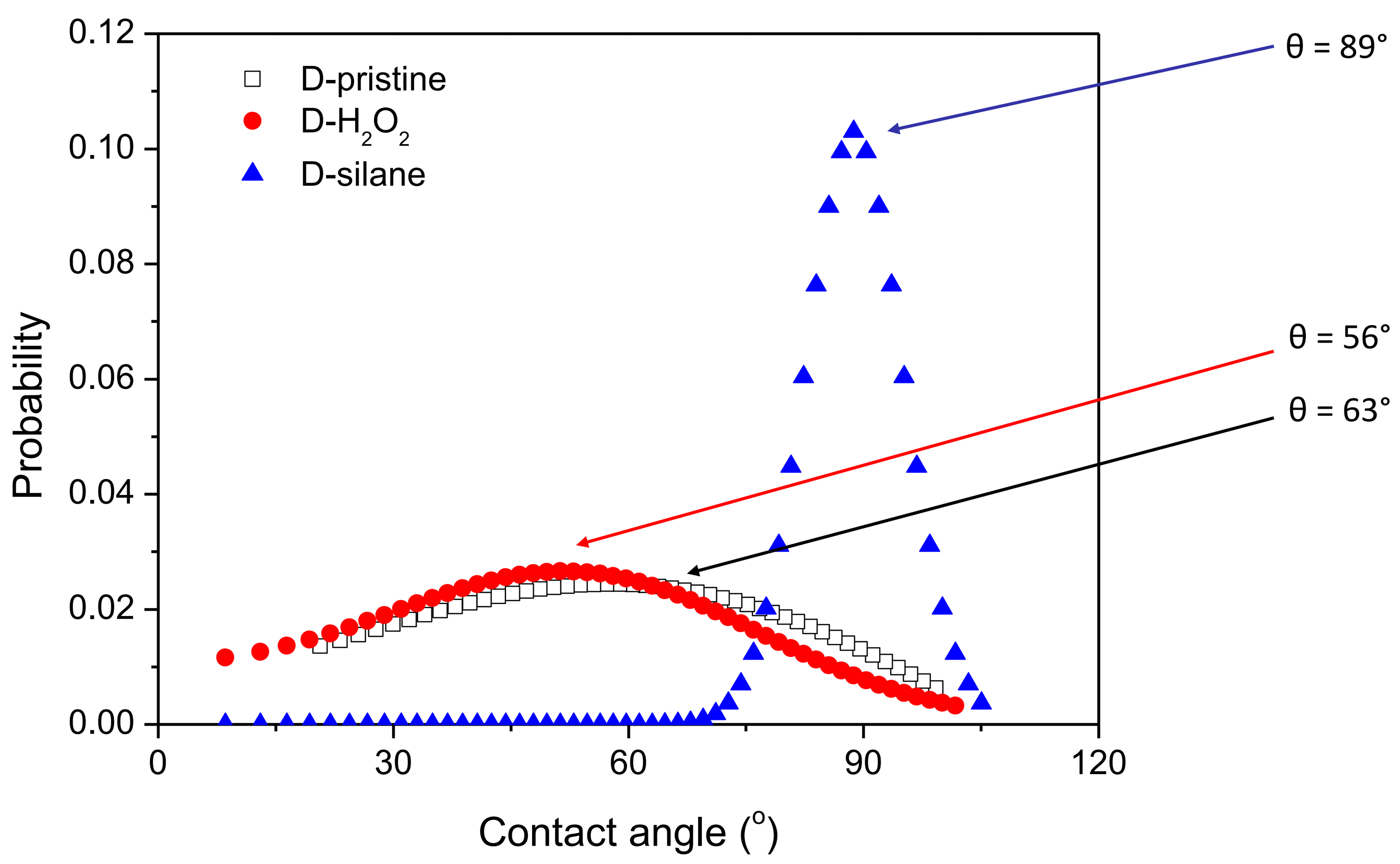


Fig. 1: Contact angle distribution of untreated coal and chemical treated coal powders using a falling particle method.

Packed Bed Pore Size Distribution

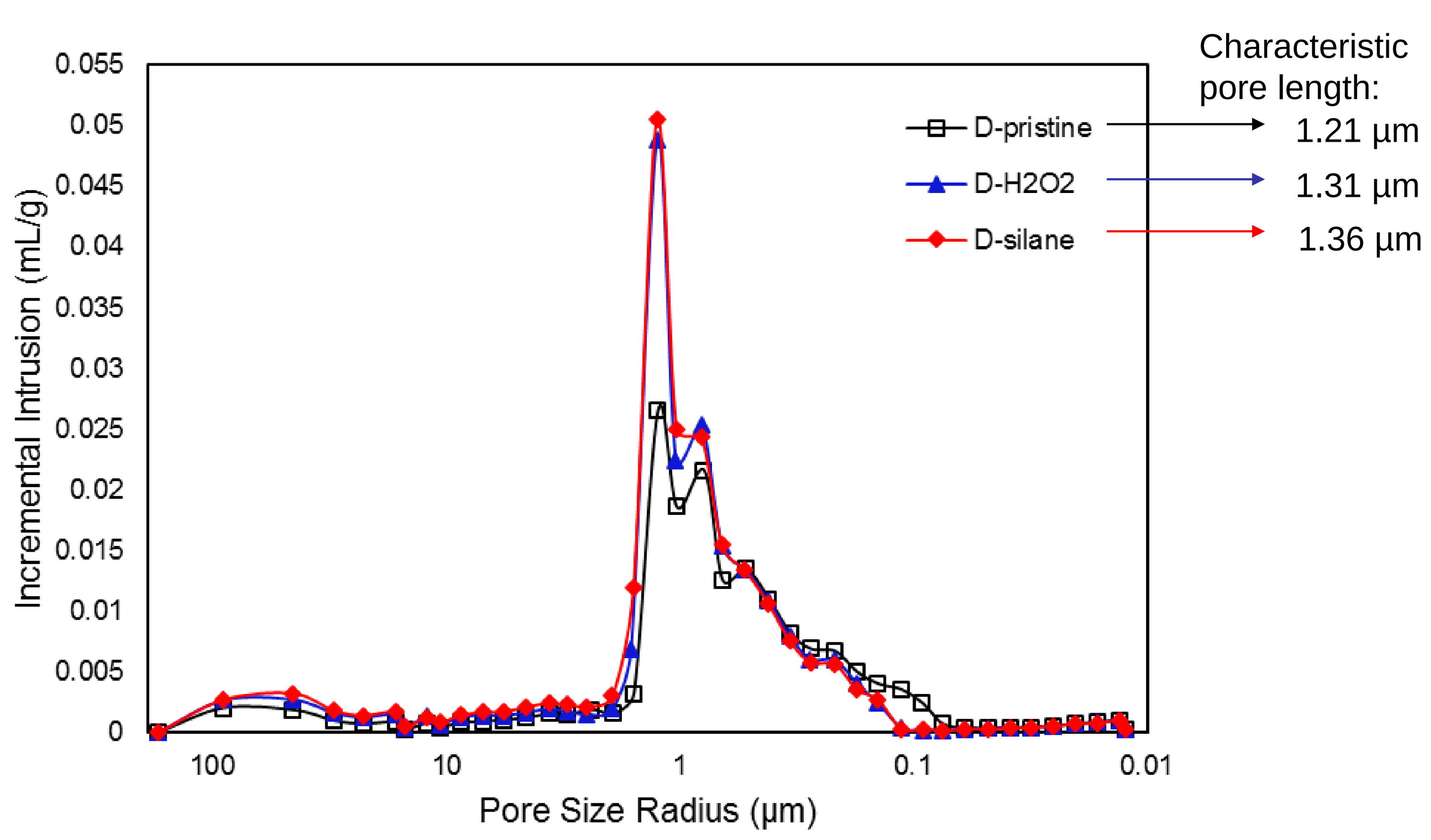


Fig. 2: Pore size distribution for untreated coal and chemical treated coal powders.

Core Flooding Results

Table 1: Artificial cores of untreated and chemical treated coals.

	Mass (g)	Length (mm)	Particle Size Range (µm)	Porosity (%)	Absolute Permeabilty (mD)	Effective Stress (bar)
D-pristine	30.0	52.2	53-212	21.7	0.93 ± 0.15	64.8
D-H_2O_2	29.2	49.5	53-212	26.8	1.24 ± 0.21	64.9
D-silane	30.5	53.7	53-212	26.3	0.98 ± 0.11	63.7

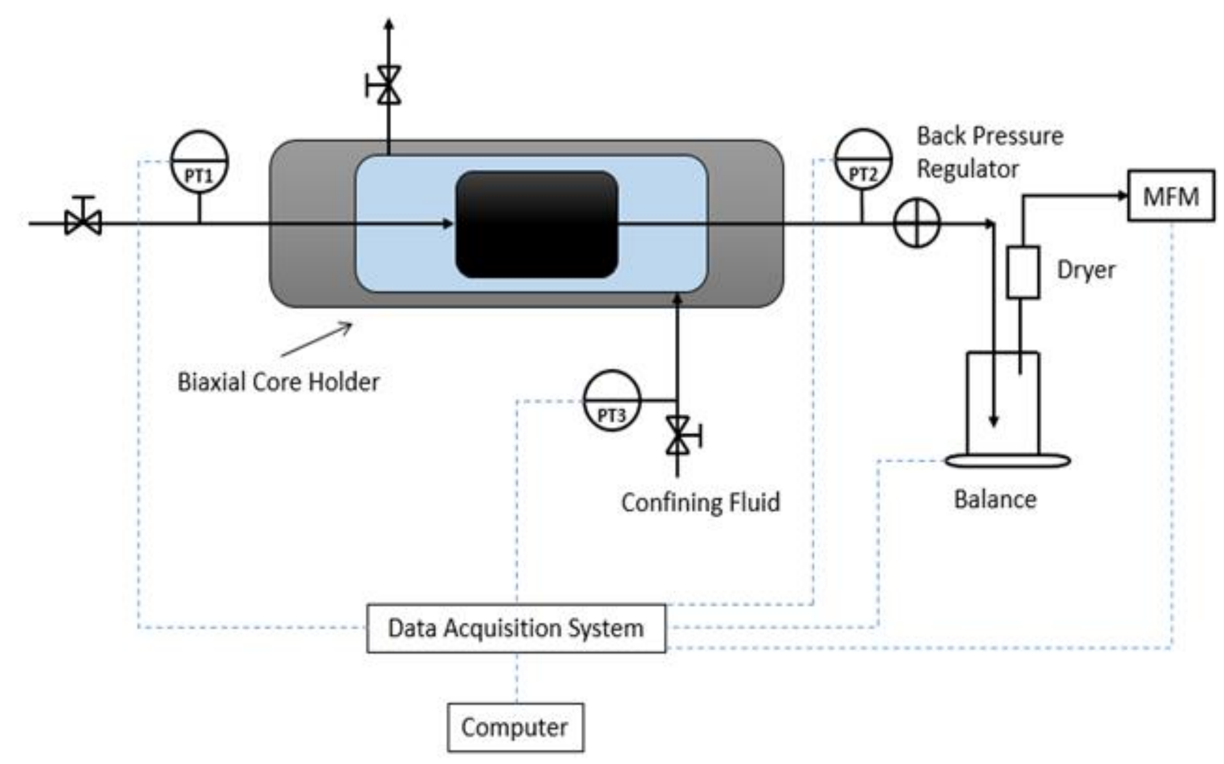


Fig. 3: Schematic of the core flooding apparatus used for steady-state relative permeability measurements of packed coal beds. The key equations used to calculate permeability were:

Relative Permeability Curves

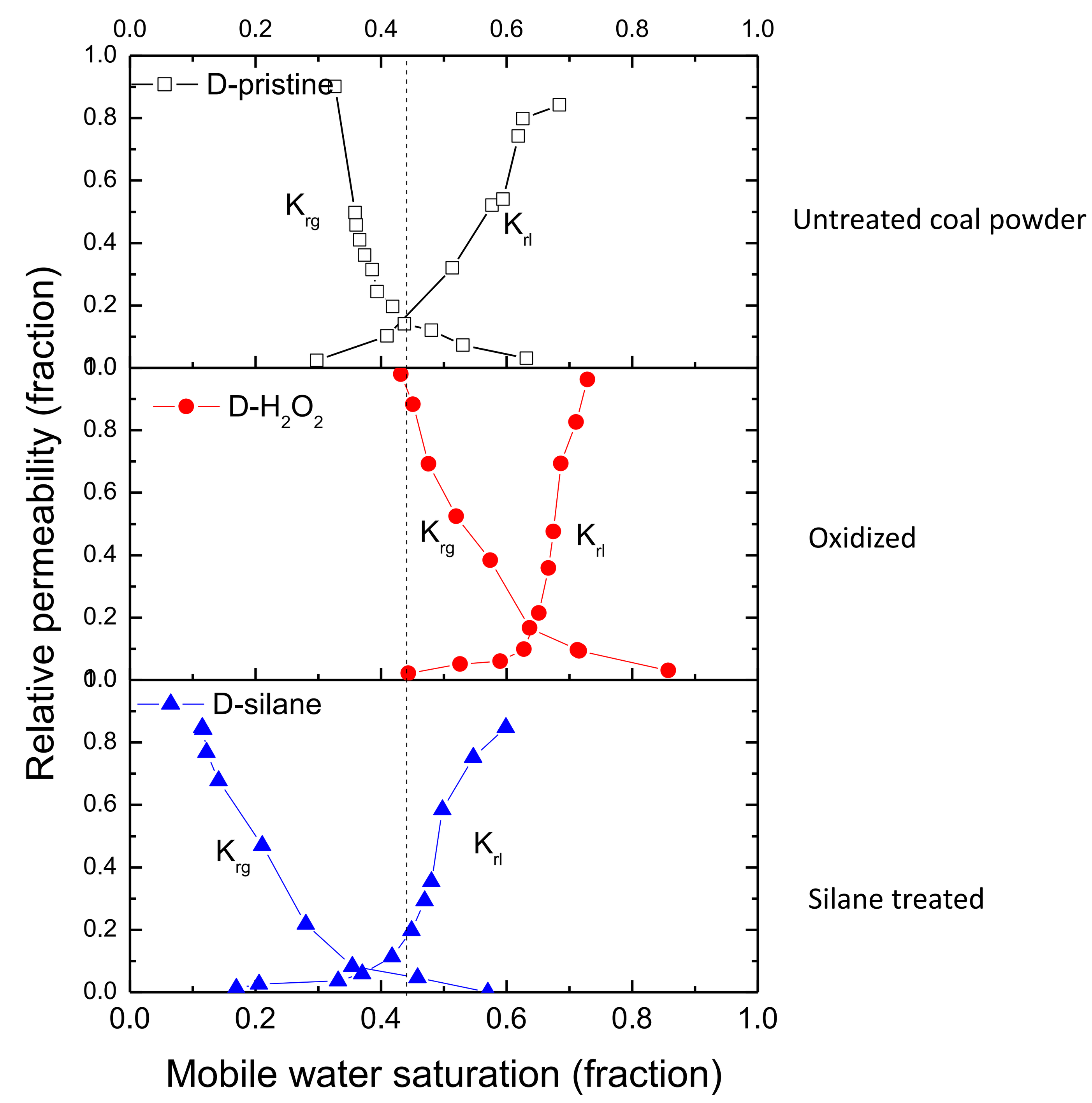


Fig. 4: Relative permeability of artificial cores derived from untreated coal and chemical treated coal powders.

Figure 4 shows the relative permeability curves for all the three samples, which suggest that the silane treatment has changed the coal surface from mildly water wet to a non-water wet surface. Differences in the crossover point, residual water saturation and slope of the curves between the samples can also be seen.

Conclusion and Future Work

1. Packed bed method has enabled the construction of repeatable cores to study relative permeability in isolation from the effects of natural coal cleat network geometries and heterogeneity.
2. It has been shown that the coal surface wettability changes the relative permeability behaviour of the coals. Crossover point, residual water saturation and slope of the curves vary with the contact angle.
3. This result suggests that the silane treatment has changed the coal surface from mildly water wet to a non-water wet surface.

Future work plans:

- To progress in understanding the combined effects of coal surface properties and the geometry of the cleat network, we propose to use 3D printing technology to construct artificial coal cores with repeatable cleat structures.

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