An Investigation on Impact of Creep on Coal Permeability and Gas Drainage Efficiency

1. Statement of Problem

Coal as a soft rock experiences compaction when pore pressure depletes and effective stress increases during Coal Seam Gas (CSG) drainage. The increase in effective stress during gas drainage causes the reservoir to undergo compaction (Schatz and Carroll, 1981). This mechanical induced compaction causes permanent deformation and effective stress increases during Coal Seam Gas (CSG) drainage. The findings of this study may contribute to a better understanding of the impact of creep on coal permeability as a critical factor influencing gas drainage.

2. Knowledge gap

The impact of creep, as a long-term phenomenon, on coal permeability has not been considered during gas drainage.

3. Methodology

3.1. Experimental study of impact of creep on permeability using a tri-axial rig (Fig. 2)

Capabilities and characteristics:
- Axial stress > hydrostatic stress (axial stress is additional to hydrostatic stress, \( \sigma_{z} = \sigma_{1} + \sigma_{2} + \sigma_{3} \))
- Axial displacement and radial gauges

Coal sample:
- High volatile bituminous (Bowen Basin)
- Vertical sample

3.2. Development of a permeability model and numerical simulation

A new permeability model including viscoelastic deformation of coal has been developed by incorporating viscoelastic term of Nishihara model (Nishihara, 1952) in stress-strain equation suggested by Jaeger et al. (2007) for anisotropic poroelastic media.

The developed model can be presented as follows:

\[
\frac{1}{k} = \frac{1}{k_0} + \frac{1}{k_	ext{vis}} 
\]

where,

\[
E_1 = E_{exc} + E_{ex} \left(1 - \exp \left( -\frac{P_{exc}}{\eta_{ex}} \right) \right), \quad E_2 = E_{exc} + E_{ex} \left(1 - \exp \left( -\frac{P_{exc}}{\eta_{ex}} \right) \right)
\]

where, \( E_x \) and \( E_1 \) are the elastic and viscoelastic moduli, respectively, \( \eta_x \) and \( \eta_1 \) denote the viscosity coefficients. Also, subscripts \( e \) and \( v \) denote elasticity and viscoelasticity.

4. Results and discussion

A test was carried out to investigate the effect of the creep induced by change in effective stress on coal permeability during desorption of methane gas. When the coal sample reached equilibrium under constant hydrostatic and axial stress condition, the pore pressure was reduced to simulate gas drainage. Effective stress was changed in three steps from 0.99 MPa to 0.49 MPa and 0.43 MPa by changing pore pressure under constant axial and confining stresses (Fig. 3).

The experimental results of desorption test using methane show that increase in effective stress with pressure depletion leads to continuous decline in permeability due to time-dependent deformation. Viscoelastic creep as a partially irrecoverable mechanism can cause significant decrease in permeability during gas drainage. The findings of this study may contribute to a better understanding of the impact of creep on coal permeability as a critical factor influencing gas drainage.

5. Conclusions

The experimental results of desorption test using methane show that increase in effective stress with pressure depletion leads to continuous decline in permeability due to time-dependent deformation. Viscoelastic creep as a partially irrecoverable mechanism can cause significant decrease in permeability during gas drainage. The findings of this study may contribute to a better understanding of the impact of creep on coal permeability as a critical factor influencing gas drainage.

6. Acknowledgements

The author would like to acknowledge the School of Mechanical and Mining Engineering of the University of Queensland for provision of a scholarship for his PhD research.

7. References