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Compressive strength and permeability of thermally-cracked coals: implications for gas storage and transport in subsurface coal seams

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Adsorptive gas transport (such as CO_2) in subsurface through coal matrix alters the dimension of pores and cleats and results in reduction of coal formation permeability. We propose thermal-cracking could be a potential method to increase the coal-permeability. We tested a number of coal samples from Bansgara colliery, India and compared the permeability and strength of the air-dried vs. thermally-cracked samples. Samples were heated at 280°C for 36 hours and then quickly chilled to produce thermal-cracks mostly along the bedding planes, which were confirmed by microscopic study. We tested the mechanical strength keeping the bedding planes perpendicular (α=90°) and parallel (α=0°) to the loading directions.

The peak compressive strengths of air-dried samples from room to 15 MPa confinement were noted as 14-44 MPa and 12-37 MPa for α=90° and 0° conditions, respectively. The mechanical behavior of the thermally-cracked samples, interestingly, was not straight forward. The peak compressive strengths of thermally-cracked samples were comparable to those of air-dried samples when α=90°. Interestingly, when α=0°, the peak-strength dropped by 82% at room pressures and 67% at 15 MPa confining pressures with respect to the air-dried samples under similar conditions. The stress strain profile of the deforming coal samples showed initial shallow slopes indicating pore closure, and then a steep slope in the elastic limit. Most of the samples were brittle and failed at the yield point. Few samples showed slight ductile signatures and plastic flow at higher confinements. Axial splitting was observed in samples at low confinements. At higher confinements, fracture pattern was more dominated by shear cracks as compared to tensile cracks. Our results also show that porosity of the samples increases by 30-35%. Gas permeability (N_2 used as a probing gas) of the thermally cracked samples at 6.5 MPa confining pressure and 1 MPa pore pressures are 1.31 and 4 md for α=90° and 0° conditions, respectively. Permeability of air-dried samples at similar experimental conditions are 0.2 and 0.7 md for α=90° and 0° conditions, respectively.

We interpret that the loading sub-parallel thermal-cracks further opened and connected each-other during loading and therefore failed at lower stresses when α=0°. The interconnected pore and cleat network also resulted in permeability enhancement. Interlocking network of coal matrix resist the deformation of coal, and thermal cracks penetrate in coal matrix to reduce the entanglement of macerals in coal and lower its mechanical strength. In contrary, under α=90° loading conditions, the horizontal thermal cracks closed due to perpendicular load rather than

opening further, and thus in those samples the strength reduction is less prominent. We conclude that thermal-cracking is a prospective method in enhancing the subsurface coal-permeability of deep-seated coal seams from micro to millidarcy. However, it must be ensured that the load imparted by the wellbore (injecting or recovery wells) on thermally cracked coal reservoir should act perpendicular to its bedding.