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Full Length Article

Quantitative investigation of anisotropic characteristics of methane-induced strain in coal based on coal particle tracking method with X-ray computer tomography

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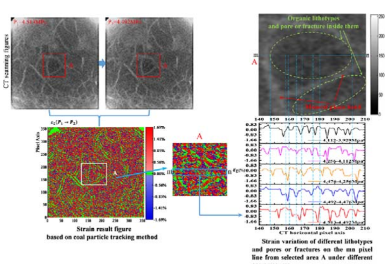
GRAPHICAL ABSTRACT

During the process of methane adsorption, the experimental data are obtained from the gray level matrix of CT scanning figures under two adjacent gas pressures (e.g. P1, P2). These data are calculated by the coal particle tracking method for the strain result. The strain variation of different lithotypes and pores or fractures is acquired on the mn pixel line from selected area (e.g. A) under different gas pressures.



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ABSTRACT

In order to quantify the anisotropic characteristics of coal swelling deformation during the process of methane adsorption, the inner mesoscopic structures of coal are scanned with computerized tomography (CT) and a coal particle tracking method (CPTM) is proposed to quantitatively calculate the strain of coal particulates in view of the pixel gray level matrix of CT image. The results show that the spatio-temporal distribution of coal mesoscopic deformation is inhomogeneous during the process of methane adsorption. From the spatial distribution, some parts of coal swell and other parts shrink. The mineral phase and porosity or fracture inside them are mainly swelling deformation and little shrinkage deformation. The swelling and shrinkage deformation is varying constantly with different gas pressure in the organic lithotypes of varying macerals and pore or fracture inside them. The expansion deformation tends to first squeeze the original pore or fracture inside them for more expansion space. From the temporal distribution, the magnitudes of adsorption deformation is also not uniform along with the decrease of gas pressure. After the adsorption balance, the change magnitudes of strain tend to decrease. The mesoscopic deformation of coal samples is anisotropic and the macroscopic deformation is swelling. This is verified by the cumulative total strain values of coal, which are obtained from the mesoscopic

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strain calculation results. This study presents mesoscopic CT and strain calculation results images of coal deformation. These data will provide the basis for the study of physical structure and mechanical properties of coal with adsorbing methane.

1. Introduction

As the associated resource of coal, coalbed methane is one of the alternative energy sources of conventional natural gas. However, the occurrence state of coalbed methane in coal is different from that of conventional natural gas. Coal rock is a complex porous and fractured medium [1–9] and typical non-uniform multiphase composite material [10]. When methane, carbon dioxide or other gases are absorbed into the coal medium, the physical structure of coal will be modified.

Many studies [11–16] have shown that coal will expand after gas or water adsorption and shrink after the desorption. The swelling/shrinkage characteristics have also been discussed. Goodman and Larsen [11,12] found that there are varying degrees of swelling and shrinkage in coal, which is irreversible to some degree during the interaction of coal molecules with CH_4, CO_2, and H_2O molecules. Larsen et al. [13,14] have investigated that because the larger aromatic sheets tend to orient parallel to the bedding plane, the heterogeneous strain and swelling of higher rank coals become greater perpendicular to the bedding plane. Based on molecular simulation, Narkiewicz and Mathews [15] confirmed the swelling anisotropy of coal, which is more inclined to the vertical level. Liu et al. [16] have reported that the swelling response of coal to water adsorption is anisotropic with the

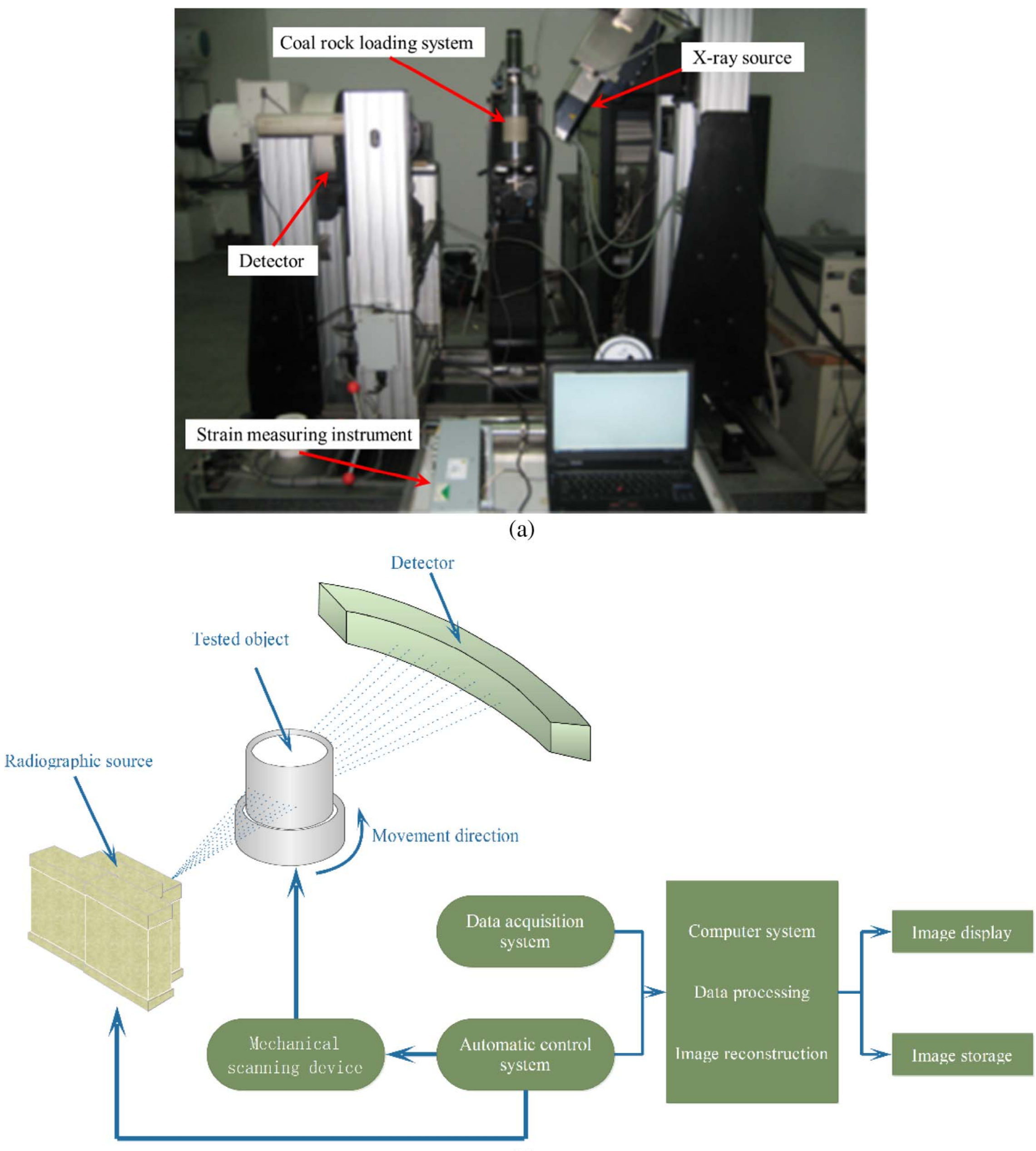

Fig. 1. CT scanning experimental system and schematic.