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ORIGINAL PAPER

Tensile Fracture Propagation in Deep Coalbed Methane Layers Under Brazilian Test: A Quantitative Analysis Using Digital Rock Technology and Deep Learning-Based Image Segmentation

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Abstract

Tensile fracture propagation is a critical aspect of both coalbed methane exploitation and underground coal mining. A significant gap in the existing knowledge is the quantitative understanding of tensile fractures' initiation and propagation within the context of the existing pore fracture network. This research addresses this gap using such cutting-edge technologies as deep learning, computed tomography (CT) scanning, scanning electron microscope (SEM), and mechanical loading under Brazilian Test conditions. Coal samples from the Ordos Basin of China underwent step-by-step loading, and CT scanning was conducted before and after each loading step. Then, the tensile fractures' evolution was investigated. A deep learning technique was employed for accurate image segmentation. The developed models were transformed into a user-friendly Windows-based App, providing a valuable resource for fellow researchers. The analyses revealed insights into the initiation, propagation, extension, and growth of tensile fractures. Two-dimensional (2D) and three-dimensional (3D) analyses considered fracture length, aperture, density, and volume, leading to the formulation of relevant rock mechanical and geomechanical models. This research contributes valuable insights into the intricate interplay between natural fractures and tensile fractures' dynamics based on the pore space evolution pattern. The findings have significant implications for coalbed methane extraction and coal mining.

Highlights

- Rock mechanical and geomechanical models were established to study the tensile fracturing phenomena.
- Loading conditions would strongly affect initiation, growth, and propagation pattern of the tensile fractures.
- Existing pore fracture network had a great impact on length, aperture, and density of new fractures.
- Deep learning proved to be a strong tool for segmentation of coal pore fracture network on the CT images.

Keywords Deep coalbed methane · Fracture characterization · Tensile fracture · Brazilian test · Digital rock technology · Deep learning

1 Introduction

Tensile fracture propagation plays a critical role in coalbed methane (CBM) extraction, which includes capturing the trapped methane within the coal layers underground. In CBM extraction, methane is obtained by drilling wells into coal seams (Geng et al. 2014) and removing groundwater (Haldar 2018). The extraction of methane results in increased tensile stress in the overburden layer leading to wellbore instability. Consequently, tensile fractures initiate and propagate around the wellbore. Moreover, methane extraction from CBM reservoirs is commonly carried out using hydraulic fracturing (Dave Healy 2007; King et al.

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