Research Advances

Morphology and Propagation of Hydraulic Fractures for CBM Wells

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Objective

As the most widely used and effective technique in reservoir reconstruction of unconventional natural gas, hydraulic fracturing has been achieved good effect in CBM development. It is important to note that coal seam is both source rock and reservoir, and that hydraulic fracturing will make an impact on the coal resource exploitation, especially on the reservoir and its roof and floor. However, the morphology of hydraulic fractures is so complex that the mathematical models and conventional fracture monitoring techniques always fail to describe them. In this work, three fracturing samples were prepared by coal and similar materials for physical simulation experiments, and the fracturing process was monitored by the acoustic emission instrument. Finally, the dynamic propagating process of hydraulic fractures, the mechanism of T-shaped fracture, I-shaped fracture and traverse were explained.

Methods

According to the stratification, the raw coal is cut into three isopachous bulks (140 mm), and then the three coal samples were bored and the simulated wellbores were fasten. The fracturing samples were surrounded by cement, and the roof and floor were prepared with different proportions of sand, cement, gypsum and coal dust. Two pieces of thick paper are inserted into the roof of the sample 3 to simulate artificial fractures. According to the well depth, in-suit stress and lithology of the research area, three experiments were designed and conducted with a large tri-axial hydraulic fracturing test system. The vertical stress of the sample 1 is the smallest of three-dimensional stress, while the vertical stresses of the samples 2 and 3 are both larger than the minimum principal stresses of them. The roof and floor use similar materials of various proportions to characterize the difference of mechanical properties with coal. During the fracturing process, the injection pressure and acoustic emission characteristics are real-time monitoring. To better trace hydraulic fractures, green fluorescent pigment is added to the fracturing fluid.

Results

In the experiment, the injection pressure is on the rise before the coal cracks, and it increases rapidly after the initial slow growth. After the coal cracks, the injection pressure drops to some extents. The large amplitude and high frequency fluctuations of injection pressure indicate that there are numerous large-scale fractures generating in the hydraulic process.

The cumulative AE hits of the sample 1 is the maximum among the three experiments. The curve of AE hits versus time for the sample 1 is a little smoother than the other two, and no obvious ups or downs appear (Fig. 1). Furthermore, the differential of horizontal principal stress of sample 1 is also less than the others, meaning that all the seepage resistances of various directions show little difference in the sample 1. The hydraulic fractures of the sample 1 are stochastic propagating along the weak planes in the coal with a tortuous extending path and complex morphology. On the curves of AE hits versus time for the samples 2 and 3, there are both abrupt changes (Fig. 1), which indicates that the coal is a kind of fragile material and new fractures will form after the injection pressure reaches the fracture pressure. The horizontal differential principal stress increases gradually, leading the hydraulic fractures present simple and straight morphology and propagate towards the direction that perpendicular to the minimum principal stress.

When the physical simulation experiment is completed, many complex hydraulic fractures can be observed in the coal after disassembling the fracturing sample. The hydraulic fractures are correlated well with the injection pressure curves and acoustic emission characteristics,

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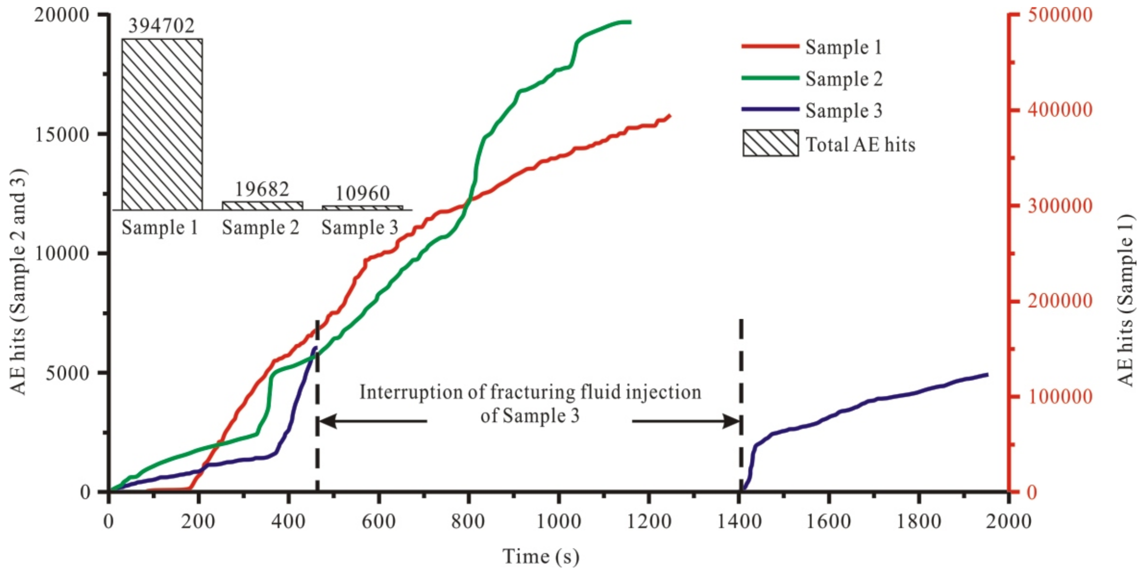

Fig. 1. AE hits vs. time for the hydraulic samples.

which show that there are more hydraulic fractures in the sample 1 than the samples 2 and 3. The vertical stress of Sample 1 is the smallest, so horizontal fractures can be clearly observed in the coal. The smallest stress appears to be the horizontal one of the samples 2 and 3, and thus, obvious vertical fractures can be observed in the coal. When the vertical fracture propagating, it usually form horizontal branches on the interface between the coal and the roof or the floor, and present "T" or "I" shaped structure. Two artificial fractures were preset in the roof of the sample 3 to study the influence of preexisting fractures on the hydraulic fracturing, the result shows that the fracturing fluid infilters into the preexisting fractures and it subsequently penetrates the roof.

In the physical simulation experiment, the interface between the coal and the surrounding rock cannot reach a cemented condition like stratigraphic deposition. In addition, the roof, floor and surrounding rock have different mechanical properties. If the strength of the roof and the floor is stronger than the coal, the height of fractures will be significantly controlled by the roof and the floor, and the fractures can only propagate in the coal seam. When the fractures extend vertically to the weak plane, the fractures are obstructed by the stress and then propagate horizontally along the interface. Consisting of vertical and horizontal fractures, the overall shape of fractures present "T" or "I" shaped structure.

Conclusion

The propagation of hydraulic fracture is a discontinuous dynamic process. With the injection of fracturing fluid, the hydraulic fracture will be produced and extended along the weak plane of coal until the injection pressure is not high enough to crack the coal. The fractures in coal clearly exceed those in surrounding rocks, and exhibit complex morphology. Both vertical and horizontal fractures develop in coal and interweave with each other, forming a connected network. The in-suit stress controls the propagation of fractures, leading the fractures extend in a perpendicular direction toward the minimum principal stress. The differences of mechanical properties between coal and roof and floor have certain inhibiting effect on the propagation of vertical fractures. However, the vertical stress and the interfacial property are the major factors that influence the formation of the "T" shaped and "I" shaped fractures.

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