Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 191 (2017) 291 – 298

Procedia Engineering

www.elsevier.com/locate/procedia

Symposium of the International Society for Rock Mechanics

Study on Fracture Mechanism of Hydraulic Fracturing in Sandstone by Acoustic Emission Parameters

Ye Lou, Guangqing Zhang*, Xiaoxiao Wang

State Key Laboratory of Petroleum Resources and Prospecting, No.18, Fuxue Road, Beijing 102249, China
College of Petroleum Engineering, China University of Petroleum, No.18, Fuxue Road, Beijing 102249, China

Abstract

A real-time monitoring system was established for 10-channel acoustic emission (AE) in hydraulic fracturing in the laboratory, with a hydraulic fracturing test conducted on two different sizes of natural outcrop cores under unconfined pressure and confining pressure respectively. Then, a discussion was carried out on the microscopic response in rock to the formation and growth of hydraulic fracture under confining pressure and unconfined pressure. The study of AE parameters shows that the change of RA (Rise Angle) in hydraulic fracturing process is always opposite to that of AF (Average Frequency). Also, AE parameters have higher dispersion under unconfined pressure. With breakdown pressure as a dividing point, as pumping pressure changes under unconfined pressure, the dominant internal fracture mechanism of rock will turn from tensile failure to shear failure. But under confining pressure, the transformation of the dominance is reversed, namely from shear failure to tensile failure. This phenomenon indicates that despite the same hydraulic fractures in macro scale under both confining pressure and unconfined pressure, there may be a large difference in microstructure between the hydraulic fractures formed under both pressure conditions respectively.

Peer-review under responsibility of the organizing committee of EUROCK 2017

Keywords: hydraulic fracturing; acoustic emission; fracture mechanism; breakdown pressure; parameter analysis

1. Introduction

Hydraulic fracturing technology has become the primary means of reservoir stimulation since its first application in North America in 1949 [1]. At present, as the conventional oil and gas resources are increasingly exhausted, and

* Corresponding author. Tel.: +86-13701353475.
E-mail address: rambus_ddr@163.com

Peer-review under responsibility of the organizing committee of EUROCK 2017
doi:10.1016/j.proeng.2017.05.184

the yield of unconventional oil and gas resources rises gradually, hydraulic fracturing has grown into a more critical factor to artificial production's increase [2]. From the perspective of theoretical research, with the constant development of fracture mechanics and its application to rock engineering, scholars have come to realize that the nonlinear areas have an important influence on the mechanical behavior of a hydraulic fracture before and after its formation, while the occurrence of micro cracks is an important sign of nonlinear rock failure [3].

At present, some technologies, such as X-ray, have been successfully applied to the study of fracture problems [4], and some scholars identify the fracture mechanism in accordance with the surface roughness of hydraulic fractures [5]. Compared with other hydraulic fracture monitoring techniques, AE has been widely used in the field of rock engineering [6]. Besides, the monitoring system can reflect the spatial distribution of micro ruptures in real-time, and then describe the fracture morphology. In addition, analysis of AE waveform can help to identify the fracture mode of micro cracks [7]. Aki put forward the focal mechanism analyses, and it has been widely accepted in laboratory experiment [8]. Ohtsu [9] and Ishida [10] applied the analysis of fracture mode to the research of hydraulic fracturing, but it couldn't achieve real-time feedback calculation results because of the constraints from the performance of the existing instruments. Compared with focal mechanism analysis, parameter analysis is more capable of identifying the fracture mechanism in the real-time monitoring process of hydraulic fractures [11, 12]. The application of dynamic monitoring in fracturing process provides an important basis for changing the pump pressure and proppant injection rate, and improving the reservoir performance.

Through physical simulation of large-size triaxial hydraulic fracturing in outcrop rocks in the laboratory, this paper studied the changing tendency of AE parameters with pump pressure in the process of hydraulic fracturing, and explained the fracture mechanism of micro cracks in the process of hydraulic fracturing based on the characteristic of AE parameters; discussed the difference in fracture mechanism of macro hydraulic fracture at the stage of initiation and propagation, and analyzed the feasibility and necessity of establishing a real-time crack mechanism monitoring for hydraulic fracturing.

2. Experimental procedure

The rocks used for hydraulic fracturing testing were collected from an outcrop area in Sichuan province, known as yellow loose sandstone. The outcrop rock was processed into cube samples A and B. Sample A's size: $300 \times 300 \times 300$ mm^3, and B's size: $600 \times 300 \times 300$ mm^3. The wellbore has a diameter of 15 mm and a length of 250 mm. The embedding depth of the wellbore in Sample A is 100 mm, while that in Sample B is 230 mm. SAEU2S, the AE acquisition instrument from Soundwel was used for acquisition of AE waveform signals in the process of hydraulic fracturing testing. 10 SR150N sensors from Soundwel, which have a diameter of 19 mm and a sampling frequency ranging from 22 kHz to 280 kHz, were adopted. A 40 dB signal amplifier was mounted in the front end of the AE monitoring system. Its signal sampling frequency equals 3 MHz, and 35 dB was selected as a measurement threshold value after a noise test by hydraulic fracturing testing.

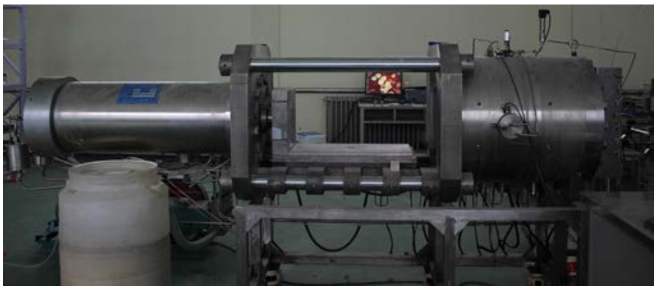

Fig. 1. RTM-1 large scale tri-axis hydraulic fracturing physical simulation apparatus.

As shown in Fig. 1, hydraulic fracturing testing was completed by RTM-1 large-size triaxial simulation apparatus. A hydraulic fracturing experiment was conducted on Sample A under unconfining pressure by the use of RTM-1 pumping system and AE monitoring, as seen in Fig. 2(a). In the testing process of Sample A, 2% guanidine gum