**World Journal of Mathematics and Physics**
**ISSN: 2960-0103**
**DOI: 10.61784/wjmp240162**

# MICROSEISMIC CRACK MONITORING TECHNOLOGY

Andrew Dean
*University of Pretoria, Pretoria, South Africa.*

**Abstract:** Hydraulic fracturing technology has been widely used in oil and gas production as the main technical means for the development of unconventional oil and gas reservoirs. Microseismic monitoring technology is an effective means for fracture evaluation during the hydraulic fracturing process. The principle of microseismic monitoring technology and the development history of this technology at home and abroad were introduced, and the positioning method of microseismic events was described. Two microseismic monitoring methods for unconventional oil and gas layer fracturing were reviewed, namely, well monitoring technology and surface monitoring technology. Its principles, characteristics and development are elaborated and compared, and finally the development direction of microseismic monitoring technology is discussed.
**Keywords:** Geophysics; Microseismic monitoring; Source positioning; Well monitoring; Surface monitoring

## 1 INTRODUCTION

Microseismic monitoring technology is a geophysical technology that monitors production activities by observing microseismic events [1]. This technology analyzes and calculates the geometric characteristics of the fracture network, that is, the orientation, length, height and other information, evaluates the fracturing effect in real time, understands the artificial fracture situation during the fracturing stimulation process, and guides the optimization of the next fracturing plan to increase oil recovery. The purpose [2]. The theoretical basis of this technology is acoustic emission, Moore-Coulomb theory and fracture mechanics criteria [3]. Compared with conventional seismic exploration technology, the difference between microseismic monitoring technology and conventional seismic exploration technology is that it requires the location, time and magnitude of the earthquake source [2, 4].
Microseismic monitoring technology originated in the 1940s, 1976 Sandia National Laboratory established the underground microseismic observation method in 2000. In the 1980s, this technology mainly focused on the fracture imaging inversion method. In the 1990s, multi-stage geophones appeared and were widely used [5]. In recent years, with the large-scale development of unconventional oil and gas resources, microseismic monitoring technology has developed rapidly. This technology evaluates the effect of fracturing operations by analyzing the data obtained after fracturing, and provides a basis for further well pattern adjustment.

## 2 MICROSEISMIC SOURCE LOCATION

Microseismic source positioning is the core and purpose of microseismic monitoring. During the fracturing process, the increasing pressure causes cracks in the rock, that is, micro-seismic events occur in the formation, and the micro-seismic signals are represented by P Waves and S-waves propagate in the form of waves. After an earthquake event occurs, the earthquake source is the initial location of the earthquake and the time of the earthquake, expressed as (x0, y0, z0, t0). As microseismic events gradually occur in time and space, nearby geophones receive the wave signals emitted by the microseismic events.
, Since microseismic signals have the characteristics of weak energy and short duration [5], the acquisition system must first preprocess and reasonably filter the received microseismic events, and analyze and calculate their amplitude spectrum, frequency spectrum, energy envelope and frequency band. Microseismic signal characteristics such as range, etc., and then judge and determine effective events [5], so that the microseismic signals after filtering the background noise are displayed consistently, ensuring the authenticity of each received microseismic signal, and avoiding the entry of false signals. This is the microseismic Real-time monitoring is the key to success or failure. In the analysis of the observation point (xi, yi, zi), if a higher signal-to-noise ratio (S/N) is found, the time ti when the elastic wave of the earthquake source reaches the observation point can be determined, so that the source and the source can be calculated The distance between observation points. Theoretically, earthquake source information can be obtained through data analysis of 4 observation points, and sometimes even 3 are enough. By solving this series of microseismic source points, the microseismic positioning results are continuously updated to form a dynamic diagram of the crack extension, and the length, width, top and bottom depth, length of the two wings, and orientation of the crack can be intuitively obtained. In actual positioning, due to the influence of various factors (such as background noise, etc.), the positioning point must be a larger area. When the number of observation points is increased, the positioning accuracy is improved, and the obtained earthquake source is more accurate and credible [2, 4, 6].

## 3 MICROSEISMIC MONITORING METHOD OF UNCONVENTIONAL OIL AND GAS LAYER FRACTURING

Microseismic monitoring methods for unconventional oil and gas layer fracturing are generally divided into microseismic well monitoring technology and microseismic ground monitoring technology.

### 3.1 Microseismic Well Monitoring Technology

The first mention of microseismic well monitoring technology was in Fessenden's report in 1917. He proposed that the detection of ore body locations can be detected using geophones and in-hole source monitoring. Subsequently, in-hole seismic exploration research began to gradually develop abroad, and this technology was gradually developed abroad. Domestic application began in 1984. Shengli Oilfield and Liaohe Oilfield conducted relevant experiments on this technology, which kicked off the domestic research on microseismic well monitoring technology [7].

Microseismic well monitoring is a main method of fracturing microseismic monitoring. It refers to receiving microseismic wave signals through high-sensitivity geophones arranged in adjacent wells or in the same monitoring well, and recording the signals synchronously, so that on-site analysis and solution of microseismic events can be achieved. A technology to achieve the purpose of monitoring microseismic events [8-10]. The monitoring accuracy of this technology is higher than that of ground monitoring technology. Its most obvious advantage is that the interference noise is smaller and the signal-to-noise ratio is higher [8].

The monitoring data processing process of borehole microseismic is mainly divided into three parts: preprocessing of monitoring data, identification of effective events and final positioning of the earthquake source [11]. First, microseismic monitoring data must be preprocessed, using perforation records to determine the azimuth angle of the three-component geophone, and use this azimuth angle to correct the monitoring data; secondly, because the complex noise environment will affect the identification of effective signals, It is necessary to carry out a series of filtering processing on the microseismic signals with larger energy generated by fracturing. The complex noise environment mainly includes random noise, strong energy low-frequency background noise, strong energy disturbance signal, wellbore wave and guided wave, etc. After filtering, Able to accurately pick up P waves and S waves in the record Wave; then, to pick up effective microseismic events, the method based on the long and short time window energy ratio (LTA/STA) is mainly used at home and abroad for automatic picking, because this method can greatly improve the picking efficiency. Finally, the source inversion method of first wave and direct wave and the relative positioning method are comprehensively used to locate the microseismic source [11].

Microseismic well monitoring technology in my country has been in a follow-up state for a long time. In 1985, VSP technology was officially listed as a "Seventh Five-Year Plan" research project by the former China National Petroleum Corporation; in 1999, Shengli Oilfield carried out cross-well seismic experiments to study inter-well reservoir connectivity; in 2007, the high-density Walkaround The VSP experiment was realized for the first time in the Tuha exploration area; in 2014, PetroChina carried out the DAS optical fiber seismic experiment in the entire well section for the first time, which enabled the application of in-hole monitoring technology in many aspects [7].

### 3.2 Microseismic Ground Monitoring Technology

Microseismic ground monitoring technology refers to the deployment of a large number of geophones in the ground area to form a 3D measurement network to pick up and analyze microseismic signal data, and monitor microseismic events to evaluate the fracturing effect [8-9, 12]. Surface monitoring is often a useful complement to well monitoring. McMechan proposed in 1982 that the problem of source positioning for ground monitoring can be solved by using the migration model of the reflection seismic data volume; Kiselevitch et al. newly defined a coherence coefficient in 1991 and proposed an acoustic emission imaging method for microseismic ground monitoring; in June 2004, hydraulic fracturing ground microseismic monitoring technology was applied for the first time in the Barnett shale area [3]. According to the layout of monitoring instruments, microseismic ground monitoring technology can be subdivided into surface monitoring technology and shallow well monitoring technology [8].

Surface monitoring is to place the geophone 20 to 30 cm away from the surface. Since the random noise on the surface is strong and the microseismic signal energy is weak, most of the longitudinal and transverse wave signals are submerged by the noise when they are transmitted to the surface. Therefore, the geophone is generally required to be placed at a certain distance from the wellhead, and at With the wellhead as the center, they are arranged in a multi-directional covering arrangement to achieve the effect of microseismic energy accumulation, thereby better achieving monitoring effects.

The energy scanning positioning method is a commonly used microseismic event positioning method in surface monitoring. Shallow well monitoring refers to placing the geophone in a shallow well with a certain depth. The purpose is to minimize the impact of the ground on the energy attenuation of microseismic signals. The data processing and interpretation methods for shallow well monitoring are the same as those for surface monitoring [8].

For the large-scale array monitoring method used on the surface, it has a huge advantage due to its large number of geophones. However, its low success rate in positioning processing and complex construction prevent it from being used as a daily monitoring method. Theoretically, as long as the observation area is extremely quiet, a single geophone can observe microearthquakes below magnitude 0, but it is difficult to have such an observation environment [6]. twenty three Comparison between borehole monitoring and surface monitoring Microseismic borehole monitoring technology and microseismic ground monitoring technology have their own advantages and disadvantages. Well monitoring can achieve high horizontal and vertical positioning accuracy, and the technology has matured [13]. Its biggest advantage is that the interference noise is much smaller than that on the ground, the signal-to-noise ratio of the recorded signal is high, and high-quality data can be obtained [13]. Its limitation is that the placement of the geophone array is limited to a certain line segment, which may cause a series of errors. The cost of underground equipment is expensive and the array construction is complex and time-consuming [6].

Due to the advantage of large monitoring azimuth angle, ground monitoring can more accurately determine the direction of microseismic cracks, and the horizontal positioning results have higher accuracy [8, 12], and the large number of geophones placed makes this technology have a wider monitoring range. However, since the number of deployment points often reaches hundreds, the total number of geophones can be measured in units of tens of thousands, resulting in excessive investment costs. Moreover, geophones placed on the ground are seriously affected by surface interference, making real-time processing difficult [8].

## 4 DEVELOPMENT DIRECTION OF MICROSEISMIC MONITORING TECHNOLOGY

With the development and continuous improvement of my country's oil and gas exploration and development technology, microseismic monitoring technology will face challenges with different application purposes in every link from exploration to development. Moreover, this technology will face different challenges depending on the exploration objects.

### 4.1 Ground Monitoring is Gradually Becoming a Trend

Although well monitoring technology and ground monitoring technology each have their own advantages and disadvantages, in recent years, as researchers have continued to study and conquer microseismic ground monitoring technology, it has been proven that ground monitoring technology can obtain credible data and can also basically Meet the needs of depicting crack shapes. The biggest advantage of surface monitoring technology is that it can monitor horizontal well fracturing or oil field development and water injection processes in a large area or range. At present, major oil service companies are working hard to develop ground monitoring technology, triggering a technology boom, causing the business volume of this technology to rapidly increase significantly around the world. my country's unconventional exploration technology is still in its initial development stage, and there are very few field wells for underground observation. Therefore, surface microseismic monitoring technology will be more used. This technology is also the direction of development and efforts [9].

### 4.2 Well Monitoring Becomes more Refined

Although microseismic well monitoring technology has achieved real-time processing, there is still much room for improvement in its accuracy. In well monitoring, the data transmission capabilities of instruments will gradually improve, and multi-well monitoring will also become an option. Moreover, the calculation of polarization direction analysis and the accuracy of first-arrival pickup will be further improved and improved through interactive analysis and iterative solution [9].

### 4.3 Installation of Permanent Geophones and Long-Term Dynamic Monitoring of Oil Reservoirs

With the emergence of instrumented oil fields, the installation of permanent geophones to monitor microseismic events induced by underground fluids plays an important role in the development of oil and gas fields. The requirements for this permanent detector are to be cost-effective, such as low maintenance costs, the ability to automatically detect events, and the ability to realize real-time data recovery, etc. In the stage of unconventional oil and gas production, reservoir drive monitoring is essential. Because my country's unconventional oil and gas fields rely on reservoir drive measures such as gas injection and water injection to maintain stable production, microorganisms caused during gas injection and water injection can be used. Seismic events are used for reservoir-driven monitoring to achieve three-dimensional imaging of the fluid front inside the rock. Reservoir engineers can optimize the overall oil production plan by analyzing fracture imaging and improve the oil recovery rate and development rate of oil and gas fields. Compared with the microseismic events generated by ordinary fracturing operations, the microseismic events generated by this kind of water injection and gas injection will have smaller energy and lower signal-to-noise ratio, and require special denoising processing and positioning method research [9].

### 4.4 Developing a Fast and Accurate Seismic Moment Tensor Inversion (MTI) Method

The seismic moment tensor inversion (MTI) method starts from the source mechanism of microseismic, and through the analysis and explanation of the rock fracture process, fracture mechanics and strain mechanics, it describes the cracks in the source area that generates the microseismic signal, and obtains richer source parameters.. The traditional seismic moment tensor inversion method is time-consuming and complex, so there is an urgent need to develop a fast and accurate moment tensor inversion method. Seismic moment tensor inversion can analyze the signals and radial patterns obtained from underground geophones to determine the fracture surface and slip degree. It can provide information such as the direction, volume and proppant distribution of the fracture, and can also provide information for establishing geomechanics. The framework also helps to achieve the goal of increasing production [13].

## 5 CONCLUSION

Microseismic source positioning is the core and purpose of microseismic monitoring technology. The advantage of microseismic well monitoring technology is that the microseismic signal obtained has a high signal-to-noise ratio and the positioning results have high vertical accuracy; its disadvantage is that the monitoring range is limited and the geophones are linearly distributed in the well. The advantage of microseismic ground monitoring is that a larger number of geophones can be placed to obtain a larger monitoring range and the direction of fractures can be determined more accurately. The disadvantage is that the information on the surface is seriously interfered, and thousands of geophones cause acquisition the cost is too high.

With the advancement of unconventional oil and gas exploration and development, it is necessary to continuously improve and upgrade new methods and technologies of microseismic monitoring technology to maximize benefits. Microseismic monitoring technology continues to develop: Microseismic ground monitoring technology is gradually becoming a development trend due to its high signal-to-noise ratio and accurate data; microseismic well monitoring technology still has a lot of room for improvement in terms of accuracy; with the With the emergence of instrumented oil fields, the installation of permanent geophones to monitor microseismic events induced by underground fluids plays an important role; through reservoir driving measures such as gas injection and water injection, stable and high production of unconventional oil and gas can be maintained; traditional seismic The moment tensor inversion method is time-consuming and complex, and there is an urgent need to develop a fast and accurate moment tensor inversion method.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

## REFERENCES


[1] Dong Enbo. Current status and development trends of microseismic monitoring technology. Inner Mongolia Petrochemical Industry, 2016(1): 108-112.

[2] Yan Yongxin, Zhang Yonghua, Chen Xiang. Research on the application of microseismic technology in fracture monitoring. Frontiers of Earth Science, 2013, 20(3): 270-274.

[3] Zhong Wei. Application of microseismic monitoring technology in hydraulic fracturing of shale gas wells in southern Sichuan. Chengdu: Chengdu University of Technology, 2015.

[4] Zhao Boxiong, Wang Zhongren, Liu Rui. A review of microseismic monitoring technologies at home and abroad. Advances in Geophysics, 2014(4): 1882-1888.

[5] Duan Yinlu, Li Qian, Yao Weiping. Hydraulic fracturing microseismic fracture monitoring technology and its application. Fault Block Oil and Gas Field, 2013, 20(5): 644-648.

[6] Liang Beiyuan, Shen Chen, Leng Chuanbo. Progress in research and development of microseismic fracturing monitoring technology. Progress in Geophysics, 2015, 30(1): 401-410.

[7] Zhao Bangliu, Dong Shitai, Zeng Zhong. Yesterday, today and tomorrow of well seismic technology—Development and application prospects of borehole seismic technology. Petroleum Geophysical Exploration, 2017, 52(5): 1112-1123.

[8] Liu Bo, Liang Shirley, Rong Jiaojun. Microseismic monitoring technology and applications of unconventional oil and gas layer fracturing. Petroleum Geology and Engineering, 2016, 30(1): 142-145.

[9] Liu Zhenwu, Saliming, Wu Furong. Current status and development direction of unconventional oil and gas microseismic monitoring technology of China National Petroleum Corporation. Petroleum Geophysics, 2013, 48 (5): 843-853.

[10] Yang Bingxiang, Yang Yingtao, Li Rong. Application of downhole microseismic fracture monitoring technology in staged fracturing of horizontal wells. Oil and Gas Well Testing, 2015, 37(3): 59-61.

[11] Lu Shichao, Guo Xiaozhong, Jia Likun. Processing and interpretation of microseismic monitoring data in hydraulically fractured wells. Oil and Gas Reservoir Evaluation and Development, 2013(6): 37-42.

[12] Liu Yaowen, Liao Rugang, Zhang Yuan. Examples and understanding of well-site combined microseismic monitoring of gas reservoirs in Fuling shale gas field. Natural Gas Industry, 2016, 36(10): 56-62.

[13] Wu Jianguang, Zhang Ping, Lu Hao. Application of microseismic event positioning based on amplitude superposition in ground monitoring. Journal of Jilin University (Earth Science Edition), 2017, 47 (1): 255-264.