Analysis of Noise Characteristics in Microseismic Monitoring

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Abstract. The effective signal energy of microseismic data is weak, and the received data will contain a lot of noise because of its special source excitation mode. At the same time, because the wave will inevitably lose energy in the process of propagation, the signal on the section is weak amplitude, weak continuity, even the effective signal on the whole line is submerged by noise, and the signal-to-noise ratio of the data is very low. In this paper, the common noise in different monitoring methods is analyzed, and the common processing methods in production are summarized.

1. Introduction
In the early stage of unconventional reservoir development, different wells need different observation methods. The commonly used micro-seismic monitoring measures are deep well observation, shallow well observation and surface observation. Deep well observation has a high S/N ratio because the geophones are close to the fracturing zone, and can record extremely small events during the fracturing process. However, in the early stage of unconventional oil and gas reservoir exploitation and development, it is not conducive to a wide range of promotion. Because of the sparse well location, surface observation is to lay hundreds of geophones on the surface of the fractured area to improve the signal-to-noise ratio and reliability of positioning data through the advantage of quantity. In shallow observation, the geophones are placed in 4-6 wells at depths of about 300 meters. To a certain extent, this method can avoid the low velocity zone near the surface, which is beneficial to the reception of microseismic signals, but the cost of drilling makes this monitoring method more expensive. However, the characteristics of noise and microseismic signals are quite different in different observation modes under different fracturing modes. Through the spectrum analysis of the data, we find that in most cases, the frequency of the effective signal is significantly different from that of the noise, and the ideal effect can be achieved only by filtering processing.

2. Noise characteristic analysis and filtering effect of different monitoring modes in hydraulic fracturing environment
Because of the excitation mode of the special source, the energy of the effective signal is very small, and the received data will contain a lot of noise. At the same time, because the wave will inevitably lose energy in the process of propagation, the signal on the section is weak amplitude, weak continuity, even the effective signal on the whole line is submerged by noise, and the S/N ratio of the data is very low. In this section, we expose the noise characteristics and filtering effect under different monitoring modes by analyzing the data under different observation modes.
2.1. Noise characteristics and processing methods of microseismic deep well monitoring in hydraulic fracturing environment

The event S/N ratio of microseismic deep well monitoring is the highest relative to surface and shallow well monitoring. Generally speaking, the obvious event waveform can be seen before filtering. A data file with relatively clean background, obvious event energy and no obvious random noise is selected to analyze its background noise and event signal. It can be found that the frequency of events is mainly concentrated in about 100Hz, and the noise is mainly low-frequency noise below 20Hz and some random noise, as shown in Figure 1.

![Figure 1. Spectrum analysis of background noise and events in deep well monitoring.](image)

(a) Raw data. (b) Spectrum Analysis of the noise. (c) Spectrum Analysis of the event.

1) Strong low frequency interference

There are often strong low frequency interference signals in micro-seismic deep well monitoring, as shown in Fig. 2. The frequency of the interference signal is stable, and the interference signal is about 50HZ from the beginning to the end of the interfered channel. This interference mainly comes from AC and can be eliminated by bandpass filtering. From the filtered data, it can be seen that the event signal can be distinguished more clearly.

![Figure 2. Contrast diagram before and after filtering processing for the strong low frequency interference.](image)

(a) Before filtering. (b) After filtering.

2) Strong high frequency interference

At present, microseismic data acquisition often uses geophone sensitive to high-frequency information, which makes very weak high-frequency signal stronger. Therefore, regardless of the quality of field construction, there will be a lot of high-frequency noise. As can be seen from Fig. 3, the high frequency noise of deep well monitoring is stable with time, and its energy relative event is weak. This kind of high frequency noise belongs to high frequency environmental noise. The noise source is mainly the thermal noise of the instrument and various relatively stable high frequency interference sources in nature. The noise can be effectively removed by band-pass filtering.
(3) Strong linear interference

Because the strong linear interference noise produced by wellbore operation, this kind of noise has obvious linear characteristics in waveform record, and multiple waves are produced by the reflection or refraction of the formation. This kind of noise is difficult to carry out spectrum analysis, so it can not be removed by band-pass filtering.

(4) Random interference

Microseismic deep well monitoring detectors generally have a deeper settling depth than conventional geophones, and the environment is very complicated, and the detector is more difficult to fix. Therefore, there will be poor coupling of geophone or local vibration, which is the main cause of random noise monitoring in deep wells. As shown in Fig. 5, this kind of random noise only occurs in individual channels, and the vibration waveforms are not correlated with each other. This shows that the vibration does not propagate with the formation, but comes from the geophone itself. This kind of noise only occurs occasionally, and the chance of simultaneous occurrence with the event signal is not very much, so it will not have a great impact on location without special processing.
2.2. Noise characteristics and processing methods of microseismic surface monitoring in hydraulic fracturing environment

Surface survey makes the noise interference of ground microseismic monitoring very complex, which is mainly the environmental noise collected during the acquisition process. The signal-to-noise ratio of surface microseismic is much lower than that of deep well monitoring data. The low signal-to-noise ratio is due to the weak effective signal, which is relative to noise. In order to effectively present the event signal of microseismic ground monitoring, noise must be effectively suppressed. There are two basic types of surface monitoring noise: one is periodic noise, the other is accidental linear noise.

(1) Strong DC component

In surface monitoring of microseismic, severe strong low-frequency noise occurs usually, as shown in Fig. 6. Its amplitude is usually 1-2 orders of magnitude larger than the microseismic event signal, and its frequency is concentrated below 5HZ. Because of the frequency difference between this kind of signal and microseismic event signal, this kind of noise can be effectively eliminated by band-pass filtering and single-frequency noise elimination technology. From the data after filtering, it can be seen that the strong low frequency noise has been basically removed, and the original masked event signal can be highlighted.

Figure 6. Strong low-frequency noise of surface monitoring. (a) Raw data. (b) Spectrum Analysis of the raw data. (c) The signal is highlighted after filtering

(2) Periodic noise

Geophones are widely distributed in surface observation, and there are periodic persistent disturbances of a certain frequency in local traces due to mechanical vibration.

Figure 7. Periodic noise of surface monitoring. (a) Raw data. The area marked in the figure is periodic noise. (b) Spectrum Analysis of the noise data. (c) Noise signal weakened after filtering.
(3) Linear interference
In the process of fracturing monitoring, strong linear noise occurs due to fixed large-scale vibration. As shown in Figure 8, the event signal of monitoring data is clear, the waveform and continuity are good is continuous, and the energy of noise signal is similar to that of effective event signal. The adaptive FK filtering method can suppress the noise and enhance the effective events, but it also makes the waveform changes in the filtering process. If the parameters are not selected properly, the travel time information of the waveform itself will be destroyed.

![Figure 8. Strong Linear Noise in Ground Monitoring](image)

(a) Raw data. (b) Spectrum Analysis.

(4) Mechanical Vibration in Fracturing Construction
In the process of fracturing construction, such as pumping, strong mechanical vibration is induced, which is transmitted along the surface or air to the geophone and causes obvious interference. As shown in Fig. 9, the spectrum analysis shows that the main frequency is mainly around 100Hz. This kind of noise has strong energy and irregular occurrence. So, it usually does not need special treatment.

![Figure 9. Long period vibration noise and random noise](image)

2.3. Noise characteristics and processing methods of microseismic shallow well monitoring in hydraulic fracturing environment
The noise of shallow observation is mainly strong low frequency and random noise. It is difficult to see the effective waveform in the general gain when displaying the image. Because the amplitude of the strong low-frequency noise is about 20 times that of the signal, and the energy of the effective signal is relatively suppressed. This kind of noise can be removed by de-direct current component, while random noise can be effectively removed by band-pass filter, as shown in Figure 10.
Figure 10. Comparison of pre-denoising and post-denoising of shallow observation data. (a) Raw data. (b) Spectrum analysis (c) Raw data are processed by removing low-frequency noise and random noise.

In addition, shallow observation is more widely distributed than deep well observation. As microseismic surface observation, there exists periodic continuous interference of a certain frequency in local traces due to mechanical vibration. As can be seen from Fig. 11, the frequency of this periodic noise is mainly concentrated in about 50HZ, which can also be removed by predictive filtering.

Figure 11. Elimination of periodic noise in shallow observation. (a) Raw data. The area marked in the figure is periodic noise. (b) Spectrum Analysis of the noise data. (c) Noise signal weakened after filtering.

3. Conclusion

By analyzing the monitoring data of deep well observation, surface observation and shallow wells observation, we get the noise characteristics under different monitoring conditions. According to its different characteristic information, the corresponding denoising processing has achieved good results.

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References

[1] Chen Yin, Yalin Li, and Furong Wu. (2018) The feasibility analysis of joint microseismic monitoring in Sichuan, China. https://doi.org/10.1190/segam2018-2997911.1
[2] Y. Tang, H. Zhang, J. Li, C. Yin and F. W. 2018. Focal mechanism determination for induced seismicity using the neighbourhood algorithm. Geophysical Journal International. Volume 214 :1715-1731
[3] Huang, W., Wang, R., Gong, X., & Chen, Y. 2018. Iterative deblending of simultaneous-source seismic data with structuring median constraint. IEEE Geoscience and Remote Sensing Letters. Volume 15. No.1:58-62
[4] Chen, X., Wang, R., Huang, W., & Jiang, Y. 2018. Clustering based stress inversion from focal mechanisms in microseismic monitoring of hydrofracturing. Geophysical Journal International. Volume 215. No.3:1887-1899
[5] Huang, W., & Wang, R. 2018. Random noise attenuation by planar mathematical morphological filtering. Volume 83.01:11-25