The application of vibroseis in VSP logging in Sichuan and Chongqing area

Li Ge1*, Jian Tang1, Li Zhang1, Jie Yong1, Liang Kang1

1BGP Southwest Geophysical Company, CNPC, Huayang road, Chengdu, Sichuan, 610213, China

*Corresponding author’s e-mail: geli_wt@cnpc.com.cn

Abstract. In 1970s, vibroseis was introduced to do seismic exploration in China. After then, vibroseis equipment was researched and produced in China. The electro-control system of the force working on the ground, of vibroseis signal recognizing or installing, and of RT quality-controlling, which is based on the digital self-adapting method, enlarged the application of vibroseis not only the areas but also the quantity in seismic exploration. And then, vibroseis equipment became one of the important seismic equipment. As the producing of shale gas developed, and the traffic conditions improved, the vibroseis equipment and techniques began to work in VSP logging in Sichuan and Chongqing area, south-west of China. The effect of the vibroseis in VSP logging will be analyzed from the theory to the consistence and high S/N ratio of VSP data which be acquired by vibroseis.

1.WORKING THEORY

The signal of vibroseis can last long and makes uniform amplitude, which is better than the signal of explosive. The signal lasts long, and the reflected signal lasts long too. The signal from different layers mixed together which can’t be recognized. So the correlation technique is the key point of the vibroseis.

The signal a (figure 1) is acquired by geophone from vibrator directly, which is the standard signal here. The signal b is the first break, c is the reflection from layer A, d is the reflection from layer B, e is the stack signal of b, c, d by geophone, which is the raw data of vibroseis. VSP data f can be obtained by signal a and e with correlation technique.

Figure 1. the theory of vibroseis

The essence of correlation of two waves is the similarity degree of their waveforms, the result of correlation calculation is a function varying with time. So it’s clearly that the data acquired by...
vibroseis is different from which by explosive. For example, the first break of data acquired by vibroseis is the correlation result of standard signal and data acquired by geophones (figure 2). Figure 3 shows coefficient of correlation, which can be obtained by correlation calculation. The coefficient is maximum at t1, t1 is the first break time and the coefficient curve is the waveform of the first break. The wave peak is picked as first break because there are some sidelobes.

![Figure 2. the first break obtained by correlation calculation](image)

![Figure 3. the waveform of first break](image)

Correlation calculation is a kind of digital filter too, it includes autocorrelation filtering and cross-correlation filtering. The amplitude character of filter is same as the signal, and the frequency spectrum is the negative frequency spectrum when the signal is done autocorrelation filtering. The cross-correlation function of signal a(t) and b(t) includes the common part of two signals only. So the character of autocorrelation filtering is to make the phase zero, the wavelet scanning of vibroseis is autocorrelation filtering of acquired signal. The common frequency is kept in cross-correlation filtering, which is applied to attenuate noise.

2. the analysis and application of the vibroseis VSP data

2.1 data analysis
The vibroseis VSP data which has done cross-correlation filtering has high S/N ratio because the environment noise has been attenuated in some degree. Figure 4 shows the difference between the data acquired by vibroseis and explosive. It’s clear that the explosive VSP data has some high frequency environment noise, where the the vibroseis VSP data is better.
2.2 Velocity
Figure 5 is the wavelets of the vibroseis VSP data, the consistence is well. The wavelet is uniform, it’s very easy to pick the peak, which is better than the first break picking. So the velocity and time-depth relationship of V0 VSP from the vibroseis VSP data should be better than it form the explosive VSP data.

2.3 Tar value
The geophone string would be moved up when V0 VSP acquisition was done which is limited by the number of geophones. The source must be shooting at same position a few times to get integrated borehole data if the explosive is applied. The consistence of data must be weakened because the shooting conditions are different. The explosive VSP data in Figure 4 shows the uneven amplitude between different shots. Figure 6 shows how to get tar value. The tar value is precisely because the consistence of vibroseis data is well, and the change of amplitude is closer to true.
Figure 6. Tar value from vibroseis data

2.4 Frequency analysis
The signal is geophysical signals made by mechanical equipment in vibroseis acquisition. The frequency character can be designed, but limited by the mechanical feature, in some cases the width of the frequency is not enough. So the explosive acquisition is recommended if high resolution data is needed.

Figure 7. the comparing of V0 VSP corridor-stack (vibroseis acquisition) and seismic stack

3. Conclusion
1. the vibroseis data has high S/N ratio
2. the vibroseis data has better consistency, which is well to get tar value, velocity and time-depth relationship.
3. the amplitude of vibroseis data is even, which is close to the true attenuation in the layers.
4. vibroseis acquisition has very low influences to environment, and high efficiency and low cost.
5. the frequency band of vibroseis data is limited, it’s not suitable if high resolution required.
Acknowledgments
The paper was supported by the national project numbered 2016ZX05022001-004-002 and we also appreciate the contributions of our colleagues.

References
[1] Huang, W., & Wang, R.. 2005. Basilica signal analysis. Volume 83.01:11-25
[2] D. E. Diller. System and Method for vibroseis application in VSP logging: U.S. Patent Application 13/606,029[P]. 2010-7-6.
[3] Gou, L., & Zhang, R.. 2010. Theory of vibroseis. Volume 13.01:10-20
[4] Ge, L., & Zhang, L, VSP, 2019. acquisition report of Well Wei 213 in Weiyuan structure. Volume 15.02:11-22