Importance of using optimum gauge length for DAS measurement to observe geophysical events

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DAS (Distributed Acoustic Sensing) technology has been introduced to the oil and gas industry since the beginning of the century for the purpose of monitoring pipelines and detecting intruders. However, its application to geophysical exploration only began around 2011. Conventional DAS are able to measure measures the change in the amplitude of backscatter, but it has been confirmed that there is a problem with linearity[1)]. The latest optical fiber sensing technology which uses differential phase data named "heterodyne Distributed Vibration Sensing" (hDVS) solved this problem which led to its use from around 2014. This system can record high-quality seismic data, including the Vertical Seismic Profile (VSP)[2)]. Three-dimensional imaging can be performed using the 3DVSP method, and it has already come to be used in Japan[3)]. It has been reported in recent years at occasions such as SEG and the Seismological Society of Japan conferences, that the natural earthquake data recorded using optical fiber and hDVS have been confirmed to be similar to data recorded using seismometers[4) 5)].

There are some differences between DAS and conventional sensors. One significant difference is that DAS provides distributed measurement, while the spatial resolution of the DAS data is determined by the gauge length (GL). GL is a measurement distance, equivalent to moving average filter.

For conventional DAS system, GL is set in an optical domain, so that one system provides only one GL value or maybe few variations by changing laser pulse width. On the other hand, hDVS does phase differentiation over a GL in digital domain instead of optical domain, allowing different or optimal GL processing after data acquisition, which is an ability that is unique to hDVS amongst the available DAS techniques.

When GL becomes a parameter, the bigger the GL gains, the higher the SNR of the data will be, but along with sacrificing the resolution generally. When seismic waves were considered using Ricker wavelet with a center frequency of 40 Hz and a velocity of 1,000 m/s, the equation below was obtained[6)].

GL_{opt} = ratio V / f_p

Where ratio is GL/spatial wavelength with values of between 0.4 and 0.54 as optimum value considering SNR and resolution, V is the velocity, and f_p is the peak frequency. This means that changing GL from one value to the other value with significant difference, the hDVS data would show or enhance different events in the same data set.

From 2017, demonstration tests of hDVS including earthquake observations using various different optical fiber cables have been conducted in Japan. Some data sets contained different Geophysical events recorded, so that event separation was performed using different GL against raw data. Different images were obtained from the same data set enhancing different events.

For DAS data acquisition, it is important to select optimal GL for the event expected prior to acquire the data, which would be challenging in most of cases.

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Keywords: DAS, hDVS, optical fiber, gauge length, seismic monitoring, event separation

