Earthquake observation in a borehole over 250 ˚C using high temperature optical fiber and DAS technology

*Tsunehisa KIMURA[1]

1. Schlumberger

DAS (Distributed Acoustic Sensing) technology has been used to meet the demands of pipeline monitoring and intrusion detection in Oil & Gas business since 2011. The latest optical fiber sensing technology using differential phase data called "hDVS" (heterodyne Distributed Vibration Sensing), now enables DAS to record seismic signal including VSP (Vertical Seismic Profiling)[1)]. Three-dimensional imaging can also be performed by a 3DVSP method[2)]. We have introduced the observation of natural earthquakes and waves, targeting the tsunami detection, using the hDVS device at recent meetings of JpGU and the seismological society of Japan (SSJ)[3)].

Late 2018, we conducted an experiment of natural earthquake observation using the hDVS system at the geothermal well in Japan. A high temperature optical fiber logging cable with 300 ˚C rating was run in a deviated well having a maximum depth of about 1,600 m and connected the third generation hDVS acquisition system to the optical fiber (single mode fiber) and recorded natural earthquake events for 5 days. The maximum temperature recorded at a depth of about 900 m was more than 250 ˚C. Under such a high temperature environment, almost all electronic, electric and magnetic sensors including seismometers cannot operate for a long time. Even with the use of DAS equipment, there is no precedent as far as I know, at least it is the first attempt in Japan.

A weight of 2 m length and 25 kg weight was attached to the high temperature optical fiber logging cable, and the observation was started by lowering the weight to the depth of 977 m inside the casing in order to avoid the weight becoming stuck in the open hole section of the well. With continuous recording with 60 seconds as one file, data of 975 m section from the surface was recorded for 5 days. In this paper, we report on the result of verifying how much observation of natural earthquake waves can be performed by using continuous measurement data.

During the observation period, we succeeded in capturing six natural earthquake events. Two of them were medium-scale earthquakes published in the earthquake information of the Japan Meteorological Agency (JMA). An example of this was recorded as follows.

(21st of November, 2018 04:09:49.9 Latitude 30˚24.0'N Longitude 130˚9.0'E 123km depth M5.2)

Earthquake data recorded by hDVS is shown in Fig. 1.

The arrival time of the P-wave analyzed from the waveform is 4:10:12.2 JST on 21st of November at the deepest part of the borehole and 4:10:12.5 JST near surface. Measurement parameters were gauge length 4 m, spatial sampling 1 m, and sampling period 1 msec. We also conducted reprocessing to change the gauge length and confirmed that data with higher S/N can be obtained. Reprocessing the raw data for an optimized gauge length is a capability that is unique to hDVS amongst the available DAS techniques.

We also compared it with continuous seismometer records by NIED (Hi-net). The nearest Hi-net station from the wellsite (just about 4km away), is compared with the recorded hDVS data, and it was found that they match well. For small earthquake events, S/N was higher in the measurement data of hDVS in some cases, which will be shown during the presentation.

It was confirmed that hDVS/DAS system can be used to monitor natural earthquake events while monitoring the reservoir or other purpose under very high-temperature condition such as geothermal well or very deep well that reaches a mantle, if the condition of the optical fiber is good.

Acknowledgements: JMA and NIRD data are used as a reference earthquake data for comparison. We thank these organizations.

References:

1) Kimura, T., Lees, G., and Hartog, A., Optical Fiber Vertical Seismic Profile using DAS Technology, JpGU 2016 (RAEG 2016, STT17-12) Extended Abstract.

2) Kimura, T. et al, Hybrid 3D VSP Using Fiber-Optic Technology and a Conventional Borehole Seismic Array Tool, EAGE Copenhagen 2018 (Th H 10) Extended Abstract.

3) Kimura, T., Kobayashi, Y., Naruse, R., and Xue, Z., Earthquake events monitoring in a well using Optical Fiber and DAS Technology, JpGU 2018 (STT50-04), Kimura, T., Summary of Earthquake Events Recorded in Japan using DAS Technology, and Future Vision, SSJ 2018 (S02-P12).

Keywords: DAS, hDVS, optical fiber, high temperature, seismic monitoring, earthquake