The potential of utilizing intelligent Distributed Acoustic Sensor and existing single-mode and multimode optical fibers for monitoring the reservoir characteristics

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Summary

Over the past three years there has been significant growth in the application of Distributed Acoustic Sensing for application in the wellbore for seismic surveys, flow profiling, frack operations and identifying well integrity issues.

Time-lapse three dimensional vertical seismic profiling (3D-VSP) has been used for monitoring reservoir characteristics such as monitoring the carbon dioxide (CO2) injection and Steam Assisted Gravity Drainage (SAGD) production.

With the proven ability to run the intelligent Distributed Acoustic Sensor (iDAS) on multimode (MM) fiber cables, a large number of wells in Canada which are currently instrumented with multimode (MM) optical fiber cables for Distributed Temperature Sensing (DTS) can now be utilized for a number of acoustic wellbore monitoring applications including three dimensional vertical seismic profiling (3D-VSP). We will present examples of iDAS measurements for a number of different optical fiber cable installations and compare the results of single-mode and multimode fibers with geophones.

Introduction

Vertical seismic profiling (VSP) provides an improved resolution and frequency content for reservoir monitoring. The checkshots in observation wells indicated a velocity decrease of about 100m/s to 250m/s due to the steam injection zones and the reservoir level [1]. In Steam Assisted Gravity Drainage (SGDA) fields, the use of conventional geophones may be limited by the high temperature in the reservoir which may reach 250^{o}C.

Distributed Acoustic Sensor (DAS) can offer significant benefits for wellbore monitoring applications [2]. Continuous profiling along the entire wellbore, provides increased lateral and vertical resolution with a high repeatability between different surveys. High temperature multimode (MM) optical fiber cables have been installed for DTS measurements in many SAGD wells to monitor the steam temperature. In addition, multiple well VSP acquisition can be acquired by time-synchronizing a multiple iDAS units to an external trigger signal or a GPS clock [3, 4]. With proven ability to use intelligent Acoustic Sensor (iDAS) with multimode optical fiber cables, a large group of wells become viable for 3D-VSP surveys to monitor the reservoir characteristics over a wide area [5].

The operation of intelligent Distributed Acoustic Sensor (iDAS)

The iDAS measures using the same underlying principle as that of the DTS and an Optical Time-Domain Reflectometer (OTDR). Here, a pulse of light is sent into the optical fibre and, through scattering in the glass, a small amount of the incident light is scattered back towards the sensing unit. The iDAS, however, is capable of determining, from this scattered light, a component which indicates changes in the local axial strain along the fibre. By recording the time of arrival of this returning light, the iDAS can determine the position at which each component of the returning light was generated. As this backscattered light is generated all along the fibre, the system so builds up a profile of the backscattered light, and hence a dynamic profile of the strain, all along the fibre. By repeatedly firing pulses into the fibre, the changes in strain can be determined at acoustic speeds, and so, provided the system has sufficient sensitivity, the acoustic signal can be measured all along the fibre [6]. The dynamic strain/ acoustic signals can be recorded with a sampling resolution down to 0.25m with a spatial resolution down to 1m [6]. However, for seismic applications, a spatial resolution of 10m is normally used to optimize the signal to noise performance and the frequency response of iDAS.

Method & Examples

A thorough evaluation of distributed acoustic sensing for borehole seismic has been undertaken which has successfully qualified the use of the intelligent Distributed Acoustic Sensor (iDAS for seismic applications [6]. This evaluation included several important facets of real operational use of optical cables. Firstly, an evaluation of the deployment of the optical cable showed that the iDAS data was useable irrespective of deployment method (Figure 1).

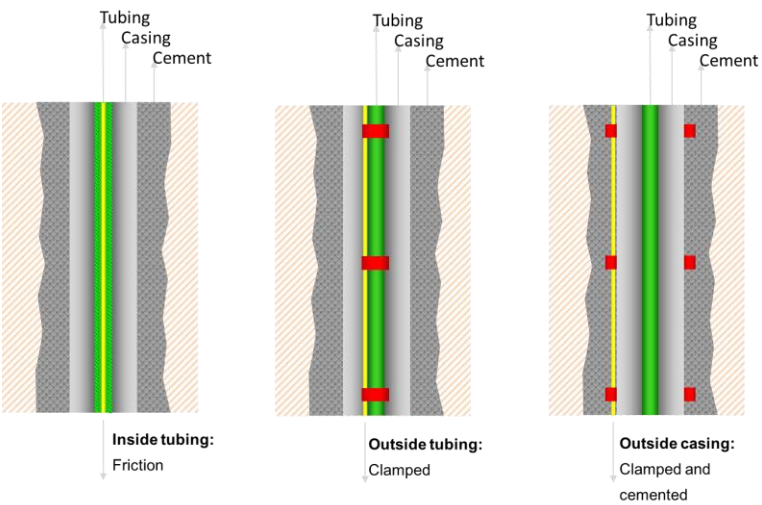

Figure 1. The optical cable has been run lose within tubing (or within coiled tubing, strapped along production tubing, and cemented outside the casing, directly connected to the formation.

Secondly, seismic surveys were recorded in shut-in then flowing conditions in the same well and acoustic energy source. The resulting data showed that although there was additional noise caused by the movement of produced fluids, a coherent and accurate seismic profile was able to be recorded (Figure 2).

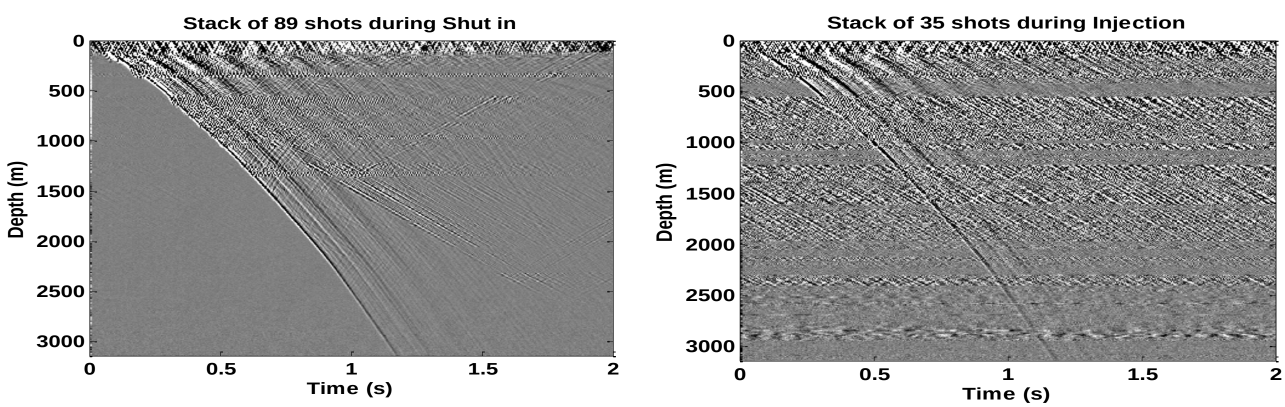

Figure 2. The left frame shows a shut-in data gather sample. The right frame is the same well but recorded seismic during production. As can be clearly seen, the formation features are clearly visible and once the flow noise removed, a coherent seismic data set [6].

Thirdly, the comparison between DAS and conventional geophone seismic surveys were investigated. The comparison have been made on both field developments with permanently installed downhole geophones, and also on between geophone arrays on wireline. (Figure 3). This has allowed a direct comparison between the DAS and geophones after the data migration [7].

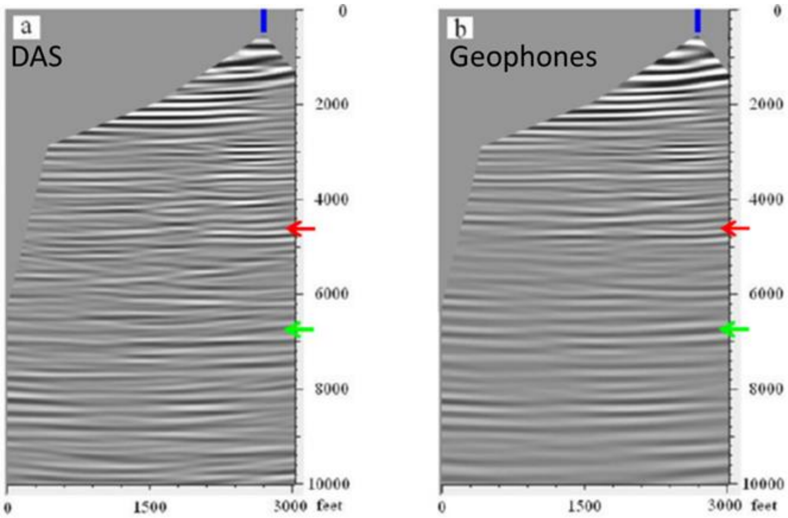

Figure 3. A migrated seismic image using DAS data on the left panel, is compared to a migrated data set using conventional geophones [7].

Fourthly, and most importantly for a mature producing area, comparison between the use of iDAS on single-mode and multi-mode optical cables [8]. Using a cable with both SM and MM fibres and two iDAS interrogators, the response of both fibres were recorded simultaneously (Figure 4).

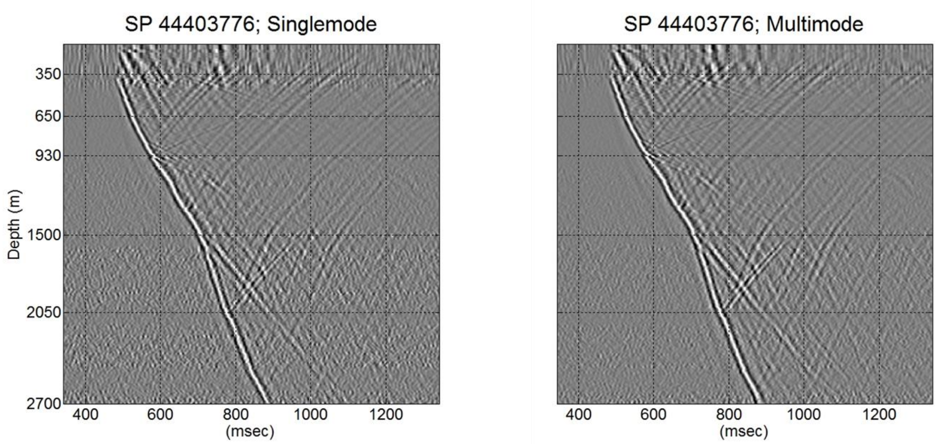

Figure 4. Single mode (left panel) and Multi-mode (right panel) sesimic gatherings, and demonstrating effective use of either fibre type [8].

Further examples of seismic signal processing imporvements and flow profiling using multi-mode cables will be presented, together with a discussion about seismic directionality using optical cables.

Conclusions

Confidence in the DAS technology to record useful well data has grown significantly over the past three years. As many wells have installed cables the opportunity now arises to re-evaluate the field potential using seismic surveys, and also define specific well production profiles. The cost of doing such data gathering is significantly cheaper than intervention services – and thus ideal to adopt in these opex restrictive times.

Using iDAS, existing wells with MM fibres installed for the DTS are now effectively “microphones within the reservoir”. In particular, a large group of wells are now become viable for 3D-VSP surveys to monitor the reservoir characteristics over a wide area.

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