MAKING SENSE OF UNCONVENTIONALS WITH DAS

Marcel A. Grubert, Xinyang Li and J. Andres Chavarria, OptaSense, USA, review the applications of distributed fibre optic acoustic and temperature sensing in unconventional reservoirs.

The use of distributed fibre optic acoustic and temperature sensing (DAS/DTS) has advanced and optimised the development of unconventional reservoirs worldwide. DAS technology can be permanently installed behind casing, semi-permanently installed on the production string or temporarily installed using wireline or coiled tubing. After permanent installation of the DAS fibre, there is no need for further wellbore interventions.

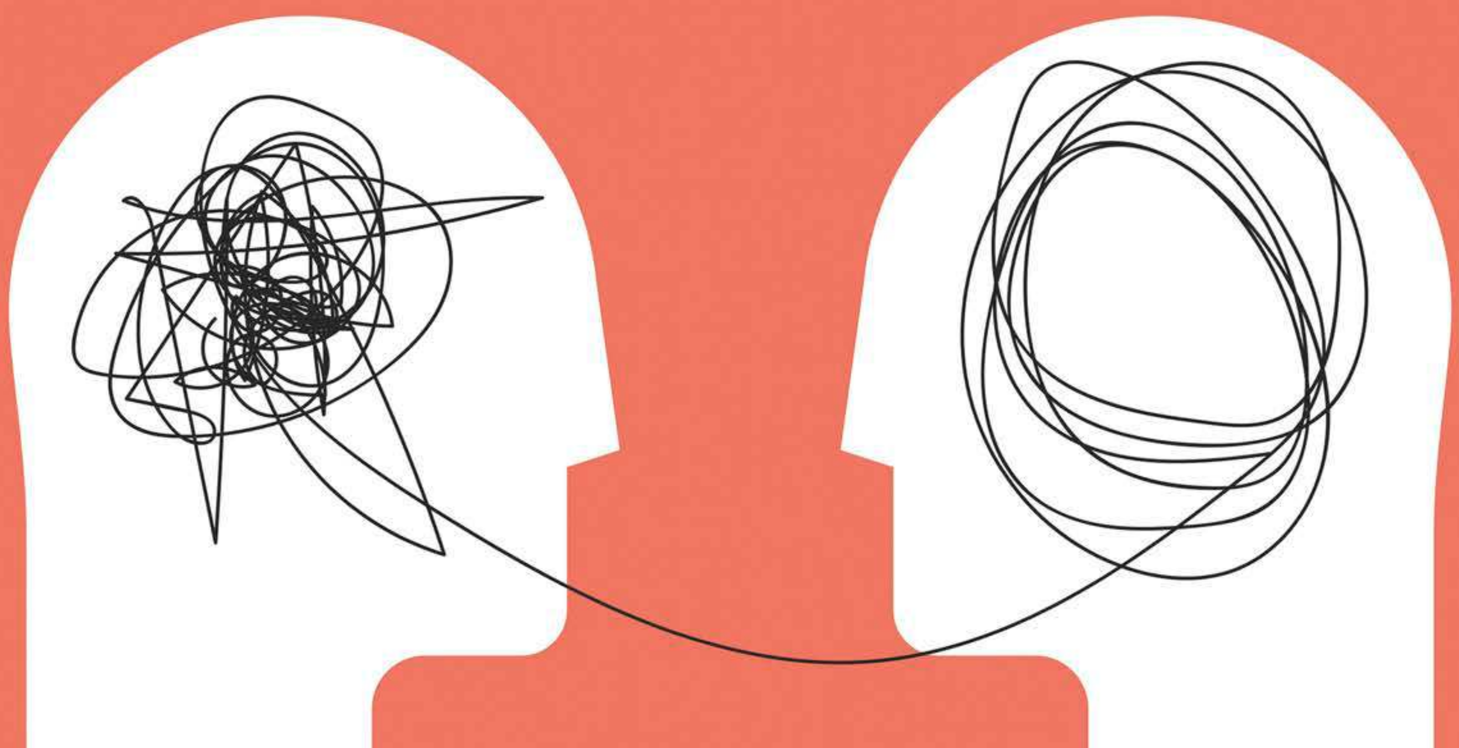
The wide range of applications for DAS/DTS means it can cover the whole lifecycle of the well, including seismic measurements, wellbore integrity assessments such as cement curing and leak detection, completion monitoring – which allows for hydraulic fracture optimisation – as well as production and injection flow monitoring and artificial lift assessment (Figure 1).

The three main applications in the unconventional reservoir arena are hydraulic fracture profiling, which determines the proppant distribution and assesses stage communication; cross-well communication, which establishes possible reservoir connection paths between a fibred well and its surrounding wells; and production flow profiling, which reveals from which clusters and stages the well actually produces.

Hydraulic fracture profiling

The goal of the hydraulic fracture profiling acquisition is to determine operational and completion design efficiencies. For this purpose, DAS and DTS acquired data is monitored live during the perforation phase and the actual hydraulic fracturing pump phase, as well as for approximately 3 hours after the stage is completed to obtain an adequate warm-back profile.

Since DAS is capable of following the acoustic shock waves of a perforation to its exact origin, it is a suitable tool to check if the clusters are perforated correctly on depth. Furthermore, the successful installation of the bridge plug can be determined by examining the acoustic feedback of the setting and release tool.



During the hydraulic fracturing process, the DAS and DTS waterfall plots (Figure 2) are visualised over the pump data (e.g. slurry rates, pressures, concentrations). This allows for analysis of initial stage isolation (ball seating), subsequent isolation failures (e.g. cement breakdown, inter-fracture connections) and the actual proppant deposition profile over the entire stage.

The determination of the proppant and fluid profiles into each cluster is achieved by correlating the DAS signal intensity for each of the clusters to the recorded slurry rate and downhole concentration. The definition of a 'good' stage completion is a uniform deposition of proppant into each cluster. This makes several assumptions, i.e. the clusters are set in a homogeneous, hydrocarbon bearing formation where the rock is capable of refilling the fractures, and that the fracture geometries are similar. An in-depth analysis can show deviations of the actual pump job from the desired ideal, identify toe and heel stage biases, inactive clusters and super-active clusters and in general compare different stage designs during the well completion based on their individual completion parameters. At the end of the job, all designs used in that particular well are compared, and the optimal design is noted for future well completions.

Another advantage of using DAS during the fracture programme is that it can monitor the performance of vendor products. For example, different isolation methods or diverters can be employed in a well and their effectiveness determined. Pump plans can be optimised and changed for the next stage treatments based on current performance and observations. Screen-outs can be identified towards individual clusters. Overall, a detailed analysis of the vendor products, sand pumped and operations plan can greatly reduce costs and risks in all subsequent wells.

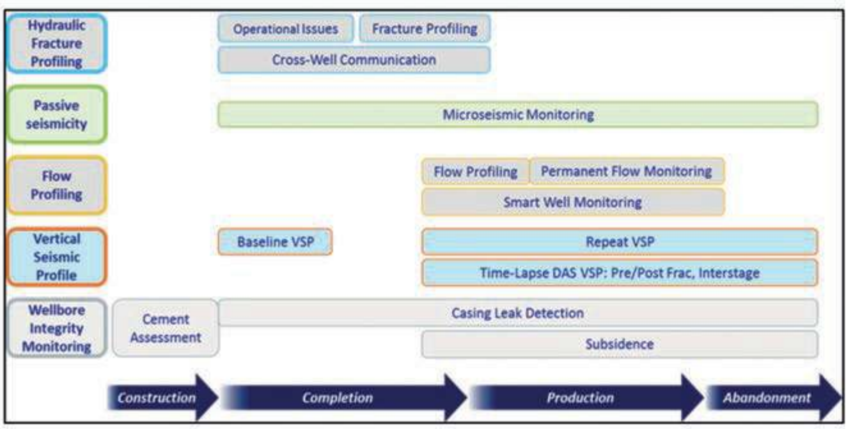


Figure 1. *Applications for DAS/DTS.*

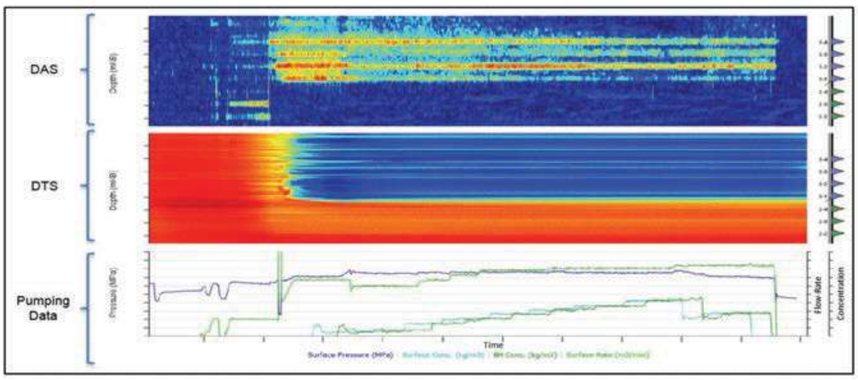


Figure 2. *DAS/DTS data visualisation during hydraulic fracture operation.*

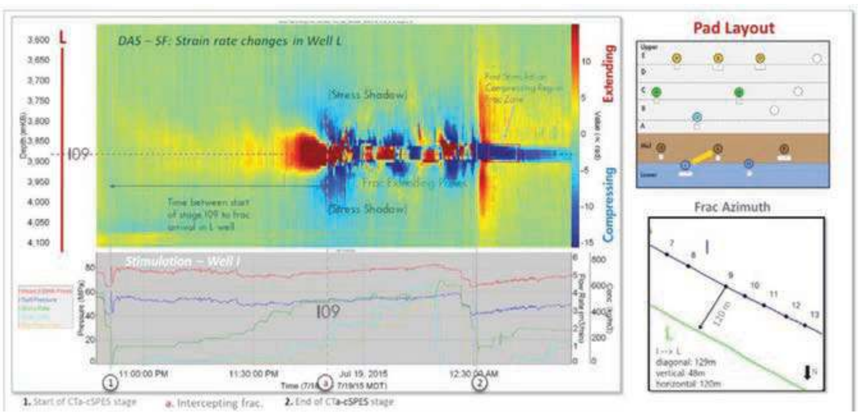


Figure 3. *Cross-well communication strain change during treatment observation of a nearby well.[1]*

Finally, in comparison with other completion design optimisation methods, the turnaround time when employing fibre is relatively short. Initial qualitative data is available immediately, while an initial stage proppant profile is available within a few hours. A detailed analysis of procedure, completion design efficiency, isolation effectiveness and diverter methodology can be supplied in a matter of days.

Cross-well communication

In a cross-well communication acquisition, one or more fibred wells monitor the hydraulic fracture completion programme on several nearby wells. This is done through DAS and DTS, where the DAS records the approaching strain front that travels from the offset treatment well towards the fibred well; it also identifies the instances of fracture hit when the fracture actually connects with the (uncompleted) fibred well. The DTS monitors the temperature around the wellbore and can help validate actual fracture hits.

An example of monitored strain change is shown in Figure 3.[1] The waterfall plot shows positive stress changes (extension of the fibre) in red and negative strain changes (compression of the fibre) in blue. As a fracture from a nearby well approaches the fibred well the stress increases until the fracture tip hits the fibre. At that point a large stress increase is recorded. As the fracture continues past the well, alternating compressions and extensions in the rock are recorded until the pump job is finally completed and the fracture relaxes towards closure. Surrounding stress field (stress shadowing) can be identified with leads to estimates on fracture width, fracture lengths, and fracture heights (if DAS micro-seismic data, which is recorded by the same interrogator, is utilised).

Furthermore, a detailed 3D map can be created showing the fracture origination point on the treatment well and the fracture hit location on the fibred well. This allows for a mapping of the (more dominant) fractures and helps in identifying bypassed areas that have not been completed. Comparing the fracture hits on different completion designs for that particular treatment well then allows optimisation of any further designs.

Cross-well communication analysis in general is employed for wells that are within stress field and fracture reach of the fibred well. From past experiences this has been measured, based on formation and reservoir conditions, up to 3000 ft. The further away the well, the lower the stress readings are.

Production flow profiling

Production flow profiling can be undertaken in a long-term monitoring fashion, where the DAS interrogation box is left at the wellsite and continuously records data. More often though it is used for one or multiple short-term acquisitions to acquire production logging tool (PLT)-like data to determine an averaged production inflow profile, intervention treatment injection profiles or to determine the influence of child wells onto the flow profile of the fibred parent well.

Unconventional wells, although often thought of as steady-state producers, show a remarkably unsteady behaviour as individual fractures charge and discharge. As such it is difficult to acquire a good inflow profile with regular PLTs, since they not only disturb the well with their up and down movement and wellbore obstructions, but also only measure a relatively short time interval. Inflow profiling measurements with DAS on the other hand are performed over a larger time span of at least 12 – 24 hours and then averaged.

Depending on the flow rate and fluid produced (liquid, gas, mixture), different analysis methods ought to be used and often the combination of DAS and DTS data is advisable. High-rate gas flow is easier to see in the DAS data due to the more intense flow noise (Figure 4).[2,3]

For low-rate liquid flow, which is less energy intensive, it is difficult to pick up enough acoustic noise over the background noise level to get an adequate inflow profile. In this instance looking at the low-frequency part of the DAS data, which is driven by temperature changes, can be helpful.[4] Cycling the well (shut-in/start-up) can create small temperature slugs which can help in determining inflow regions and rates. In combination with a regular DTS data-based model this can be used to ascertain inflow profiles.[3]

Additionally, the DAS and DTS data is used to qualitatively examine the flow behaviour in the well, such as shut-in and start-up behaviour, unloading for artificial lift operations, fluid interfaces and phase behaviours, slugging effects and functionality of downhole equipment (gas lift mandrels, inflow control devices, safety valves, electric submersible pumps, etc.).

Overall, production flow profiling is an important part of the completion design and optimisation process involving fibre optics. It validates the 'uniform placement' idea employed under the hydraulic fracture profiling approach, directly correlates completion design execution with actual profitable inflow from the well and hence allows the operator to locate their completions in zones that are actually oil bearing and producing.

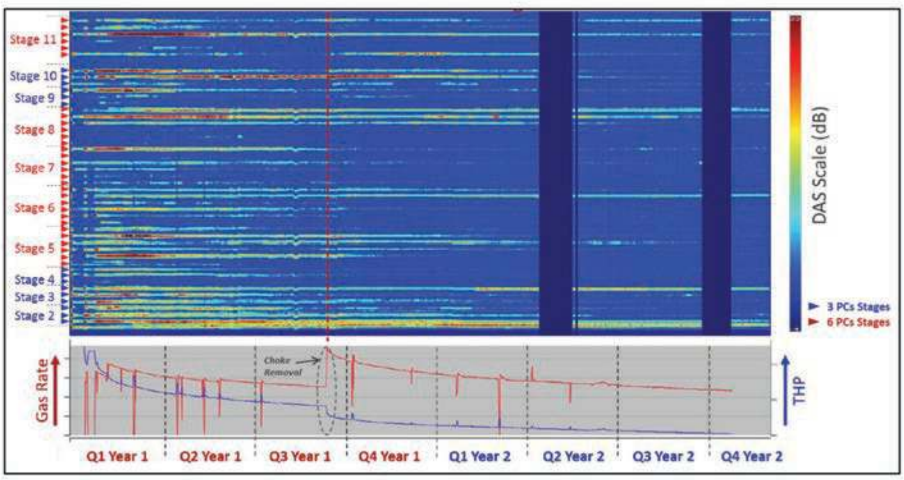


Figure 4. *Long-term flow profile monitoring on gas well (two completion designs used).[3]*

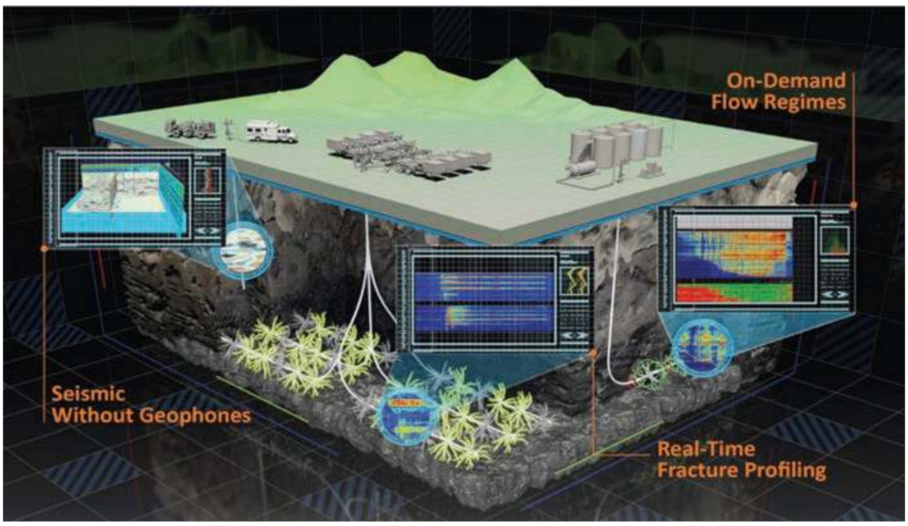


Figure 5. *Distributed fibre optic sensing – well placement and completion design optimisation.*

Conclusion

The application of fibre optic sensing (both DAS and DTS) has become mainstream in the development of unconventional reservoirs. New developments in interrogators have increased the accuracy and hence the value of the information, and are in the process of replacing previous preferred methods e.g. geo-phones (Figure 5). The flexibility of the fibre deployment and the wide range of applications make it justifiable in most plays because it can decrease the number of future well interventions. Although its initial cost can decrease the value of the individual fibred well, it quickly increases profitability and saves costs on any further wells drilled, due to the insights obtained into operational and completion design optimisation.

References

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