Mapping the orientation of downhole sensing cables and control lines using an engineered hybrid distributed acoustic sensing system

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• Definition of the problem
  • Risk and additional cost of behind-casing fiber optic cable installations
    i. Extra downhole hardware
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• Proposed engineering hybrid DAS solution
• Field trial results
• Summary
DAS operation

- Simultaneous measurement of acoustic amplitude, phase and frequency at every metre along fibre
- 40,000 independent measurement points
- Acoustic phased array detector

Tom Parker et al., EAGE First Break volume 32, pp. 61-69, February 2014
Downhole Fiber Optic Cables Installation

- Encapsulated Fiber Optic Cable
- Locked Casing Centralisers
- Cable Clamps
Conventional Cable Mapping and Oriented Perforation

- Clamp assembly with long metal bars placed beside fibre optic cable
  - Metal bars provide a significant enough metal anomaly for wireline tools to detect using rotating sensor
  - Significant length of metal bars required to make it possible to target clamps with wireline point sensor
- Metal anomaly mapper data often validated with 360 degree ultrasonic imaging of casing and cement
- Subsequently zero-phased perforating guns can be oriented using a eccentric weight and indexing adapter
• Create a sealed (disposable) sensor package capable of measuring and communicating relative bearing

• Relative bearing is typically the clockwise angle from the high side of a deviated wellbore to a downhole toolface
  – In this instance to the sensing fiber cable

• Leverage the ability to acoustically sample every position along the fibre with DAS

• The Cable Orientation Beacon comprises:
  – Sealed pressure tight housing (10kspi Working Pressure)
  – Relative bearing sensor
  – Measurement and driver electronics
  – Downhole battery
  – Sound source

❖ Device must be deployable downhole without compromising completion.
❖ Such as enclosed within the envelope of typical cable clamp.
Batteries are installed to beacon prior to dispatch from Silixa and end caps are welded on.

Low power electronics monitoring an internal temperature sensor.

A microprocessor is coded with an operational sequence including an activation temperature.

*Multiple beacons are placed outside casing along the deviated or horizontal wellbore.*

When a pre-defined downhole temperature is reached the beacon switches to full operation mode.

The program can include a delay between temperature switch-on and full operation to allow for other planned operations such as cementing.

Microprocessor converts measured RB to a coded driver signal to the sound source.

Sound source is activated for 30 seconds every 30 minutes to prolong battery life.

*DAS is used to interrogate fiber from surface*

Interrogation continues until each beacon is identified

Optical distance of signal can be tied to the casing tally depth of each beacon installed depth

Beacon relative beacon at each depth indicates path of cable outside casing.
Engineering Solution

- Beacon must remain in keyed orientation within the clamp so that measured relative bearing is the same as the sensing cable.
- Clamped beacon should present as low, and well friendly a profile as possible.
• Installation on the rig floor must be safe and easy
  • Beacons are secured into the clamps offline so that there is no risk of dropping into well
• Beacons and clamps should integrate well with other installation hardware: clamps and centralisers
• Proximity to DAS sensing fibre should enable beacon signal capture
2017 Initial Field Trials

- Two horizontal well trials in North America
  - Trial 1: 15 beacons spread along the horizontal
  - Trial 2: 5 beacons placed in the horizontal
- One deviated well trial in North Sea
  - Trial 3: 5 beacons placed with hydraulic control line package. DAS sensing fibre introduced by intervention to survey beacons
North America Fiber Optic Cable Mapping

- 15 cable orientation beacons spread along lateral with encapsulated fiber optic cable
- DAS recorded on fiber during casing running and after casing landed
- Cable orientation decoded from DAS data at 14 of 15 beacon locations

**Lessons Learned**
- *Increased battery life required*
  - ✓ 2018 re-design provides 7 days of battery life

![Graph showing Relative Bearing and Measured Depth](image)

Courtesy of Chevron

![Graph showing Relative Bearing and Measured Depth](image)
Customer wanted a low cost method to map the position of a control line bundle outside tubing on a new smart well completion.

The control lines ran through a secondary reservoir to sleeves in the main target.

Required option to add perforations to secondary reservoir without losing hydraulic function of deeper components.

- 5 Orientation Beacons installed outside tubing string alongside hydraulic control lines for smart completion
- Well deviation approximately 20° at beacon depth
- Fiber optic slickline cable run into tubing to log DAS
- Acoustic signature of beacons recorded and analysed
- Relative bearing of each beacon decoded from data
- Depth log of control line azimuth delivered to customer
2017 Initial Field Trials Learnings

• Battery life affected by passivation due to un-even battery draw during sound source activation.
  ✓ Electronics re-engineered to reduce and flatten battery draw using newly available components
  ✓ Relative bearing sensor replaced with 3-axis accelerometer
  ✓ Additional battery cell
  ✓ 2018 performance gives 2 weeks of downhole operation

• Difficulty in testing function at wellsite
  Although ends welded there was a roll sequence to activate a test function.
  ✓ Replacing welded end cap on one end with threaded o-ring sealed cap to allow final wellsite testing

Final beacon dimensions | OD: 1” | Length: 11.2”
Summary

• Reduced hardware makes running the casing easier and improves the chances of a successful cementing with no additional risks

• Direct DAS cable mapping (no additional cable mapping intervention survey is required)

• Provides accurate downhole depth calibration points

• The DAS can also be used for acquiring additional completion and wellbore data via a range of low-power hybrid sensors

• The permeant installation of the sensing fiber optic cable offers a cost-effective surveillance solution for the life of the well and the field
Summary

one fibre - life of field - multiple services

Borehole seismic
Cement evaluation
Fracture analysis
Flow profiling
Xwell Microseismic & Strain
Repeat seismic 3D/4D
Well abandonment

Single FO Cable Installation

DRILLING --> COMPLETION --> PRODUCT/RESERVOIR MANAGEMENT --> WELL ABANDONMENT
We would like to thank the operators for their permissions to share the field trial results presented here.
Thank you

Questions?