Multicomponent distributed acoustic sensing

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Introduction

Distributed Acoustic Sensing (DAS) data in boreholes are not commonly used for reservoir characterization because multicomponent data are needed to quantify different wave modes.

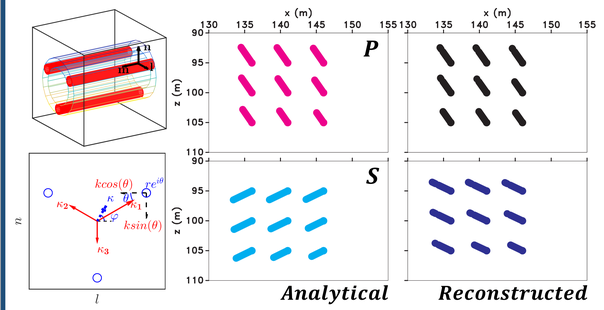
We propose two approaches:

- Using multiple parallel optical fibers with the shape sensing method based on measurements of the axial strain gradient to obtain the curvature of the cable. The curvature will be used to reconstruct the displacements.
- Using helical optical fibers to obtain dip and azimuth dependent strain measurements to reconstruct the strain tensor of the surrounding field.

Multiple Parallel Optical Fiber

The strain gradient between multiple optical fibers we can obtain the curvature of the fiber as a whole unit using the shape-sensing method.

The calculated curvature is used to reconstruct the displacement of the optical fiber at every point along the fiber.



Acknowledgement

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Helical Optical Fiber

We formulate the problem as a strain rotation problem:

$$\bar{\boldsymbol{\varepsilon}} = \boldsymbol{R}\boldsymbol{\varepsilon}\boldsymbol{R}^T,$$

where $\bar{\boldsymbol{\varepsilon}}$ is the rotated strain and $\boldsymbol{R}$ is the rotation matrix from the local coordinate along the fiber.

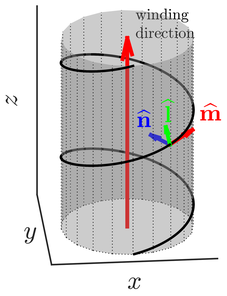
Since DAS measures strain along the optical fiber, we can reformulate in terms of the axial strain component $\bar{\varepsilon}_{mm}$:

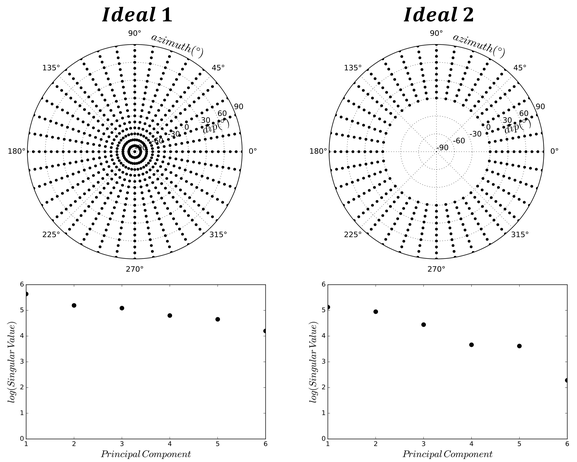
$$\bar{\varepsilon}_{mm} = \boldsymbol{G}\boldsymbol{\varepsilon},$$

where $\boldsymbol{G}$ is expanded from the strain rotation problem.

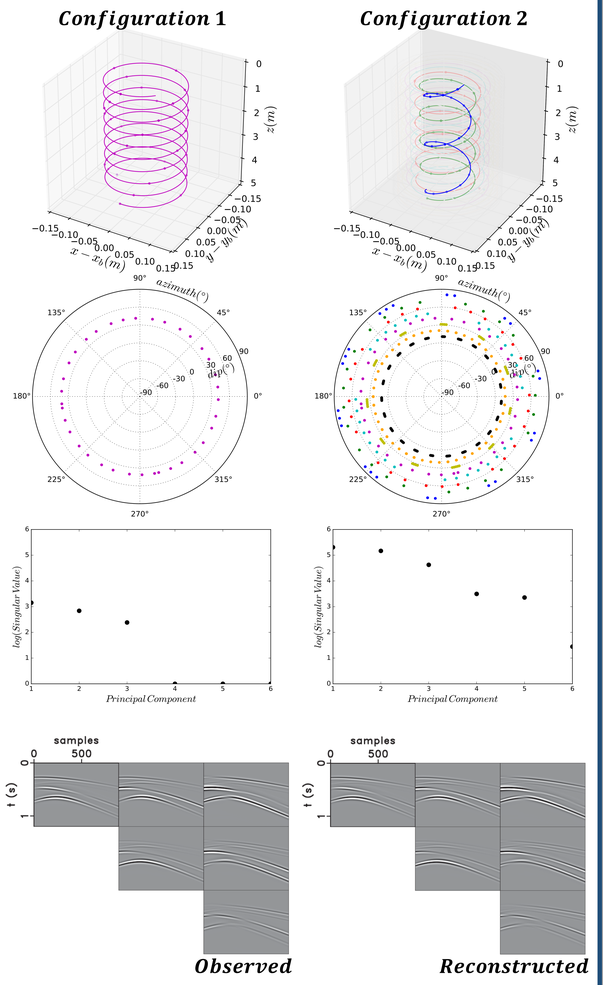
We reconstruct the strain tensor by solving the equation in a least-squares sense. We group consecutive measurements along the fiber in a window.

Adding an additional straight optical fiber in the center of the 8 helical optical fiber configuration can improve the reconstruction.

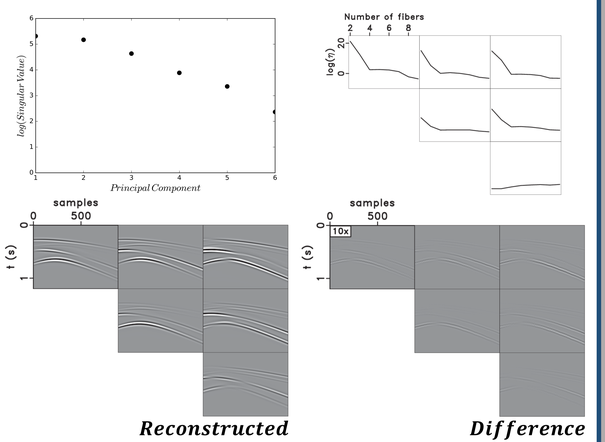




Experiment



Discussion



Conclusion

The shape sensing method applied by the parallel optical fibers is unable to accurately reconstruct correct displacements when multiple wave modes are involved.

The strain tensor can be reconstructed using multiple dip and azimuth angle dependent axial strain measurements. Such measurements can be obtained using a helical configuration under the assumption that the seismic wavelength is much larger than the reconstruction window.

Reference

Hornman, J., 2016, Field trial of seismic recording using distributed acoustic sensing with broadside sensitive fibre-optic cables: Geophysical Prospecting.

Mateeva, A., J. Lopez, J. Mestayer, P. Wills, B. Cox, D. Kiyashchenko, Z. Yang, W. Berlang, R. Detomo, and S. Grandi, 2013, Distributed acoustic sensing for reservoir monitoring with VSP: The Leading Edge, 32, 1278–1283.