Supplementary file

Enhancing fracture geometry monitoring in hydraulic fracturing using radial basis functions and distributed acoustic sensing

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Appendix A. Real field data (Case 2)

Following the analysis of Case 1, another hydraulic fracturing stage from the HFTS field data, designated as Case 2, was selected to validate the adaptability and robustness of each method under varying field conditions (Fig. A1). The figure displays the spatial distribution of strain rates (upper row) and temporal responses at three representative locations (−50, 0, 50 m; lower row). The traditional fit(w) method's results exhibit pronounced spatial symmetry, failing to capture the asymmetric perturbations observed in the field data, particularly underestimating the magnitude and extent of negative strain rate regions. Incorporating θ_z, the fit(w+θ_z) method captures some asymmetric features but still underrepresents responses in boundary areas. Conversely, the RBF method more accurately reproduces the observed asymmetric distribution, effectively restoring the differential perturbation amplitudes on either side of the main fracture. This underscores the RBF method's superior geometric adaptability and high-fidelity inversion capabilities in complex field scenarios.

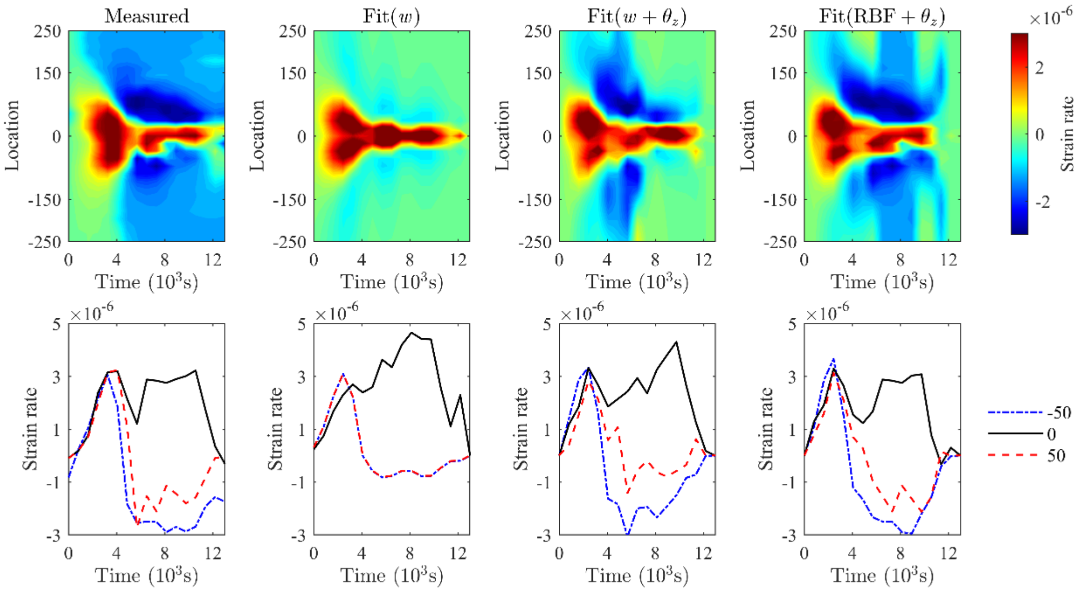

Fig. A1. Comparison of strain rate distributions and typical point responses for the HFTS data (Case 2) using different inversion methods.

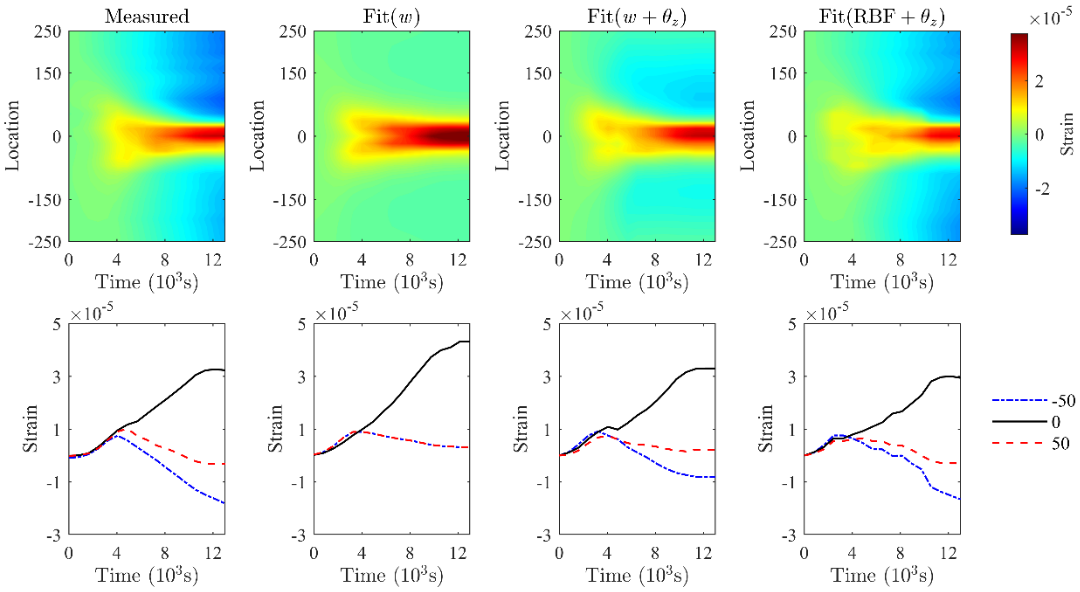

Fig. A2. Comparison of strain distributions and typical point responses for the HFTS data (Case 2) using different inversion methods.

Building upon the strain rate comparisons in Fig. A1, Fig. A2 presents the strain field fitting results for Case 2, assessing each method's geometric fitting performance under low-frequency responses. The fit(w) method's strain curves at −50 m and 50 m nearly overlap, failing to reflect the asymmetric responses evident in the field data. Incorporating θ_z, the fit(w+θ_z) method captures some curve differences but still exhibits flattened boundary trends. In contrast, the RBF method's fitted curves closely align with the measured data in overall trends, amplitude differences and negative strain regions, demonstrating its robustness in reconstructing complex geometries. Notably, at −50 m, the RBF method accurately captures the boundary variations in strain reduction, highlighting its ability to extract asymmetric information without relying on explicit structural constraints.

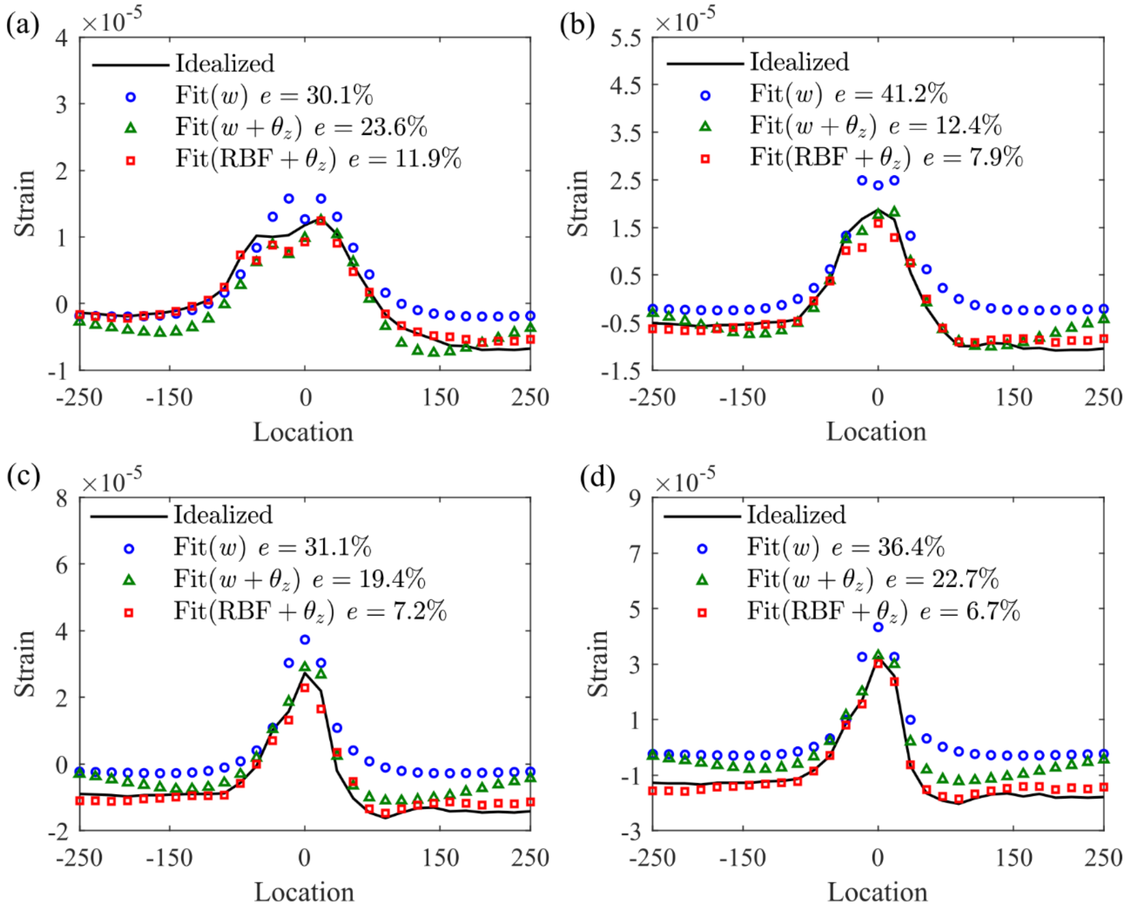

Fig. A3. Comparison of strain distribution at multiple time steps: (a) 4,900, (b) 7,300, (c) 9,800 and (d) 12,200 for the HFTS data (Case 2).

Further point-by-point analyses of representative time steps in Case 2 are presented in Fig. A3, comparing along-well strain distributions and the fits achieved by the three methods. The traditional fit(w) method consistently exhibits significant deviations across all time points, particularly smoothing out abrupt strain changes, failing to capture the asymmetric transitions observed in the measurements. Incorporating the rotation parameter θ_z enhances the fit(w+θ_z) method's performance, reducing errors; however, discrepancies remain in boundary decay trends and peak positions. In contrast, the fit(RBF+θ_z) method delivers the best fits across all time steps, achieving the lowest overall errors and closely matching the measured responses in peak positions, amplitude variations and boundary transitions.