Low Frequency Measurement System

Qiuliang Yao, De-hua Han

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Why do we need low frequency measurement

- Dispersion: integration of seismic, well-log and core data
- Attenuation: another attribute for DHI
History for lab measurement

- Ultrasonic: ~MHz
- Resonant bar: >400Hz (logging)
- Force-deformation: Hz-1000Hz (seismic)
Low frequency system: principle

- Shaker
- Elec. connector
- Sample
- Standard

Diagram:
- Vessel Head
- Rigid Top Plate
- Electronics Feed-through
- Aluminum Standard
- Ultrasonic Transducer
- Pore Fluid Line
- Linear Bearing
- Shaker Housing
Low frequency system: principle

\[ E = \frac{\sigma}{\varepsilon_{\perp}} \]

\[ \gamma = \frac{\varepsilon_{\parallel}}{\varepsilon_{\perp}} \]

\[ \frac{1}{Q} = \tan(\theta) \]

\[ V_p = \sqrt{K + \frac{4}{3} \frac{\mu}{\rho}} \]

\[ V_s = \sqrt{\frac{\mu}{\rho}} \]
Engineering challenges

- Small strain $<10^{-6}$ and small output ($\mu V$)
- Results sensitive to amplitude and phase
- Special hardware and software need be developed
  - Small signal amplifier with differential input and shield driving
  - Lock-in amplifier to deal with low signal-noise ratio
  - 24 bit 16 channel NI acquisition system
- Multiple calibrations needed
Acknowledge: CSM & Shell
What’s new: Mechanically

- Stationary sample assembly: more reliable
- In vessel shaker: better vibration mode
What’s new: Electronically
What’s new: virtual lock-in amplifier

- 1st in the world
- Separate with acquisition hardware
- 16 channels, efficient & consistent
- Better integration with processing
Software: acquisition, processing, automation
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Calibration:

Before

After
Whole system
Primary result: Dry vs. Butane saturation
THANK YOU!