Computational simulation of distributed acoustic sensing (DAS) approach to diagnose multiple-stage fractured well performance

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**OBJECTIVE**

Distributed Acoustic Sensing is a method which is used in oil and gas industry for well monitoring during fracturing treatment and production period.

The objectives of this work were:

- to build a computational model of fluid flow through a proppant pack (fracture cell) and perforation into the well and simulate acoustic wave behavior in a domain consisting of a perforation and a pipe.
- to compare simulated acoustic signals with lab-obtained acoustic measurements.
- to obtain correlation between DAS measured signal and flowrate

**APPROACH**

Modeling of the fluid flow is represented as fluid flow through the proppant pack and through the perforation into the wellbore (Fig.1). The flow is assumed as steady state turbulent process. This fluid flow creates a noise which is measured by sensors (microphones) along the center of the wellbore (Fig. 2). Amplitude-frequency characteristic of this acoustic signal is received from raw measurements of acoustic pressure via Fast Fourier Transform.

Simulation was conducted by ANSYS Fluent software, which has option of parallelization. Number of nodes in mesh (Fig.3) required for convergence of calculation is 1,500,000. Due to this huge number of grid elements it is necessary to parallelize calculation by supercomputer (Texas A&M High Performance Research Computing) on Terra cluster (8,512 Core, 304 Compute Node, Lenovo x86 HPC Cluster).

**ACHIEVEMENTS**

- **CFD Simulation**
  - Analysis of computational efficiency (Fig.4, Fig.5, Fig.6) were conducted for steady state case of gas production process, when fluid goes through the fracture cell, which is described as porous structure.
  - The pressure profiles (Fig.7, Fig.8) allow to conclude that the largest pressure drop occurs in the fracture cell.
  - Sound sources (Fig.9) are defined on the basis of Broadband Noise Sources model.

- **Acoustic Simulation**
  - Simulated time period coincides with the lab experiments (Fig.10). During this period, acoustic signals are measured in the presence of receivers in the well (Fig.11).
  - Amplitude-frequency spectrum is obtained from raw acoustic pressure data via FFT.
  - Sound pressure level is obtained from amplitude-frequency characteristics and is compared with experimental results (Fig.12).

**SIGNIFICANCE**

- The experimental study set the fundamental relationship between acoustic measurement and flow rate, and the computational model simulated the same conditions as the experiments. The relationship between sound pressure level and flow rate obeys the following correlation:

  $$ SPL = A \times \log(q^2) + B $$

- Usage of supercomputer significantly decrease time of simulation especially during transient simulation, which is necessary for acoustic simulation.

- Computational fluid dynamics and aeroacoustics models in the combination with experimental work created complete simulation program which provide quantitative correlation between fracture properties, fluid properties and acoustic signal.

- Obtained correlation could be implemented in the real field well for DAS interpretation.