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-observed 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.

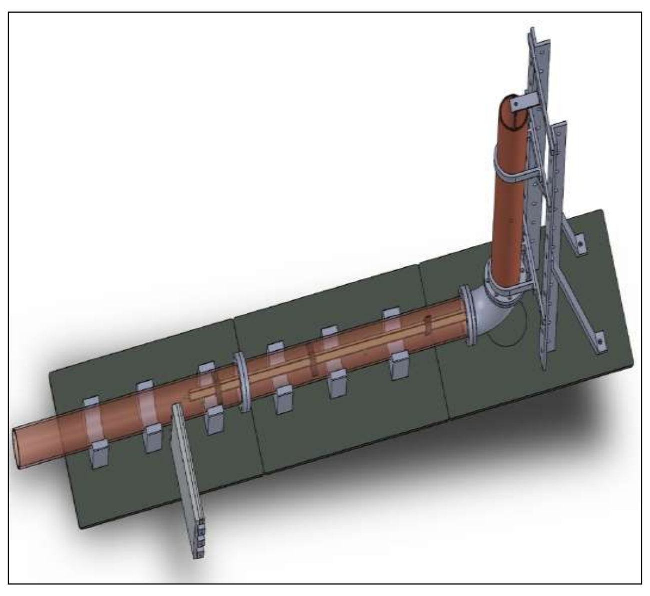

Fig.1: Experimental Apparatus

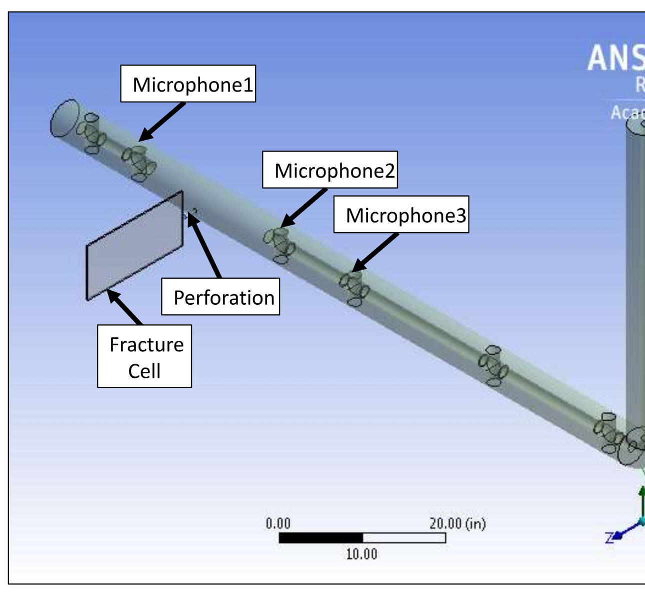

Fig.2: Simulated geometry model 3d-view

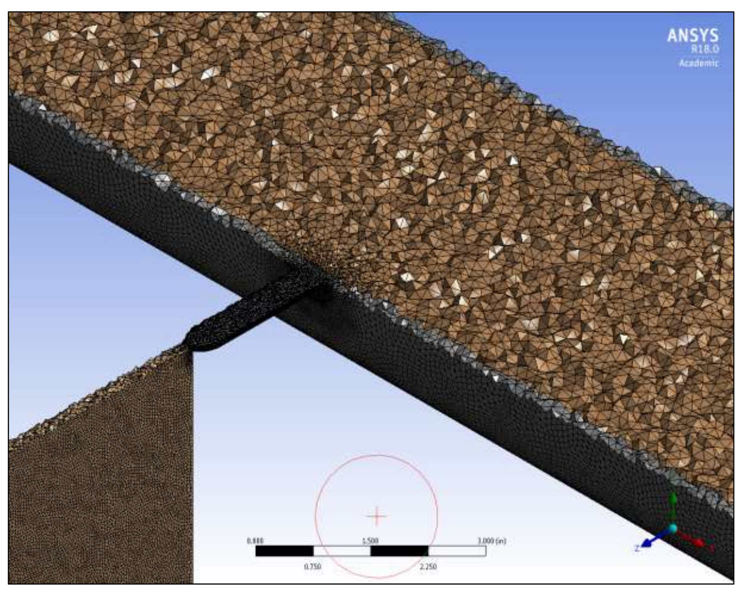

Fig.3: XZ-cross section of geometry model with mesh

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.

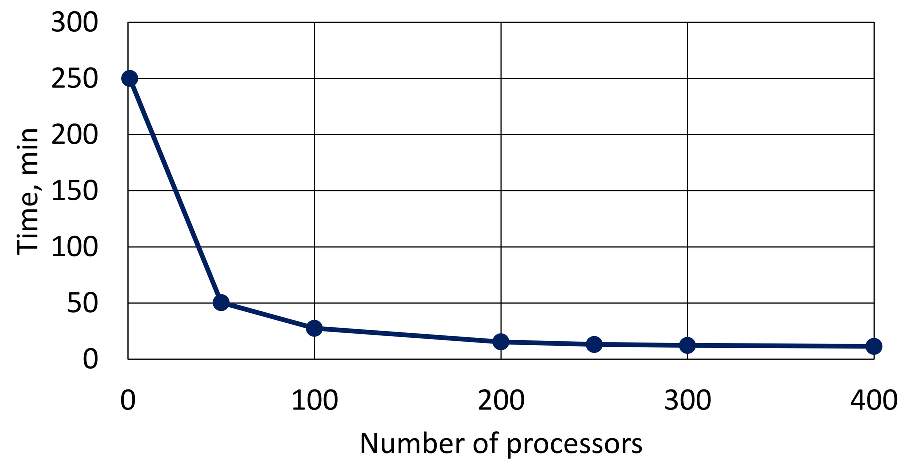

Fig.4: Time improvement of calculation

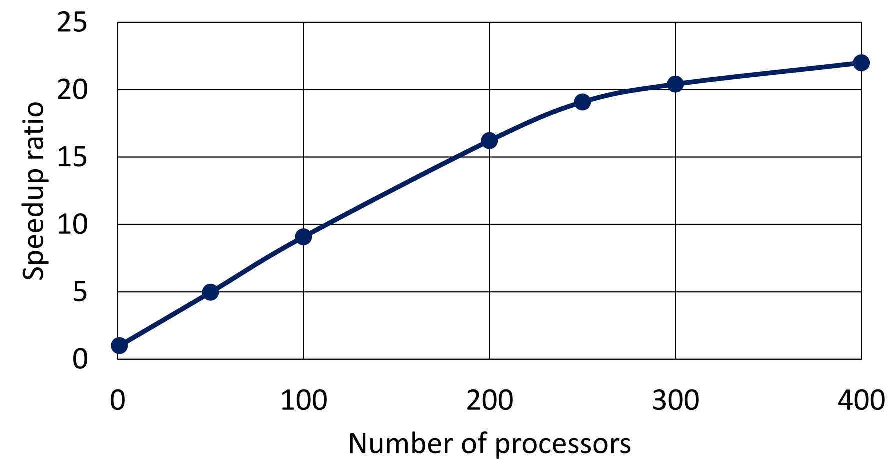

Fig.5: Speedup of calculation

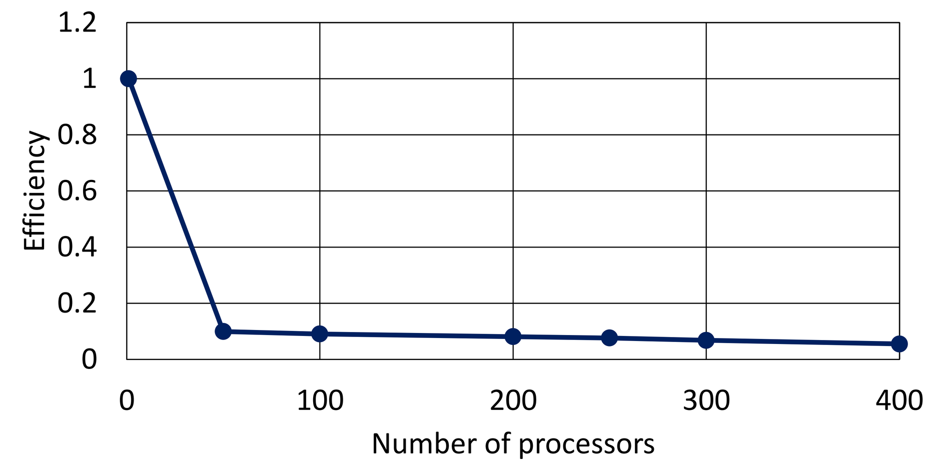

Fig.6: Efficiency of calculation

➢ 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.

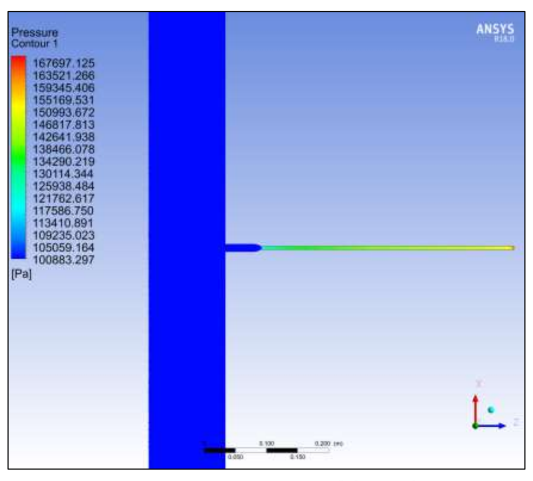

Fig. 7: Pressure profile along the wellbore

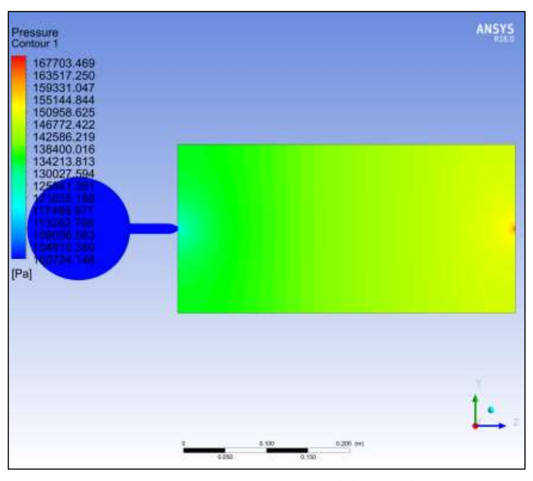

Fig. 8: Pressure profile along the fracture cell

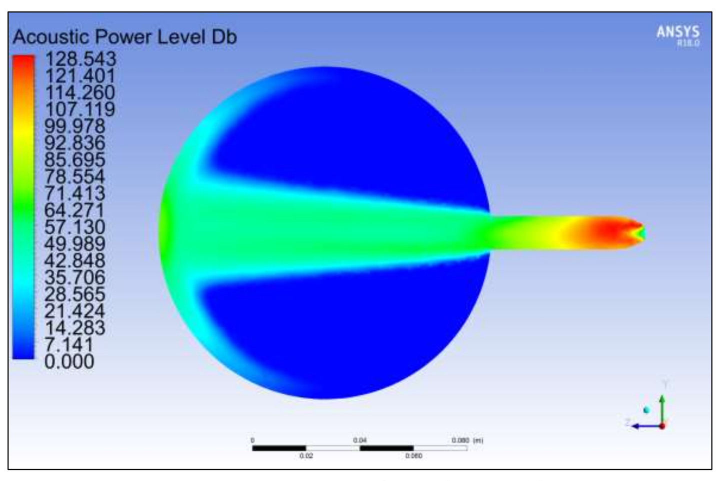

Fig. 9: Acoustic power level profile

- **Acoustic Simulation**

➢ Simulated time period coincides with the lab experiments (Fig.10). During this period, acoustic signals are measured in the points 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).

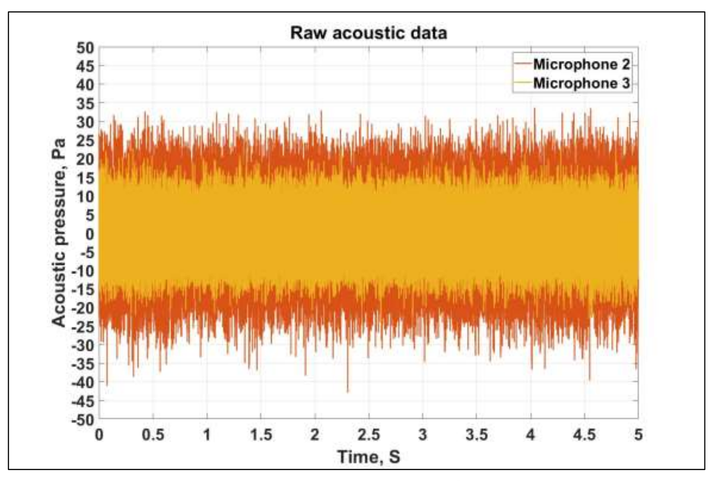

Fig. 10: Raw acoustic data from the experiment

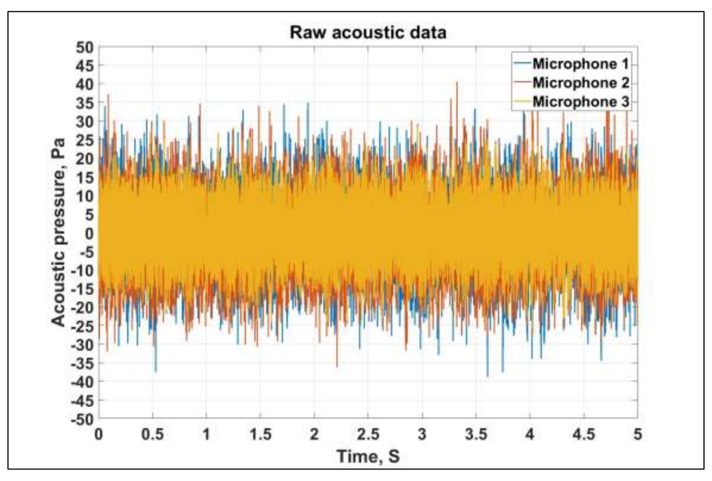

Fig. 11: Raw acoustic data from the simulation

SIGNIFICANCE

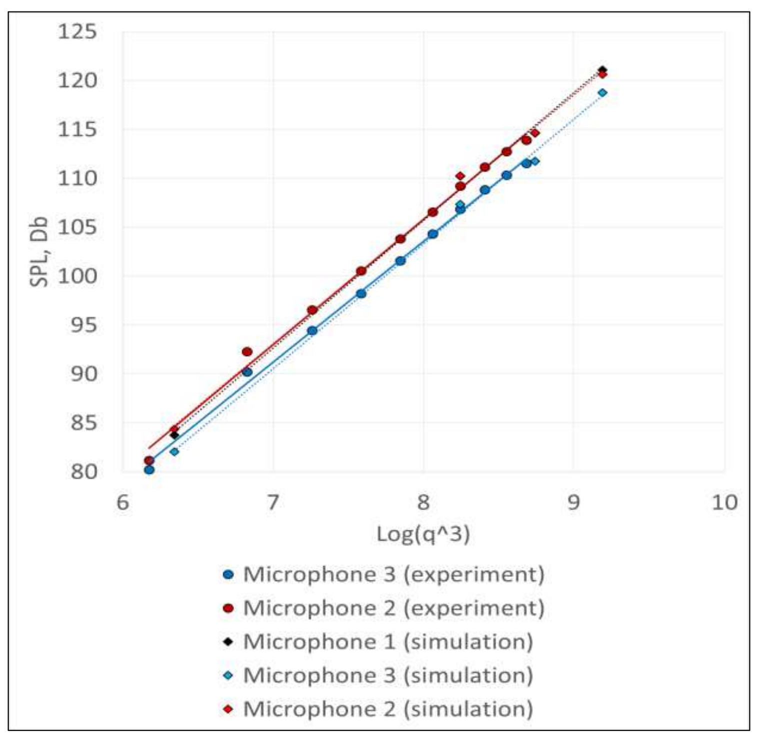

Fig. 12: Comparison of normalized correlations

➢ 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:

$$SPL = A * \log(q^3) + B$$

➢ 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.

Reference: *Pakhotina, J., Zhu, D., Hill, A. D., & Santos, R. (2017, October 9). Characterization of Production through a Fracture Cell Using Acoustic Data. Society of Petroleum Engineers. https://doi.org/10.2118/187357-MS*