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ENHANCED GEOTHERMAL ENERGY RESERVOIR SIMULATIONS FOR OPTIMIZING WELL CONNECTIONS

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Geothermal energy has been harnessed for over a hundred years and is becoming increasingly prevalent as alternative energy is popularized. Conventional geothermal power plants rely on large reservoirs of high temperature rock and a conductive natural fracture system; this natural fracture system can be very hard to come by. A recent research concept in geothermal energy, known as EGS (Enhanced Geothermal System), is a synthesized fracture system created by hydraulic fracturing. This expands the number of potential geothermal sites tremendously since any high temperature rock reservoir can be utilized for geothermal power without the presence of a natural fracture system. The principle for exploiting EGS involves drilling two parallel horizontal wells in an adequately hot geothermal reservoir (temperatures of approximately 200°C). Multiple conductive connections are established between these two wellbores by hydraulic fracturing. Cold fluid is circulated down one of the wells and flows through the fractured thermal reservoir. As it flows towards the second well, this fluid picks up heat from the reservoir. The heated fluid is circulated to the surface where, when pressure is reduced, it flashes to steam and drives turbines and generators to produce electricity. This is a carbon-free energy source. Application of EGS will enable geothermal energy development in many parts of the country where the natural fracturing required for conventional geothermal energy development are not inherently present in the subsurface.

This research focuses on the numerical simulation of this hydraulic fracture process in order to fully utilize the natural high-temperature rock reservoir at the FORGE site in Milford, Utah. The main variables studied were pump rate, pump volume, fluid viscosity, and proppant. Using Stimplan™, numerous simulations were performed; this allowed the creation of response surfaces shown below – as well as many others – that can be used to accurately predict and optimize the system with respect to different variables.

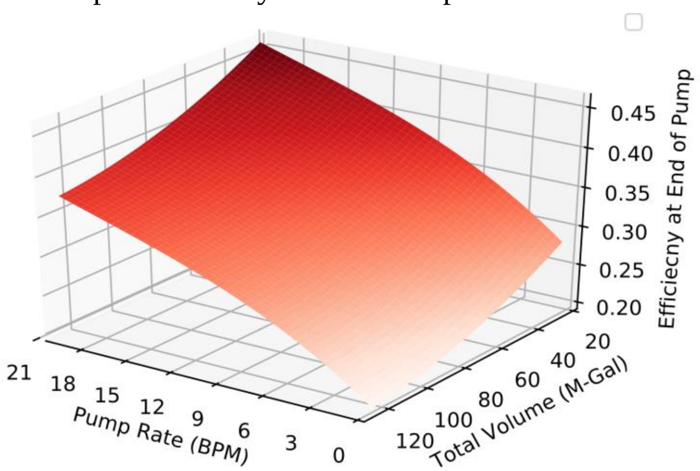

Fig 1. Efficiency response surface for pump rate vs. total pump volume

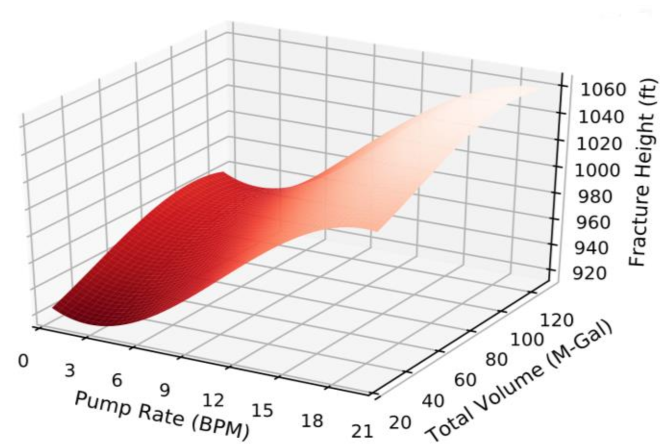

Fig 2. Fracture height response surface for pump rate vs. total pump volume

Fig 3. Table of studied variables

Studied Variable	Values Studied
Pump Rate	1 – 20 BPM
Total Volume	25 – 125 M-Gal
Fluid Viscosity	1 – 100 cp
Proppant Mesh	(20-40) – (70-140)
Proppant Conc.	0.0 – 4.0 PPG

After sufficient testing and data analysis, the following results were obtained:

- Increasing injection pump rate increased the overall efficiency, size, and pressure of the fractures.
- Increasing total pump volume decreased the overall efficiency but significantly increased the size of the fractures; volume had minimal effects on pressure.
- Increasing fluid viscosity created a more cylindrical cross section and significantly increased efficiency without driving pressures beyond manageable levels.
- The implementation of proppant increased efficiency only at higher concentrations and slightly shrunk the fractures' dimensions.
- Larger mesh proppants increased efficiency more than smaller mesh but caused a significant increase in pressure at higher concentrations.

From these results I concluded that low volume, high pump rate is the optimal pump schedule to create a high efficiency fracture system fitting the desired specifications for FORGE development. Additionally, using more viscous fluid and introducing a large mesh proppant at relatively high concentrations benefitted the system further by increasing efficiency and ensuring that the fractures will properly connect the injection and production wells.

This optimized fracture system can be created by a process with the following specifications:

- 25 M-Gal pump distributed in 3 stages at 5, 10, and 10 M-Gal, respectively
- Injection pump rate of 20 barrels per minute (BPM) for all 3 stages
- Use of a Newtonian fluid with viscosity of 100 centipoise (cp)
- Injection of a 30 – 50 mesh temperature resistant proppant at 3 pounds per gallon (PPG)

This will result in a 24% efficiency increase relative to baseline while keeping pressures below 400 psi throughout the process. The fractures will easily bridge the 600-foot gap between wells to minimize fluid loss and maximize heat transfer with a productive surface area of 425,700 ft^2.

The continuation of this research will consist of further investigation into heat transfer and energy generation for the FORGE site. I plan to produce more long-term, quantitative results for the financial feasibility of the studied hydraulic fracturing process.