TERVES

ENGINEERED RESPONSE

XO Prop Overview 10-26-17

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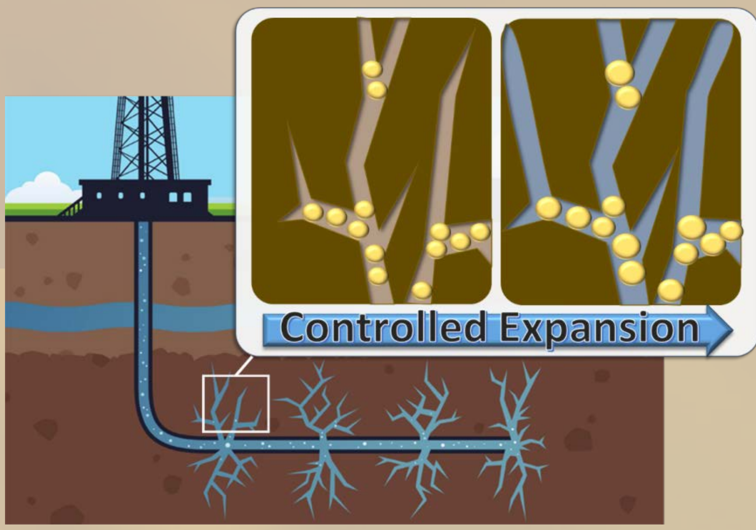
Introduction

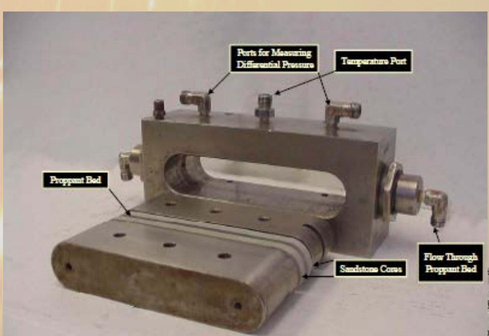
- This project is investigating the formation, application, and subsurface and production effects of novel, high modulus, swellable (expandable) proppants. The development of multifunctional proppants, such as expandable proppants, can be enabling in development of subterranean resources. Expandable proppants are theorized to provide the following benefits:

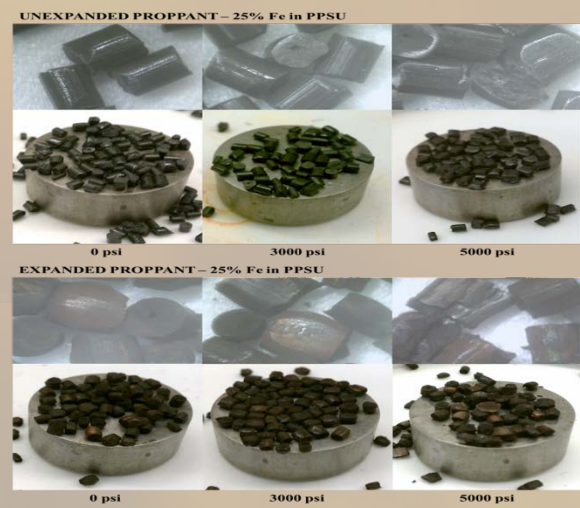
Enhanced transport: smaller, lighter proppants can be transported farther into the formation, and into fractures perpendicular to main flow channels.
Fracture Initiation and extension: Expandable rigid proppants with GPa modulus can apply 1000-10,000(+) PSI force while retaining permeability and fluid access. These forces are sufficient to initiate and extend fractures.
Offset closure forces: Expanding proppants can apply force, and increase contact area to offset embedment and closure forces, shifting the production decline curve.
Control proppant flowback: Expandable proppants can be used to quickly lock in proppant packs, reducing or preventing proppant
Impart and control formation stresses. The targeted delivery of force can be used to manipulate formation stresses

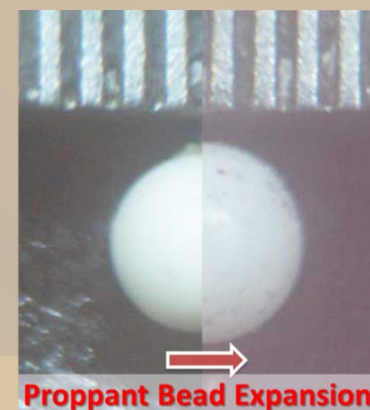


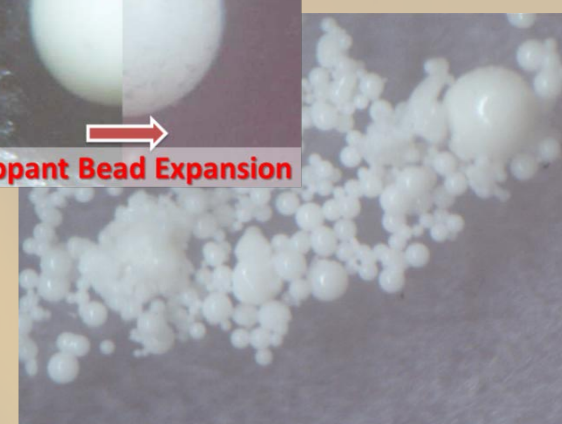
Fabrication

- Swellable proppants are prepared as a nanocomposite of a water-reactive metal or compound with a hydrolysis-resistant polymeric binder appropriate for 150-180C formation conditions. Formulations undergoing a 217% volumetric expansion. For typical oil and gas conditions of 70-90C, CaO-epoxy systems were selected for further development due to robust nature excellent mechanical properties and good manufacturability. Spherical proppants can be made using bead forming process.



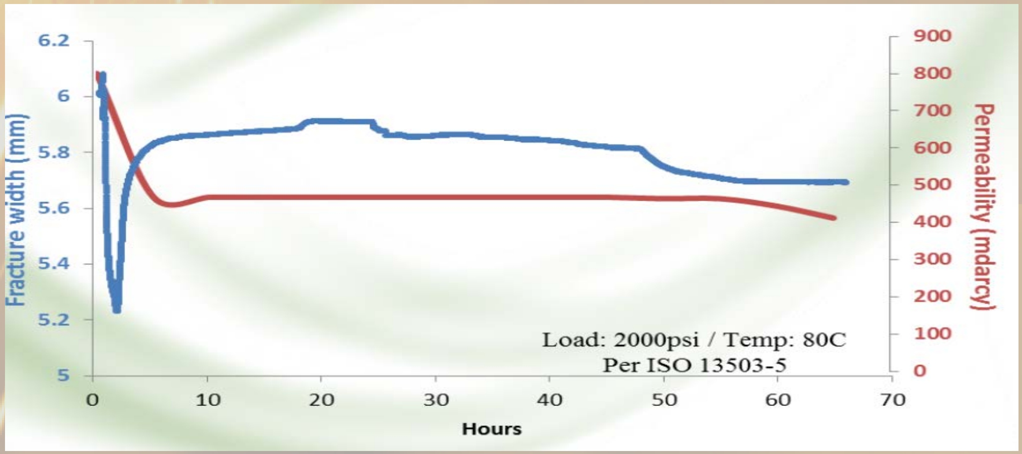


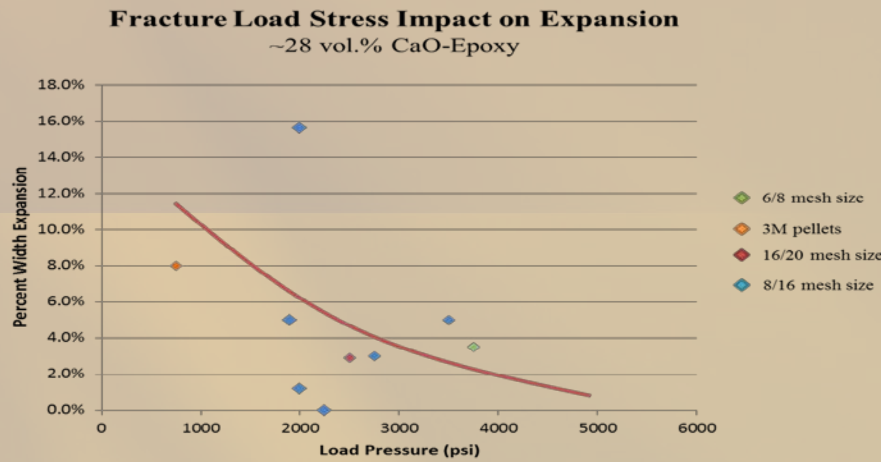




Test Results

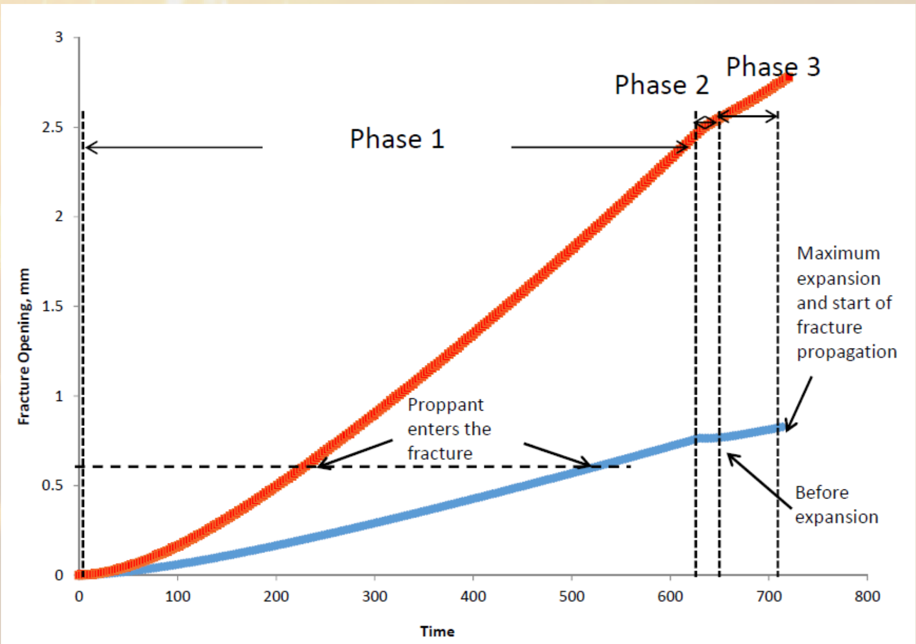
- **API conductivity test cell results:** The press was modified to enable a constant load to be applied while enabling expansion of the platens, which were instrumented with extensometers.
- Test Cell Results Showing Expansion under Load and Permeability Retention !!!!
- Test show fracture width expansion for 28% CaO-epoxy swellable proppant happens even at high closing forces!!!



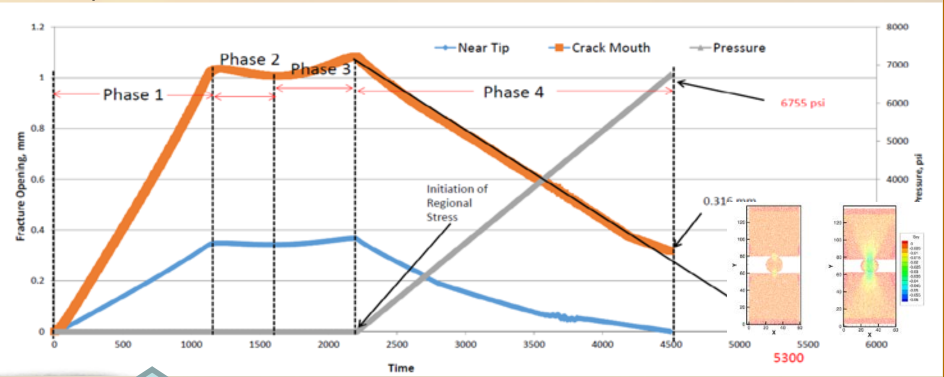


Modeling Results

- **Fracture Extension:** Extending fractures offers the opportunity to intercept high angle natural fractures and enhance the amount of formation accessed by stimulation.
- Three phases of natural fracture expansion- Phase I, fracture opening and proppant transport due to hydraulic forces, Phase II- fluid removal/drawdown, fluid pressure equal to closure force. Phase III- fracture opening due to proppant expansion.

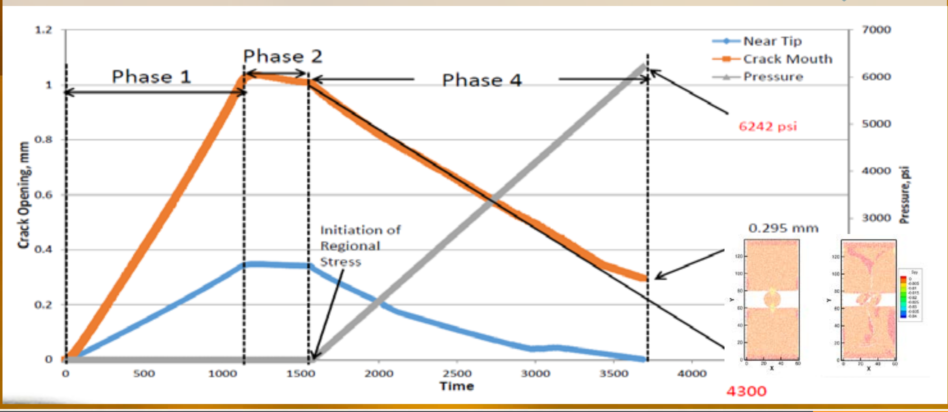


- **Offsetting Embedment:** A major issue with softer formations is the embedment of proppants into clay-bearing or more flexible systems. XO prop resists more closure stress for longer time periods.



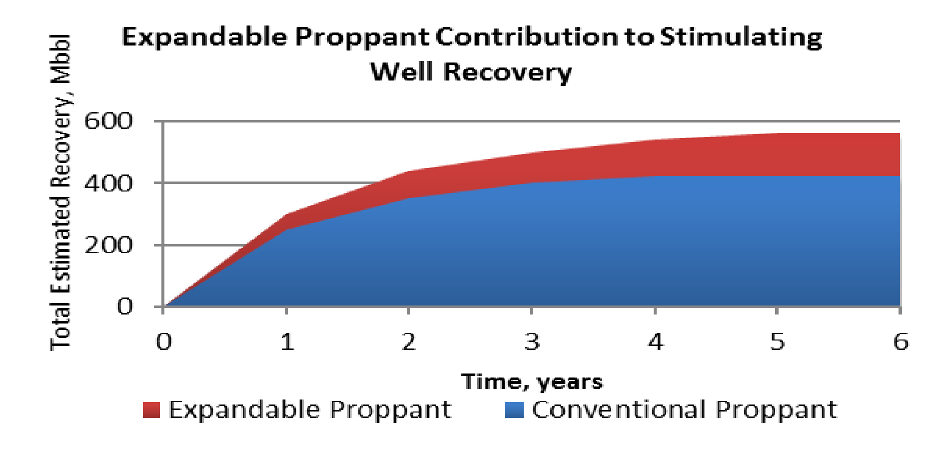
Expandable

Sand

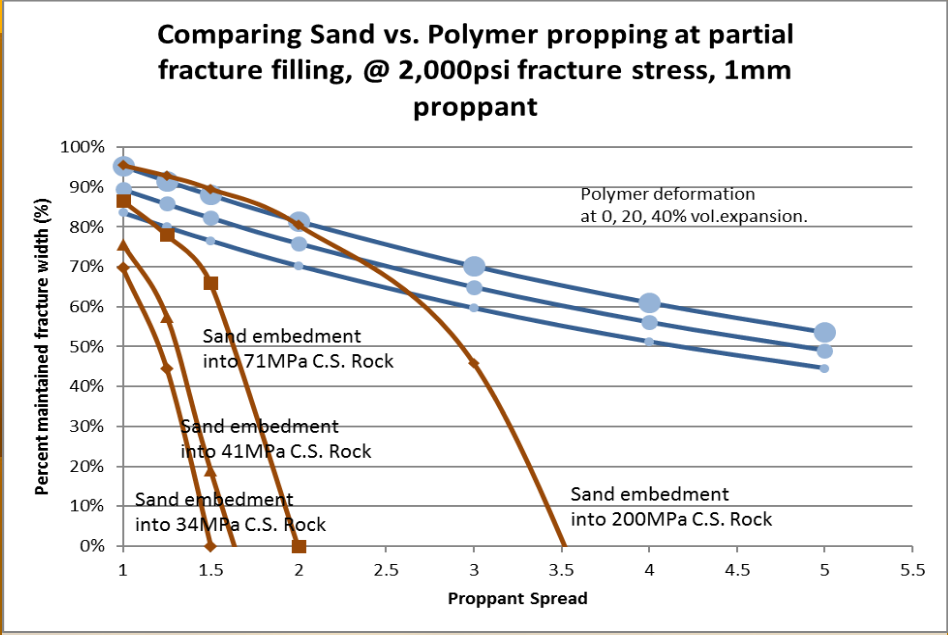


Impact On Production

- **Impact on production:** the net impact on production due to the delayed closure of the natural fractures is eroughly 23% for the well modelled



- **Less than Monolayer coverage:** In lower strength formations, polymer and expandable proppants outperform hard proppants at less than monolayer coverage due to embedment/rock fracture. This is illustrated using a rock failure point of 2000 psig.



Current Status and Future Work

- Proppant conductivity testing with different rock types.
- Currently evaluating and specifying pilot scale production equipment as well as fast-scale-up toll manufacturing alternatives for initial well tests.
- Evaluation and modelling of embedment in simulated real rocks.
- Evaluation of proppant transport into far field and natural fractures.
- optimizing proppant design (modulus/deformability) in different unconventional formations.
- Evaluating production effects with FEA simulated embedment and real (not rigid) rock properties.