4.6.1 Three-dimensional Modeling of Fracture Clusters in Geothermal Reservoirs

Presentation Number: 028
Investigator: Ghassemi, Ahmad (Texas A&M University)
Objectives: To develop a 3-D numerical model for simulating mode I,II, and III (tensile, shear, and tearing) propagation of multiple fractures using the virtual multi-dimensional internal bond (VMIB), to predict geothermal reservoir stimulation.
Average Overall Score: 3.4/4.0

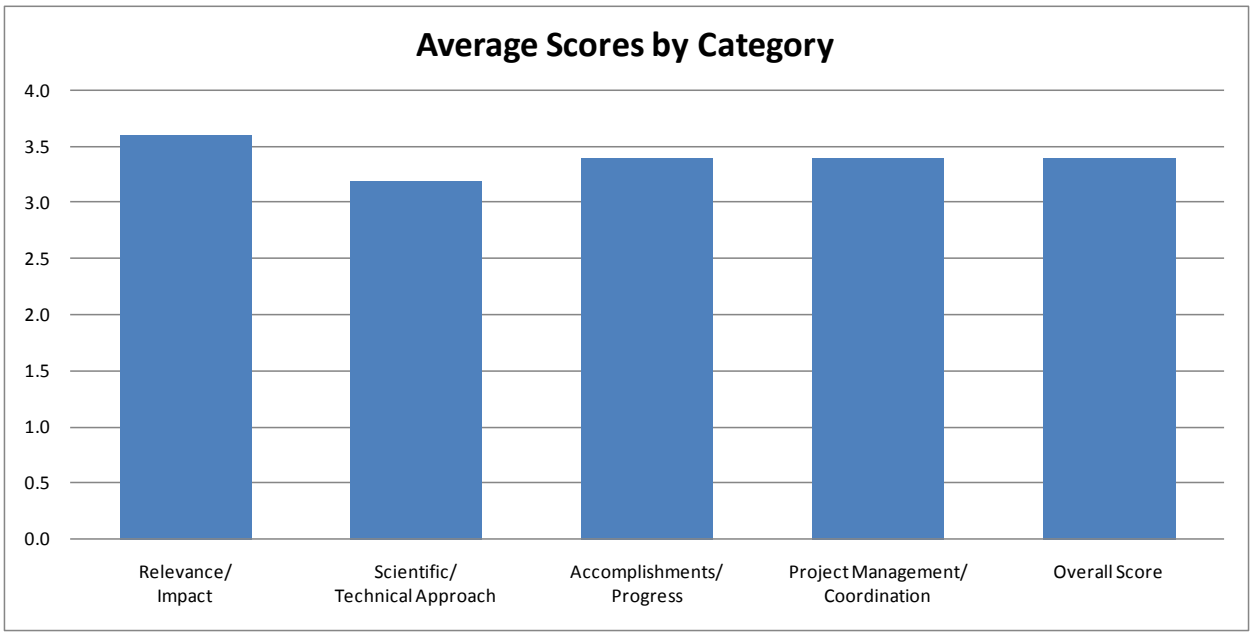

Figure 37: Three-dimensional Modeling of Fracture Clusters in Geothermal Reservoirs

4.6.1.1 Relevance/Impact of the Research

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Outstanding (4), Outstanding (4), Good (3)

Supporting comments:

- The development of fractures is critical to developing EGS. This project advances a fundamental model aimed at understanding fracture development for a variety of domains. Such a model (dubbed VMIB) provides a significant research tool to advance the science.

- This project addresses critical barriers of the GTP using an innovative approach to fracture mechanics: the predictive modeling of reservoir stimulation. This is a very important problem

which despite being identified as a key barrier has received little attention and funding from DOE.

- Fracture networks, connectivity, orientation and location are critical to site characterization. In addition, fracture initiation and propagation determine the ability of the reservoir to respond to stimulation. This research focuses on developing a 3-D computational model that incorporates all three types of fracture modes to more realistically simulate fracture propagation. This research can significantly advance our understanding of fracture interaction, propagation and network formation.

- Determining the effect of production on fracture creation and propagation is a key issue for exploiting geothermal reservoirs. Accurate numerical prediction can reduce costs and identify possible difficulties and, thus, is an essential element of the program.

- Only 25 to 30% completed, so difficult to judge ultimate impact, but investigators are making good progress.

4.6.1.2 Scientific/Technical Approach

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Good (3), Good (3)

Supporting comments:

- The virtual multi-dimensional internal bond method is sharply focused for fundamental understanding of fracture processes, which are critical to EGS development. Comparison to experimental data was impressive. I would have liked to see more information about the role of fluid pressure and gradients thereof. More discussion of the limitations and weaknesses of the approach would have been appreciated.

- The numerical approach based on VMIB (similar in spirit to peri-dynamics approaches) can potentially overcome significant difficulties in fracture mechanics, namely: path identification, mixed-mode propagation, crack propagation in heterogeneous media. The method has been validated on a specific example. The project has focused on the 2-D situation, and the extension to 3-D is far from trivial.

- Numerical studies will incorporate a range of parameters to more closely model reservoir properties such as non-linearities in rock deformation, rock heterogeneities and fracture interactions. Numerical results have been compared to analytical results for validation. Models will be calibrated with results derived from lab and field experiments. To date rock heterogeneity was not explicitly described - how different are the rock units? Are they representative of those found in EGS systems? How will upscaling from one fracture to a reservoir occur? To date, it appears that the modeled processes are isothermal. Incorporating thermal changes will improve the utility of the model.

- This is a very interesting approach that has its basis in a method (VMIB) used successfully in computational material science studies of fractures. Integrating this with a FEM code that includes thermal and pore fluid effects in a computationally efficient way is a significant challenge. Preliminary results are promising, but the test examples have not been very challenging. I would like to see more emphasis on comparing the results with observations in experiments and the results of other types of numerical simulations before progressing to more complex field simulations. For example, there have been a number of observational and computational studies of fracture growth and interaction. How does this method compare with those results, even in the absence of fluid and temperature effects? Do the computations adequately capture the behavior of laboratory specimens for a range of pressures and loading paths? I realize that the goal here is to treat more complicated and general situations, but each of the elements needs to be tested thoroughly. Although this may seem to slow progress to the ultimate goal (field simulator), I think it is necessary to have confidence in the end result.

- Good scientific approach and organization.

4.6.1.3 Accomplishments, Expected Outcomes and Progress

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- Given that this project only started last fall, considerable progress seems to have been made. The project is well founded scientifically, and has great potential for the future. I did not note any honors or awards, but the method and the progress were remarkable.

- While still in its early stage, the project has already led to 4 articles, and some significant numerical results.

- Stated completion is approximately 30%. Numerical models are being developed and tested for a subset of controlling processes. Algorithms for various processes have been incorporated. Verification of fracture propagation modeling with lab studies was completed for a subset of fracture modes. A publication has resulted and presentations at national meetings given. Quality of the researchers and facilities are excellent.

- Productivity has been excellent both in terms of progress toward goals and publication of the results. Ghassemi is experienced and expert in numerical geomechanical simulations.

- Well qualified performers. They have some good initial results.

4.6.1.4 Project Management/Coordination

Ratings of Five-member Peer Review Panel: Good (3), Outstanding (4), Good (3), Outstanding (4), Good (3)

Supporting comments:

- The project is well structured, and has achieved impressive results to date. I did not notice checks and controls in the management plan.
- The project is following its timeline, proof of an efficient management.
- Project management appears effective but little information was presented.
- Project management (Team is essentially Ghassemi with graduate students) is simple and has been effective. Collaboration with Alta Rock on a field test of hydraulic fracture mentioned in the presentation was vague, but this may be down the road a bit.
- Limited information on this metric, but no red flags.

4.6.1.5 Overall

Ratings of Five-member Peer Review Panel: Outstanding (4), Good (3), Good (3), Outstanding (4), Good (3)

Supporting comments:

- I found this to be a very impressive model, with significant potential applications for EGS. Some difficulties may be encountered when dealing with pre-existing fractures, but this could be dealt with by using broken or nonexistent bonds between the “particles”.
- This is a high-risk project as it relies on a numerical approach that has not been strongly validated before being applied to geothermal reservoir stimulation. No information other than the copy of the presentation overhead slides was available on PeerNet.
- A project summary was not submitted for this study. Consequently additional details were lacking.
- There are many numerical simulators of fracture growth and interaction, pore fluid and temperature coupling. Admittedly many of these are for more specialized problems but the superiority of the present method is unclear (at least to me).
- Very important project for geothermal R&D.

4.6.1.6 PI Response

I thank the reviewers for their comments and suggestions. They will help us in improving our approach where necessary to achieve the project objectives.