Modeling, Design, and Life Performance Prediction for Energy Production from Geothermal Reservoirs

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SUMMARY:

The objective of this project is to maintain and transfer existing Hot Dry Rock two-dimensional fractured reservoir analysis capability to the geothermal industry and to extend the analysis concepts to three dimensions. The project start date was May 22, 1997 and it runs through May 21, 1998. This is the quarterly progress report for January through March of 1998.

In this quarter, the primary focus has been on development of the Geocrack3D model, presenting initial results to the industry, and maintenance of Geocrack2D. It is important to emphasize that our modeling is complementary to current industry modeling, in that we focus on the user interface, flow in fractured rock, and the coupled effect of thermal cooling changing fracture aperture.

INDUSTRY INTERACTION:

Papers Presented at 23rd Stanford Geothermal Workshop

Two papers were presented at the Stanford Geothermal Workshop. The first paper, "Strategies for the Hijiori Long Term Flow Test," was the result of work sponsored by the Geothermal Energy Research and Development Company, Japan (GERD). Collaborating authors included R. Schroeder (Berkeley Group Inc.) and S. Okabe, N. Shinohara, and S. Takasugi (GERD). The paper presented Geocrack2D analyses of past testing at Hijiori and made initial predictions of the long-term flow test. The challenge at Hijiori is to both maintain adequate water recovery and avoid cooling of the production wells. Downhole pumps could be used to increase recovery, but because the wells are so close together, significant cooling is expected at the production wells.

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The second paper, "A Geometric Modeling Framework for the Numerical Analysis of Geothermal Reservoirs," documented the work done to develop the geometric foundation for future modeling efforts. The paper demonstrated how, by working at the feature level (fractures, wellbores, reservoir boundaries) it is much easier for the user to develop a reservoir model independent of the solution scheme to be used. Response to the paper was positive.

Collaborative Research

The final approval on a collaborative research program with the Energy & Geoscience Institute and Oxbow Power Services has been received. This project, "Modeling Production and Injection Strategies in Fracture-Dominated Geothermal Reservoir," will build on the work described above. An initial coordination meeting with TOUGH-2 and TETRAD users was held at the Stanford Geothermal Workshop, January, 1998. One strong theme of that meeting was the need for collaboration with industry. We heard that message and will act on it as the project proceeds.

National and International Collaboration

Web Site

Information and the executable programs for Geocrack2D are available on the world wide web. We continue to update and maintain the world wide web page (<http://www.mne.ksu.edu/~geocrack>). This site includes a description of our work and is a location at which the Geocrack2D software can be downloaded.

Collaboration with Hijiori Project

Geocrack2D is being used for an analysis of the Hijiori reservoir in Japan. The objective of the analysis is to match testing performed in 1991-1996 and to predict the results of the Long Term Circulation Test scheduled to start in 2000. We will be visiting Japan in April to report the results of our analyses of the 1995 flow anomaly (when injection was increased, production decreased). This work is being performed independently of this project, but is mentioned because it is an application of tools related to the project.

MODEL DEVELOPMENT:

Geocrack2D Maintenance

Several improvements were made to Geocrack2D, including capability to map arbitrary temperature solutions for initial conditions and adding a cubic boundary condition term for far-field leak-off. The cubic term more closely approximates the expected behavior of flow in a fracture into the far-field.

Geocrack3D Development

Primary effort has been devoted to development of Geocrack3D. The goal of this software is to allow the user to work at the geometry level of a problem, while the details of meshing and solution are handled automatically. What is meant by the "geometry level" is that the user defines the boundary of a reservoir and then the geometric features (fractures, wellbores) of the model. Working at this level simplifies the task of the analyst and allows easy modification of the model. After the geometry is defined the mesh will be automatically developed. This approach is similar to the work at Kansas State University and Cornell University that is being applied to NASA research on crack growth in aircraft structures.

In order to implement the geometric approach reliably, it is necessary to use topology to describe the relationships between the vertices, edges, faces, and volumes of a model. The development of the Euler operators that accomplish this has been completed. As we have previously shown, Figures 1 and 2 illustrate the use of this approach on a simple model of the Hijiori reservoir. In Figure 1 the boundary of the reservoir has been defined. Figure 2 shows the interior of the model after the wells and dominant fractures have been added. To create this model, the user simply defined a point on each fracture and a normal to the fracture. All the intersections with wells and other fractures were calculated by the program.

In this quarter, the graduate student developing the software successfully defended his thesis. The thesis documents the details of the topology, including *multi-link* structure developed as a generalization of previous work in non-manifold topology. This thesis is being mailed separately to people who have indicated previous interest.

Figure 1: External view of reservoir after insertion of fractures and wells

Figure 2: View of interior of model