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 October through December of 1997.

In this quarter, the primary focus has been on interaction with industry, development of the Geocrack3D model, and maintenance of Geocrack2D. It is important to emphasize that our modeling is complementary to current industry modeling, in that we focus on flow in fractured rock and on the coupled effect of thermal cooling.

INDUSTRY INTERACTION:

Booth at October GRC Meeting

We participated in the annual GRC meeting by having a booth that described geothermal research at Kansas State University. The booth included posters, a continuously cycling presentation, handouts, and the opportunity to talk to visitors one-on-one. Several new contacts were made, in addition to allowing us to show the current status of our work to people we already knew. Our impression was that the booth and chance to interact with industry was well worth the effort and cost involved. If funding is available, we hope to repeat this in 1998, probably as a joint booth with Stanford University. We welcome comments and suggestions from people who visited the booth.

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Proposal Preparation

In collaboration with Pete Rose and Denise Apperson at the Energy & Geoscience Institute and Dick Benoit at Oxbow Power Services, we submitted a proposal in response to DOE solicitation DE-PS07-96ID13399, "Geothermal Reservoir Technology Research, Development, and Demonstration." The research will develop capability to model flow in reservoirs dominated by fractures and will apply this capability to improve injection/production strategies to maximize economic extraction of geothermal energy.

We have received notification that the proposal will be funded, with a minor budget modification and a goal that the work be compatible with TOUGH-2 and TETRAD. A coordination meeting with TOUGH-2 and TETRAD users will be held at the Stanford Geothermal Workshop, January, 1998.

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.

GeoView Program

The GeoView program, developed by Heather Bradford, has been released and is available at the geocrack web site (www.mne.ksu.edu/geocrack). This software allows the user to view seismic data, wellbores, and fractures interactively on a PC. The software was developed as a result of discussions at the Structured Academic Review of HDR/HWR held at Tohoku University, Japan, in March of 1997.

The software was written in approximately 8 1/2 months by Heather Bradford. Such rapid development was possible as a result of the object-oriented methods being used on our 3-D modeling development. Brian Hardeman, working on the 3-D development, had previously written camera, OpenGL display, and list objects that were re-used in the GeoView program. Figure 1 shows a display of Fenton Hill micro-seismic data and wellbores. Data for Soultz is also available for display.

The software has been delivered to researchers in the USA, UK, France, and Japan.

Figure 1: Example display of Fenton Hill data using GeoView

Collaboration with Hijiori Project

Geocrack2D has been used for an analysis of the Hijiori reservoir in Japan. The objective of the analysis was to match testing performed in 1991-1996 and to predict the results of the Long Term Circulation Test scheduled to start in 2000. This collaboration will be reported in a paper at the 1998 Stanford Geothermal Workshop.

MODEL DEVELOPMENT:

Geocrack2D Maintenance

Maintenance of Geocrack2D included fixing a bug related to monitored node data. New capability was added to improve the representation of flow to a well intersecting a fracture. The previously developed flux heat transfer boundary conditions were added to the release version of the code. The new version has been posted on the web.

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. We are continuing work on the higher functions that manipulate this basic geometric data. Figures 2 through 5 show the current state of the program, demonstrating the definition of fractures and wells in the Hijiori reservoir. In Figure 2 the boundary of the reservoir has been defined. Figure 3 shows the model after the wells and dominant fractures have been added. Figures 4 and 5 show interior and wireframe views of the model. 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 the illustrated model, the program knows all volumes and boundaries. This information will make it possible to create a numerical mesh that is a subset of the geometric model. In addition, the fractures (faces) that bound each volume can be used to define the boundary conditions, independent of the mesh. Such an approach simplifies the task of the analyst preparing the model.

Cross-platform (Unix and PC) capability and improvements to the user interface will be the focus of next quarter's effort.

Figure 2: Initial definition of reservoir boundary

Figure 3: After insertion of fractures and wells

Figure 4: View of interior of model

Figure 5: Wireframe view