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Finite Element Modeling of Non-linear Coupled Interacting Fault System

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PANDAS - Parallel Adaptive static/dynamic Nonlinear Deformation Analysis System - a novel supercomputer simulation tool is developed for simulating the highly non-linear coupled geomechanical-fluid flow-thermal systems involving heterogeneously fractured geomaterials. PANDAS includes the following key components: Pandas/Pre, ESyS_Crustal, Pandas/Thermo, Pandas/Fluid and Pandas/Post as detailed in the following:
• Pandas/Pre is developed to visualise the microseismicity events recorded during the hydraulic stimulation process to further evaluate the fracture location and evolution and geological setting of a certain reservoir, and then generate the mesh by it and/or other commercial graphics software (such as Patran) for the further finite element analysis of various cases; The Delaunay algorithm is applied as a suitable method for mesh generation using such a point set;
• ESyS_Crustal is a finite element code developed for the interacting fault system simulation, which employs the adaptive static/dynamic algorithm to simulate the dynamics and evolution of interacting fault systems and processes that are relevant on short to mediate time scales in which several dynamic phenomena related with stick-slip instability along the faults need to be taken into account, i.e. (a). slow quasi-static stress accumulation, (b) rapid dynamic rupture, (c) wave propagation and (d) corresponding stress redistribution due to the energy release along the multiple fault boundaries; those are needed to better describe ruputure/microseimicity/earthquake related phenomena with applications in earthquake forecasting, hazard quantification, exploration, and environmental problems. It has been verified with various available experimental results[1-3];
• Pandas/Thermo is a finite element method based module for the thermal analysis of the fractured porous media; the temperature distribution is calculated from the heat transfer induced by the thermal boundary conditions without/with the coupled fluid effects and the geomechanical energy conversion for the pure/coupled thermal analysis.
• Pandas/Fluid is a finite element method based module for simulating the fluid flow in the fractured porous media; the fluid flow velocity and pressure are calculated from energy equilibrium equations without/together with the coupling effects of the thermal and solid rock deformation for an independent/coupled fluid flow analysis;
• Pandas/Post is to visualise the simulation results through the integration of VTK and/or Patran.

All the above modules can be used independently/together to simulate individual/coupled phenomena (such as interacting fault system dynamics, heat flow and fluid flow) without/with coupling effects. PANDAS has been applied to the following issues:
• visualisation of the microseismic events to monitor and determine where/how the underground rupture proceeds during a hydraulic stimulation, to generate the mesh using the recorded data for determining the domain of the ruptured zone and to evaluate the material parameters (i.e. the permeability) for the further numerical analysis;
• interacting fault system simulation to determine the relevant complicated dynamic rupture process.
• geomechanical-fluid flow coupling analysis to investigate the interactions between fluid flow and deformation in the fractured porous media under different loading conditions.
• thermo-fluid flow coupling analysis of a fractured geothermal reservoir system.

PANDAS will be further developed for a multiscale simulation of multiphase dynamic behaviour for a certain fractured geothermal reservoir. More details and additional application examples will be given during the presentation.

References

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