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Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

Project Accomplishment Summary

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Sandia National Laboratories
Operated for the U.S. Department of Energy by
Sandia Corporation
Albuquerque, New Mexico

PROJECT ACCOMPLISHMENTS SUMMARY

Cooperative Research and Development Agreement (#1742.08.00)

between **Sandia National Labs** and **ExxonMobil Research and Engineering Company**

Note: This Project Accomplishments Summary will serve to meet the requirements for a final abstract and final report as specified in Article XI of the CRADA.

Title: Coupled modeling of flow and fracture for the simulation of crack growth in hydraulic fracture

Final Abstract:

This work provides a methodology for a coupled flow-fracture model that includes damage modified permeability and deformation resulting from pore pressure. In the coupled model, fluid velocity and pressure are influenced by cracks that greatly decrease a material's resistance to flow. Likewise, the material's response to structural loading is significantly affected by the pore pressure of the fluid, which leads to crack nucleation and propagation. We present a new tensorial representation of damage that provides geometric information about cracks as they develop, such as the normal surface to the crack. The tensorial representation of damage also provides directionality information about weaknesses that develop in the material due to loading. This information is used to inform a tensorial permeability model, which is dependent on material degradation.

Background:

Sandia and EMRE have been collaborating on coupled modeling of flow and fracture for the simulation of crack growth in hydraulic fracture, building upon efforts from CY11. This work utilizes Sandia's open-source Peridigm peridynamics code for modeling deformation and fracture in solids, and Sandia's general purpose, open-source Albany/LCM finite element code. Peridigm and Albany/LCM are component-based open-source codes built upon Sandia's open-source Trilinos project.

This project contains only part of the work necessary to develop a simulation capability for coupled flow and fracture, focusing on development and demonstration of necessary extensions to Peridigm and Albany/LCM. In particular, Peridigm has been modified to compute a directional orientation to damage fields, which is used to inform an anisotropic permeability model (oriented along the direction of material failure) in the flow code. The internal force algorithm of Peridigm has also been modified to account for an eternally prescribed fluid pressure that will induce an added stress in the solid. The poro-mechanics capability in Albany/LCM was modified to include a porous flow model incorporating damage modified anisotropic permeability.

Any modifications made to Peridigm will become part of the Peridigm open-source release. Any modifications made to Albany/LCM will become part of the Albany/LCM open-source release. It is expected that fundamental aspects of this work will be submitted for publication in refereed technical journals in a timeline agreed by both Sandia and EMRE.

Description:

The numerical formulation was constructed via two phases respective of the flow and deformation mechanics. For the flow formulation the existing implementation in LCM was improved to incorporate a tensorial permeability such that the resistance to fluid flow is modeled as directionally dependent. In terms of the deformation modeling, the peridynamic formulation was augmented with a means of calculating the orientation of the crack surface. The orientation of the crack surface is intended to provide directionality to the damage in the solid material such that it can be used to modify the flow permeability tensor via the coupling of the two formulations.

Traditional damage metrics in peridynamic analysis are evaluated as scalar quantities. Typically, damage is calculated as the ratio of broken bonds to the original number of bonds for a material point in its pristine state. Unfortunately, scalar representations of damage in a material do not provide any information about the orientation of the crack surface, which is of vital importance in modeling engineering problems like hydraulic fracture. In order to provide a directionally aware measurement of damage, a modification of the acoustic tensor approach wass developed by determining the change in material stiffness due to perturbations in bond damage. By comparing the discretized material stiffness between various states of bond breaking, a tensorial representation of damage was formulated.

Benefits to the Department of Energy:

This work has enabled an entirely new class of problems to be addressed by the DOE's analysis codes involving flow-induced fracture of porous materials. This will be important for applications in energy production and nuclear weapons safety and expand the capability space of the national labs. This work is also piloting new efforts in code couplings involving disparate discretizations, time scales, and physics. Developing coupling algorithms appropriate for integrating vastly different physics domains is a major obstacle to solving a number of engineering problems of national interest. It is intended that the fundamental coupling work done as part of this PTS will lead to progress in this challenging field.

Economic Impact:

This work was geared at the evaluation of novel methods for simulation of fracture evolution in sub-surface environments, and for the evaluation of novel concepts for stimulation strategies for low permeability reservoirs. These drivers reflect the economic importance of developing improved techniques for economic extraction of domestic natural gas resources, which are becoming increasingly important targets for U.S. energy needs.

Project Status:

This project has been completed.

ADDITIONAL INFORMATION

Laboratory/Department of Energy Facility Point of Contact for Information on Project

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Company Size and Points of Contact

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CRADA Intellectual Property

EMRE Report: Coupled modeling of flow and fracture for the simulation of crack growth in hydraulic fracture. Any new capabilities in Peridigm remain owned by Sandia and are distributed open source.

Technology Commercialization

As this work is exploratory, there is no current commercialization plan.

Project Examples

See EMRE Report "Coupled modeling of flow and fracture for the simulation of crack growth in hydraulic fracture" for project examples.

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This summary has been approved for public release by Sandia and ExxonMobil Research and Engineering Company.

Sandia National Laboratories

By____________________________ 5/28/14
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Date

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Title:
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In order to expedite the process, if we do not receive your signed reply by 07/02/2014 we will assume your concurrence for the release of this document to the public.