SAND2012-10682P

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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 (#1742.06)

between **Sandia National Labs** and **ExxonMobil Research and Engineering Company (EMRE)**

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: Peridynamic Modeling of Driven Fracture

Final Abstract:

The primary focus of this project was to examine the suitability of peridynamics for modeling induced dynamic fractures in well-bores. The creation of a dense, highly connected fracture network that extends from the wellbore into a hydrocarbon-containing reservoir is a key step in the economic extraction of oil and gas resources in low permeability formations. Hydraulic fracturing is a commonly used well completion and stimulation technique of choice. It has been used over a million times in the energy industry to artificially create high permeability streaks within the subsurface to enhance well productivity. These fractures enhance permeability by increasing the contact area between the wellbore and the reservoir. Hydraulic fracturing relies on relatively slow loading rates and low pressures to induce fractures, and as such, the orientation and shape of the fractures is constrained by in-situ stresses. This can limit the ability to create dense fracture networks that allow for efficient drainage of the reservoir. As unconventional resources such as shale gas, tight oil, and coal-bed methane represent a substantial portion of the industry's net natural gas assets, the continued development of novel fracturing technology, as well as discovery and implementation of innovative and economical fracturing techniques, is of paramount importance.

Background:

The controlled combustion of a propellant, methodically placed inside the well-bore, produces high energy combustion gasses, which, when focused on its inner walls, can create fractures. The profile of the pressure pulse strongly affects the fracture surface area opened. Predictive models of this process can be used to maximize surface area opened by fracture, enhancing the volume of natural gas recovered.

In this project, peridynamics, a non-local extension of the classical continuum mechanics theory, was employed to study propellant driven dynamic fractures in the near wellbore region. Prior to this study, peridynamics had never been evaluated for this application.
Fracture modeling techniques based upon the classical theory of solid mechanics have demonstrable difficulty in reliably modeling all but the simplest fracture solutions. This difficulty is due in large part to the mathematical foundation of the classical theory, which is based upon partial differential equations. The classical theory does not hold on crack surfaces, as partial derivatives are not defined at these points. Unlike the classical theory, peridynamics is based upon integral equations and can be applied to fracture solutions without any mathematical difficulty. Further, the peridynamic approach does not require any of the special techniques utilized in fracture mechanics. For example, in peridynamics, there is no need for a separate crack growth law based on a stress intensity factor.

EMRE is the research and engineering arm of ExxonMobil Corporation, a leading global oil, natural gas, and petrochemicals company. Peridynamics was developed by Sandia Labs. The first open-source software implementation of peridynamics was PDLAMMPS, an implementation within Sandia's massively parallel molecular dynamics code, LAMMPS.

Description:

Peridynamics was employed to study propellant driven dynamic fractures in the near wellbore region. Specifically, the influence of the loading rate on fracture patterns was investigated. Simulations were performed and the results are compared to relevant experimental and numerical studies found in the literature.
The principles objectives of this study were:

1. analysis of the influence of rise time, decay time and amplitude of the resultant pressure pulse on the fracture pattern, and
2. investigation of the effect of material inhomogeneity and in-situ stress anisotropy on fracture initiation, propagation, branching and arrest, and

Technical details on the results of the investigation are contained within the project final report, “Influence of the Pressure Waveform on Induced Dynamic Fractures in Rocks.”

The primary role of EMRE was to direct the investigation and the computational studies. Sandia provided support of the PDLAMMPS as needed to facilitate EMRE’s numerical investigations, as well as consulting on peridynamic modeling.

Benefits to the Department of Energy:

EMRE’s use of peridynamics explored new use cases for Sandia’s PDLAMMPS code, maturing the code and identifying bugs. Additionally, their explorations of peridynamics on representative problems serve as the first steps towards validation of peridynamics for this important application area.

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.

Due to the exploratory nature of this collaborative research, it’s not possible to determine actual impact to the company, industry, economy, etc. regarding jobs created or saved, revenues generated, and other indirect benefits at this time. Exploratory research of this nature for this application is typically 10+ years from field impact, and so such impact can be most accurately accessed in hindsight. Given the preliminary nature of the work on this model, years of further research and development are necessary to mature this model to the point where it would even be capable of impacting field operations, at which point estimates of its impact would be possible.

Project Status:

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

None

Technology Commercialization

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

Project Examples

A primary application of the peridynamic method has been to map out the relationship between borehole stimulation conditions, including loading rates and peak stresses, rock reservoir mechanical properties, and in-situ confining stress conditions in order to assess the viability of propellant-based stimulation methods under various sub-surface conditions.

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Cooperative Research and Development Agreement (SC07/01742.06)
between **Sandia National Laboratories** and **ExxonMobil**

This summary has been approved for public release by Sandia and ExxonMobil

Sandia National Laboratories

By Michael L. Parks ______ 8/7/12
Michael Parks — Date
Principal Investigator

Sandia National Laboratories

By ______ 8·2·12
Manager — Date
WFO/CRADA Agreements

ExxonMobil Research and Engineering Company

By ______ 9·5·12
Title: Michael B. Ray — Date

In order to expedite the process, if we do not receive your signed reply by 09/09/2012 we will assume your concurrence for the release of this document to the public.