Wellbore Seal Repair Using Nanocomposite Materials

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Developing the Technologies and Infrastructure for CCS
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Presentation Outline

• Introduction and overview
• Materials synthesis
• Materials testing and characterization
• Seal system testing
• Numerical simulation
• Summary
Benefit to the Program

• BENEFITS STATEMENT: The project involves the development and testing of polymer-cement nanocomposites for repairing flaws in annular wellbore seals. These materials will have superior characteristics compared to conventional materials, ensuring hydraulic isolation of the wellbore after closure. The technology contributes to the Program’s effort of ensuring 99% CO$_2$ storage permanence.
Project Overview: Goals and Objectives

- (1) Develop and test **nanocomposite seal repair materials** suitable for expected wellbore environments that have **high bond strength** to casing and cement, **high fracture toughness**, and **low permeability**.
  - These materials will have superior properties compared to conventional materials to permit improved wellbore seal repair, contributing to the program’s goal of 99% storage permanence.
  - Success criteria: Materials shall have superior properties and characteristics compared to conventional materials.
(2) Evaluate the effectiveness of developed materials to repair flaws in *large lab-scale annular seal systems* under conditions expected in wellbores.

- Evaluation and understanding of the expected performance of these materials to repair flaws within sealed wellbores will lead to more confidence in the ability to ensure 99% CO$_2$ storage permanence.

- Success criteria: The degree to which system permeability to CO$_2$ is reduced after repair, cost, material availability and ease of use compared to conventional materials.
Project Task Flow

1. Synthesize nanocomposites
   Task 2

2. Macro- and micro-characterization of materials
   Task 3 and 4

3. Evaluate as repair material in integrated seal tests
   Task 5
Nanocomposites - addition of small amounts of nano-scale materials can dramatically alter properties of materials such as polymers, composites, and cements.

- Strength
- Ductility
- Reduce shrinkage
- Thermal stability
- Resistance to degradation
# Materials

<table>
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<tr>
<th>Mixture Abbreviation</th>
<th>Base Material</th>
<th>Nanoparticles</th>
<th>Content %</th>
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<tr>
<td>Reference</td>
<td>Microfine cement</td>
<td>None</td>
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<td>PCNC1</td>
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<td>Nanoalumina</td>
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</table>
Flowability related to ability to inject nanocomposite into flaws.
Flowability results
Bond strength characterization

- Slant shear test – a direct measure of nanocomposite – steel bond strength
Slant shear test results
Integrated seal system testing

- Pore fluid
- Casing fluid
- Casing
- Perforation
- Pressure cell
- Cement sheath
- Confining fluid
- Membrane
Configuration for wellbore seal system tests
Annular seal system specimen preparation

- Microannulus
- Gap
- Cement fracture
Flows through flaws

Approximate flow rate for intact specimen

Flow rate (SLM)

Microannulus    Slot    Fracture

1.00E-01

1.00E-00

1.00E-01

1.00E-02

1.00E-03

1.00E-04

1.00E-05

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Flows through flaws

Specimen with radial cement fracture

Permeability (m²)

Confining pressure (psi)

3.6E-15
3.1E-15
2.6E-15
2.1E-15
1.6E-15
1.1E-15
6.0E-16
1.0E-16

0 500 1000 1500
Repair

1. No pressure

2. Separate pressurized system

3. In pressure vessel
Microannulus repair

Confining pressure = 200 psig
Internal pressure = 200 psig
Pore pressure = 100 psig
Cement fracture repair

Before repair

After repair

Internal pressure = confining pressure
Gas pressure = 50 psig
Numerical simulations

Model of pressure vessel system

- Estimate stress and strains repair material will be subject to
- Correlate stress conditions to permeability values
Numerical simulations

Discrete wellbore model

Full-scale Cranfield model
Accomplishments to Date

– Synthesized and characterized a number of nanocomposite and reference materials. For some nanocomposites:
  • Acceptable flowability
  • Bond strength and fracture toughness substantially increased

– Testing of wellbore seal systems
  • Developed experimental methods
  • Testing pre- and post-repair condition

– Simulation model developed
Summary

– Nanocomposites are being developed and tested with favorable properties as seal repair materials.

– Future Plan: Continue material synthesis and testing with accompanying testing and evaluation of seal system repair.
Acknowledgements

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Organization Chart

Stormont (UNM) PD/PI

Taha (UNM) PI
Materials synthesis and testing

Matteo/Dewers (Sandia) Co-investigators
Materials evaluation and numerical simulations

Genedeytal
Graduate student

Ahmad
Graduate student

Gomez
Student intern

Raymer
Student intern
Publications generated from project

