Oil & Natural Gas Technology

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Fracture Diagnostics Using Low Frequency Electromagnetic Induction and Electrically Conductive Proppants

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Quarterly Progress Report

M. M. Sharma ____________________ April 30, 2015_____
Mukul M. Sharma Date

Office of Fossil Energy

2. ACCOMPLISHMENTS:

- The forward model for the low frequency induction logging problem was solved numerically using a volumetric electric-field integral equation (V-EFIE) for non-cased boreholes.
- This numerical model was run for different scenarios to better understand what the sensor and the transmitter requirements will be for the tool.
- Extended the study of secondary fields generated from various fractures to more cases of receiver and transmitter configurations (spacing, orientation), and fracture properties (size, shape, and conductivity), for non-cased boreholes.
- Acceleration of MoM iterative solver: reduction of the average number of iterations per excitation by using previous solution information to set initial guess.
- Forward direct solution techniques are now being considered for implementation since they are very suitable for inverse algorithms, which require multiple forward solutions.
- A specific coil design for tool's transmitter and receivers has been selected and plans are to build the coils by the end of summer.
- A lab setup for measuring proppant conductivity was installed. Initial measurements were performed and are now being validated.
- A lab-scale experiment which will be a scaled down version of the field measurement was designed based on scaling relations.

3. PRODUCTS:

None.

4. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS:

Name:	Yaniv Brick
Project Role:	Postdoctoral Fellow
Nearest person month worked:	3
Contribution to Project:	Need Info
Funding Support:	ICES Postdoctoral Fellowship
Collaborated with individual in foreign country:	No
Country (ies) of foreign collaborator:	No
Travelled to foreign country:	No
If traveled to foreign country (ies), duration of stay:	0 months

Partner Organizations

Organization Name: Gearhart Companies Inc.
Location of Organization: Fort Worth, Texas

Partner's contribution to the project:

- Collaborative research (e.g., partner's staff work with project staff on the project)
- Design and building of tool

More detail on partner and contribution:

- Two joint meetings were held with Gearhart to better define the tool requirements and the results needed from the simulations to help with the tool design.

5. IMPACT:

The proposed technology has the following key advantages, which is not presently offered by any technology in the market:

a. It can be executed from a single wellbore.

b. It is a direct far field measurement.

c. This tool can be run in hole during or after hydraulic fracturing. If the need arises, it can be used at any time during the well's life cycle providing a time lapse analysis of fracture growth or closure.

d. Since it obtains tri-directional signals, these tensors can be resolved to obtain a simulated volume map, which can be correlated directly to the productivity of a given well.

e. This is the only technology that can obtain propped fracture length, which governs productivity of a given well. Also it can be used to detect proppant banking or anisotropy in hydraulic fracture growth.

We anticipate that the technology will have a very significant impact on fracture diagnostics as it is cheap, repeatable, and fairly simple to run. In addition to the key critical advantages mentioned above the proposed technology can also offer the following benefits which are in line with DOE's ongoing efforts:

a. Additional recovery: This tool can improve our understanding of true stimulated rock volume, since it tracks propped volume of hydraulic fractures and not shear slip events during a fracturing job. Therefore, using this technology, we can model the reservoir better and find effective re-fracturing candidates. Also a true stimulated rock volume map can help us design better simulations for subsequent wells.

b. Reduced costs: This tool can be operated at any time during the well's life cycle and not necessarily during the hydraulic fracturing job (as is the case with microseismic monitoring). Therefore, it will be reduce the equipment load during a fracturing job, thereby reducing the environmental footprint. Since this technology, being a single wellbore application, doesn't require a monitoring well, it can be potentially deployed in any hydraulically fractured well with or without a rig (can be deployed with a MAST truck too). Due to the simplicity of deployment and ease of operation, we anticipate a much reduced cost as compared to microseismic monitoring while providing more reliable results.

c. Environmental benefits: This technology basically tracks the location of conductive proppant using the proposed electromagnetic logging tool. Therefore it can used to track if the fractures are hydraulically connected to natural aquifers. This tool can be run alongside Cement Bond Logs, in fractured reservoirs to ensure hydraulic isolation of oil and gas producing zones. Also the inverted product of this data can be combined with other geophysical data (2D and 3D seismic and/or CSEM data) to find connection with natural fractures.

6. CHANGES/PROBLEMS:

None.

7. SPECIAL REPORTING REQUIREMENTS:

None.

8. BUDGETARY INFORMATION:

EXHIBIT 1 – MILESTONE STATUS REPORT

Milestone Title/Description	Planned Completion Date	Actual Completion Date	Verification Method	Comments (Progress toward achieving milestone, explanation of deviation from plan etc.)
Task 1. Project Management & Planning				
Milestones				
Completed project management & planning	11/1/14		PMP document	
Task 2. Development of forward model using proposed tool and different fracture geometires				
Milestones				
model of fracture in well completed	6/30/15			
forward model to observe signal	9/30/15			
important operational parameters	3/31/16			
Publication #1			Paper publication submitted	
Task 3. Lab testing of available proppants in the market for electrical and material properties				
Milestones				
identify the best proppants for their electrical conductivity and strength	3/31/16		Lab test report provided for review	
Task 4. Construction of low frequency electromagnetic tool				
Milestones				
low frequency electromagnetic tool built and lab tested according to well specifications	12/31/16			
Task 5. field testing of tool				
Milestones				
Built tool deployed in well	2/28/17		Tool is deployed on well site	
publication #2			Paper publication submitted	
Task 6. Inverting the obtained field data for stimulated rock volume (SRV) map				
Milestones				
invert the tool signal to obtain stimulated rock volume (SRV) map				
Publication #3	10/31/17		Paper publication submitted	
illustrate the new technology as a fracture diagnostic tool				
Final Report	12/31/17		Final report	

EXHIBIT 2- COST PLAN

Baseline Reporting Quarter	Budget Period 1							
	Q1		Q2		Q3		Q4	
	10/1/14 - 12/31/14		1/1/15 - 3/31/15		4/1/15 - 6/31/15		7/1/15 - 9/30/15	
	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total
Baseline Cost Plan								
Federal Share	$ 133,921	$ 133,921	$ 133,922	$ 267,843	$ 133,921	$ 401,764	$ 133,921	$ 535,685
Non-Federal Share	$ 48,602	$ 48,602	$ 48,603	$ 97,205	$ 48,602	$ 145,807	$ 48,602	$ 194,409
Total Planned	$ 182,523	$ 182,523	$ 182,525	$ 365,048	$ 182,523	$ 547,571	$ 182,523	$ 730,094
Actual Incurred Cost								
Federal Share	$ 30,972	$ 30,972		$ 30,972		$ 30,972		$ 30,972
Non-Federal Share	$ 75,222	$ 75,222		$ 75,222		$ 75,222		$ 75,222
Total Incurred Costs	$ 106,194	$ 106,194	$ -	$ 106,194	$ -	$ 106,194	$ -	$ 106,194
Variance								
Federal Share	$ 102,949	$ 102,949	$ 133,922	$ 236,871	$ 133,921	$ 370,792	$ 133,921	$ 504,713
Non-Federal Share	$ -26,620	$ -26,620	$ 48,603	$ 21,983	$ 48,602	$ 70,585	$ 48,602	$ 119,187
Total Varience	$ 76,329	$ 76,329	$ 182,525	$ 258,854	$ 182,523	$ 441,377	$ 182,523	$ 623,900

Baseline Reporting Quarter	Budget Period 2							
	Q1		Q2		Q3		Q4	
	10/1/15 - 12/31/15		1/1/16 - 3/31/16		4/1/16 - 6/31/16		7/1/16 - 9/30/16	
	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total
Baseline Cost Plan								
Federal Share	$133,922	$ 669,607	$133,922	$ 803,529	$133,922	$ 937,451	$ 133,921	$1,071,372
Non-Federal Share	$ 48,602	$ 243,011	$ 48,603	$ 291,614	$ 48,602	$ 340,216	$ 48,602	$ 388,818
Total Planned	$182,524	$ 912,618	$182,525	$1,095,143	$182,524	$1,277,667	$ 182,523	$1,460,190
Actual Incurred Cost								
Federal Share		$ 30,972		$ 30,972		$ 30,972		$ 30,972
Non-Federal Share		$ 75,222		$ 75,222		$ 75,222		$ 75,222
Total Incurred Costs	$ -	$ 106,194	$ -	$ 106,194	$ -	$ 106,194	$ -	$ 106,194
Variance								
Federal Share	$133,922	$ 638,635	$133,922	$ 772,557	$133,922	$ 906,479	$ 133,921	$1,040,400
Non-Federal Share	$ 48,602	$ 167,789	$ 48,603	$ 216,392	$ 48,602	$ 264,994	$ 48,602	$ 313,596
Total Varience	$182,524	$ 806,424	$182,525	$ 988,949	$182,524	$1,171,473	$ 182,523	$1,353,996

Baseline Reporting Quarter	Budget Period 3							
	Q1		Q2		Q3		Q4	
	10/1/16 - 12/31/16		1/1/17 - 3/31/17		4/1/17 - 6/31/17		7/1/17 - 9/30/17	
	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total
Baseline Cost Plan								
Federal Share	$133,921	$1,205,293	$133,922	$1,339,215	$133,922	$1,473,137	$133,921	$ 1,607,058
Non-Federal Share	$ 48,602	$ 437,420	$ 48,603	$ 486,023	$ 48,602	$ 534,625	$ 48,603	$ 583,228
Total Planned	$182,523	$1,642,713	$182,525	$1,825,238	$182,524	$2,007,762	$182,524	$ 2,190,286
Actual Incurred Cost								
Federal Share	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Non-Federal Share	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Incurred Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Variance								
Federal Share	$133,921	$1,205,293	$133,922	$1,339,215	$133,922	$1,473,137	$133,921	$ 1,607,058
Non-Federal Share	$ 48,602	$ 437,420	$ 48,603	$ 486,023	$ 48,602	$ 534,625	$ 48,603	$ 583,228
Total Varience	$182,523	$1,642,713	$182,525	$1,825,238	$182,524	$2,007,762	$182,524	$ 2,190,286