ANALYSIS OF SLICKWATER FRACTURING PARAMETERS WITH MULTI-VARIATE STATISTICS

Master of Science in Petroleum Engineering Thesis Proposal

for

Nikita Kazakov

The attached document is a Master of Science thesis proposal for Nikita Kazakov. It contains a detailed outline of the proposed thesis work, objectives for the project and a summary of the completed class work. Your permission and agreement with the project as outlined in this document is requested.

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INTRODUCTION

Slickwater fracturing has in recent years emerged as an important stimulation technique in several basins across the United States. Slickwater fracturing allows unconventional reservoirs such as tight gas, shales and coal bed methane to become economically producible. A distinct feature of slickwater fracturing is the low viscosity liquid, usually water, which is injected as fluid and "slickened" with friction reducers. The low viscosity of the fluid also makes slickwater less contaminant to the formation and reduces the amount of residue near the wellbore.¹ In addition, slickwater can be reused from flowback and re-injected into different wells within a certain field, making this process sometimes less expensive than conventional gelled hydraulic fracturing.

This thesis proposal focuses on analyzing stimulation parameters in slickwater fracturing using multi-variate statistical analysis. The project focuses on building correlations between stimulation and production parameters and seeing how they can be related to the production rate after stimulation has been completed. Multi-variate statistical analysis is employed to sort variables that are important to production and those that are of less importance. As a backbone to analyzing slickwater stimulation variables, a database must be built to organize wells and create sorting flexibility for statistical input. The end results are of importance to the industry because they can provide sensitivity of several parameters to production, therefore making slickwater fracturing more effective and economical to companies.

<u>THESIS OBJECTIVES</u>

- 1. Obtain in-depth slickwater fracturing parameter data from petroleum companies for two reservoir types, one a tight gas and the second a shale gas reservoir;
- 2. Produce a slickwater fracturing database where parameters can be organized and sorted to be exported for statistical analysis;
- 3. Develop relationships between slickwater parameters using multi-variate statistical analyses including: cluster, discriminant, factorial and multiple regression;
- 4. Assess how slickwater fracturing parameters relate to the production of wells, and;
- 5. Deliver a methodology to analyze slickwater hydraulic fracturing treatment success parameters that can be applied to other fields.

STATISTICAL METHODS

The following statistical methods are being evaluated for incorporation in this project.

Bi-variate Statistics

This is a form of statistics that uses two variables to find a relationship between them. If certain correlations are visually found with the bi-variate techniques, then trend lines can be fitted. Trend lines can come in forms of linear, power, exponential, logarithmic, and polynomial equations. To see whether a trend is sufficiently correlated, it is possible to find the coefficient of determination, also known as the R^2 value, to determine whether the equation fits the data point with enough accuracy.²

The problem with using a bi-variate approach lies in its limitation of only comparing two variables. Slickwater fracturing can have well over 20 variables that need to be clustered and compared with their own dependencies and their dependency to the independent variable. The bi-variate approach is not able to use several dependant variables at once and compare them to a single independent variable such as production. For this job, a more rigorous statistical method is applied.

Multi-Variate Statistics

Multi-variate statistics is an analysis of more than two variables and their relationship to each other. As previously discussed, bi-variate statistics only possesses one dependant variable that could be compared to one independent variable. Multi-variate statistics can have many dependant variables which can be compared to a single independent variable. There are several subsets of multi-variate statistics that this research is focusing on.

Clustering Analysis

Clustering³ focuses on condensing a large data set of points into small separated groups. This is important in a slickwater parameter analysis because prior to analyzing parameter relationships, many parameters have to be grouped in smaller sets for an accurate regression interpretation. Clustering is a process that will be followed by multiple regressions in the slickwater parameter analysis. Figure 1 shows how cluster analysis can group variables in various orders. Figure 1 represents a dendogram, which is used to cluster single variables into groups in a hierarchical manner.

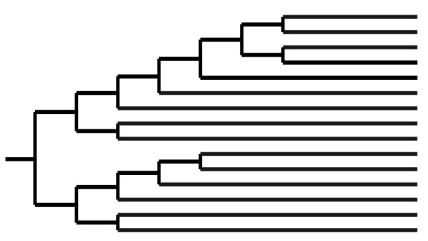


Figure 1. Example of a dendogram in cluster analysis.

Discriminant Analysis

Discriminant functions show whether a set of variables can distinguish between different clustered groups. Knowing this function in the slickwater parameter analysis will display how clustered groups are varied with certain parameters and how it would be possible to extend or shorten these groups for manageability.

Factorial Analysis

Factorial analysis uses both variable analysis and common variable analysis. It has the capability to discover new patterns within a pattern of relationships among several variables. It is useful in finding whether a large correlation of variables can be described using a smaller amount of variables, also known as factors.

Multiple Regression Analysis

This is the most conclusive out of the four functions explained here. Multiple regression allows for the comparison of multiple dependant variables upon one single independent variable. This regression shows the interdependence of the dependant variables to each other and to the main independent variable. This analysis should show trends in slickwater fracturing parameters and can fit an equation to govern the trend.

MINITABTM STATISTICAL SOFTWARE

MinitabTM is a statistical software designed for corporate environments. Its capabilities range from simple statistical methods to more complicated statistical analyses such as multi-variate statistics.⁴ It will be one of the softwares used to analyze slickwater fracturing parameter sensitivities because it works on a spreadsheet principal, just like Microsoft Excel. Initially there will be many variables present from stimulation data. The goal is to cluster that data into groups with visual trends. After clustering, different variables of data can be analyzed with respect to the production rate. Not all variables will relate to the production rate and therefore many variables will be eliminated. The countdown to useful parameters will provide stronger correlations with a more organized structure for the database.

<u>SLICKWATER DATABASE</u>

Prior to statistically analyzing slickwater parameters, a capable and flexible database will be built. The significance of a database for this project is in its sorting capability. Parameters will most likely have a clustered structured where they will be separated for statistical analysis. A multiple sorting function for parameters is a necessity from a database. Microsoft Excel uses spreadsheets and is limited to holding 65536 rows. This amount of rows is more than sufficient for holding slickwater stimulation parameters from a selected field of study. The only limitation that Microsoft Excel has is a limit to sorting by only two properties. There are third party add-ons to Excel that allow it to sort with unlimited properties. Excel would also be an advantage because MinitabTM can work directly with Excel spreadsheets.

<u>TASKS</u>

The following are the next steps in the project:

1. Having a sufficient amount of information is important to building a successful slickwater database with a plentiful number of parameters to investigate. Jonah Field, provided by Encana, has been selected and fracturing information queried from their slickwater fracturing records. In addition, Devon is providing slickwater data from a shale gas reservoir.

- 2. A functional and flexible database is being built for the slickwater and well parameters of the subject fields. This database will be able to sort parameters by different properties.
- 3. Multi-variate analysis will be performed on different slickwater fracturing parameters using MinitabTM software.
- 4. New ideas and trends will be investigated between variables and the slickwater database updated with variables that are of utmost importance to production and reserve recovery.

COURSE WORK AND RESEARCH CREDITS

Table 1. History of Graduate Courses												
Course ID	Graduate Courses	s Hours Grade Te										

Table 2. History of Graduate Research												
Course ID	Graduate Research	Hours	Grade	Term								

Table 3.	Summary of Graduate Credits	

<u>TIMELINE</u>

Table 3. Thesis Schedule (Fall 2009 - Spring 2010)																																			
		Time																																	
Activity		Aug-09		Sep-09			C	Oct-09			Nov-09			Dec-09			9	Jan-10			Feb-10			0	Mar-10			Apr-10)	Ma	10		
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Committee Meeting																				Τ															
Literature Review												Τ			Γ					Т						Τ						Τ		Τ	Π
Minitab School																																			
Data Analysis																																			
Making Conclusions																																Τ		Γ	
Thesis Writing												Τ																				Τ			
Thesis Defense																																			
Graduation - May 2010																																			

RESEARCHER BIOGRAPHY

Nikita Kazakov was born in Dushanbe, Tajikistan. He graduated with his BS in Petroleum Engineering in 2008 from the Colorado School of Mines in Golden, Colorado. He has worked as a field engineer for EOG Resources in 2007 and with Stim-Lab in 2008. He is presently working as a research assistant to the Fracturing, Acidizing, Stimulation Technology (FAST) Consortium. He is working towards earning his MS in Petroleum Engineering from the Colorado School of Mines.

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- 3. Anderson, Rolph E., Bill Black, Joseph F. Hair, and Ronald L. Tatham. *Multivariate Data Analysis (5th Edition)*. Alexandria, VA: Prentice Hall, 2005.
- 4. "Minitab[™] Features." Statistical Analysis: Data Analysis. http://www.minitab.com/products/Minitab/ (accessed April 2, 2009).