ANALYSIS OF SURFACE AND DOWNHOLE MICROSEISMIC MONITORING COUPLED WITH HYDRAULIC FRACTURE MODELING IN THE WOODFORD SHALE

by

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ABSTRACT

The work presented in this thesis focuses on using analyzed surface and downhole microseismic data for a horizontal well in the Woodford Shale in Oklahoma and compares those results with calibrated hydraulic fracture modeling. It shows the importance of microseismic monitoring of hydraulic fracturing treatments and discusses the information that can be gained by thoroughly analyzing the recorded data in conjunction with hydraulic fracture modeling. Technologies to accurately monitor fracture growth as well as to determine hydraulic fracture properties are necessary to improve our understanding of the processes occurring in the reservoir in order to optimize stimulation treatments.

Hydraulic fracture models were created for each of five stages with a three-dimensional modeling software, incorporating available petrophysical data in order to match the recorded treatment pressure and microseismic data. The hydraulic fracture models for this thesis were developed in three steps. First, a basic model for each step was built incorporating available logs, and modifying parameters to achieve a reasonable representation of the reservoir geology. These models were run to simulate fracture growth and generate pumping data. The second step was to match the observed pressure to the simulated pressure for each stage. In the third step this preliminary calibration was further enhanced and verified by matching fracture geometry to microseismic data to produce a model that reflects actual reservoir parameters on all three levels (i.e. rock properties/logs, treatment pressure data, and microseismic recordings).

Further analysis investigated how well surface and downhole microseismic data match, what difference they produced in a match if used exclusively, the errors that are associated with the data set, and if the degree of complexity of the created fractures could be assessed from the available data. It also evaluated the data in terms of reservoir characterization since communication between the hydraulic fracture network and natural fractures and faults can affect the efficiency of a stimulation treatment. The

availability of both surface and downhole microseismic recordings for a multi-stage treatment in one well provided the opportunity to directly compare the two data sets on different levels. In order to evaluate how reliable and accurate the individual technologies are, and to determine advantages and disadvantages, this thesis investigated the congruency between the surface and downhole data, as well as tried to estimate how many events are actually necessary to produce a good and fairly accurate match with a hydraulic fracture model. In the ensuing step, the recorded data was analyzed in terms of fracture complexity, as well as in terms of the relationship between the magnitude of events, time and location of occurrence, and seismic deformation in conjunction with reservoir characterization.

The fracture models produced good matches for both pressure and fracture geometry, with average deviations of -17% for the longitudinal stretch and -10% for the fracture length. Fracture height, on the other hand, could not be very well matched, with average deviations of -59% for the longitudinal models and -55% for the transverse models, which could be attributed to re-fracturing of parts and leak-off into parts of the reservoir that were already stimulated in a previous stage. Surface and downhole microseismic data overlapped in certain regions and picked up on different things in others, giving a more complete picture of microseismic activity and fracture growth if used together. However, they deviated in terms of vertical event location with surface data showing more upward growth and downhole data showing more downward growth.

In general, the downhole microseismic data showed that the stimulation treatment was successful in creating a fairly complex hydraulic fracture network for all stages, with microseismic recordings making flow paths visible governed by both paleo and present day stress. A plot of event magnitude versus event-to-receiver distance identified Stages III and V as the stages with the most events of larger magnitude, implying interaction with pre-existing structures which facilitate large magnitude events. This was supported by analyzing the speed of event generation, as well as the cumulative moment for all stages. Overall, the link between 'loud' events and the intersection of faults lead to the assumption that the fracture network generated during Stage V most likely communicated with a fault structure.

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