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Novel and Permanent Measurement of Formation Pore Pressure

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SUMMARY

We introduce a novel approach to measure directly the formation pore pressure and temperature during injection and production operations. We analyze a set of acquired data and compare with conventional injection operation data. Through a system identification algorithm, we process the raw data and remove noise from the data. The overall result shows that the novel sensor technology applied provide the direct and reliable measurements of formation pore pressure and temperature.

Introduction

The JIP project MESPOSH (Measurement of Pore Pressure in Shale) was initiated in 2005 to solve this major shortcoming in the oil and gas industry: to measure reliably the pore pressure in shale and low permeable formations. This effort has now resulted in a novel and practical tool with a wireless communication platform to monitor pressure and temperature outside the well casing. Namely, a set of specially-designed pressure and temperature sensors is installed outside a steel casing, surrounded by a cement grout. The measured data are then transferred into the annulus well through wireless communication. Thanks to this novel approach, the formation pore pressure and temperature can be monitored permanently in real time without interrupting or pausing injection and production operations. When implementing the technology it appears that the strongest application drive comes from injection and the experience so far is mainly from such operation.

Herein, we introduce the novel sensor and a related methodology for data processing that enables to measure directly and monitor the formation pore pressure and temperature during injection and production operations. The novel technology sensor is currently installed in a produced water injection (PWI) field in the North Sea and monitors the formation pore pressure since July 2012. In this study, we analyze the acquired data set and compare with conventional injection operation data such as the downhole pressure and temperature (DHP, DHT), injection rate, etc. In addition, through a system identification algorithm based on the coupled Thermo-Hydro-Mechanical (THM) model, we process the raw data and remove noise from the data (e.g. thermally-induced pressure). The overall result shows that the novel sensor technology applied provide the direct and reliable measurements of formation pore pressure and temperature.

Novel sensor and installation

Figure 1 shows a schematic illustration of the sensor unit and installation. Two sensor units (A and B) are installed. Sensor A is placed on the outside of the inner tubing and measures in the annulus between the inner tubing and the casing, while Sensor B is placed in the cement outside of the casing. The data at Sensor B are then transferred into the annulus well through wireless communication

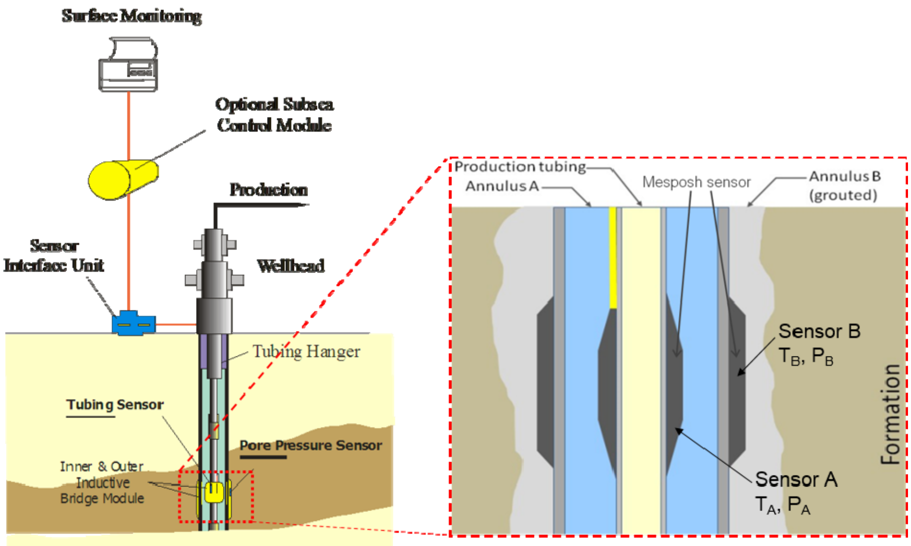

Figure 1 *Schematic illustration of the novel sensor installation. Each measurement by sensor units is defined as follows:* T_A*=Injection fluid/inner tube wall temperature;* T_B*=Near well temperature;* P_A*=Annulus pressure;* P_B*=Near well pore pressure.*

When the fluid is trapped inside the low permeable cement and/or formation (e.g. shale), the rapid shrinkage or expansion of pore structure and fluid is induced by temperature change. This can cause a change in pore pressure without immediate flow dissipation. This is so called the undrained heating effect (Roshan and Rahman 2010). The over-shooting of pore pressure then dissipates through the hydraulic diffusion process until the drained condition is reached. The time for pore pressure dissipation depends on the permeability and stiffness of related porous media. The novel sensor unit is embedded in a low permeable cement layer and connected (feeling the pressure change) through a small contact area. Then, the associated thermally-induced pressure slowly dissipates through the small contact area and then through the cement layer. This rather complex system seems to be responsible for the pressure anomalies (i.e. high oscillation in the pressure measurement at point B), particularly near the shut-in periods. In the next section, we introduce an efficient approach to reduce the pressure anomalies.

Thermally-induced pressure removal

We aim ultimately to measure pressure outside the sensor unit, more precisely speaking, the formation pressure. This would involve getting a result with 1) no major effects of thermally-induced pressure in low permeable surrounding domain. We choose a simplified model which solves directly for the pressure outside the sensor unit (P_D). We assume that the formation (or reservoir) pressure changes very slowly compared to thermally-induced fluctuations in pressure due to injection.

Figure 2 shows the result when the simplified model is applied to a set of measured data. The data are acquired since July 2012 at the Grane well 25/11-G-36 that is in a PWI field. The model looks promising to remove most of the thermally-induced pressure from the measured data.

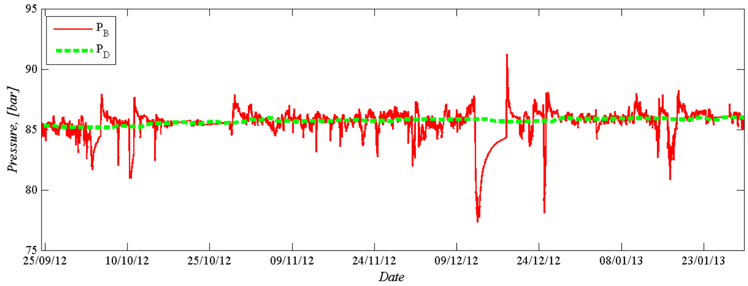

Figure 2 *Processed pressure data (green dashed line) to remove the thermally-induced pressure in comparison with the unprocessed pressure data (red solid line).*

Conclusions

We introduce a novel approach to measure directly the formation pore pressure and temperature during injection and production operations (e.g. without shut-in). In this study, we analyze a set of acquired data and compare with conventional injection operation. In addition, through a system identification algorithm (based on the THM model), we process the raw data and remove noise from the data. The result shows that the novel sensor technology applied provide the direct and reliable measurements of formation pore pressure and temperature.

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