Field Test for Real Time Monitoring of Piezoresistive Smart Cement to verify the Cementing Operations

Research Themes

With some of the reported failures and growing interest in environmental and economic concerns in the oil and gas industry, integrity of the cement sheath is of major importance. The disaster at Macondo claimed eleven lives and caused severe injuries and record-breaking sea pollution by the release of about five million barrels of crude oil. Therefore, proper monitoring and tracking the process of well installation and the performance during the entire service life has become important issue to ensure cement integrity. Smart cement has been developed, which can sense any changes going on inside the borehole during cementing and during curing after the cementing job. The smart cement can sense the changes in the water-to-cement ratio, different additives, temperature and any pressure applied to the cement sheath in terms of piezoresistivity. The failure compressive strain for the smart cement was 0.2% at peak compressive stress and the resistivity change is of the order of several hundreds making it over 500 times more sensitive.

In this study, a field well was installed and cemented using the smart cement mixture with enhanced piezoresistive properties. The field well was designed, built, and used to demonstrate the concept of real time monitoring of the flow of drilling mud and smart cement and hardening of the cement in place. A new method has been developed to measure the electrical resistivity of the materials using the two probe method. LCR meters (measures the inductance (L), capacitance (C) and resistance (R)) were used at 300 kHz frequency to measure the changes in resistance. The well instrumentation was outside the casing with 120 probes, 18 strain gages and 9 thermocouples. The strain gages and thermocouples were used to compare the sensitivity of these instruments to the two probe resistance measure in-situ in the cement.

Change in the resistance of hardening cement was continuously monitored since the installation of the field well for over 500 days. Also, a method to predict the changes in electrical resistance of the hardening cement outside the casing (Electrical Resistance Model - ERM) with time has been developed. The ERM predicted the changes in the electrical resistances of the hardening cement outside the cemented casing very well. In addition, the pressure testing showed the piezoresistive response of the hardened smart cement and a piezoresistive model has been developed to predict the pressure in the casing from the change in resistivity in the smart cement.

Recent Accomplishments

It has been successfully demonstrated the instrumentation and working with smart cement in the field model test.
The following were accomplished during the field testing.

The two-probe method was effective in measuring the bulk resistance of the drilling fluid, and smart cement slurries.
Field test demonstrated the real-time monitoring of the well bore with drilling fluid and smart cement slurries.
Based on the concept developed in this study, it was possible to predict the changes in the resistance of the hardening of smart cement using a model developed. The predictions agreed well with the experimental results.
The smart cement used to cement the field well was very sensitive to the applied pressure, piezoresistive cement. Using a nonlinear p-q model the change in electrical resistivity of smart cement was related to the applied pressure in the casing.
It is possible to predict the pressure in the casing and also the stress in the cement sheath by measuring the change in resistivity of the smart cement.

Also this technology has been tested for over 4 years using laboratory models, and one and half year of testing and monitoring in our own 40 foot field well. Laboratory model and field model have clearly demonstrated applicability of the new technology. In July 2015 a provisional patent has been filed to protect this system, and our non-provisional has been filed in July of 2016. The following are some of the recent publications on the field testing of smart cement.

1. C. Vipulanandan, B. Basirat, A. Reddy; S. Dighe, H. Farzam, N. Amin, (2016). "Field Test for Real Time Monitoring of Piezoresistive Smart Cement to Verify the Cementing Operations". Offshore Technology Conference.
2. C. Vipulanandan, B. Basirat and A. Reddy, (2016). "Field Study on Piezoresistive Smart Cement and Drilling Mud for Real Time Monitoring the Installation and Performance of the Cemented Well". AADE Fluids Technical Conference and Exhibition.
3. C. Vipulanandan and A. Reddy, (2016). "Smart Foam Cement Characterization for Real Time Monitoring of Ultra-Deepwater Oil Well Cementing Applications". AADE Fluids Technical Conference and Exhibition.

After finishing various scales of lab and field testing, the smart cement project is now ready for pilot testing in oil wells. We are currently working with Oil gas companies, Baker Hughes and PetroChina for pilot testing of this technology.

Issues

Field testing of smart cement posed implementation problems, which have been successfully solved. The first major problem was the design of efficient and feasible probing system. Probing system outside the casing was designed which did not affect the integrity of the cementing and the casing. The next major hurdle was developing an air tight pressurizing system to test the sensitivity of the field model. We have used small tubes placed in the cement for pressure testing of the field model instead of pressuring the casing which was not feasible in lab scale.

Currently we are working improving the monitoring system for pilot test.

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