Detection and quantification of Gas leak in Smart cement.

G P Panda, and C. Vipulanandan[1], Ph.D., P.E.
Center for Innovative Grouting Material and Technology (CIGMAT)
Department of Civil and Environmental Engineering
University of Houston, Houston, Texas 77204-4003
E-mail: guruprasadpanda@uh.edu, cvipulanandan@uh.edu Phone: (713) 743-4278

Abstract: Smart cement is sensitive to stress, temperature and chemical changes occurring in it. In this study the sensitivity of 1 day cured smart cement to gas migration through it is studied. Smart cement slurry is kept in High pressure and high temperature device and cured for 1 day before test. The trends observed in the resistivity change pattern are indicative of gas migration happening inside cement.

1. Introduction

Approximately around 1.7 million operational and abandoned oil wells are present. Rates of oil well failure reported by industry is between 2%-45%.The most common reason for failure were defective, insufficient or improperly installed cement or casing. As per Pennsylvania state Database, around 6.3% of oil wells have well barrier problem from the years 2005-2013. (Ingraffe 2012). In Gulf of Mexico, around 43% of oil wells have sustained casing pressure (Bruffato et al .2003).Well Barrier and integrity failure occurs during drilling and one of the main reasons is gas migration occurring from formation.

Gas leakage may be described into three stages initial stage, intermediate and long term gas leakage. Main reasons for gas migration failure .At initial stage gas migration occurs due to incorrect cement densities, poor mud and filter cake removal leaving route for gas migration, premature gelation leading to hydrostatic pressure control, high shrinkage of cement. Excessive fluid loss creates increases space in the cement slurry for gas to enter and high stresses around cement sheath leads to the formation micro annulus.(Bonett & Pafitis, 1996).

Another important aspect is the real time monitoring of gas oil wells including cement hydration. Real time monitoring is necessary to detect and sense gas migration. Acoustic logs measure the cement quality from the degree of acoustic coupling of the cement to casing and formation. (Gowida, Ahmad, Elkatatny, Mahmoud, & Fahd, 2018). Although properly run cement bond log provide reliable well integrity and zonal isolation but does not detect gas leakage and cement hydration. To detect real time gas leakage, smart cement developed by Vipulanandan must be used as a monitoring tool with electrochemical Impedance measurements.

2. **Objectives**

The overall objective is to evaluate the sensing characteristic of smart cement cured for 24hours to detect gas leaks

3. Material and Method: Specimen was prepared using class H cement with water –cement ratio of 0.4.Conductive filler of 0.2% were used make the specimen piezoresistive. After mixing, the smart slurry is put inside High Pressure High Temperature device and the change in resistivity due to gas migration is observed. High Pressure and High Temperature device is modified to measure the resistance while the fluid loss test is being done. HPHT device has an area of 22.58cm^2 and can withstand a pressure of around 2000psi.Gas migration test was done using nitrogen gas as it does not react with the cement components. During the entire test, vertical and horizontal resistances of the slurry are measured using LCR device. The change in resistance is correlated to resistivity which is material property.

Gas Migration under Open condition – When outlet valve is kept open, the gas is allowed to migrate through the hardened cement. The change in resistivity during this phase is observed. Under open condition, gas migration initially causes fluid loss in the cement slurry. Precisely, this condition replicates the behavior of gas migration occurring in oil wells. Then the gas migration after fluid loss is observed. The applied pressure for gas migration under open condition is kept at 100 psi. At this stage, the outlet velocity is plotted with different applied pressure.

Results and Discussion

Smart cement has piezoresistive behavior, i.e. resistivity changes due to application of stress. Piezoresistive cement resistivity changes due to applied stress and this property makes this cement unique compared to other normal cement. Piezoresistive behavior of one day cured smart is shown.

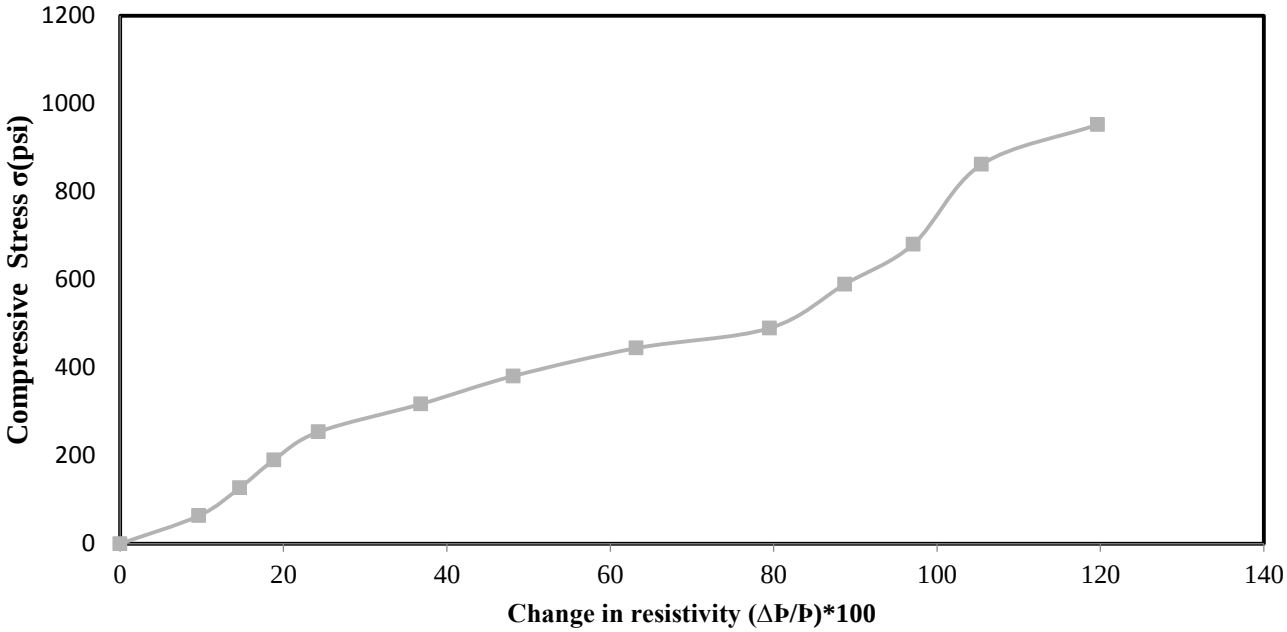

Figure 1: Resistivity change in smart cement at slurry state due to gas Migration.

In figure 1, the resistivity of the smart cement changes due to compressive stress.135% positive change in resistivity is observed in smart cement due to compressive stress.

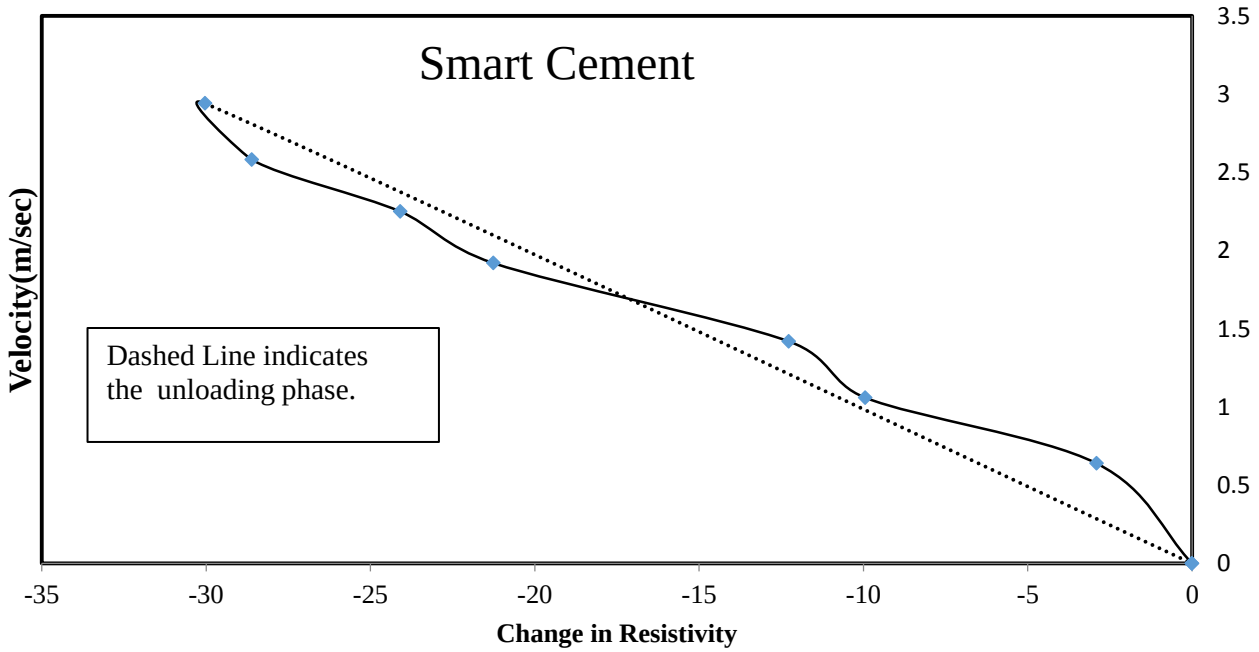

Figure 2: Resistivity change smart cement at hardened state due to gas migration.

In figure 2, due to continuous applied pressure on the smart cement slurry, the resistivity of smart decreased by 45%. The change in resistivity is positive when compressive load is applied and negative in the case of gas migration in the smart cement.

From the change in resistivity, gas migration velocity can be ascertained. It can be correlated to pressure which is applied on hardened cement. Gas migration in hardened smart cement reduces the resistivity by -35%. After the pressure is released, smart cement recovers back to previous resistivity value.

5. Conclusion: Gas migration is well acknowledged problem in oil wells. Smart cement can be used to detect and quantify gas leakage by monitoring the resistivity change in hardened cement.

6. Acknowledgements:
This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT), University of Houston, Houston, Texas

7.References

1)Al-Buraik, K., Al-Abdulquder, K., Arameco, S., Bsaibes, R., & Dowell, S. (1998). Prevention of shallow gas migration through cement. *IADC/SPE Asia Pacific Drilling Technology*, 67–74.
2)Al-Yami, A., Mukherjee, T. S., Riskiawan, A., & Wagle, V. (2017). Optimum Practices to Mitigate Gas Migration Problems in Deep Gas Wells (Russian). *SPE Russian Petroleum Technology Conference*, (October), 16–18. https://doi.org/10.2118/187700-RU
3)Al-yami, A. S., & Aramco, S. (2015). An Innovative Cement Formula to Mitigate Gas Migration Problems in Deep Gas Wells : Lab Studies and Field Cases Field Experience with Conventional Cement Formulations, (2000).
4)Al-yami, A. S., Ramasamy, J., & Wagle, V. (2017). Chemical Additives for Oil Well Cementing, *6*(4), 1–14.
5)Bonett, A., & Pafitis, D. (1996). Getting to the Root of Gas Migration. *Oilfield Review*, *8*(1), 36–49.
6)Gowida, A. H., Ahmad, Z., Elkatatny, S., Mahmoud, M., & Fahd, K. (2018). SPE- 192360 -MS Cement Evaluation Challenges.