Implementation of a Novel Wellbore Strengthening Technique Using a Proprietary Bridging Material – Success Case Study from Umm Ghadir Field in Kuwait

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ABSTRACT

Loss circulation and differential sticking are a significant source of non-productive time (NPT), where interbedded formations with varying pore pressure, porosity, and permeability are drilled together within the same section. In some instances, operators have limited choices to drill with excessive overbalanced across weak and lower pressured formations to meet well design targets. The challenge is aggravated if severe to complete loss circulation is encountered at the start of the section and it becomes mandatory to cure these losses and perform Formation Integrity Test (FIT) before drilling further through the low- and high-pressure interbedded formations.

This paper covers similar challenges to drill through troublesome reactive shale formations and highly depleted and fragile loss zones across carbonate formations in Umm Ghadir field in Kuwait. A comprehensive engineered approach was utilized to simulate characteristics of induce fractures across such fragile and weak formations based on downhole reservoir conditions and rock characteristics.

The combination of sized and resilient bridging materials along with deformable latex based sealing polymers has shown improvement to stabilize wellbore by increasing the hoop stress in the near wellbore. This is achieved by the particles bridging in the fracture, either at, or close to, the mouth of the fracture and forming a low-permeability seal. This allows the fluid and pressure trapped between the seal and the fracture tip to dissipate into the formation, allowing the fracture to close. Providing the particles used to form the bridge have sufficient strength, the bridge becomes compressed but prevents the fracture from fully closing. This imparts a hoop stress around the wellbore, increasing the near-wellbore strength.

This papers also includes case histories from Umm Ghadir Field in Kuwait for utilizing such compressive approach using customized bridging additives to improve wellbore strengthening and achieve formation integrity test. This application was applied with unique hesitate squeeze method after repeated failure to achieve FIT results after multiple cement jobs. The FITs were successful after implementation of this technique. The sections were continued to be drilled with customized bridging additives in fluids system to eliminate any risk associated with differential stuck pipe or induce losses.

EXTENDED ABSTRACT

Introduction

The major challenges observed drilling horizontal wells in Kuwait which leads to non-productive time are related with wellbore instability, stuck pipe and loss circulation incidents. The challenges were aggravated having interbedded reactive shale streaks along with weak, depleted and vugular formations to be drilled in the same section. It is required to stabilize the wellbore with proper inhibitive system, perform necessary good drilling practices to ensure good hole cleaning and downhole pressure is managed without exerting extra pressure across the wellbore to avoid inducing losses. The fluids system is incorporated with proper bridging and reinforcing additives to strengthen the well bore.

The losses evident at initial stage need to be monitored closely for any increasing trend and appropriate Lost circulation materials are used to heal fractures created during mud loss situations by bridging, plugging and or sealing the point of interest. Particles can be used in a preventative manner, by including material in the active fluid system while drilling. Care should be taken to ensure that materials are not larger than the openings found in shaker screens otherwise they will be 'screened out' and effectively wasted. The purpose is to arrest drilling induced fractures at an early stage before significant losses will occur. Correctly sized particles used in a preventative manner should bridge the fracture opening thereby reducing fluid loss to the fracture and preventing fracture growth[2].

Modeling can be used to show, in an ideal scenario that in the case of LCM's such as graphitic materials that work to seal induced fractures can significantly open the safe pressure window by allowing higher fluid column pressures with minimal losses[6]. It is proposed in this paper that an ideal combination of LCM's that work specifically to bridge induced fractures with hard particles and fill the intra-particular spaces between solids with a micronized deformable material to form a highly efficient seal in the case of induced

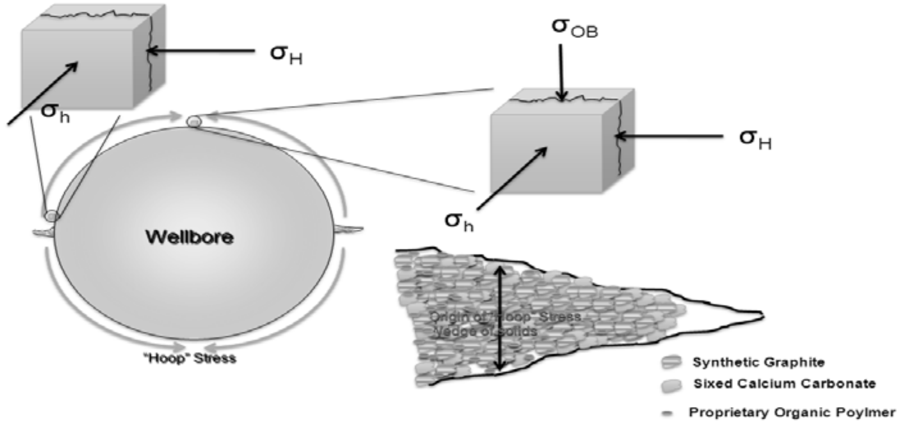

Figure 1 – Wellbore strengthening mechanism

fractures.

The presence of submicron deformable material alone also works to increase the efficiency of the leaky semi-permeable membrane characteristic of shale and prevents the latent pore pressure equilibrium leading to hole collapse. The ideal combination of LCM's thus opens the available pressure window by limiting mud loss by induced fracturing and also limiting hole collapse from formation pore pressure increase by slow fluid injection.

Optimized Bridging and Sealing System

The optimized bridging and sealing system (OBSS) consists of a combination of highly resilient carbon based additives with a deformable micronized sealing polymer. This combination of materials has been shown to effectively bridge and seal induced fractures when drilling and/or circulating across complex geo-pressured zones and through the curve when used in oil based mud. A 20x microscopic image of the blended product is shown in Figure 2.

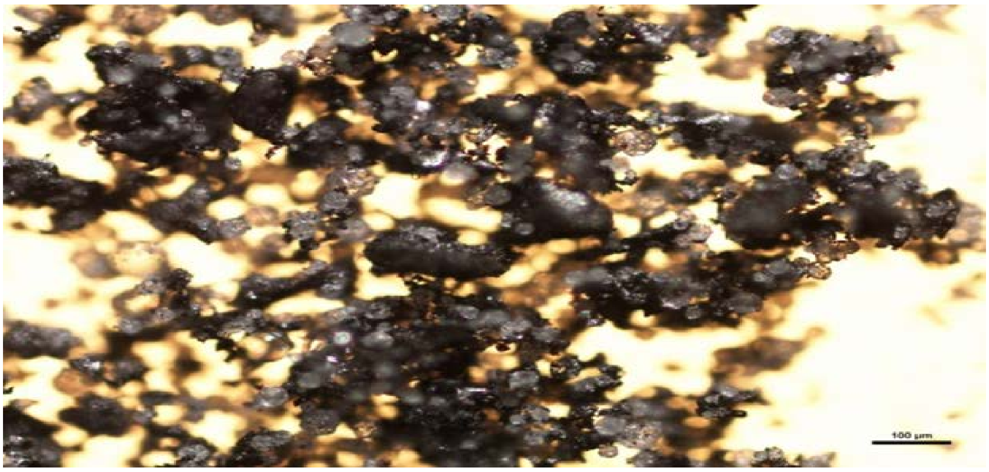

Figure 2: 20X Microscopic image of Optimized Bridging and Sealing Blend

Figure 3 shows the particle size distribution of the micronized deformable polymer component of the blend.

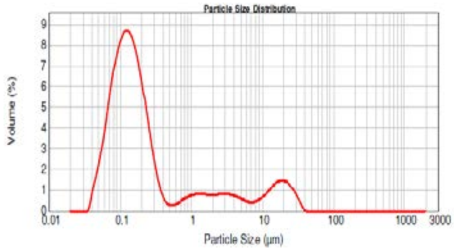

Figure 3: Particle size distribution of Micronized Deformable Polymer dispersed in deionized water

Particles in this size range work to effectively seal the intra-particular spaces found in a filter cake in both water based and oil based muds. Particles in this size range are also able to increase the efficiency of the semi-permeable membrane which is characteristic of the shale surface which assists osmotic drive of formation fluid towards the wellbore. This feature is described more in the next section. Figure 4 shows the particle size distribution of the optimized bridging and sealing system. With the wide distribution of resilient particles found in this blend combined with the submicron deformable particles, this LCM is able to compact within the tips of induced fractures, create a sealed filter cake, and halt further propagation of fractures.

Micronized Deformable Polymer

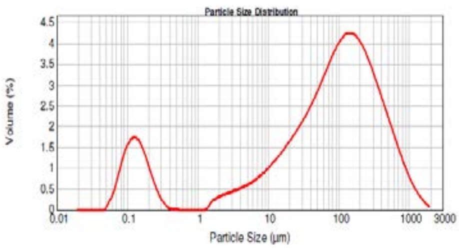

Figure 4: Particle size distribution of Optimized Bridging and Sealing System dispersed in deionized water

Shale with its very small pore throats on its own can be defined as a 'leaky' semi-permeable membrane, which does provide some osmotic fluid flow from low to high ionic concentrations. This explains the benefit of adding 20%NaCl to a mud without any other additives to achieve some wellbore stability. Oil based muds are excellent at acting as a barrier to the transfer of fluid into the pores of shale due to their hydrophobic nature and can even allow formation water to flow osmotically towards the borehole with the brine found in the internal phase of the mud. The functionality of the micronized deformable polymer component is thought to increase the efficiency of the semi-permeable membrane created by the face of the shale formation.

Formation of Internal Filter Cake

The tendency of differential sticking increase with high differential pressure caused due to high overbalance and depleted formation pressures across relatively high permeable formations. , high wellbore pressures or both, are exerted over a sufficiently large area of the drill string. The bottomhole assembly is held in the cake by a difference of pressures between the hydrostatic pressure of the mud and the pore pressure around the surface of the wellbore. When a low permeability internal cake is formed, the pressure differential between the hydrostatic pressure of the mud and the external filter cake is reduced. The differential pressure between the mud column and formation is preserved which is necessary to prevent spalling shale or hole collapse. Due to the fine size and viscoelastic nature of the particles, the micronized deformable polymer has the ability to create a low permeability internal filter cake which helps to reduce the incidence of differential sticking.

The ability of the micronized deformable polymer to form an internal filter cake has been proven in a laboratory setting. In the study, two 30 minute dynamic filtration tests are done on low porosity ceramic discs (3-20µ), one with a standard water based mud and the same mud with deformable polymer included. Fluid loss values are plotted over square root time to observe the nature of the filter cake. In a dynamic fluid loss test, a filter cake builds initially and is relatively static in thickness over the course of the 30 minute test. In the base fluid, as expected, filtration values over square root time are increased linearly after the initial external filter cake forms.

In the fluid containing submicron deformable polymer however, filtrations over square root time deviate from linearity and the rate of fluid passing through the filter cake decreases over time. An example of this effect is shown in Figure 5. This is an indication that an internal filter cake is being built within the disc as particles are being deposited over time thus slowing the filtration rate.

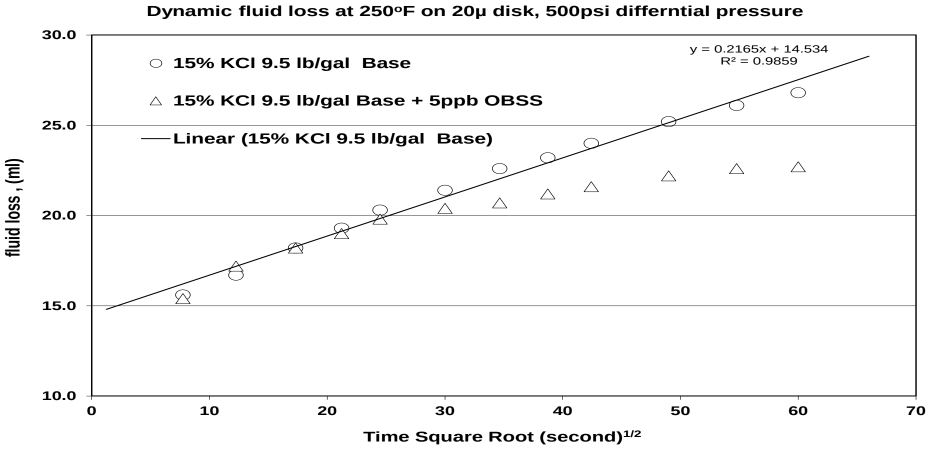

Figure 5: Dynamic fluid loss over square root time for a 15%KCl 9.5 lb./gal WBM base fluid and the same base fluid with OBSS added.

Based on the assumption of the formation of an internal filter cake, using measured fluid loss values, and a modification of Darcy's Law, test results using deformable submicron polymer in a fluid can be compared to base results to calculate pressure differences between at the interface between the fluid and filter cake, the interface between the filter

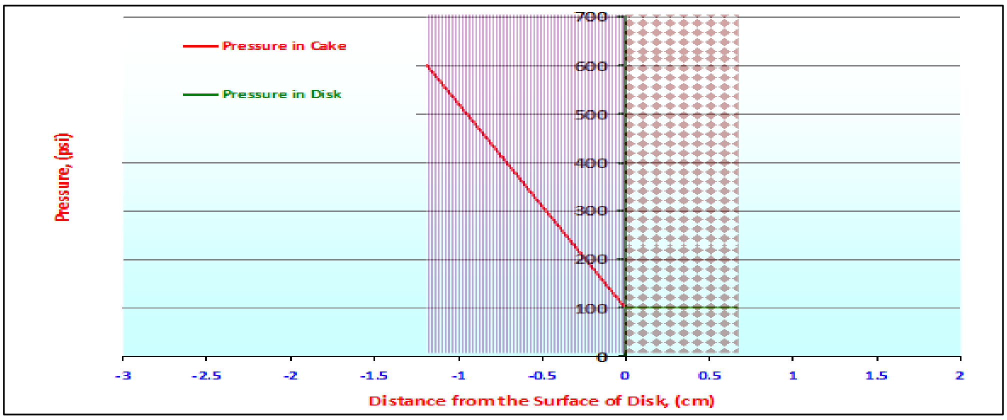

Figure 6: Calculated pressure profiles for a base fluid (WBM) after 60 minute dynamic fluid loss testing at 250°F on a 3μ disc

cake and ceramic disk and the back pressured face of the filter cake. Figure 6 gives an example of the theoretical effect of a fluid containing submicron deformable particles maintaining a high pressure differential at the interface between the disc and filter cake but there is a reduced pressure drop within the filter cake when compared to the base fluid shown in Figure 6. This is an ideal scenario for mitigating the incidence of differential sticking during drilling.

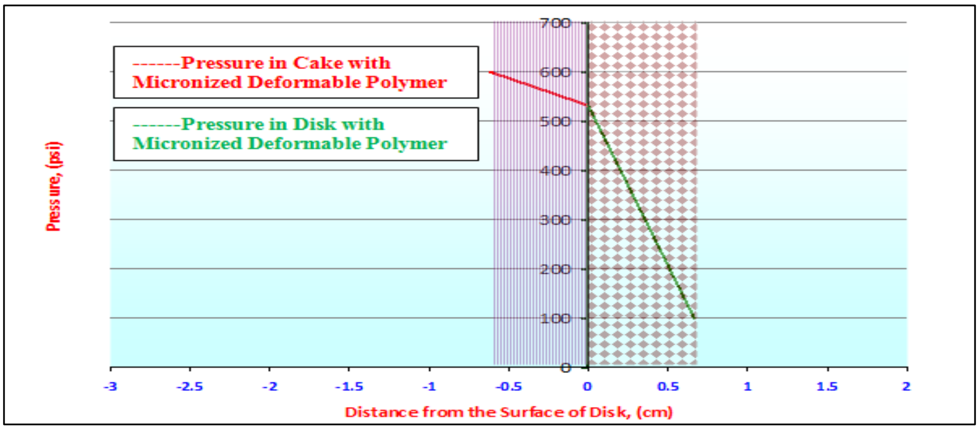

Figure 7: Calculated pressure profiles for a base fluid (WBM) with 10ppb of an Optimized Bridging and Sealing System after 60 minute dynamic fluid loss testing at 250°F on a 3µ disc

Field application

Case study 1 – On a horizontal 8 ½" side track section, it was planned to be drilled with Water base fluid of 9 ppg equivalent to drill through interbedded shale streaks along with weak, depleted and vugular formation. The complete losses were occurred from beginning of section. Multiple cement plugs were performed to arrest losses. Evident after 7th cement plug to achieve success to arrest losses and limit this to have dynamic losses of 18 bbl./hr. @ 600 gpm. The static losses were 9 bbl./hr. Unable to perform formation integrity test before operations decided to continue drilling the section.

The optimized bridging solution with different grades of resilient graphite, calcium carbonates flakes and deformable sealing polymers (~80 ppb & 50 bbl. volume) was decided to spot across the weak formation. Pulled string to top of wellbore strengthening pill. Flushed string with 37bbl of mud with slow GPM. Wait on soaking for 2 hours. Checked static losses, found static. Closed Annular and utilized hesitate squeeze method. Observed pressure build-up to maximum 120 psi with 0.5-1.5 bbl. then gradually dropped to 11psi with maximum 14.5bbl squeezing. Kept annular closed for 20minutes and observed pressure drop to 9psi. Open annular and checked static losses. Observed no static losses. Again, closed annular and squeezed with total 15bbl with Hesitate method (0.5bbl) and observed pressure increased from 39-43 psi with maximum 15bbl squeezing. Kept close annular and observed SICP-29 psi to 9 psi drop in 20minutes. Open annular and checked static losses and observed no static losses.

Ran back in hole and circulated out the mud. Observed no dynamic losses at 400/450/500/550/600/650gpm. Washed down & RIH back to TD. Circulated out the mud with 3bph@500 and 9bph@600bph dynamic downhole losses. Spotted 2nd pill of 100bbl and 150 ppb wellbore strengthening pill (90 ppb resilient graphite + 60 ppb of Calcium Carbonate flakes) at TD and POOH slowly to expected top of pill. Attempted to flush string but observed pressure shoot-up and bit plugging. Closed BOP and carried out reverse squeezing through casing. Observed pressure build-up with 1.0-1.5 bbl. Built- up pressure 200-400psi (in stages) with 0.5bbl pumping. Squeezed total 30bbl with maximum pressure 400psi. Open BOP and checked static losses and observed no static losses. Established circulation. Ran in hole with 8 1⁄2" assembly to bottom. Circulated out the mud and checked dynamic losses Zero @500 gpm & 3bbl/hr. @600 gpm. Observed zero static losses. Continue to drill the section to TD without any major losses.

Conclusion

The instability in horizontal wells can be the result of pressure fluctuations in the wellbore. The greater the pressure fluctuations, the greater the severity of the problem. Effective wellbore pressure management is key to reducing the risk associated with drilling in fractured or highly laminated zones.

The addition of a synthetic organic sealing polymer can enhance the sealing ability of customized fluid based on calcium carbonate and graphite and prevent loss circulation while minimizing the potential for differential sticking.

The initial leak off is normally fast because there is no filter cake. As the cake builds up and the applied pressure increases, the filtration period becomes longer and the differences between initial and final pressure become smaller. At the end of squeeze job the pressure fall off becomes negligible.

Wellbore strengthening works by bridging fractures to improve local hoop stress and fracture reopening resistance rather than increasing borehole rock strength.

Hesitate squeezing optimized bridging solutions proven to be effective to improve wellbore strength and enable to drill the sections without induces major losses.

NPT due to differentially stuck pipe or lost circulation has been reduced by applying the wellbore-strengthening package, improving success rates in problematic wells.

References

1. Adasani, M., 1967, The North Kuwait oil fields: 6th. Arab Petroleum Congress, Kuwait.

2. Carmalt, S. W., and B. St. John, 1986, Giant oil and gas fields, in M. T. Halbouty, ed., Future petroleum provinces of the world, American Association of Petroleum Geologists Memoir.

3. ASTON, M. S., ALBERTY, M. W., McLEAN, M. R., De JONG, H. J., and ARMAGOST, K. Drilling Fluids for Wellbore Strengthening. SPE 87130, SPE/IADC Drilling Conference, Dallas, March 2-4, 2004.

4. FETT, D., MARTIN, F., DARDEAU, C., RIGNOL, J., BENAISSA, S., ADACHI, J., and PASTOR, J. Case History: Successful Wellbore Strengthening Approach in a Depleted and Highly Unconsolidated Sand in Deepwater Gulf of Mexico. SPE/IADC 119748, SPE/IADC Drilling Conference & Exhibition, Amsterdam, 17-19 March 2009.

5. SIDDIQUI, M. A., Al-ANSARI, A.A., Al-AFALEG, N.I., Al-ANAZI, H. A., HEMBLING, D.E., and BATAWEEL, M.A., Drill-in Fluids for Multi-Lateral MRC Wells in Carbonate Reservoir-PSD Optimization and Best Practices Lead to High Productivity. *SPE 101169*, 2006.

6. VICKERS, S., COWIE, M., BURGESS, M., and ANDERSON, D. The Application of Specifically Formulated Bridging Materials To Successfully Reduce Pore Pressure Transmission To Enable Depleted Fractured Reservoirs To Be Drilled and Produced Without Incurring Formation Damage. *SPE107753*, European Formation Damage Conference, Scheveningen, 30 May-1 June 2007.

7. VICKERS, S., COWIE, M., JONES, T., and TWYNAM, A.J. A new methodology that surpasses current bridging theories to efficiently seal a varied pore throat distribution as found in natural reservoir formations. *AADE 06DFHO16*, 2006.

8. Luigi P. Moroni, Stephen Vickers, John Trenery, Wael El Sherbeny. ENHANCING BRIDGING AND SEALING TO DRILL HIGHLY OVERBALANCED WELLS. Rio Oil & Gas Expo and Conference 2010

9. BAKER HUGHES LABORATORY TEST REPORTS (6052 and 7299).

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