Sealant improves drilling in depleted sands

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DRILLING THROUGH DEPLETED sands can result in lost returns, increasing nonproductive time (NPT) and escalating mud costs. Traditional remedies to cure losses often complicate drilling and completion. An innovative, preventive solution has been proven in different fields while drilling through a series of highly depleted sands.

INTRODUCTION

Lost circulation problems related to drilling through depleted sands are compounded by the low fracture gradient in the sands and the high mud weight required to minimize compressive failure in adjacent shales. Typical lost circulation control techniques are costly and may not be applicable. For depleted sands, it's better to manage lost circulation by preventing the problem, not curing it.

Lost circulation material (LCM) can be ineffective when used to prevent lost returns in depleted sand, because most conventional LCMs are too large to bridge pore throats. These large LCMs may also be harmful to the fluid system because they tend to contribute to the external filter cake thickness and increase the potential for pipe sticking.

A novel loss prevention material, deformable sealant MAX-SHIELD™, was developed to increase the pressure before fracture initiation. Field tests indicate mud losses in highly depleted sands can be reduced with this formation sealing product.

DRILLING FLUID DESIGN

An inhibitive water-based mud (WBM) with a low fluid loss was selected to maximize shale stability and minimize filtrate invasion into the depleted sands. The deformable sealant is added to the drilling fluid prior to drilling depleted sand formations at concentrations from 2% o 4% by volume. This concentration is determined according to the degree of depletion, permeability and pore throat sizes of the depleted sands.

MAX-SHIELD is a modified water-insoluble polymer but highly dispersible in fresh-to-saturated saltwater-base mud. It is designed to reduce pore pressure transmission by internally bridging pore throats of the low-permeability sands and shale micro-fractures.

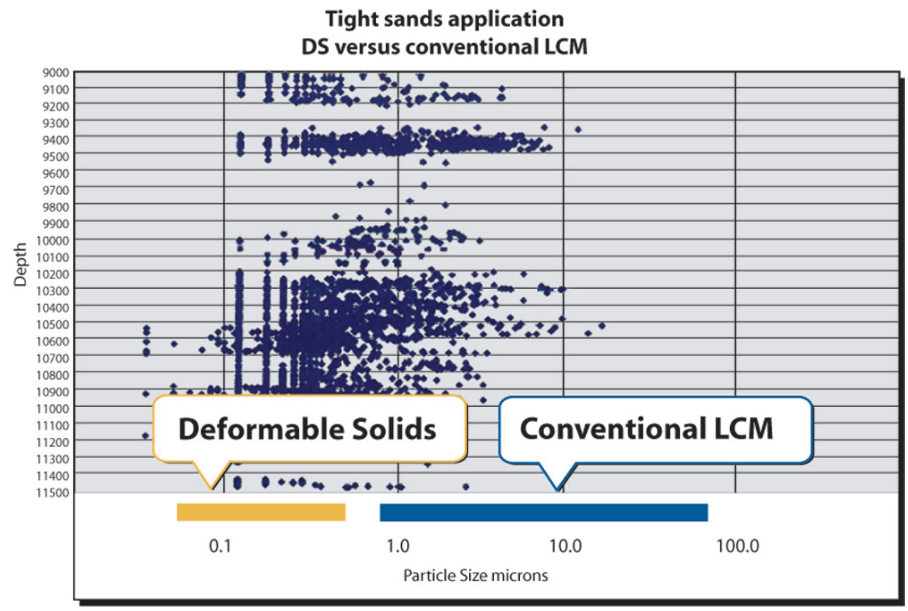
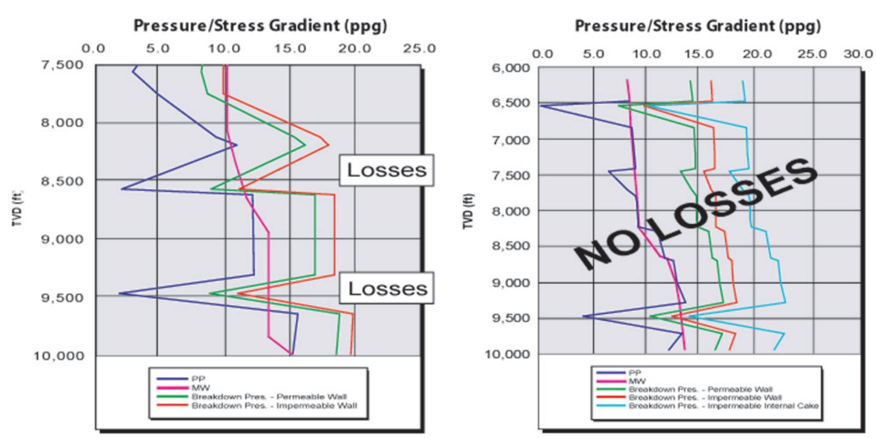


Figure 1 (above): The small particle size contributes to external and internal filter cake formation. Figures 2a (below left) and 2b (below right): Mud weight, minimum horizontal stress and breakdown pressure for Well A and Well B.



Because the product comprises deformable colloidal particles, it will bridge at the borehole interface of low-permeability sandstone formations and form an internal cake. This bridging creates an internal filter cake and contributes to external filter quality.

These bridging and sealing characteristics appear to enhance "rock strength" and increase formation fracturing resistance. Consequently, the window between pore pressure and fracture pressure is widened, which allows the depleted sand to be drilled with required mud weight without triggering losses.

WELL COMPARISON

A geomechanical study was conducted on 2 wells of similar geological and pressure profiles. Well A was drilled without this approach and Well B drilled using the internal cake technology. For Well A, fracturing and mini-fracturing data were available for the Lower Hensley sand with a Total Vertical Depth (TVD) of 14,200 ft. This information was used to calibrate the in-situ stresses models. The maximum and minimum horizontal stress gradients were estimated to be 1.02 psi/ft and 1.01 psi/ft by using a Poisson's ratio of 0.25, Biot's constant of 0.96, and overburden gradient of 1.0 psi/ft.

Using the lower Hensley sand as a calibration basis and considering the effect of reservoir depletion on maximum /minimum horizontal stress ratio, stresses in other sands were estimated. The breakdown pressure was determined for theoretical permeable wall, impermeable wall and internal cake cases by using the constrained rock mechanics parameters and near borehole stress models.

Geomechanical analysis indicates that mud weight used in depleted sands in Well A was above breakdown pressure for permeable and impermeable cake cases and was higher than minimum horizontal stress. Therefore, new fractures generated and propagated, resulting in significant mud losses without using DS.

The mud weight, minimum horizontal stress, and break-down pressure profiles for Well B were obtained with the same geomechanical parameters, which are shown in Figures 2a and 2b. In Well A, which experienced severe mud losses, the mud weight was higher than breakdown pressure for both the theoretical permeable and impermeable cake cases, and the minimum horizontal stresses in 3 depleted sand formations. In Well B, these depleted sands would have been fractured and significant mud losses would have occurred if no deformable sealant has been used. However, because of its sealing characteristics, no mud losses occurred in Well B.

SOUTH TEXAS WELL

Another example used to validate this approach was the 12 ¼-in. section of a South Texas well drilled from 8,000 to 10,514 ft. A mud weight increase from 12 lb/gal to 16.3 lb/gal was required to reach the next casing point due to a pressure transition zone. The presence of several highly depleted sands prone to mud losses and differential sticking presented a challenge to the drilling operation. 9 ⅞-in. casing was set at 8,000 ft, and a formation integrity test (FIT) was performed 15 ft below the shoe to ensure that scheduled mud-weight increases were possible.

The initial FIT result (Figure 3) indicate fluid leak-off started at 15.3 lb/gal EMW, and pumping was stopped at 16.1 lb/gal EMW to avoid fracturing the formation.

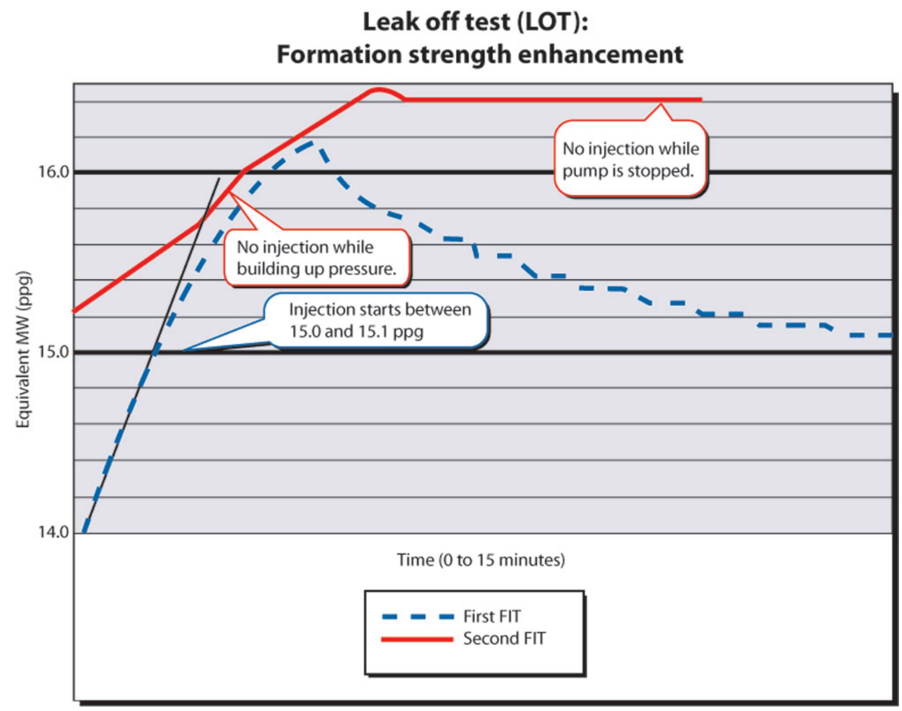


Figure 3: Leak off test data indicated an effective sealing of pressure and an effective formation strength enhancement.

Data indicated maximum possible safe mud weight was now only 14.6 lb/gal after taking into consideration a trip margin. This resulted in the inability to drill the transition zone in 1 section as planned. Since the planned hole diameters were already small, there was no room for contingency casing, and the entire well architecture was jeopardized. A decision was then made to add 3% deformable sealant to the mud, drill 1,500 ft, and then perform another FIT. Drilling further without running the liner would depend on the FIT.

The second FIT was performed at 9,640 ft. The pressure was increased to 16.5 lb/gal equivalent, without injection. The test was satisfactory, and drilling resumed. The planned TD at 10,514 ft was reached within 9 days with a 16.1 lb/gal mud, and the liner was run to bottom and cemented. There were no mud losses, further indicating that the internal cake approach did enhance fracturing resistance.

CASE HISTORIES

A series of depleted sand sections were to be drilled in another field through the 12¼-in., 9½-in. and 6½-in. intervals. Some of these sandstone formations were expected to have an extremely low depletion pressure, with differential pressure as high as 8,000 psi.

The internal cake approach in conventional WBM was planned to eliminate differential sticking, mud losses and logging problems that the operator had encountered on offset wells. The product was to be added at a concentration of 3% by volume. This concentration was to be maintained throughout the 3 intervals.

On the first 2 wells, all sections were successfully drilled without differential sticking or mud losses in the depleted sands. All logging runs were made without incident, and several days of rig time was saved compared to offset wells. This reduction in drilling days and cost was achieved with improvements to the basic water-based mud used previously in this field. This was considered a major achievement because problems had occurred on most wells drilled by the operator in this field.

CONCLUSIONS

Field use and geomechanical studies indicate that mud losses associated with severely depleted tight sands can be reduced with the use of this deformable sealing product. Prevention of mud losses, improved drilling efficiency, reduced cost and better wellbore stability were observed. Highly depleted tight sands can be drilled economically with a better understanding of the sand's pore bridging mechanisms and formation of an internal mud cake.