Manage WPC to maximize reservoir deliverability

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CONTROLLING LOSS OF circulation during well construction is more than just selecting the proper type of lost circulation material (LCM). A fully engineered wellbore pressure containment (WPC) approach is required. During the planning phase, this approach incorporates borehole stability analysis, equivalent circulating density (ECD) modeling, leak-off flow-path geometry modeling, and drilling fluid and LCM material selection to help minimize effects on ECD. During the execution phase, real-time hydraulics modeling, pressure-while-drilling (PWD) data, connection flow monitoring techniques, and timely application of LCM and treatments are proving to minimize and in some cases eliminate losses in high-risk areas. This process is captured and applied through WPC services utilizing borehole stability modeling service, WPC "look-ahead" hydraulics modeling software and WPC platform engineering software.

PLANNING

Prevention of drilling non-productive time (NPT) begins with selecting the proper fluid, one that exhibits low or fragile non-progressive gel strengths. A common characteristic of these fluids is minimizing the requirement for commercial colloidal materials and preventing the build-up of colloidal-sized drill solids. Both high performance water-base and invert emulsion fluids are available that are low-colloid, polymer-base systems.

The use of geomechanical modeling in well planning can provide the safe mud window within which the ECD should be constrained. Static mud weight predictions (to mechanically stabilize the well bore) are influenced by parameters such as in-situ stress and pore pressure gradients, wellbore orientation and formation material and strength parameters. However, exposure to the drilling fluid alters the near-wellbore pore pressure. Inter-granular stresses and rock strength can cause progressive wellbore instability. Obtaining an accurate picture of potential issues can require sophisticated wellbore stability simulators that evaluate time-dependent instability developments and account for fully-coupled mechanical, thermal and chemical effects.

Hydraulic simulations using proprietary software determine projected ECD levels after the mud weight operating windows have been identified in the wellbore stability modeling process. Conversely, the effect of ECD fluctuations due to various operating conditions on wellbore stability can also be evaluated. The principal factors in wellbore hydraulic predictions include pump rate, hole and drill pipe geometry, hole cleaning efficiency, rate of penetration, and drill pipe rotation speed. Based on extensive experience in correlating hydraulic and wellbore stability modeling in the pre-well planning process, current work couples these hydraulic models with data acquisition services to provide a "real-time" platform to provide a "look-ahead" visualization in terms of hydraulics and hole cleaning during the well construction process.

Once the combined wellbore stability and hydraulics modeling results have identified potential weak zones versus the expected ECD, further evaluation of the potential lost circulation fractures follows. The same data used for the geomechanical modeling can be further applied to model fracture geometry characteristics. Simple models may only model fracture width, which is very important, but the complete geometry of fracture height, width and length is needed for optimal results. If concerns about losses through permeable zones exist, the pore size can be estimated based on permeability with the Carman-Kozeny equation.

Halliburton's approach uses these parameters to identify a proper pretreatment to help prevent lost circulation, or a proper mitigating treatment to help cure lost circulation if it occurs.

TWO COMPONENTS

Halliburton's WPC application strategy has two components: prevention (pretreatment) and correction (remediation).

Prevention is more effective than remediation. Important information obtained from Drilling Engineering Association joint industry experiments (DEA 13) done on 30x30x30-in. blocks gave insight into prevention of lost circulation in general, and in oil-base fluids versus water-base fluids in particular. The experiments demonstrated that an adequate loading of properly sized materials causes tip screen-out immediately after the fracture is initiated, preventing pressure transmission to the fracture tip with subsequent further growth and propagation.

Development of specially manufactured dual composition resilient carbon material has made a significant difference in the ability to pretreat effectively. One important characteristic of some of these materials is resiliency, a compressive property allowing it to mold itself into the fracture, promoting screen-out and a pressure seal. The material can rebound if the pressure decreases, thus continuing to plug the fracture completely.

PRETREATMENT

Carrying smaller size LCM in the active drilling fluid system when drilling probable lost circulation zones can minimize or eliminate losses. The size distribution selected depends on the expected permeability/pore sizes. Pretreatment can have the added benefit of mitigating wellbore breathing and seepage losses while drilling depleted zones. Graphitic carbon and sized calcium carbonate have proven to be effective primary materials when carried as a pretreatment in the drilling fluid, and many times they are generally the main constituents of initial lost circulation treatments.

As drilling progresses, additional make-up materials should be added to maintain pretreatment levels. Because higher concentrations of materials can aid in fracture tip screen-out and prevention of further fracture propagation, subsequent treatments can be added to the drilling fluid system more effectively as sweeps. This type of addition helps ensure that the wellbore contains a higher concentration of particulate materials in general, and the larger particles in particular. This approach can further enhance the effect of the LCM without loading the entire active system with a high concentration of LCM.

DRILLING A PERMEABLE ZONE

When LWD tools indicate that the bit is entering a possible permeable weak zone identified during the planning phase by the wellbore stability and fracture mechanics analysis, a treatment containing larger size graphitic and sized calcium carbonate material is pumped to help enhance the WPC capability by building a "stress cage" around the wellbore. The treatment is circulated to the weak zone where a squeeze pressure is applied to initiate and then quickly plug the fracture that is created. By preventing further pressure transmission to the fracture tip while preventing the fracture from closing near the wellbore, hoop stresses are increased, resulting in an increase in the relative WPC capability. This new technique is based on conventional knowledge but requires understanding of rock mechanical properties that allows the specific treatment to be designed with software.

DRILLING NON-PERMEABLE ZONE

Alternatively, a chemical treatment may be more effective in a non-permeable formation where a lack of fluid leak off may inhibit the formation of a pressure plug while preventing fracture closure near the wellbore. One example of this application is a system that forms a flexible sealant that plugs the fracture aperture as close to the borehole as possible. This is a two-component system: the sealant material is pumped down the drill pipe, and the drilling fluid is pumped down the annulus.

These two components mix below the bit and react before entering the lost circulation zone or created fracture. A spacer is used before and after the reactive pill pumped down the drill pipe. These systems are designed to work in water-, oil- or synthetic-base fluids. While very effective in curing lost circulation, in many cases a more important application is to improve wellbore pressure containment capabilities for improved shoe leak-off test (LOT) results or for further drilling in an open-hole interval to extend a casing shoe depth.

THE FUTURE

While the fundamental theory of lost circulation is better understood than ever before and new planning tools and systems are available, much work remains to be done. One-sack, pelletized LCM containing graphitic carbon and other larger sized particulate material can be quickly mixed and applied with the rig mixing equipment and pumps, but what if the situation calls for a chemical treatment that can be quickly applied? A conventional cross-linked polymer system requires both time to clean out pits and hydrate the polymer, as well as fairly precise knowledge of the downhole temperatures for design purposes. To alleviate these short-comings, Halliburton has developed a polymer suspension system that can be delivered and pumped from tote tanks.

This material reacts below the bit to produce a highly viscous and cohesive flexible mass to enter the fracture and help prevent further pressure transmission to the fracture tip. A recent field test yielded good results after an operator in the US Mid-Continent area used the system after several failed attempts to regain circulation. After 9 ⅝-in. casing was set, a drilling break was encountered at 9,197 ft followed by complete loss of circulation. The 9.2 lb/gal active mud system was carrying 18-20 lb/bbl LCM at the time. Pills containing 50 lb/bbl of various sizes of LCM were also pumped with no success. After drilling without returns for 191 ft, it was decided to attempt to stop the losses again. Several types of LCM were mixed and two 80 bbl pills containing 50 lb/bbl LCM were pumped, but circulation was not regained. Cumulative mud losses to this point were approximately 5,000 bbl.

The cementing unit was used to pump a 5 bbl diesel spacer, an 11 bbl pill of the active polymer, followed by 5 bbl of diesel spacer and 11 bbl of water. The rig pumps were then used to displace the pill. Full circulation was regained at 5,860 ft and the mud was conditioned. After staging to bottom, the operator was able to log the well successfully.

A recently developed dual-reaction product has also proven very successful. It contains graphitic carbon plus other sized particulate material to help enhance fracture tip screen-out. In addition, it contains a synthetic polymer component that hydrates when placed in water, increasing the polymer volume by up to 400 times and enhancing the ability to prevent further pressure transmission to the fracture tip. However, OSPAR regulations prevent the use of this material in the areas governed by this agreement because the synthetic polymer does not meet biodegradation specifications. For those operating in the North Sea, a newly developed system containing a natural polymer offers similar hydrating and swelling capability and meets OSPAR specifications.

CONCLUSION

Future planning ability will be enhanced as we couple wellbore models with fracturing models to include both near-wellbore and far-field effects on the fracture geometry. Further improvements will come as downhole data transmission capabilities increase where rock strength data can be obtained in near real time from sonic data, allowing us to modify our initial plan more quickly. As we obtain the ability to better visualize what occurs downhole, we can anticipate the development of better materials and systems to treat the problems, either before or as they arise.

REFERENCE

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