Pre-treating fluids with lost circulation materials

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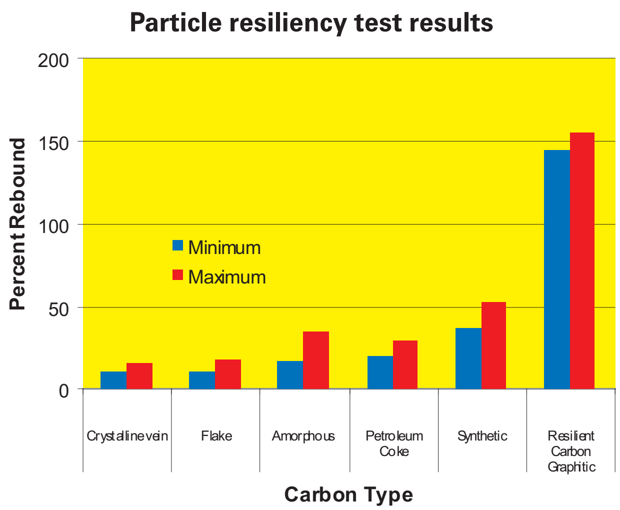
CONTROLLING CIRCULATION loss during well construction is more than just selecting the proper type of lost circulation material (LCM). A fully engineered approach incorporates a number of planning tools, including:

- Borehole stability analysis;
- Hydraulics modeling to estimate equivalent circulating density (ECD);
- Drilling fluid and LCM material selection to help minimize effects on ECD.

Planning should include means to provide on-site monitoring using pressure-while-drilling (PWD) and connection flow monitoring and timely application of LCM and treatments.

Results from a new laboratory study on LCM testing as well as data from the



Drilling Engineering Association joint industry experiments conducted in the 1980s demonstrate a rationale for pre-treating drilling fluids with combinations of resilient graphitic carbon and sized calcium carbonate where a high probability for loss of circulation exists.

Simplified treatments using engineered combinations of LCM in a single sack may be used for drilling depleted sands, seepage losses and severe lost circulation. At times a more specialized treatment may be required, such as a two-component system pumped down the drillpipe and annulus simultaneously, forming a flexible seal in the fracture and isolating the borehole pressure from the fracture tip.

The road to success begins early in the planning process.

Borehole stability modeling, fluid selection, hydraulics modeling, and LCM selection and application method are important issues.

BOREHOLE STABILITY MODELING

Parameters like in-situ stresses, pore pressure, strength, well trajectory, and hole angle heavily influence mud weight predictions required to mechanically stabilize the borehole. Near-wellbore pore pressure, effective stresses and strength can be altered as a result of drilling fluid exposure and can influence time-dependent borehole instability.

The first stage of wellbore stability analysis consists of identifying and interpreting the problems observed in the field. Wellbore instability observed while drilling can be grouped into five basic types:

- Washout or hole enlargement;
- Tight hole or creep;
- Altered, damaged, or plastic zone;
- Wellbore breathing;
- Lost circulation.

The first three types of instability are associated with the near wellbore region.

Lost circulation and wellbore breathing are attributed to mud invading the far field as a result of either hydraulically-induced tensile fractures or losses occurring to permeable formations or other types of thief zones such as natural fractures and faults.

Running too high a mud weight can initiate a hydraulic fracture in an intact formation. The fracture may propagate, depending on the maximum borehole pressure, and the formation will take in drilling fluid.

Results obtained from modeling can provide the upper and lower limit for a safe mud weight as a function of the hole inclination angle.

The upper limit is the mud weight above which extension fracturing or fracture propagation can occur.

The lower limit is set by formation pore pressure or the minimum mud weight required to prevent borehole collapse, whichever is greater.

FLUID SELECTION

Using a synthetic-base fluid (SBF) that contains no commercial clay or organophilic lignite can lower the colloidal content of the mud and produce a greater tolerance for drill solids.

As drilling depth and the percent of solids increase, the ECD, viscosity and yield point of this fluid remain stable. Specially-developed, fast-acting thinners can produce flatter rheology profiles in both cold water and downhole environments.

The unique combination of materials can provide stable viscosity through a wide range of temperatures, high resistance to contaminants and low ECD. Operators have used the clay-free system in more than 120 Gulf of Mexico wells. One major independent operator saved an average of $500,000 per well on an 11-well program. Effective hole cleaning and deepwater performance while cementing (with full returns) saved $2.5 million in rig time.

A record-setting Gulf of Mexico deepwater operation recorded 80% less SBF lost overall while drilling, tripping, running casing, and cementing, which resulted in a savings of $1.3 million. This system received one of the Top Ten Hart's MEI Well Construction System Awards in 2003.

HYDRAULICS ECD MODELING

Hydraulic simulations help determine projected ECD levels when the mud weight operating windows have been identified. The principal factors in wellbore hydraulic predictions include:

- Pump rate;
- Hole and drill pipe geometry;

- Hole cleaning efficiency;
- Rate of penetration;
- Drill pipe rotation speed.

To help constrain ECD predictions within an acceptable window, operating ranges for each major factor should be determined. The iterative simulation process can produce ECD predictions that can be used with some confidence. When the ECD boundaries have been determined, a decision can be made based on the anticipated severity of drilling fluid losses.

Well economics can influence whether to pretreat the system with LCM or deal with the problem when/if it occurs. Usually, a drilling fluid system pretreated with LCM contains less LCM than one formulated when losses occur. The ECD increases of a pretreated system are usually less than those of fluids more heavily laden with LCM.

FURTHER LABORATORY WORK

Initial tests performed with a test apparatus and protocol for evaluating the lost-circulation control capabilities of drilling fluids under dynamic circulating conditions were promising, so nine companies joined in the Global Petroleum Research Institute, GPRI 2000 Project DC3 joint industry project to leverage this effort.

The objective of improving SBM formulations to yield elevated fracture propagation pressure similar to water-base muds (WBMs) was to be accomplished through a series of 25 selected tests using a variety of core samples, mud formulations, and LCM.

LCM type, concentration, and particle size distribution are important factors. Particle type seems the most important variable for obtaining a fracture sealing response using the test apparatus.

Repeated fracture sealing responses were seen in tests using resilient graphitic carbon (RGC) and, to a lesser extent, thermoset plastic granular LCM, while calcium carbonate LCM tests failed to show fracture sealing responses. Other LCMs tested gave an intermediary response, showing some fracture conductivity impairment.

The RGC LCM showed sealing responses in a variety of core materials, from high permeability castlegate sandstone to low permeability Pierre 1 shale.

Fibers (F) did not effectively increase the reopening pressure when used alone, and gave some indication of possibly being detrimental. An experiment with RGC plus sized calcium carbonate (SCC) in a 1:2 weight ratio showed this combination was effective for increasing the fracture reopening pressure.

When repeated with fiber added in a 1:1:1 (RGC:SCC:F) volume ratio, the combination was not effective. Field experience has shown fibers are capable of stopping lost circulation, but these data indicate that fibers should possibly be used in smaller amounts than other materials.Also, SBM without LCM generally showed a nonsealing response in low permeability (~2 mD) sandstone independent of fluid loss characteristics, i.e., high vs. low.

One of the more unique characteristics of RGC is resiliency, a compressive property allowing it to "mold" itself into the fracture tip, promoting screen-out. If pressure is released, the material "rebounds," thus continuing to plug the fracture completely.

Particle resiliency has been tested in the laboratory for six types of carbon materials, each subjected to an initial pressure of 10,000 psi. Once the pressure is released, the particles rebound in volume, though in widely-varying degrees.

The RGC clearly outperforms the other carbon materials in its ability to rebound, which can explain its utility in fracture tip screen-out applications.

Pretreatment is recommended when drilling probable loss zones, such as a "rubble" zone, and can have the added benefit of mitigating wellbore breathing, seepage losses, and/or potential lost circulation while drilling depleted zones.

RGC and SCC have proven to be effective pretreatment materials, and they are generally the primary constituents of initial lost-circulation treatments.

In general, 5 to 10 lb/bbl of RGC plus 10 to 15 lb/bbl of SCC is used as a pretreatment. A total weight of 20 to 25 lb/bbl is desirable.

SUBSEQUENT TREATMENTS

As drilling progresses, additional make-up materials can be added to maintain pretreatment levels.

Normalizing Weight of other LCM against RGC by Using Specific Gravity

Material	SG	Factor	Example* (ppb)
RGC	2.1	1.00	20
SCC	2.7	1.29	25
Walnut	1.2	0.57	0
Fiber	0.5	0.24	5

*50 ppb pill

Premixing LCM materials before use, rather than on the fly, helps ensure proper amounts and particle size distributions are maintained.

In some cases, a "concentrate" can be pre-mixed and then diluted with the active mud on location to the desired LCM level.

One-sack products are also engineered for these specific applications.

Because higher concentrations of materials can aid in fracture tip screenout and prevention of further fracture propagation, later treatments can be added to the drilling fluid system more effectively as sweeps containing a nominal 50 lb/bbl of selected materials.

DRILLING THE WELL

Close monitoring of PWD data and the use of an accurate hydraulics model that accounts for the effects of cuttings loading, drillpipe rotation and fluid compressibility will aid in preventing lost circulation.

With proper interpretation, these tools can provide insight on shallow water flows, kicks and well control, fluid loss/gain (breathing), leak-off tests (LOTs) and lost circulation, hole cleaning, hole collapse and packoffs, mud properties and drilling practices.

Determining an accurate LOT is critical to helping prevent lost circulation, but carrying the LOT to the fracture extension can lower the maximum mud weight that may be used to safely drill the interval without lost circulation.

LOST CIRCULATION MATERIAL

The individual materials normally combined to remedy lost circulation incidents can be classified as:

• Deformable solids such as resilient graphitic carbon, ground battery casings and ground tires, etc;

• Particulates such as SCC, walnut hulls, etc;

• Fibers such as ground peanut and almond shells, etc.

RGC has been the most effective single LCM and should be considered for the main ingredient in most combinations. It has a minimal effect on rheology. Pills containing more than 100 lb/bbl RGC have been pumped through mud motors to successfully control lost circulation.

The RGC has also been used individually and in lower concentration combinations for such diverse applications as controlling seepage losses, preventing lost circulation while drilling depleted sands, and curing losses in horizontal boreholes penetrating faults.

A recent well experiencing significant losses into an unmapped fault/fracture zone did not respond well to traditional calcium carbonate pills. A 30 lb/bbl combination pill with essentially equal volumes of RGC and SCC cured losses almost immediately, and the operator resumed drilling.

More typical pill concentrations are 40 to 60 lb/bbl or higher, though up to 80 lb/bbl of combination RGC/SCC (non-fiber) materials have been pumped through motor assemblies successfully.

ENGINEERED COMBINATIONS

Premixed combinations containing specified materials and sizes for different applications can be maintained onsite to simplify treatment and inventory requirements. For example, drilling depleted sands and preventing seepage losses may be handled with a blend of fine RGC and other LCMs in a pellet form.

If losses are expected in the payzone, a blend of acid soluble lost-circulation control materials designed for use in nondamaging fluids can be used. This blend is 97% soluble in 15% hydrochloric acid, is compatible with all drilling and completion fluids, and has a bimodal size distribution.

CONCLUSIONS

Implementing a thorough plan is essential to mitigating lost circulation with non-aqueous fluids. Preventing lost circulation in non-aqueous fluids can be easier than restoring circulation.

RGC has proven to be one of the more effective lost circulation mitigation materials in both the field and laboratory. "One-sack" engineered combinations of sized LCM can simplify lost-circulation treatment.

Sizing lost-circulation treatments by volume of material is a more realistic approach than using weight, particularly when incorporating materials with a relatively low specific gravity.

Chemical systems that form pliable or flexible ultra- high viscosity treatments may be necessary to treat the most severe lost circulation events. ■