Coordinated displacement technology leads to improved wellbore clean-up, reduced costs

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DISPLACEMENT OF THE drilling or drill-in fluid to clear brine has become a very important process in the overall wellbore completions program leading to optimized hydrocarbon recovery. Poor displacements can lead to less-than-planned production rates due to formation damage. Other consequences of an inefficient displacement include stuck packers, completion tool setting problems, increased rig and filtration time, increased disposal costs, and increased corrosion pitting. Advancements in fluid spacer chemistry, specific completion clean-up tools and advanced displacement software have all contributed to a more efficient displacement process, leading to lower operation costs and increased production.

PLANNING

In the past, the primary objective of a good displacement was efficient change-out of one fluid to another. Today, additional displacement objectives include efficient solids removal, wellbore clean-up, proper surface wetting, and engineered modeling of the displacement operation.

For planning purposes and proper well site execution, completion fluid displacement software has been developed. Historically, drilling fluid hydraulics is well addressed while multi-fluid displacement is less studied or modeled in the industry. Mud displacement must be carefully designed to ensure the proper separation of the mud system from the completion fluid while maximizing wellbore cleaning. By computer-modeling the hydraulics and displacement profiles of completions fluids, many potential problems can be identified before the pumping starts, and appropriate modifications can be made. This is even more important for deepwater applications where the flow path and operation procedures are more complex. To meet these needs, an integrated mud displacement software system, DISPLEX, has been developed to design and analyze the completion fluid displacement operations.

Technical features of the DISPLEX system include:

A combined Multi-Task Wellbore Filter and ULTRA-CLEAN Casing Scraper form a component of the Custodian One-Trip Wellbore Cleaning System.

- Flow dynamics of multi-fluid displacement in 3D wells.
- Forward or reverse circulation.
- Circulation sub and flow by-pass.
- Deepwater applications with choke/kill/boost lines.
- Free-fall / back filling (u-tubing) calculation.
- Critical flow rate for turbulence for fluids at different geometries.
- ECDs / pressures at various depths vs. time.
- Dynamic annular hydrostatic/total pressure profiles.
- Choke pressure can be manually applied, computer-calculated to avoid u-tubing or to maintain downhole pressure for well control purposes.
- On-screen fluid displacement / flow pattern animation.
- Import survey data from text (ASCII) file or PDF file.
- Clean-up tools visualization.
- Standoff calculation due to the inclination, tool joint, hole sizes.
- Efforts of eccentricity due to standoff on hydraulics.
- Pump stroke calculation.
- Pressure drop gradients for fluids at selected section.
- MS Word summary report (2-page) with concise job details.

Benefits:

- Optimize equipment requirement (pump pressure).
- Improve displacement efficiency.
- Reduced filtration costs.
- Safer operations (ECDs) and cleaner wellbores.

This modeling software has been used for planning and executing numerous displacement operations. Depending on whether the application involves deepwater, inland water or land, input data will dictate which capabilities of the modeling software to use. Each displacement fluid can be customized based on its rheological behavior using Bingham Plastic, Power Law or Hershel Bulkley models. This type of model can be a valuable aid to ensure that spacer volumes and properties are adjusted to meet wellbore requirements, qualify rig equipment before a job starts, and increase efficiency by recommending more effective pumping schedules that also minimize waste disposal.

In some cases, cementing units are used to pump spacers. Predicting the required pump rates, maximum pressures that will be encountered, and hydraulic horsepower requirements are all part of the planning process. Pre-planning with utilization of the modeling software will determine the proper pump specifications and type of displacement that will be required.

CLEAN-UP TOOLS

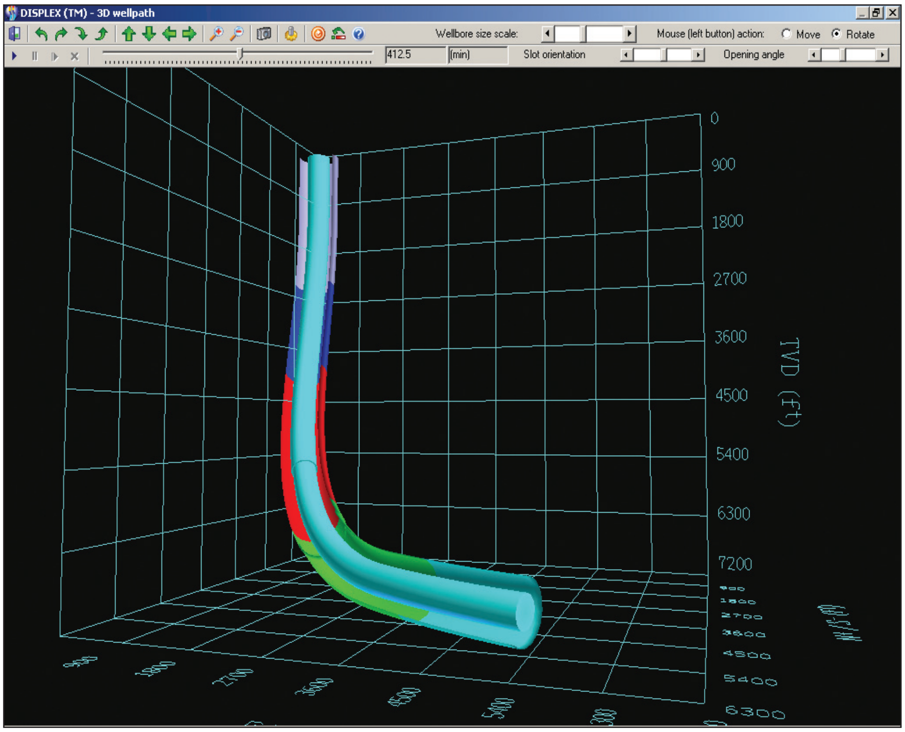
Another important aspect of a successful displacement operation is the employment of proper clean-up tools. The removal of drilling-related debris is one of the primary goals of the displacement process. Drilling debris can be a major financial risk, and investing in an integrated wellbore clean-up system is an efficient, cost-effective way to manage that risk. A properly designed wellbore clean-up system eases the transition from drilling to production by combining several high-performance tools to seek out debris, collect it and eliminate it, all in a single trip. These clean-up tool systems can be run together as integral parts of a complete wellbore cleaning system or individually to perform specific functions.

Debris removal has becoming increasing more efficient with the deployment of these tools. For example, the development of a new tool, referred to as a circulation sub or flow by-pass tool, can be placed in the drill string immediately above the liner. This tool has ports open to the annulus, allowing fluid to bypass into the larger, lower flow rate area between the drill pipe and casing. This increases flow and annular velocity to facilitate debris removal in this typically very hard-to-clean area of the wellbore. Other typical tools for enhanced wellbore clean-up include multi-task filters, scrapers, dress-off mills, magnets, brush off tools, BOP jet subs, inflow test packers and junk catchers.

SPACER DESIGN

Fluid spacers with specialty additives for cleaning, oil removal and wetting are another integral part of the overall displacement and wellbore clean-up process. Proper selection of clean-up tools and an optimized hydraulic program providing optimized flow rates and regimes will not result in a clean wellbore without a properly designed spacer program. During the drilling operation, the wellbore sections become exposed to mud and mud particles. Drilled solids become attached to the casing, tubulars and become part of the filter cake. Regardless of the type of completion, these solids, if not removed, may damage the reservoir or prevent the completion assembly from reaching total depth. A good spacer design will facilitate removal of these unwanted solids from the wellbore.

The clean-up design must also maximize cleaning with the smallest possible volume for economic and environmental considerations. In many offshore and land locations around the world, the discharge of spacer waste is prohibited. Spacer designs will vary depending on



The DISPLEX software system includes 3D well profiles that illustrate the flow dynamics of multi-fluid displacement.

whether the fluid in the hole is water-based or oil/synthetic-based. Other considerations include cased or open hole displacement, direct or indirect displacement operation, and required density for ECD and safe well control.

The clean-up of water-based fluids is much easier than oil- or synthetic-based fluids. Most wellbore clean-up applications where synthetic- or oil-based fluids are utilized are performed in casing and require that nearly all the oil be removed from the casing and the casing be rendered water wet. Spacers have historically varied in design, comprising both aqueous and non-aqueous phases. The aqueous phase is usually comprised of cleaning and wetting surfactants. The non-aqueous phase is usually comprised of solvents or other hydrocarbon-based compounds for oil- or synthetic-based drilling fluid clean-up. A typical spacer design sequence for removing oil/synthetic-based drilling fluid to brine during a direct displacement would be as follows:

1. Oil or synthetic spacer.

2. Lead push spacer comprising viscous, weighted fluid with cleaning additive.

3. Tail spacer comprising cleaning and water wetting additives.

4. Viscous brine spacer.

5. Brine.

The initial oil or synthetic spacer is normally comprised of the base makeup oil or synthetic being used in the drilling fluid. This is to thin the tail of the drilling fluid and initiate the cleaning process.

The next lead spacer is high viscosity to maintain pill integrity and keep the spacer in laminar flow even at high flow rates. The spacer must be large enough to allow for 5 to 10 minutes contact time based on the pump rate. The density of the lead spacer must be adjusted for well control reasons and should be at least or slightly more dense than the fluid being displaced. The next tail spacer is usually mixed with the completion brine as the based fluid and contains cleaning and wetting agents. This spacer is designed to be in turbulent flow and will remove any residual debris. Both of these spacers should cover 1,000 ft of the annulus at its largest diameter. Other spacer designs will vary somewhat, depending on mud composition, indirect displacement, and cased versus open hole application.

Mud displacements have become much more detailed and efficient in field application. Displacement modeling tools, new wellbore clean-up tools and spacer design have all contributed to more efficient displacements resulting in cleaner wellbores and thus enhanced production.

DISPLEX is a registered trademark.