Drilling hydraulics

The material in this section provides a straightforward explanation of what is covered by the broad term "hydraulics" along with a description of basic hydraulic principles utilized in drilling. The intent is to explain generally how hydraulics impacts the drilling process. A brief description of the equipment related to hydraulics is also provided.

The hydraulics chapter in the previous (11th) edition of the IADC Drilling Manual included a step-by-step procedure to design a bit hydraulics program meant to enable the operator and/or contractor to achieve maximum penetration rates with the equipment available. The section on "bit hydraulics" is now included in the Drilling Practices (DP) chapter of this manual, which covers improved drilling efficiency.

Drilling hydraulics refers to how the drilling fluid in the circulating system exerts pressure throughout the system, particularly in the wellbore.

Hydraulic parameters

The amount of pressure exerted by the fluid depends on the depth of interest, the fluid properties, wellbore geometry and whether the fluid is static (not circulating) or in a dynamic (circulating) condition. When static, the pressure exerted on the wellbore by the drilling fluid (often called bottomhole pressure or BHP) is simply the fluid density or mud weight (MW) multiplied by the true vertical depth (TVD).

Circulating the fluid generates dynamic friction (f). Among other factors, friction is dependent on fluid viscosity and velocity, and is directly proportionate to both. That is, the higher the velocity (or circulation rate) and the higher the viscosity, the higher the friction pressure. Friction is added to the pressure exerted by the MW to give a total pressure that may be expressed in terms of an equivalent density. Any back pressure that may be imposed at the surface, for instance by circulating through a choke, will also act to increase either the static or the dynamic BHP. Note that while BHP in the strictest sense refers to the pressure at the bottom of the wellbore, the pressure in the wellbore at any depth may be determined by calculating the MW times that depth plus the friction generated at that depth plus the surface back pressure, if any.

The circulation rate component of friction is controlled by the driller. The fluid properties are measured and controlled by the mud engineer for the most part.

Density and viscosity are the most important fluid properties involved in drilling fluid hydraulics' calculations. Density is often referred to as MW and is expressed in different ways depending on the system of units in use.

Density

Density is a measure of fluid mass per unit volume. The density units in common use are ppg, lbm/cu ft, kg/cu m, and kg/l. The conversion factors between these units are listed below.

1 ppg = 7.481 lbm/cu ft
1 ppg = 119.82 kg/cu m
1 ppg = 0.11982 kg/l

The density of fresh water under standard conditions (atmospheric pressure and 60°F of temperature) is 8.34 ppg or 1.0 kg/l (also expressed as 1,000 kg/cu m).

Like most other substances, the mass of a fluid expands with heat and contracts with cold. The density of the same fluid, therefore, can be different when measured at surface or measured at the bottom of a well. The value of fluid density depends on the temperature and pressure that the fluid is under. This is especially true when using oil (diesel or synthetic) based muds. The density increases as pressure on the mud increases and decreases as the temperature of the mud increases. It is essential, especially in high-pressure high-temperature (HPHT) wells using oil based muds, to account for the effects of temperature and pressure on the mud density.

Viscosity

Viscosity (often denoted as μ) is a measure of fluid resistance to flow. A fluid with higher viscosity results in higher pressure drop when passing through the same pipe or annular space at the same flow rate.

Viscosity measurements are commonly referred to as fluid rheology. Viscosity is measured with a viscometer or rheometer. Some of these instruments can measure fluid under various temperatures and pressures. The commonly used units of viscosity in the drilling industry are centipoise (cp), pound force-second per square foot (lbf-sec/sq ft), and Pascal second (Pa-sec). The conversion factors between these units are listed below.

1 cp = 0.0000209 lbf-sec/sq ft
1 cp = 0.001 Pa-sec

The viscosity of fresh water at standard conditions (atmospheric pressure and 60˚F) is 1 cp. Note that funnel viscosity (FV) may be measured as well. FV is measured by pouring a known volume of fluid into a Marsh funnel and timing how long it takes in seconds for one quart of the fluid to run out of the funnel. FV of fresh water is generally considered to be 26 sec. FV is a relative measurement only and may be useful for comparing the viscosity of different fluids. FV has very little utility, however, in determining actual frictional pressure downhole.

