HXR
DRILLING SERVICES

Fluids, Hole Cleaning and Tripping Optimization

Overview

Hole cleaning in highly deviated wells is probably one of the most misunderstood concepts. Primarily, relying on Plastic Viscosity and Yield Point (PV & YP) are relics of the Bingham Plastic model that do not accurately model most of the drilling fluids that are in use in the oil field today. The Bingham Plastic model assumes that a fluids rheology reacts linearly to shear rate and shear stress. It was developed to describe the behavior of water-based mud containing clays but does not adequately describe the behavior of modern polymer muds and with the introduction of oil based muds the Bingham Plastic model becomes virtually useless. PV & YP are relied upon too heavily, mainly YP, and for the most part optimum hole cleaning ranges are old rules of thumb from vertical hole practices drilled with WBM. But what are PV & YP? The PV is the slope of the line between the 600 and 300 RPM rheology readings. The Bingham Plastic model, being a 2 parameter model, is only reliant upon the 600 and 300 RPM rheology readings. PV for all intents and purposes is the viscosity of the fluid, or resistance to flow due to inter-particle friction. PV is affected by the amount, shape and size of those particles, and the viscosity of the base fluid. The YP estimates a portion of the total viscosity that comes from attractive forces between the particles in the mud or essentially the point at which the gels built up in the mud break and the fluid begins to flow (0 shear rate). The figure below demonstrates the difference between actual rheology readings versus the Bingham Plastic model.

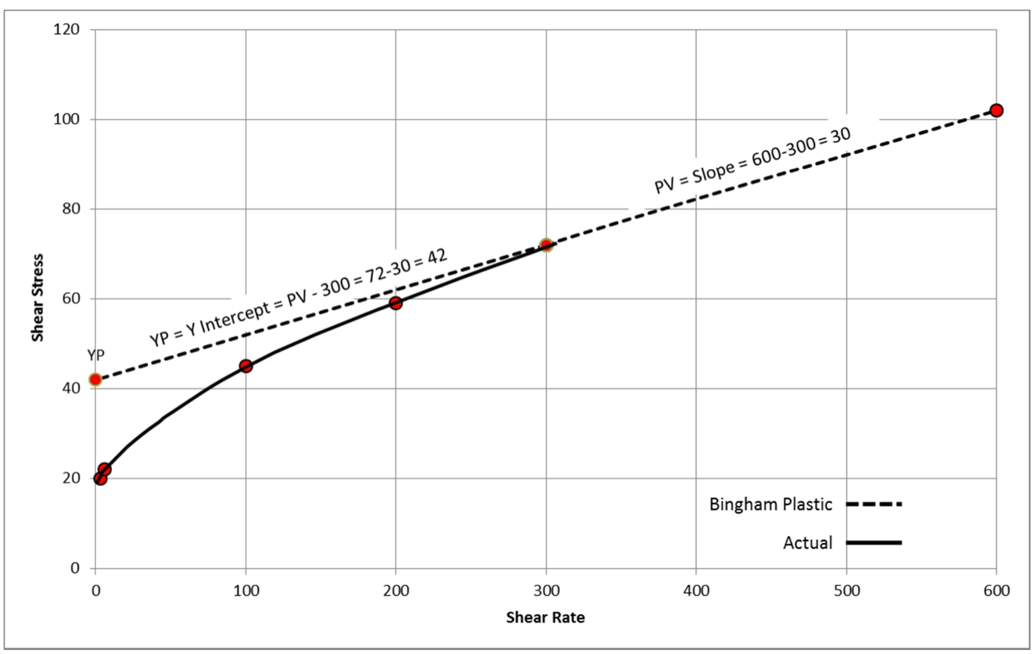
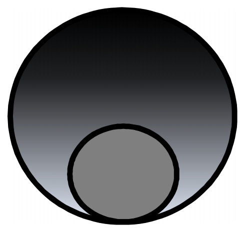


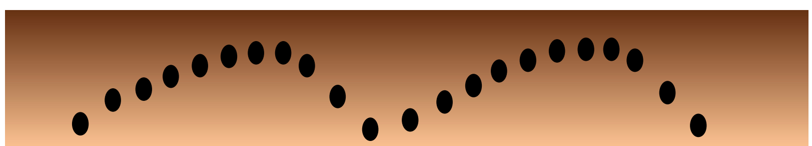
Figure 1: Demonstrating actual rheology readings compared to the Bingham Plastic Model

Why we take rheology readings and why YP is inaccurate

The point of taking rheology readings it to understand the fluid characteristics at different shear rates or more importantly how the fluid will react in the annulus while drilling. In high angle hole sections the pipe is lying on the low side of the hole creating a flow channel on the high side with reducing annular velocities towards the low side.



In highly deviated holes, cuttings even when moved into the high flow area do not have very far to fall due to gravity and exhibit saltation flow. This where cuttings move into the high flow area only to return back to the low side, similar to how sand dunes are formed.



To counter act this, the low end fluid rheology must be kept high enough to effectively clean the hole in these low velocity areas on the low side coupled with pipe rotation and flow rate. The 6 RPM rheology reading should target a value equal to the hole size. In smaller hole sections, 8-1/2" or 6-3/4", when ECD's can become problematic the 6 RPM can be lowered to 0.8 x the hole size.

So why do we rely on YP and why do we care? The traditional goal of calculating the YP was to determine the shear stress at 0 RPM or more operationally how much force it would take to break the attractive forces between the particles in the fluid and cause it to begin to flow. We know that most fluids do not exhibit Bingham Plastic flow, we have rheology readings to prove it. More importantly, we have a 3 RPM rheology reading which is much less than the YP, not to mention we can now extrapolate a zero shear rate or τ_0. So why do we us it? Many times while attempting to increase the YP the high end rheology will be elevated thereby increasing the PV and ultimately parasitic pressure losses limiting flow rate and negatively effecting hole cleaning. By concentrating on the low end rheology the high ends can be taken care of via surface solids control equipment and dilution strategies.

A More Robust Rheology Model

There has been a progression in rheology models since the 2 parameter Bingham Plastic model was created in 1916 by Eugene C. Bingham. The industry has since moved to a more inclusive 2 parameter Power-Law model which was effective in accurately modeling pseudo plastic fluids, or shear thinning fluids (water based polymer muds) to the now industry accepted 3 parameter Herschel-Bulkley model. With Fann viscometers basically on every rig in the world the Hershel-Bulkley model should be used for almost all fluids run in the oilfield today.

Hole Cleaning Indicators

While drilling high angle wellbores torque and drag measurements should be your number one indicator of hole cleaning. Completely basing hole cleaning off of Equivalent Circulating Density (ECD) trends taken by down hole MWD PWD tools can be miss leading. As stated previously, cuttings will fall to the low side of the hole and if they are not properly disturbed by pipe rotation due to fluid coupling and effectively moved out of the wellbore with good low end rheology and flow rate they will remain on the low side of the hole. PWD sensors measure the hydrostatic and frictional pressure losses in the annulus, or ECD. If the cuttings are not entrained in the fluid they are not increasing the effective density of the mud thereby not increasing the pressure seen by the PWD tool. What does this mean? It means that you can actually see a decrease in ECD with a decrease in hole cleaning efficiency. Not to anyone's surprise, as the hole loads up with cuttings you will effectively increase the drag. Keeping a close eye on your drag trends, more importantly deviations in drag trends, is the number one indicator of hole cleaning in a highly deviated well. An example of how this can be skewed is by adding an excessive amount of lubes. Lubes can mask hole cleaning problems if they are misidentified. Generally, anything over 3% lubes will provide diminishing returns or greasing. The importance of pick up, slack off and rotating weight road maps is paramount when identifying hole cleaning issues. Torque trends can also indicate hole cleaning issues but are less effective. It should be noted that all the information available should be taken into account. Keeping a close watch on the shakers and taking note of cuttings returns can be a very good indicator of hole cleaning. If you are drilling ahead at 300 fph and you're noticing a decrease in cuttings across the shakers and a decrease in ECD, chances are you're not cleaning the hole. This can also be skewed in sections where WBM is used and the cuttings are taken into solution. In addition to drag trends, a good hydraulics model should be used to track expected ECD trends versus actuals. Running rheology sensitivities on ECD and pump pressures in conjunction with updated Fann readings can provide an indication of anomalous activity downhole.

Short Tripping/Wiper Trips, Backreaming & Tripping

Short Tripping/Wiper Trips

Short tripping or wiper trips in a highly deviated well should be avoided. Due to the nature of highly deviated wellbores, shallow TVD with respect to measured depth, surge and swab loads on a wellbore can quickly deteriorate wellbore quality and cause irreversible wellbore instability. In addition to surge and swab loading, if correct tripping practices are not used while coming out of the hole packoffs can be experienced creating downhole pressure spikes exceeding the fracture gradient causing losses and wellbore instability. To further complicate the problem these “self-induced” wellbore instability issues can be misinterpreted as geologic instability. While tripping out of the hole, ANY indication of tight hole should assumed it is caused by pulling the BHA into a cuttings bed. If this occurs one should trip in the hole 3-5 stands prior to brining the pumps on; bringing the pumps on immediately usually results in a packoff. Once the BHA is free from the cuttings bed the pumps should be brought up slowly closely monitoring the pressure.

Backreaming

Backreaming can be a very effective tool to clean the wellbore up prior to running casing if done correctly. Circulating on bottom will never remove all of the cuttings from the low side of the hole. The only way to effectively clean all of the cuttings out of the wellbore is to backream. Backreaming should be done at the same RPM and full circulating rate the section was drilled with. It should be noted that due to the bit being off bottom and the string being pulled in tension one can encounter higher shock and vibration loads due to increased side forces then noticed while drilling. Once backreaming is commenced one should not stop until a hole inclination of at least 30° is reached. Care should be taken while backreaming through the rat hole section as annular velocities will decrease due to the increased hole size and can create a large cuttings bed. Once inside the casing the hole should be circulated clean. Backreaming inside casing may be necessary to reach 30° and should maintain the same parameters while in open hole. Backreaming is not a prefect science. Close attention must be paid to pump pressure, torque and hookloads while coming out of the hole. Any indication that the hole is torqueing up or packing off should be assumed a cuttings bed and the pulling speed should be slowed. When drilling with a motor, slide sections may be interpreted as a packoff noted by an increase in pump pressure but this may be due to differential pressure induced by the bit opening the hole up due to the adjustable bent housing offset. While backreaming any tight hole should be assumed as a cuttings bed. If encountered.

Tripping

Prior to pulling out of the hole on elevators the hole should be circulated until the shakers are clean. Pulling off bottom at 1 stand per bottoms up will reduce the chance of washout. A set number of circulations should be avoided as the hole will tell you when it is clean. Prior to pulling on elevators swab models should be run to develop a trip schedule based on an allowable swab margin. One misconception is that once one is in casing the pulling speed can be increased. This is not the case as swab loads are still acting on the open hole section while pulling inside casing.

Sweeps

Sweeps for the most part are ineffective in high angle wellbores if not built correctly. Fluids will take the path of least resistance. Due to the pipe riding on the low side of the hole creating a higher velocity flow path on the high side, fluids will naturally tend to the high side. This is exasperated with high viscosity sweeps. Studies have shown that in a highly deviated wellbore low viscosity, weighted sweeps exceeding the drilling mud weight by 3-4 ppg providing a 200'-400' column in the annulus along with pipe rotation +80 RPM (increasing RPM will produce a greater effect) can be effective when fully circulated. Weighted sweeps due to their increased density combined with gravity and viscous coupling due to pipe rotation have the ability to scour the low side of the hole where cuttings beds form. Additionally, the increased mud weight provides more buoyancy further increasing carrying capacity. Although this sounds ideal, there are many operational constraints to creating an effective sweep in a highly deviated wellbore. Typically, more than one sweep is necessary and to effectively sweep the hole 3-4 should be planned. Due to ECD constraints in smaller hole sections usually coupled with longer measured depths and shallower TVD's, building a sweep 3-4 ppg over mud weight is not ideal and can cause lost returns or seepage losses. In larger hole sections where hole cleaning issues are most pronounced and one is not ECD limited, sweeps can be more effective. Although, for example, to create a 400' annular volume in a 16" open hole with 5" DP a ~90 bbl sweep would have to be built which may be above the capacity of most pill pits. Another operational concern is capturing this volume of fluid on surface and not entraining it in the active system increasing the mud weight and effecting normal drilling operations. The problem with sweeping the hole is that as soon as one returns to drilling cuttings beds will begin to form again due to the nature of highly deviated wellbores creating an endless "preventative maintenance" sweeping program that slows the operation, is costly and has the ability to cause more harm than good when not conducted properly. Most sweeps that are used in the field today do not follow this procedure and for the most part channel on the high side of the hole and do nothing more than sweep the less deviated hole section less than 35°. This is usually noted by the sweep coming back early or producing little to no additional cuttings at the shakers. In all, with proper mud rheologies and monitoring the hole can effectively be cleaned without pumping sweeps. If a sweep must be pumped it must be built correctly, otherwise it is a waste of time and money and can create adverse effects both downhole and to the active mud system.