Avoid Getting Differentially Stuck Drilling Depleted Zones

Michael Davis, SPE, Drill Science Corp.

Abstract

1. First always keep the pipe moving. If not up and down then rotate. It seems as soon as a connection takes longer than normal; your stuck. If you have a rig available that can drill stands (top drive), use it because there will be fewer connections and less chance to get stuck. When not moving and pumping wall cake builds up and wall contact is possible. Note that if there is wall contact with moving pipe, the dynamic coefficient of friction is often less than half of the friction force of static pipe. Also because of rotation there is a layer of moving fluid always between the pipe/collars and the hole preventing contact, suction and pinning of the pipe to the wall. If there is a problem and work must stop, ROTATE or WORK THE PIPE UP and DOWN. If you leave it still it will be stuck.
2. Trying to touch on the keys to minimize differential sticking is decrease the wall contact area. This can be done by decreasing the OD of the BHA and/or increasing the size of the hole. Also the design of the BHA can be a design that minimizes contact. Spiral flex collars can have 25% of the contact of regular drill collars. This will mean 25% of the pinning force available to grab the pipe.
3. Decrease the filter cake. This can be done in various ways. Contact your drilling mud professional.
4. Decrease the amount of differential from the mud hydrostatic and the formation pressure. This means being prepared to drill with less overbalance if possible. Managed Pressure Drilling (MPD) or Underbalanced Drilling (UBD) accomplishes this.
5. Have the best methods to free pipe ready to use. Conventially the first thing to do upon being differentially stuck is to slump the pipe downward and rotate (the natural thing for an inexperienced hand though is to pull up). Next, if well control and stability conditions allow, U-tube the pipe to take differential pressure off the stuck point. Next spot an agent downhole to eat at the wall cake and lubricate at the stuck point.
6. Have the jars configured correctly. If the mechanism most likely is differential sticking then design the jars position in the BHA to provide maximum impulse force that will mean movement that is needed to get the BHA off the side of the hole and the suction there. There are excellent computer simulators for designing jars for differential sticking on the market. Find a technician to help you from the companies that supply jars.
7. Use the jars correctly. Some consider that putting torque and jarring down when differentially stuck is the best way to get free. If using combined loading (overpull or compression and torque) keep in mind that the tensile and compressional loading of the pipe are diminished. Use the correct

combined loading equations carefully. These equations can be found in API RP 7 G.

8. Keep mud weights as light as possible (see #4).
9. Keep differential low with LCM that is designed properly and will plug in the pore throats and not make a thick wall cake. A thick wall cake is like a suction cup and you will be stuck.

   There are two methods of losing mud: Darcy flow through the permeability of the sand and the pressure differential across the sand face AND actual fracture of the sand. Two different mechanisms and two different ways to cure this with LCM designs. Flow through the permeability of the sand with material that plugs of the flow paths and essentially lowers the permeability (k) of the sand near the wellbore and screening out a fracture tip are two different phenomenon. This first must be understood clearly in order to plan and strategize with operational tactics designed to solve TWO DIFFERENT ISSUES with one common surface manifestation; loss of drilling mud. The literature has numerous methods for plugging permeability and plugging tensile fractures. Know ahead of time which one of these is most likely or if both are likely be prepared to use dual methods. You can calculate how much depletion will cause how much loss from permeable flow using Darcy's equation. You will need the pressure differential of the mud hydrostatic and the current sand pressure and also permeability. Look at Darcy's equation and remember that most of the time while drilling there is an overbalance and so Darcy Flow into sand is possible. Darcy's law is used extensively in petroleum engineering to determine the flow through permeable media - the most simple of which is for a one dimensional, homogeneous rock formation with a fluid of constant viscosity.

$$Q = \frac{kA}{\mu L}\left(\frac{\partial P}{\partial L}\right)$$

where Q is the flowrate of the formation (in units of volume per unit time), k is the relative permeability of the formation (typically in millidarcies), A is the cross-sectional area of the formation, μ is the viscosity of the fluid (typically in units of centipoise, and L is the length of the porous media the fluid will flow through.

$$\partial P/\partial L$$

represents the pressure change per unit length of the formation. This equation can also be solved for permeability, allowing for relative permeability to be calculated by forcing a fluid of known viscosity through a core of a known length and area, and measuring the pressure drop across the length of the core.

The reason losses stop is because of the filtrate and the wall cake that is formed causes the permeability on the wellbore wall to become so low as to disallow further flow. There must be some loss to create the "skin" that prevents further flow. A paper written long ago suggests that a critical differential exists at 3000 psi yet if you do the calculations you might find that the formation has less permeability and 3000 psi is too low or more permeability and 3000 psi is too high. Remember that the Fracture Gradient (tensile strength) of the rock is a function of pore pressure.

$$S_h = [v/(1-v)] \cdot (S_v - P_o) + P_o$$

If the sand is depleted the fracture pressure goes down as a function of pore pressure. If you want to know the exact amount that the fracture of the sand is decreased as a function of pore pressure we may re-arrange the above equation to yield the following relation: (1-2v)/(1-v) for every 1 ppg of depletion. v = Poisson's ratio and varies between .2 and .45 for sands so the FG will diminish by .75 - .18 respectively. This means that for brittle sands depletion has a big effect on Fracture Strength of the sand and for rubbery sands it has less effect. This makes sense. This equation is Eaton's formulation for fracture gradient according to law's of lateral constraint. They have been studied and debated for years and are now generally regarded as decently accurate.

10. Create a cardboard sliver 1" wide by the total length of your BHA divided by the scale of the electric log you have available that identifies and qualifies the sands that may cause differential sticking in your open hole section. For example let's say your total BHA consists of Bit, Stabilizer, Drill Collar, Stabilizer, Drill Collar, Stabilizer, Drill Collar, Stabilizer, 2 Drill Collars, XO, 15 Joints of heavywate drillpipe, XO to drillpipe, and this total length is 625' long and the log scale is 1":100' then make the sliver of cardboard1" x 10" long and make the first 6¼" represent the BHA with the Drill Collars and Stabs and HWDP represented, to scale, on the 1" sliver of cardboard. Slide this up and down the log to represent the depth your drilling to quickly see where the biggest potential to get stuck is or perhaps where you already are stuck at and this may help in your plans and operations to either remain unstuck and/or remediations to get and stay unstuck.
11. Note that the warning signs of differential sticking can be seen on the weight indicator as an increase in initial torque that breaks off and decreases after a few seconds. This can be an indicator that the pipe is being pulled into an underpressured zone causing the initial torque that is gradually overcome because of the pipe movement as seen in the rotation of the pipe after a connection or other stoppage.
12. Use small spiral or square drill collars and blade stabilizers to reduce the contact area.
13. Control drill suspected zones since excessive ROP raises the concentration of drill solids and increases the effective mud weight in the annulus and this increases the differential pressure and filter cake across the sticking zone. Depleted zones should be isolated with casing whenever possible.
14. Practice frequent wiper trips. Rapid identification of the cause for stuck pipe and immediate proper action are required to successfully remedy the problem. Time will only worsen the problem.

Summary for prevention success

Keep the pipe moving and if the rig breaks down get the pipe out of the hole. Minimize mud weight, ECD's and EAD's (the amount of cuttings in the hole at any time meaning lower ROP). Keep the mud system loaded with LCM of broad spectrum of particle sizes designed to plug the formation of interest (get a professional to help you design this based on anything, logs, cores, that you know about the depleted sand). Minimize connection times. Don't take surveys. Run a gyro at the end of the well. Trust me on that probably the most common time to get stuck differentially is taking a survey. DON'T. Run an expensive, wireline retrievable (just in case!), digital survey tool that doesn't require that you stop moving pipe. Be aware of where your BHA is in relation to your formations in the open hole at all times (step 10). It will be worth it.

What to do if stuck?

One important step in freeing stuck pipe is to determine the stuck zone. The following methods are available for this purpose: Pipe stretch charts – a quick on-site method for locating the stuck zone. Specific charts for different pipe sizes are used by correlating pull load to pipe stretch. Logging devices such as the free point indicator and the drill pipe recovery log. Old and frequently used, the free point indicator has the major disadvantage of providing information only about the interval above the stuck zone. The drill pipe recovery log defines stuck pipe intervals and free intervals, even if they are numerous.

Freeing Stuck Pipe

There are three main procedures to free differentially stuck pipe and sometimes they are used together for a successful result:

1. Mechanical method is based on the release of pipe through the physical destruction of the filtercake bond when rotating and jarring down.
   A. Establish that Differential Sticking is the mechanism, i.e, stuck after a connection or survey with full unrestricted circulation across a permeable formation (*Sand, Dolomite and possibly Limestone*).
   B. Initially circulate at the maximum allowable rate. This is to attempt to erode the filter cake.
   C. Slump the string while holding 50% of make-up torque of surface *pipe (unless mixed string of pipe is being used).* Use an action similar to what would be used with a bumper sub - see note below.
   D. Pick up to just above the up weight and perform step 2 again.
   E. Repeat B & C. Increasing to 100% make-up torque until string is freed or until preparations have been made to: either - *spot a releasing pill via a chemical method* or - *conduct "U" tube operations.*
2. Chemical method refers to spotting a pill across the stuck zone. An effective spotting fluid may work through mechanisms as: reduction of hydrostatic pressure (lower fluid density), dehydration of filtercake and reduction of the pipe/filtercake friction coefficient (lubricant and surfactant addition to the fluid). When stuck in salt, spotting a freshwater pill across the zone that has the drillstring stuck will wash away the pinching salt and free the pipe or BHA.
3. Hydrostatic method refers to reducing the hydrostatic on the annulus so as to decrease the differential across the overbalanced zone that the drilling string is stuck against. This can be accomplished via several methods: Nitrogen injection into the well resulting in a decrease of mud density and reduction of hydrostatic pressure. 1. This method requires the presence of a nitrogen truck at the well site and so this truck might be called out as soon as your deemed "stuck". 2. Pumping a lighter fluid on top of the annulus. 3. Or "U-tubing" the annulus and effectively lowering the height

of mud in the annulus by pumping lighter fluid into the drillpipe then bleeding the standpipe pressure, thus the annulus mud height lowers. Caution should be used in “U-tubing” especially if small nozzles are in the bit since cuttings and debris may plug the small nozzles since flow is from the hole back through the nozzles into the drillpipe using this method.