

# VIBRATION MITIGATION

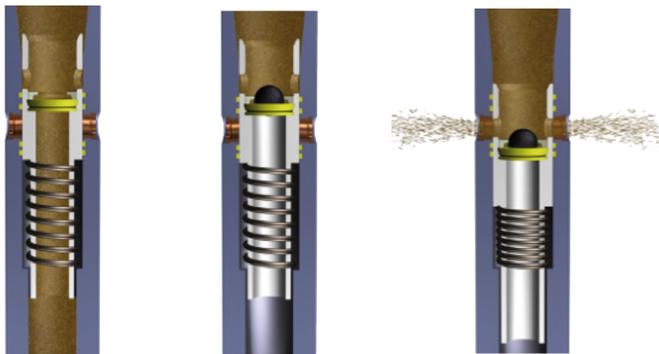
Farhod Hamidov, BICO Drilling Tools, Inc.,  
and Sachin Rajadhyaksha & Meghan Paulson,  
K&M Technology Group, show how operators can use bypass  
tools to optimise hole cleaning and off bottom vibration mitigation  
in horizontal wells.

**H**ole cleaning has always been a challenge while drilling high angle or horizontal wells. Prior to tripping out of a horizontal well, effective hole cleaning is essential to reduce the risk of stuck pipe while tripping out with the BHA and running the casing/liner to bottom. Typically, high angle/horizontal wells are drilled in the laminar flow regime. As a result, the flow rate is not sufficient to stir up the cuttings that are laying on the low side of the wellbore. Therefore, in order to achieve effective hole cleaning, additional energy is required in the form of high speed rotation.

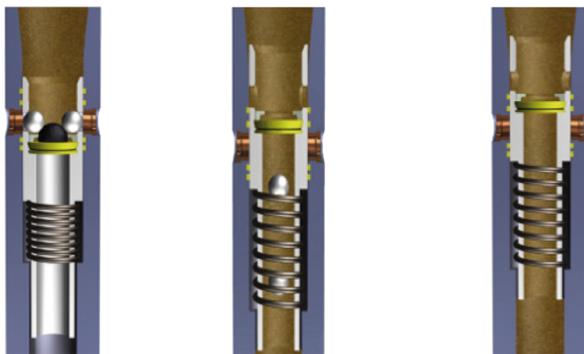
Many unconventional horizontal wells utilise rotary steerable tools with a downhole motor, to drill the lateral section. Once off bottom, rotating with high surface RPM (in addition to motor generated RPM) has caused significant damage and/or failure of downhole tools as result of high lateral vibrations. Furthermore, rotating big bend setting motors for extended periods of time with high RPM has also proven to be damaging to the motor and has

caused LIH incidents. This introduces additional well cost in the form of tool repairs, additional trips.

If it were possible to increase the flow rate to a point where the flow regime in the annulus converts from laminar to a turbulent regime, the turbulent flow itself would be sufficient to stir up the cuttings from the low side of the wellbore to achieve the hole cleaning objective. This would ensure that additional energy in the form of high off bottom surface RPM is no longer required for hole cleaning, cutting down the additional well cost as result of tool failures/damages. However, this is usually not possible due to BHA and hydraulics limitations that prevent pumping at very high flowrates.



**Figure 1.** PBL activation procedure. Drilling mode flow to bit (left), vinyl activation ball seated (centre), open position flow through ports (right).



**Figure 2.** PBL de-activation procedure. Steel de-activation balls dropped and pumped down pressure up (left), balls sheared through seat tool reset (centre), drilling mode flow to bit (right).



**Figure 3.** Fast Ball (left). Fast Dart (centre). Split Flow (right).

A flow bypass tool above the BHA will ensure that a higher flowrate can be achieved by eliminating the BHA (motor, MWD and RSS) and bit pressure losses from the circulating system providing the hydraulics capability. Additionally, since the high flowrate will not be seen by the BHA components, they are not required to be designed for these high flowrates. Once at TD or prior to a trip, this bypass tool can be activated to increase the flowrate above the critical velocity to achieve turbulent flow in the annulus and thus provide effective hole cleaning without inducing and damage/failure to the BHA.

## Turbulent flow

The Reynolds number (NRe) is a dimensionless number that is used to determine whether a fluid is in laminar or turbulent flow.

$$N_{ReG} = \frac{\rho V^2}{19.36 \tau_w}$$

Where:

V – Annular velocity.

$\rho$  – Fluid density.

$\tau_w$  – Shear stress at the wall.

The critical Reynolds number which indicates the onset of turbulence is calculated based on the below:

$$N_{CRe} = 3470 - 1370n$$

Where, n – Power law index.

The power law index is based upon the FANN 35 curve which will determine what Reynolds number is required to achieve the transition from laminar to turbulent.

As a general rule of thumb, a Reynolds number of >2100 is required to achieve the transition and >3000 is required to achieve a fully turbulent regime.

The Reynolds number is dictated by the following parameters:

- ▶ Drilling fluid density.
  - The higher the density, the higher the Reynolds number.
- ▶ Fluid rheology.
  - The lower the viscosity (thinner the fluid), the higher the resultant Reynolds number.
- ▶ Annular velocity.
  - The smaller the annular flow area, the higher the Reynolds number for a flowrate (sensitive to hole washouts).
  - The higher the flow rate, the higher the Reynolds number.

## Considerations

To design for turbulent flow as a primary means of hole cleaning, the following things need to be considered in the well design:

- ▶ Hydraulics – The pressure losses should be calculated to determine the highest flow rate possible with the bypass sub.
- ▶ Rheology – The low-end mud rheology (Fann 35 100, 6 and 3 rpm values) should be designed to be as thin as possible. This thinned mud rheology is not required while drilling the high angle section and can be achieved towards the end of the section prior to circulating the hole clean.
- ▶ Reynolds number – The Reynolds number should be calculated to determine if turbulent flow can be achieved and its sensitivity to changes in mud rheology and hole size. If the hole is excessively over gauged turbulent flow might not be achievable.
- ▶ ECD impact – The higher flowrates after opening the bypass sub will result in a significantly higher ECD. The ECD impact should be calculated and evaluated against the minimum fracture gradient in order to avoid losses.

## Procedure

- ▶ Once at TD, pump down ball to activate the PBL sub to bypass flow. This flow bypass can be designed to 100% bypass or split flow based on hydraulics requirement to achieve turbulent regime.
- ▶ Increase the flow rate to intended rate to achieve turbulent regime.
- ▶ Monitor cuttings volume over the shakers (compare to previous wells with laminar flow).
- ▶ Circulate until shakers are clean.

The PBL Multiple Activation Bypass System is a simple and reliable tool that can assist in reducing drilling costs and risks associated with different types of hole conditions. With increased activity and demand for horizontal and ERD drilling, it has become apparent that there is a need for such a tool that removes excessive rotation when on bottom, while preventing detrimental BHA damage.

By activating the PBL tool, the operator has ability to increase the flow rate up to 300%. It has been proven that this increase in flow changes the characteristics of the fluid from laminar to turbulent flow.

PBL tools offer other various key features:

- ▶ Multiple cycles on a single trip in well.
- ▶ Tool will close when pumps are turned off.
- ▶ Large no-gos to allow third party ball passage.
- ▶ Autolock option to trip dry pipe.
- ▶ 100% fluid bypass when activated.

Additional features include the Fast Ball™, Fast Dart™, Booster Bypass™ and Split Flow™ systems, which are designed for horizontal and extended reach wells. The Split Flow Dart option is designed to enhance hole cleaning ability while not pumping excessive fluid through the MWD/LWD, RSS (rotary steerable system), drilling motor or drill bit causing possible washouts and difficulty steering. Additionally, it provides a cooling effect on sensitive components of the BHA, thus helping reduce the detrimental effect of the bottomhole temperature. This simple and reliable system can save operators large amount of rig time, reduce BHA damage and repair costs, and result in overall cost savings (Figure 3).

## Case study 1

US land well in the Haynesville drilled to 17 583 ft MD (12 200 ft TVD) in 6 3/4 in. hole size – 7 7/8 in. intermediate casing set at 11 423 ft. The 6 3/4 in. horizontal lateral was drilled with a 16.05 ppg oil based mud and a Motor + MWD BHA with 4 in. drill pipe. The parameters used while drilling the lateral were 250 gpm and 80 rpm. (Table 1, Figure 4).

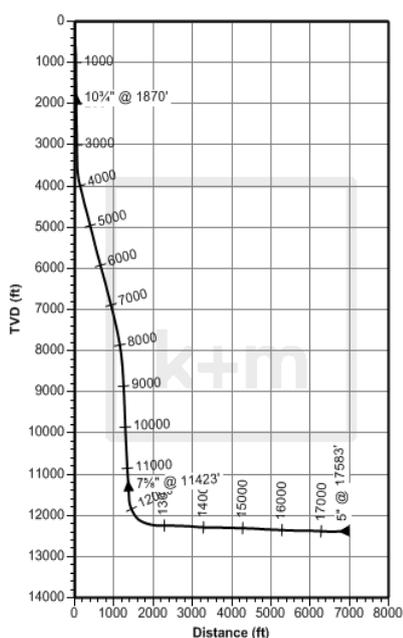


Figure 4. PBL application - hole cleaning - drilling scenario - 6 3/4 in. hole run no. 3.

## Case Study 2

US land well drilled to 10 000 ft MD (5000 ft TVD) in 6 1/8 in. hole size – 7 in. casing set at 4000 ft MD. The 6 1/8 in. hole was drilled with Motor + RSS BHA

with 4 in. drill pipe. The section was drilled with 200 - 250 gpm and 80 - 100 surface rpm [downhole BHA rpm: 180 - 200] (Table 2 and Figure 5).

## Conclusion

If off bottom high speed string rotation during clean up cycle is a concern (vibrations, tool failures, etc.), a PBL tool can be used as an alternative for achieving the hole cleaning objective. Activating the tool to bypass flow above the BHA will allow for higher flowrate by eliminating the BHA and bit pressure losses. Depending on the hydraulics and ECD limitations, if high flowrate can achieve a turbulent regime across the drill pipe annulus, this can be effectively used to achieve the hole cleaning objective without subjecting the BHA to high speed off bottom rotation, thus preventing any further risk of damage/failure to the BHA. ■

Table 1. Case Study 1.

	Drilling (flow through BHA)	PBL activation (BHA bypassed)
Flow rate	250 gpm	375 gpm
Standpipe Pressure	5984 psi	6084 psi
Mud weight	16.05 ppg	16.05 ppg
ECD	16.90 ppg	17.73 ppg
Annular Velocity (across 4 in. DP)	212 ft/min.	320 ft/min.
Reynolds Number	1934	3133
Annular Flow Regime (across 4 in. DP)	Laminar	Turbulent

Table 2. Case Study 2.

	Drilling (flow through BHA)	PBL activation (BHA bypassed)
Flow rate	250 gpm	400 gpm
Standpipe Pressure	5400 psi	4560 psi
Mud weight	12.50 ppg	12.50 ppg
ECD	16.14 ppg	20.00 ppg
Annular Velocity (across 4 in. DP)	295 ft/min.	470 ft/min.
Reynolds Number	1750	3370
Annular Flow Regime (across 4 in. DP)	Laminar	Turbulent

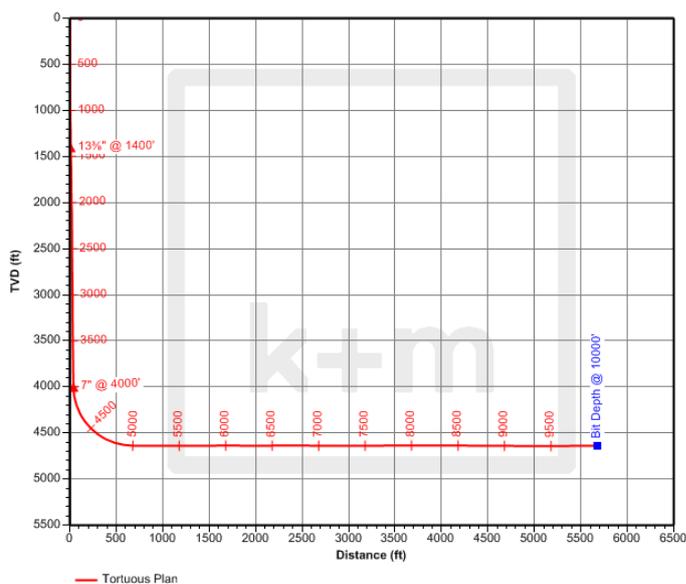


Figure 5. PBL application - hole cleaning.