BHA Design

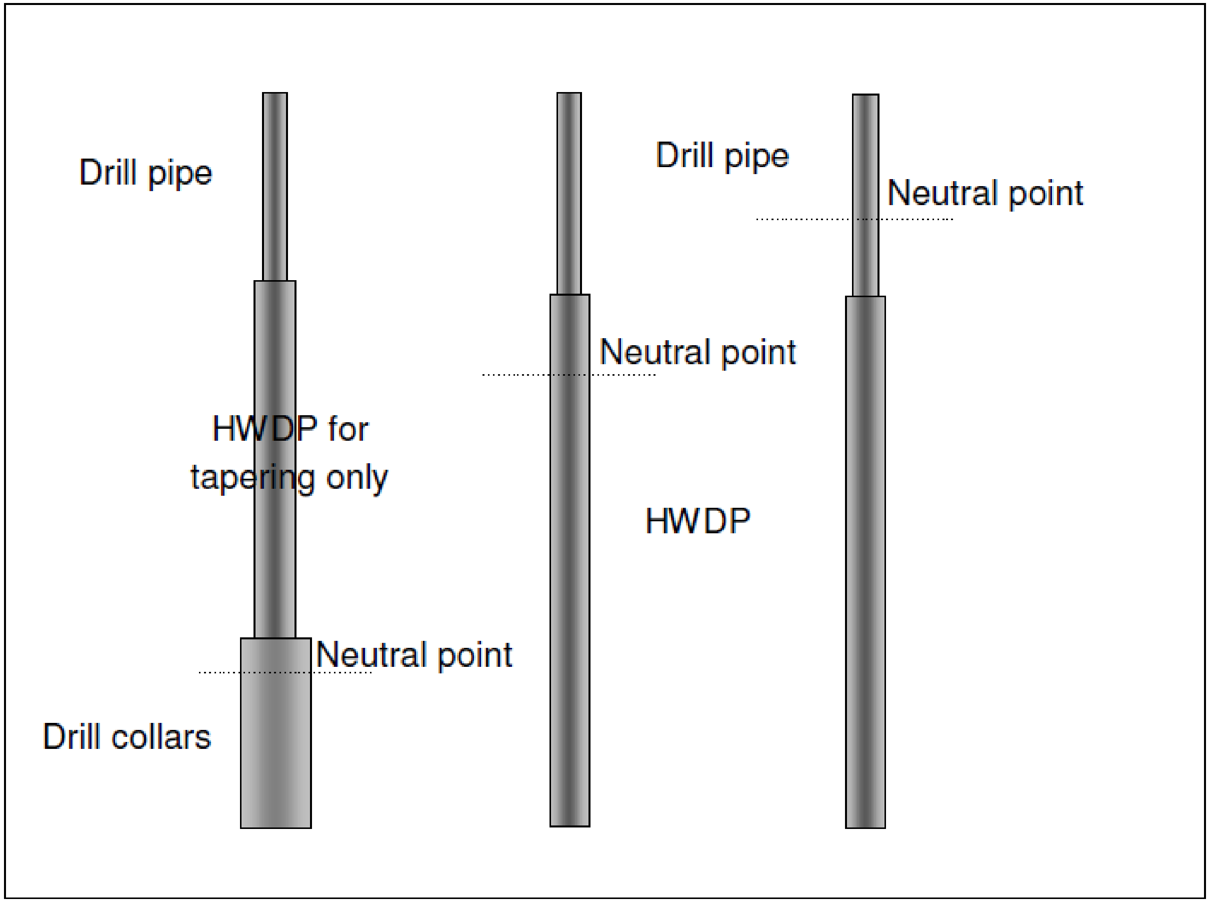
Drill Collar vs. Heavy Weight Drill Pipe

Use minimum number of drill collars in the BHA. The noticeable exception is the drilling of vertical wells.

The main advantages of omitting drill collars in inclined wells are:

- HWDP assemblies are lighter which reduces drag. This results in less stick slip
- and improved tool face control in sliding drilling mode.
- HWDP's result in less internal pressure drop. Hence more pressure becomes
- available for hole cleaning and bit drive.
- HWDP connections are far less prone to fatigue failures than drill collar
- connections (see Appendix 1).
- Rig handling of HWDP's is faster and safer than drill collars.
- HWDP's have less contact area than drill collars and therefore have a smaller
- risk on getting stuck.
- HWDP's will result in less ECD due to the larger annular clearance.

Neutral Point



The neutral point can be placed within drill collar, HWDP or Drillpipe. In case large washouts have occurred in offset wells it is bad practice to run drillpipe and/or HWDP in high compression. The pipe might bend into the washout leading to excessive bending stress and twist-off.

Friction factor

- Operational issues could be flagged in the planning phase if friction factors used for torque and drag modeling, calibrated properly.
- It is important that the string is not reciprocated while recording rotating weights, and vice versa.
- It is good practice to measure up/down weights before the connection is made. This can give an indication of hole cleaning in the well.
- Take readings at a few depths inside the casing, while tripping in.
- Be aware that the hookload reduces when the flow rate increases due to the 'pumpout‘ effect. Always ensure that hydraulics is integrated with the torque and drag calculation.
- Rotating-on-bottom data is dependent on the momentary ROP, WOB, and TOB. As these can fluctuate rather strongly, rotating-on-bottom torque and drag data are not very meaningful in determining friction factors.
- For none complex wells an open hole/cased hole friction factor of 0.3/0.2 is a good starting point. It is assumed that OBM is used.
- In planning the well the highest hook loads occur when POOH and should be calculated assuming no flow and no rotation.
- Generally OBM will lead to lower friction factors than WBM.
- Do not calibrate friction factors bases on measurement when drilling the shoe track. Both torque and drag are always higher when compared with drilling openhole so results become too conservative.
- In case of no offset data the following values can be used: PDC: 0.2-0.4, Tri-cone 0.05-0.1

Use of drag charts during the drilling operation

- In the execution phase of the well the drag chart can be used to monitor the drilling process. Particularly when drilling ERD wells the drag chart in combination with other drilling data can be used to asses the hole cleaning quality.

Bending Strength Ratio (BSR)

- BSR is the ratio of the relative bending stiffness of the box to the pin for a BHA connection. It is used as an approximate indicator of the suitability of a connection between two BHA components.
- In theory, high BSR's cause accelerated pin failure and low BSR accelerated box failure.
- BSR ratio's should be checked for each BHA connection. Particular crossover connections between drill collar and HWDP require attention.

$$BSR = \frac{Z_b}{Z_p} = \frac{\left[\dfrac{D^4 - b^4}{D}\right]}{\left[\dfrac{D_{rg}^4 - d^4}{D_{rg}}\right]}$$

Where:

BSR = Bending Strength Ratio

Z_b = Box section Modulus [in^3]

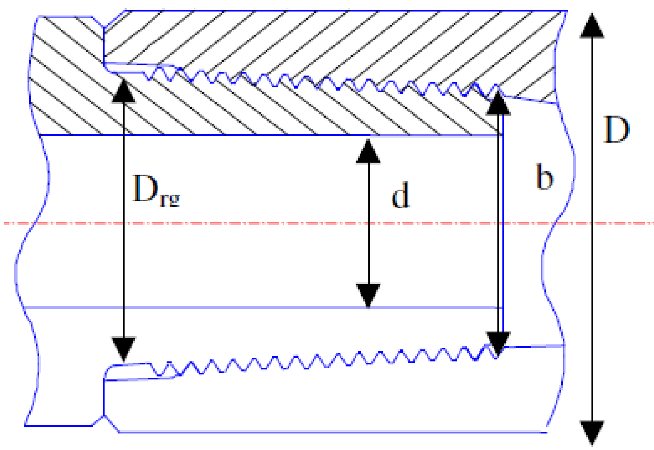
Z_p = Pin section Modulus [in^3]

D = Outside diameter box [in]

b = Inside diameter box [in]

d = Inside diameter pin [in]

D_{rg} = Stress relieve groove diameter [in]



Shouldered BHA connection with stress relieve groove.

Stiffness ratio

BHA's are tapered to avoid local areas of high stress at section changes. To quantify the abruptness of a change between BHA sections the stiffness ratio (SR) is used. It is defined as the ratio of the upper and lower section modulus (Z):

$$SR = \frac{Z_{lower}}{Z_{upper}}$$

where the section modulus is calculated from

$$Z = \left(\frac{\pi}{32}\right)\left(\frac{OD^4 - ID^4}{OD}\right)$$

• SR< 5.5 for routine drilling or very low failure rate experience
• SR<3.5 for severe drilling or for significant failure rate experience

Stiffness ratios are particular relevant for the larger hole sizes (>8.5") because the annular clearance between drilling tools and hole is the largest.

Connection strength under combined loading

• For routine drilling operations it is sufficient to check that predicted torques do not exceed the make-up values.
• In case high torques in combination with high tensile loads are expected it is necessary to evaluate the combined torque-tension capacity of tool joint and pipe body. Specialized software exists, which provides the well engineer with a so-called 'operational torque-tension
window'.
• For a given make-up torque the allowable operational torque and external tensile load can be determined.
It is particular important to check the drill string crossovers since they are often a weak link.