

Bottom Hole Assembly and Mud Motor for Directional Drilling

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The success of any drilling operation especially directional drilling operations depends upon the selection and design of Bottom Hole Assembly. Therefore, it is very important to know the components and its working in a BHA. Any failure to BHA design may result in complete failure of the drilling operation. For this purpose there should a complete knowledge of what the BHA is compose of and what are the factors that have to considered while design of a BHA. Certain parameters like maximum permissible dogleg severity, maximum bending stress, neutral point of compression and tension etc. has to be calculated for designing a BHA. When there is a miss calculation in any of these factors it may lead to complete or partial failure of the BHA. Down Hole Mud Motors are also another important criterion in directional drilling. Therefore, it is equally important to know the components and its working principle of the down hole mud motor or positive displacement motor. This paper deals with the components of BHA and Down Hole Mud Motor and their working for directional drilling. Proper understanding of the components is critical in design concept of the BHA and mud motor. Knowing what component if required where is vital. So this paper gives a clear idea of all the components and their role in the BHA and mud motor as well.

Key words: Bottom hole assembly, mud motor, directional drilling.

The successful drilling of a wellbore completely depends on the success of BHA. The BHA is to provide force the drill bit and to control the direction of the well. The BHA is the component of the drill string that includes the core bit, outer core barrel, various subs, and the drill collars. It hangs below the drill pipe and provides weight to drill or core bit to induce the teeth to penetrate the formation. The BHA is mainly composed of heavy and stiff drill collars, which can be put in compression without buckling. It plays a great role in drilling operation. The mud motor is hydraulically actuated device. The purpose of motor is to generate the rotational speed and torque needed to operate the drill bit. The down-hole drilling motor

has undergone substantial changes and improvement over the past 50 year making it proven and reliable tool even in most rigorous of drilling environments. Today, most of all drilling applications have a became a planned routine operation¹⁻⁶.

BHA for directional drilling

Bottom-hole assembly used for directional drilling is different from that used for normal vertical drilling operations. Though some of the components are same for vertical and directional drilling there are some components that are specifically for directional drilling. The components of a directional drilling BHA are:

DrillBit

The basic function of drill bit is to cut the rock. The drill bit has cutting edges which grinds the rock at the bottom. The cutting action depends upon the type of bit used.

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Fig. 1. Drill Bit

Junk sub

The junk sub is a narrow pass designed to collect small pieces of metal, such as bearing balls and rollers from bearing and broken bit teeth. As the name suggests it is like a junk collector. It collects the junk materials while drilling. If those junks are left alone in the bottom hole they may cause problems while drilling.

Shock sub

The shock sub is used to dampen the vibration produced by drill bit during drilling. When the drill bit makes a hole it actually bounces off the surface slightly due to its cutting action. The shock sub absorbs this small bouncing action. The main function of the shock sub is that it prolongs the life of the bit.

Roller reamer

Roller reamers are used while drilling hard rock formations. It cuts the wall of the hole to gauge. The roller reamer helps to keep the borehole in correct dimension throughout while drilling. It also serves to keep the BHA in the centre of the hole.



Fig. 2. Roller Reamer

Stabilizers

Stabilizers are used to centralize the BHA in the bore hole. It always keeps the BHA at the centre of the borehole and maintains good drilling operation. While drilling the hole the motor may get deviated from its path due to its torque. The stabilizers are used to avoid such deviations to the motor.



Fig. 3. Stabilizer

Drill collar

Drill collars are one of the most unavoidable components of the BHA. The main function of drill collar is to provide weight for the bit. Weight on bit is an essential factor that has to be considered while drilling. It also provides strength needed to run in compression. The drill collar avoids directional control problems while drilling directional wells.

The different types of drill collar are:

Square drill collar

The main function of a square drill collar is that it provides continuous centralization while drilling. This design also maximizes the bending resistance of the collar. Another big advantage of the square design is that it reduces the axial vibrations while drilling.

Spiral drill collar

As the name suggests the spiral drill collar is made up of long spiral column. The main advantage of the spiral design is that it reduces the risk of differential sticking. Since there are spirals or grooves the chances differential sticking is minimized.

Non Magnetic drill collar

Since there are many moving parts in the BHA there may be a chance of production of a magnetic field. The interaction between the BHA

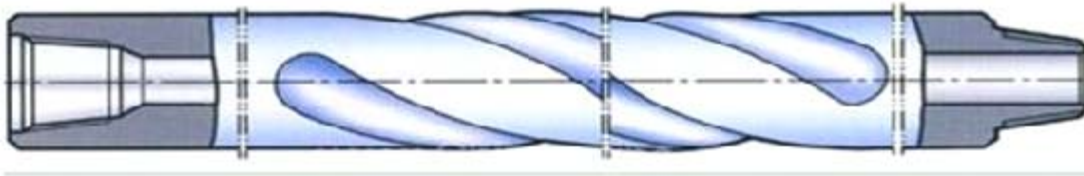


Fig. 4. Spiral Drill Collar

and the wall of the borehole may produce a magnetic field depending upon the composition of the formation, because some formations may contain some magnetic materials. The interaction between various components of BHA also causes the formation magnetic fields. The non magnetic drill collar plays a vital role in such situations. It minimizes the chance of such magnetic interactions.

Classification based on size

Based the size or diameter the drill collar is classified into two types namely as medium and large round collars. The medium drill collars add weight to the BHA while reduces the stress between large collars and drill pipe. The role of large drill collar is to provide stiffness to the drill bit section.

Table 1. Various diameter HWDP with their outer diameter, inner diameter and weight per foot

OD (inch)	ID (inch)	Weight (lb/ft)
3 ^{1/2}	2 ^{1/6}	26
4	2 ^{9/16}	28
4 ^{1/2}	2 ^{3/4}	42
5	3	50

Key seat wiper

Keyseat are run either in the BHA or in the drill pipe. The main function is to ream the key section out of the wall of the hole.

Drilling Jar

The drilling jar is used to shake free the BHA if it is stuck. While drilling when the BHA got stuck the drilling jar shake the BHA and retreat it to its original position. The main thing that has to be considered is that the drilling jar should not be used or fitted as crossovers between the collar and HWDP.

Pendulum assembly

This technique is used to drop the angle of well while drilling high angle wells. The pendulum

Heavy weight Drill pipe (HWDP)

Heavy weight drill pipe is a small drill collar with pipe tool joint. It has the same outer diameter as that of the rest of drill pipe but has higher wall thickness. The wall thickness of HWDP may be as much as two to three times that of the normal drill pipe. It adds weight to the drill bit. The following Table 1 shows a chart of various diameter HWDP with their outer diameter, inner diameter and weight per foot.



Fig. 5. Heavy weight Drill Pipe

assembly brings the direction of wellbore back to vertical. It works by using gravity assistance as its basic principle for deviating back to vertical. There are two forces acting here: one is perpendicular to the direction of well bore and the other is in the same line as the well bore. It is the side force that is responsible for bringing the BHA back to vertical position.

Fulcrum Assembly

The fulcrum assembly is used to make an angle or deviation from vertical. The fulcrum assembly has a stabilizer fitted near to the drill bit, this act as leverage to deviate the well. The higher the length of lever the greater the angle of deviation. The leverage is a function of weight on

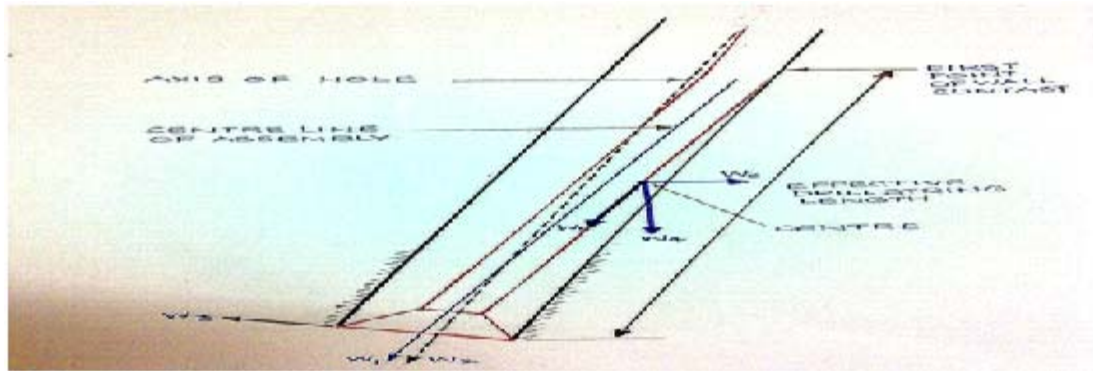


Fig. 6. Pendulum Assembly

bit, when the weight on bit increases so does the leverage. So to build a highly deviated well the WOB should be high.

Packed hole assembly

The packed hole assembly uses a number of stabilizers to reduce deviation tendencies. When

we use more than one stabilizer it adds stiffness to the BHA and does not deviates from the planned well profile. An accurate knowledge about the formation being drilled is required while arranging the stabilizers. The position of stabilizers depends on the drilling characteristics of that location.

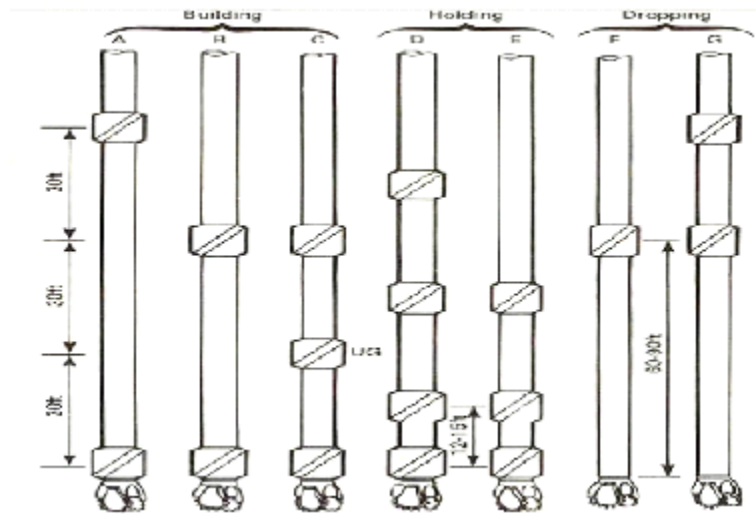


Fig. 7. Packed Hole Assembly

From the Figure 7 we can observe the different arrangements of stabilizers. For different circumstances, the arrangement of stabilizers and their position varies accordingly. We can see that the type A, B, C are used to build an angle, types D and E are used to maintain the angle and finally type F and G are used to drop the angle or to come back to vertical position.

MUD motor

Mud motor is also known as positive displacement motor. It is a hydraulic driven motor to rotate the drill bit. The bit rotates independent of the drill string. It is named as mud motor for the reason that it is driven by drilling mud. Mud motor is the now the most commonly used technique for directional drilling or deviated wells. The force of the drilling fluid rotates the motor and drives it.

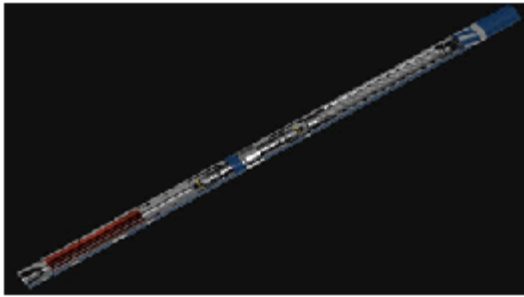


Fig. 8. Mud Motor

Mud motor consists of three main components, named as power unit, transmission unit, bearing section. Let us discuss each of these components in detail.

3.1 Power Unit:

The power unit is the most important section of the mud motor. The rotational motion of the motor is derived from the power unit. The hydraulic energy of the mud drilling mud is converted in to mechanical energy of the motor. The power unit consists of a rotor and stator of helical lobes. The rotor has one lobe less than the stator. Due to this difference in number of lobes between the rotor and the stator, an eccentricity is developed. When the fluid passes through the power unit, it rotates the rotor and hence creates the rotational motion of the motor. The design of the rotor and stator is such that it can accommodate any type of drilling fluid, be it be oil-based mud, water based mud, air, or foam the power unit can accommodate them and convert their hydraulic energy to mechanical energy. The rotational force derived is a function of the mechanic energy and the mechanical energy derived is a function of hydraulic energy of the fluid. The higher the hydraulic energy the greater the mechanical energy derived and higher is the rotation or torque of the motor

Transmission unit

The transmission unit controls the motion of the rotor. It also transmits the rotational force of stator to the drive shaft. The function of transmission unit can be compared to that of transmission system of a car.

Bearing section assembly

The bearing assembly consists of thrust bearings and radial bearings along with drive shaft. The main function of the bearing assembly is to

provide smooth rotation of the drill bit. If bearings are not used it may cause wear and tear of several parts of the mud motor.



Fig. 9. Transmission Unit



Fig. 10. Bearing Section Assembly

CONCLUSION

A proper arrangement of the BHA and its components are essential factors for an effective directional drilling operation. Knowing the function of each component and its area of usage is must before going for any kind of drilling operation. Selection of tools are vital for a successful drilling operation especially directional drilling. When there are mistakes while selection of tools it may lead to various drilling problems. These problems

include bursting of pipe, pipe stuck up etc. There is single method that can be adopted for drilling a directional well. The requirements for one type trajectory and angle of deviation may be different from the other. If there is a shale formation or a loose circulation zone or there is chance for mud cake formation reamers and wiper plugs has to be used to prevent stickups. Use of spiral drill collars also required in such areas. Collection of proper geological and drilling data is critical for a successful directional drilling operation. Calculation of trajectory and angle of deviation has to be perfect and justified, accordingly we have to select the tools for making the trajectory.

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