DIRECTIONAL WELL PLANNING: EFFECT OF KICK-OFF POINT ON BUILD-UP RATE

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ABSTRACT: *Well planning is the most vital part of drilling engineering. It describes all the operations, calculations and risk factors consideration starting from spudding the well, its trajectory, total depth and then to completion phase. It requires extensive and most up-to-date knowledge of drilling engineering principles, offset well data, geological constraints, availability of surface location, wellbore trajectory, expected pore pressure and formation fracture pressure data, rate of penetration (ROP) in different formations and specifically in the build-up section, knowledge of the area to drill prospect well, latest deflection tools and their utilization in a specific environment and different drilling problems associated with directional drilling and their possible solutions. Kick-off point (KOP) and build-up rate (BUR) selection has also been included while planning a directional well and measurement while drilling (MWD) technique has been applied to measure the real time evaluation of well inclination and azimuth of directional well. This paper describes how build-up rate in directional well is affected by the selection of kick-off point and how desired well bore trajectory is achieved by the use of latest deflection tools in bottomhole assembly (BHA).*

Keywords: Kick-off Point, Build-up Rate, Measurement While Drilling

1.0 INTRODUCTION

Drilling is a subsurface operation in which a wellbore is drilled into the reservoir to provide a path for reservoir fluids to move from subsurface to surface. After drilling to the total depth, the wellbore is then cased with a steel production casing which is then cemented. Cased hole provides the exact dimensions to the wellbore for the installation of production equipment inside the casing and surface equipment at the wellhead to regulate fluid flow rate.

Before the start of actual drilling at the well site, well is planned and sketched on the paper and all the risk factors and well planning aspects are considered during this planning phase [1,2]. The probability is increased to drill a usable, problem free and economical wellbore when more efforts are put during well planning phase. Well planning efforts include proper and effective utilization of offset well data, analysis of the cost factors and the application of up-to-date knowledge and latest drilling tools to drill cost effective well.

2.0 DIRECTIONAL WELL PLAN

Directional well planning is not so simple as vertical well planning because of the fact that directional well planning requires a high level of competency to plan an optimized wellbore trajectory to land exactly on the target based on surface well location and target point coordinates, kick-off point, build-up rate, azimuth, horizontal departure, length of the build-up section, build-up section stability, true vertical depth (TVD), drillstring and BHA design compatibility with wellbore profile, casing setting depths and casing design, potential borehole problems while considering geological constraints and the use of available technology to drill prospect well [3]. Utilization of measurement while drilling is obvious when drilling a directional well to get real-time data of well inclination and azimuth to hit the target properly.

In directional drilling, kick-off is an intentional deflection of the wellbore from its vertical path with respect to designed well inclination, azimuth and BUR. Kick-off point or kick-off depth is the vertical depth from which wellbore is given deflection in a particular direction with specific build-up rate. In the beginning, the well is drilled vertically up to KOP using simple BHA configuration and then it is deflected using a deflection tool, e.g. positive displacement mud motor (PDM) with bent sub or rotary steerable system (RSS) in the BHA. Milled tooth bit, PDM/ RSS, MWD, Universal Bottom Hole Orientation sub and drill collars, making an effective BHA and it maximizes the chances of desired kick-off.

Kick-off depth selection is made preferably in soft or soft to medium formation to have a successful kick-off. However, if the formation is medium to hard or hard formation is present at selected KOP, a high level of experience and tolerance is required to deal with this type of critical situation because in case of hard formation it is difficult to achieve kick-off at the start. A controlled and designed ROP must be maintained while drilling a directional well and more specifically the build-up section to have wellbore stability.

Well inclination is the angle of the wellbore with the vertical. This angle is measured in degrees and it is created after KOP when the build-up section starts and with every foot of drilling this angle increases as per selected BUR. Maximum well inclination depends upon KOP, BUR and horizontal departure. MWD technique is used to measure real-time data of well inclination and azimuth.

Azimuth is the direction of a deviated wellbore to which it is drilled relative to magnetic or true North Pole. Usually it is expressed in degrees and measured in a horizontal plane in clockwise direction from north.

3.0 DIRECTIONAL WELLBORE TRAJECTORIES

A number of directional wellbore trajectories are used based on KOP, BUR and horizontal departure to drill directional well [4]. Figure 1 shows a detailed description of three types of directional well trajectories that are used in directional drilling. Type-I is build-and-hold trajectory in which initially the well is drilled vertically up to KOP and then deflection of the wellbore starts as per given BUR using a deflection tool. After achieving the maximum angle, the well inclination is held constant while drilling through the hold-up section with packed BHA and hitting the reservoir. Type-II is continuous-build trajectory in which the reservoir is hit just after the maximum well inclination has been provided. In this type of

trajectory there is no hold-up section. Type-III is an "S" trajectory in which initially the wellbore is deflected to its maximum well inclination followed by a hold-up section and then wellbore penetrates the reservoir vertically when the drop-off angle is provided. Among these three trajectories, Build-and-hold trajectory requires the lowest well inclination and continuous build trajectory requires the highest well inclination to reach the target zone.

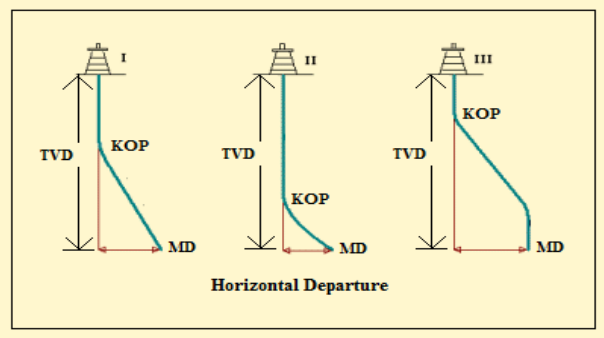

Figure 1: Directional Well Trajectories

4.0 EFFECT OF "KOP" ON "BUR"

In directional well planning KOP and BUR are the most important parameters to be discussed and designed properly to have maximum wellbore stability and less drilling problems considering geological and equipment constraints. KOP and BUR are proportional to each other and it can be written as:

$$KOP \propto BUR$$

More the kick-off depth more will be the build-up rate. Figure 2 presents a scenario of a directional well in which three options for KOP are available to hit the same target considering fixed horizontal departure and Type-I trajectory i.e. build and hold. KOP-1 is at shallow depth and it requires low BUR to hit the target. KOP-2 is at some deeper point than KOP-1 so it requires more effective BHA configuration with high BUR requirement to hit the same target. In this scenario more stresses and more drag are felt by the drillstring and then by the casing. Utilization of PDM with bent sub to drill the whole build-up section in this situation may be an economical option to kick-off from KOP-1 and KOP-2. KOP-3 is the deepest kick-off point among these three options and it requires the highest BUR among three available options to hit the same reservoir.

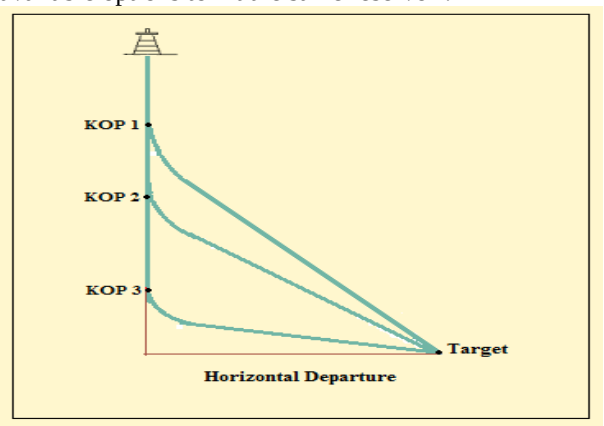

Figure 2: Effect of KOP on BUR

KOP must be selected considering formation strength, lithology, and wellbore stability and then a decision is made on BUR, maximum well inclination and utilization of a specific compatible deflection tool. For shallow and medium-deep KOP, aggressive BUR is not required so PDM with bent sub can work fine in this situation. However, in case of deep KOP, e.g. KOP-3, highest and aggressive BUR is required and the use of RSS is inevitable [2,5] to drill stable and problem free wellbore because if by the use of an unsuitable deflection tool once the wellbore path goes away from the designed path, extensive well corrections may be required to align the well to its designed path which causes non-productive time (NPT) and in turn drilling well cost will rise. Nowadays, worldwide in petroleum industry RSS is being utilized as deflection tool. RSS is a specialized deflection tool which is programmed with drilling mud flow rate and by changing the mud flow rate at the surface, RSS orientation in wellbore is changed. RSS helps to optimize directional drilling by providing full rotation to reduce drag, decreases the chances of pipe sticking and improves ROP with efficient borehole cleaning. In comparison, PDM has some limitations and constraints which RSS does not have. PMD is not obsolete yet but its application is somewhat limited relative to RSS. When drilling the build-up section, PDM with bent sub works under sliding mode in which drillstring does not rotate from the surface, only the bit which is attached to the bottom of PDM rotates when drilling mud flows through rotor-stator system of PDM. During sliding mode, there are lots of chances of pipe sticking as there is no rotation in the drillstring; it only slides into the wellbore. Moreover, oil based mud damages molded elastomer of the stator of PDM. These limitations are overcome by the use of RSS, in which there are very less chances of pipe sticking as it rotates continuously and it can work efficiently in different types of drilling muds with a wide range of build-up rates and drill the build-up section effectively with an optimum ROP.

5.0 CONCLUSION

- Well planning efforts, proper utilization of offset well data, deployment of latest drilling tools related to drilling directional wells, suitable application of engineering principles and experience of the area dictate the success of prospect well.
- A successful directional well plan in all the aspects increases the probability to have an economical and a usable well which is according to the requirement of production and reservoir engineer.
- In directional drilling KOP is proportional to BUR and it should be selected in soft formation at shallow depths to increase the probability of successful kick-off. In case of deep KOP, aggressive BUR is required to hit the target so application of latest deflection tools like RSS is a must to create required well inclination.

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