ADVANCES IN WELL DESIGN

Kerunwa Anothny[1], P. O. Fekete[2], C. I. C. Anyadiegwu[3]

[1, 3] Department of Petroleum Engineering, Federal University of Technology, Owerri,
[2]Department of Petroleum and Gas Engineering, University of Port Harcourt,
NIGERIA.

[1] anthonykerunwa@rocketmail.com, [2] feketepaul@yahoo.com, [3] drcicanyadiegwu@yahoo.com

ABSTRACT

Modern drilling technologies are emerging progressively to meet current challenges in well operations. Operators are going into much more complex environments, and drilling conditions become much tighter. Conventional well designs are no longer able to handle these new environments. The result is increased drilling costs, Non Productive Time, hole collapse, etc. While well engineers are worried by these developments, the busy schedule of most companies does not give room for delegating staff to proper study and research as to implement recent improvements into pre-drill plans. In some cases, economics may not favour adoption of new drilling methods as well. This work is a review of selected advances in well design available to oil industries today. Particularly emphasis was laid on the well design aspects of Drilling with Casing (DWC), Managed Pressure Drilling (MPD), Solid Expandable Systems, Air drilling and Geo mechanical Modelling for wellbore stability. To show the benefits of these advanced well design applications, case studies from different well operations have been presented. The yardstick for measuring these benefits is conventional drilling and well designs methods. While these results might not have covered all areas of improvements in well design, it is expected that this review will provide oil companies with an idea of trends in well design and areas for improving drilling performance at various operational levels. Hole problems will be minimised by such large margins that cost savings in drilling budget becomes significant. Reoccurrence of well problems may be minimised.

Keywords: Drilling, well, design, plan, environment, DWC, MPD, cost

INTRODUCTION

In the previous years, oil and gas industries faced the challenge of increasing the value of petroleum reserves, optimise upcoming investments and reduce risk and uncertainties associated with operations. Today, operators are targeting deeper zones, marginal fields, complex trajectories and high risk environments. The result of this is an increased pressure on all the crew involved in bringing the hydrocarbons to surface, including well engineers.

Hydrocarbon exploration has been intense during the past years and industry is now searching in total depths and water depths never thought before (Bland et. al., 2005; Rocha et. al., 2003). According to Kelessidis (2007), the environment is very hostile and challenging for the drilling industry, characterized with high pressures and high temperatures, hard rock, and presents severe wellbore stability problems.

There is an increased pressure on the drilling business to develop better, faster and cheaper drilling methods and well construction. Since the turn of the twentieth century, rotary drilling has been the dominant technique for well production in the oil and gas industry. According to a study conducted by the Gas Technology Institute (GTI) in 1995, 50 % of the well production time is spent on making the hole, 25 % on tripping, and the rest of 25 % on casing/cementing (xu et al, 2003). Hence, any cost savings or cost overruns on the other hand will significantly affect the entire field development budget. These challenges have fuelled the emergence of new improved technologies for optimised drilling and current advances in drilling engineering.

This paper presents a number of ongoing advances in drilling engineering with a focus on well designs. A brief explanation of the principle behind these advanced well design technologies is given, followed by their applications in today's challenging oil and gas business.

Well design encompasses every step taking to meet all challenges and scenarios anticipated during drilling of a well. The purpose of the design is to draw up drilling systems, tools and equipments that will help the driller achieve the drilling objective which is to drill cheaper and more reliable wells. Hence, a suite of programs will be required, including mud program, bit program, well path design, casing program and cementing programs.

The challenges experienced in well design include;

1. Design input data can be inaccurate thus leading to poor prediction of downhole conditions.
2. Poor communication between the rig site crew (most times less literate) and the desk engineers providing the designs.
3. Even with good mud designs, hole problems traceable to wellbore instability (pack-offs, stuck pipe, shale swelling, bit balling, etc) continue to surface.
4. The many and varied technologies available to assist in drilling complex wells are often underutilized.

In light of the current workloads imposed on today's drilling engineers and well supervisors, there is little or no time to study develop and implement the most "fit for problem" technologies in drilling activities.

Managing drilling problems require understanding how practices and technologies can improve the risk profile and add value. The objectives of this research are;

1. Conduct a study with the mind to identify newly improved and emerging well design technologies
2. To provide well engineers a summarized outlook on current technology trends thereby simplifying the task of searching for these information
3. Present innovative well planning process that will aid drilling engineers to reduce non-productive time during drilling operations, improve safe and effective well delivery from start to finish, and manage well costs more efficiently

Because multiple resources exist that detail the workings of these technologies, this article provides only a brief description for review (Al-Umran, et al, 2008; Jianhua, et al, 2009 and Nas, et al, 2009).

Drilling with Casing (DWC)/Drilling with Liners (DWL)

DWC and DWL are applied methods and key technologies to manage drilling hazards. This method of hazard management can be deployed to reduce risk in many hole sections or casing sizes and is a relatively simple, safe, and inexpensive insurance when drilling through trouble zones.

Connection time savings equate to 12 %, assuming 3.5 minutes for 90 ft drillpipe and 5 minutes for 40 ft casing with on-bottom rate of penetration (ROP) of 50m/hr. At 100m/hr ROP the saving increases to 18 % (Figure 1).

Managed Pressure Drilling (MPD)

Managed pressure drilling (MPD) is an advanced form of primary well control usually employing a closed and pressurized circulating drilling fluids (mud) system (Appensix A1), which facilitates drilling with precise management of the wellbore pressure profile.

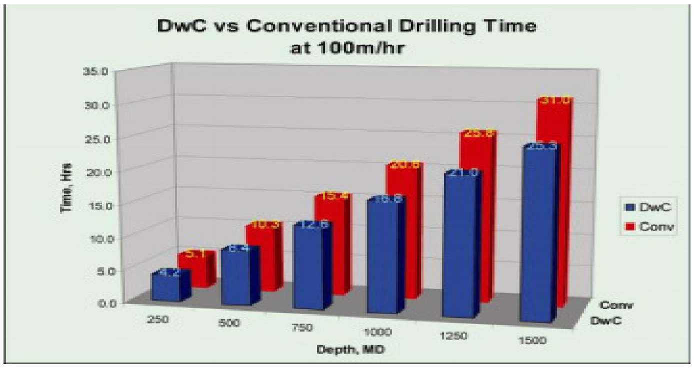

Figure 1. Comparing conventional drilling with DWC at 100m/hr(After Pritchard, 2011)

MPD design enables drilling with a closed and pressurized circulating fluids system. At the minimum, a rotating control device (RCD), drill string non-return valves (NRV), and a dedicated choke manifold are required. (The rig's existing choke manifold should not be used as a drilling choke. Its role must be reserved for conventional well control.) This minimum system enables the drilling decision-maker to view the whole of the circulating fluids system as one may a pressure vessel.

Amounts of surface backpressure may be applied as needed to prevent continuous flow of reservoir fluids to surface while drilling. When drilling with an essentially incompressible fluid, surface backpressure has an immediate impact on the wellbore pressure profile.

The equivalent weight of the mud in the hole at the time is thus determined:

Circulating (dynamic), $EMW = MW_{HH} + \Delta AFP$

Not circulating (static), $EMW = MW_{HH} + \Delta BP_{SURFACE\ BACKPRESSURE}$

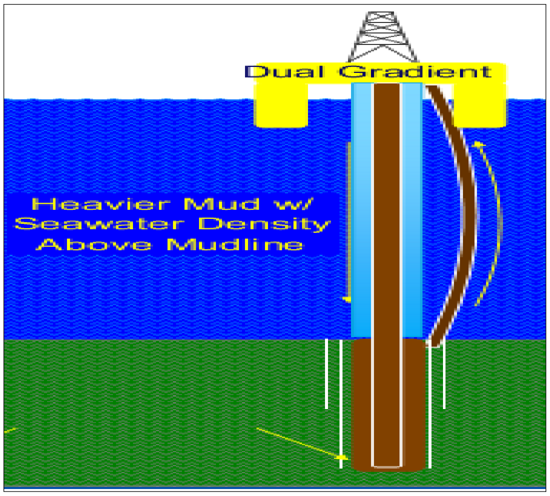

Figure 2. Dual-gradient technology application(After Cox, 2010)

The ability to add varying amounts of surface backpressure when not circulating, that amount being roughly equal to the circulating annular friction pressure (AFP) when the last stand was drilled in, adds an important element to the equation. It also allows drilling nearer balanced.

Dual Gradient (DG), with or without a marine riser, is a variation of MPD applicable to depleted formations and to avoid grossly overbalance associated with a tall column of annulus returns in deepwater riser systems. Hydraulically speaking, DG tricks the well into thinking the rig is closer than it is; removing some of the weight of mud and cuttings, creating two or more pressure vs. depth gradients via injection of light liquids, subsea pumps, down - hole pumps, or combinations thereof in annulus returns path (Figure 3).

Solid Expandable Systems (SES)

Solid Expandable Systems (SES) were initially developed because of a need to reduce drilling costs, increase production of tubing-constrained wells, and to enable operators to access reservoirs that could otherwise not be reached economically. In downhole applications, solid expandable technology reduces or eliminates the telescopic profile of the wellbore (Figure 3). In the open hole, the technology extends casing intervals in preparation for drilling through trouble zones or when an unplanned event in the wellbore requires sacrificing or compromising a casing point as designed in the drilling plan.

GEOMECHANICAL WELLBORE STABILITY MODELLING

Geomechanical wellbore stability modelling is probably one of the most recent and most effective well design principles today. Oil companies are massively embracing this new concept to ensure optimal mud weight prediction and prevent hole pack offs or collapse and well trajectory.

The first step here is to develop a model that represents rock behaviour under load due drilling activities as well as tectonic activities. Conventional well design considers the two boundaries for mud weight window to be pore pressure (lower bound) and fracture gradient (upper bound). The problem with this model is that it does not account for rock behaviour or failure criteria. While this procedure will prevent loss circulation and kicks, the mud pressure is not enough to prevent hole pickoffs which are as a result of the in situ stress state of the rocks. However, with geomechanical models, a new lower bound for mud weight is predicted to cater for hole instability. The result is reduced NPT, caused by hole problems such as stuck pipe, breakouts, wash-outs and caving.

Applications

Drilling with Casing

DWC eliminates other NPT involved in operations such as reaming, circulating high viscosity pills, conductor cleanout runs, etc. Figure 3 shows an example of flat time reduction.

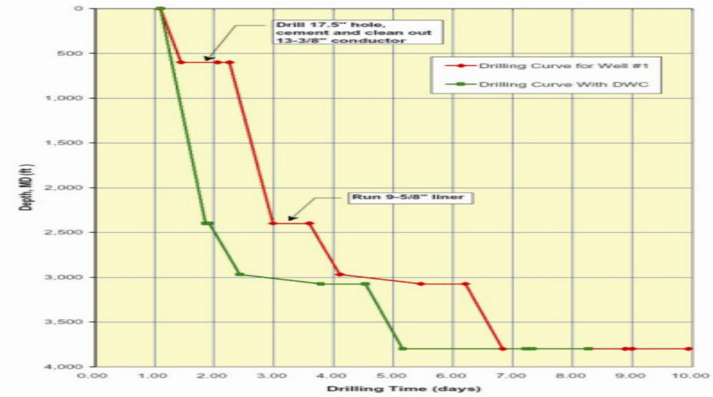

Figure 3. Reduced Flat Time due to DWS systems (After Pritchard et al, 2010)

There are other potential savings from unscheduledevents, for example, hole collapse. Typical total time savingsfrom DwC range from 30 % to 50 % of the time from section spud to leak-off test. Results published by Gaurina-Medimurec (2005) on the subject of casing drilling are shown in figure 4. A five well pilot program was undertaken as phase 1 in an effort to introduce casing drilling technology at Lobo. The objective of these first wells was to determine if casing drilling technology could deal effectively with the specific issues encountered at Lobo to reduce overall drilling cost. Performance on

These five wells steadily improved and matched that of conventional drilling by the time the last well was completed. This occurred even though there was obviously considerable room for further improvement in casing drilling system. The phase two program proved that casing drilling could eliminate the formation related trouble time experienced with conventional rigs. This allowed additional wells to be drilled that would otherwise be uneconomical. The wells were not drilled trouble-free, but the trouble was associated with the mechanical equipment limitations as shown below. These mechanical problems can be fixed, as opposed to the formation related problems that are encountered when drilling with conventional rigs. In fact, solutions to most of the problems that caused lost time in phase two have already been implemented.

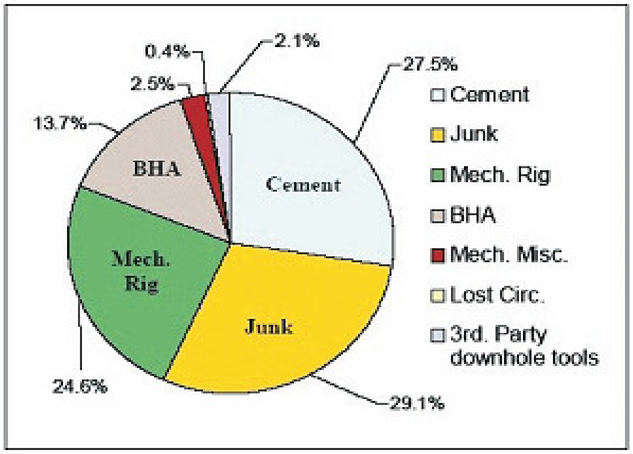

Figure 4. Trouble time for phase two casing drilled wells - improvements from casing drilling (After Guarina-medimurec, 2005)

Geomechanical Wellbore Stability Modelling

Geomechanics applied to well design will ensure wellbore stability and hole integrity are maintained checked and improved on. Figure 5 below shows improved well design achievable by this procedure. For the well shown below, the previous design was of the conventional method. The result is that the mud window for the second casing was too narrow - almost like a straight line. This means hole problems are bound to occur at this depth. Tool loss, stuck pipe, side tracking and other drilling problems can be anticipated and no same well engineer goes into drilling with such a bad design. However with the help of geomechanical modelling a new profile was generated which offered better mud weight design window and thus better and faster drilling.

CONCLUSIONS

At the end of this review, it is observed that all drilling operations have risk that can never be fully eliminated but it can be mitigated and managed. The key to mitigating and managing risk lies in understanding the importance of the stage-gated planning process, developing

SMART objectives, acknowledging and defining possible uncertainties and risks applied to practices and technologies.

Well design is an all encompassing procedure; excellence in performance is a multidisciplinary responsibility.

Complex wells require multi-disciplinary alignment to ensure and sustain performance. Aligning objectives is necessary and critical to managing drilling hazards and achieving successful well execution. All disciplines must understand the trade-offs of their requirements and how the uncertainties of the earth model influence risk management and therefore the well design.

Attaining success with well designs depends on a cognizant and deliberate recognition of the project's risks. If executed effectively, the process yields a comprehensive awareness that provides a foundation to not only mitigate and manage risk but optimize operations. The basic premise of advanced well design is to eliminate, reduce, or prepare for risks and hazards by following a distinct process. The risk assessment process should be applicable to and conducted for any operation. The process implemented should be used to critically challenge each facet of the well design.

In the final analysis it is important to understand how practices and technologies can improve the ability to mitigate and manage risk and improve the ultimate value of the well. Any mitigant must decrease the likelihood of the occurrence of any hazard. The risk profile and risk-adjusted cost should be financially beneficial to the overall operation. Well design begins with well planning and excellence in performance is dependent on successfully applying new technologies to manage risks.

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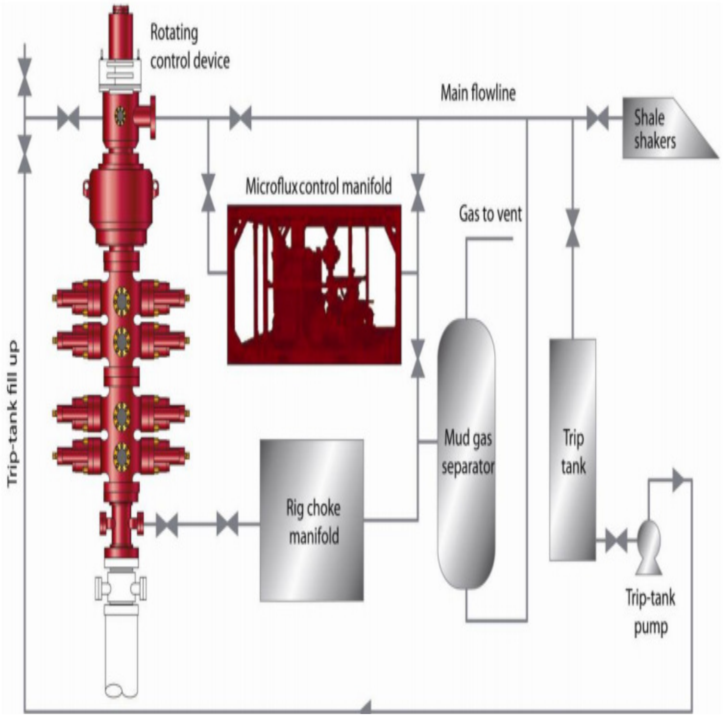
APPENDIX-A

MPD SET UP



Appendix A. (After Pritchard, 2011)