Analysis and Discussion of Drilling and oil Well Completion Operations

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Abstract

Drilling is one of the stages of oil exploration, carried out after the prospecting phase, and involves all the operations done since the beginning of the well to its delivery, (to the production team). The objective of this study is to analyse and characterize exactly the major processes performed during the drilling of an oil well. These are processes that involve a high investment and financial risk, where safety and efficiency are key words and crucial for an economic viability. The correct sizing of these processes, the way they are guided and run, become the key to a drilling´s success. It is in this context that the analysis of procedures and the operational issues relating to these processes, become extremely important for the oil industry, and for society, since oil is the main source of energy today, contributing to the formulation of best practices and improvement of the drilling technology. For a better understanding of all operations, the main equipment used in the drilling of a well is, covered first, and only after, drilling operations are properly mentioned. The drilling program and the completion of a well is, presented at the end, which describes in detail all operations, including how to proceed in case of the abandonment of a well.

Key words: Well, Oil industry, *Drilling* operations, Safety, Efficiency, Completion.

1. Introduction

Oil plays a vital role in the development of day-to-day societies, being, considered as the main strategic product of today's global energy. Due to the continuous development of society, the demand for energy is increasing, resulting in the need to explore and produce more and more. It is in this context that the oil industry is a strategic sector in the fundamental functioning of modern economies. The problem is that, with this increased consumption, more accessible oil reserves are depleted at a fast pace and it becomes necessary to explore new areas where the complexity and the risk of operations are larger, requiring knowledge, technologies and personnel. There are also further questions about the impact caused on an environment, which makes the challenge of the oil industry to not only overcome the structural complexity of the areas explored, but to also be, produced in a sustainable way. Thus, the analysis of operations conducted during the drilling of an oil well is extremely important, and contribute to the improvement of the technology used and the implementation of best practices in future operations.

2. Rotary Drilling Method

The rotary method consists in lowering into a well, animated by a rotation movement, a drilling string that has, at its end, a steel drill. The drilling is, accomplished through the rock's formation by the combined movement of the rotation of the drill bit and from the weight on it, compressing the rock, causing its fragmentation.

This primary purpose is to bring to the surface the cuttings generated during a drilling. A fluid is, then pumped inside the drilling string, known as drilling fluid, which, through holes at the end of the drill bit, returns to the surface through the annular space between the drill string and the walls of the well, carrying with it the cuttings, as it can, be seen in Figure 1.

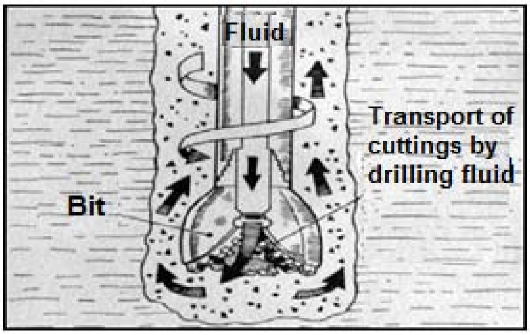

Figure 1- Rotary Drilling Method (http://stochasticgeomechanics.civil.tamu.edu/efd/Definitions.html).

As the rock is, being fragmented and the generated cuttings removed continuously from the fluid flow, the advancement of the well commences. The rotary drilling is a process that requires a lot of energy. Part of this energy is transmitted mechanically to the drill in the form of rotation and the other in the form of weight, being this, the principle of perforation.

The weight transmitted to the drill results a lot from the constitution of the drill string. The whole drill pipe and the drill bit thus, constitute it. The drill pipes, usually from steel, have a box (tool- joints) at one end and at the other a threaded pin, which allows it to be, connected to each other. There are, basically, three types of drilling pipes: the drill collars, the heavy weight drill pipes (HW) and the drill pipes, each of which, performs a specific function in the drilling string. The drill collars are the first to be, placed on the drill bit and are responsible for supplying most of the compressive load in the form of weight.

The drilling string, combined with the transferring weight and the rotary motion, is the responsible piece for the fragmentation of the drilled rock. Generally, the drill bits are, formed by the body frame cutter (determines the application of the drill, being for softer or harder formations) and the preferential jets or channels that allow the flow of the drilling fluid and the cleaning of the bottom of the well, as it is drilled. As it pierces the drilling string, it is removed, and a steel casing string with a diameter smaller than the drill is lowered and cemented in the well between the annular space of the casing string and the borehole wall, allowing the advancement of the drilling in safety. Then the drilling string is, introduced again into the well, and the process is, repeated until reaching the final depth.

3- Drilling rigs

A drilling rig or a drilling platform is the framework to drill wells, ensuring access to reservoirs and responsible for storing most of the equipment. Regarding the location of the operations, these probes can be, classified into two types: land rigs, designed for onshore, and, offshore rigs destined for offshore operations. The drilling rigs are classifated by marine and land drilling. In Figure 2, there is a schematic illustration of the classification of rotating probes.

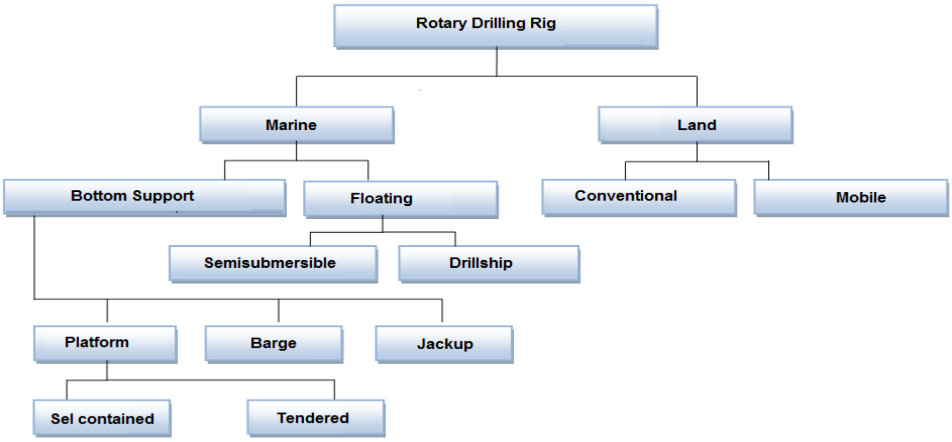

Figure 2- Classification of rotary drilling rig (Adapted from Applied Drilling Engineering, 1986).

3.1- Basic rig components

Drilling rigs, whether for land or sea, have the same basic drilling equipment. Therefore, the responsible equipment for each function in a rotary drilling rig is, grouped into components called "systems of a probe." Figure 3 illustrates the basic equipment of a rotary drilling rig.

The main systems of a probe are system load-bearing, material handling system, rotary system, fluid circulation system, monitoring system, surface security system and the system of generation and transmission of energy. The fluid circulation system is also responsible for the maintenance and treatment of fluids.

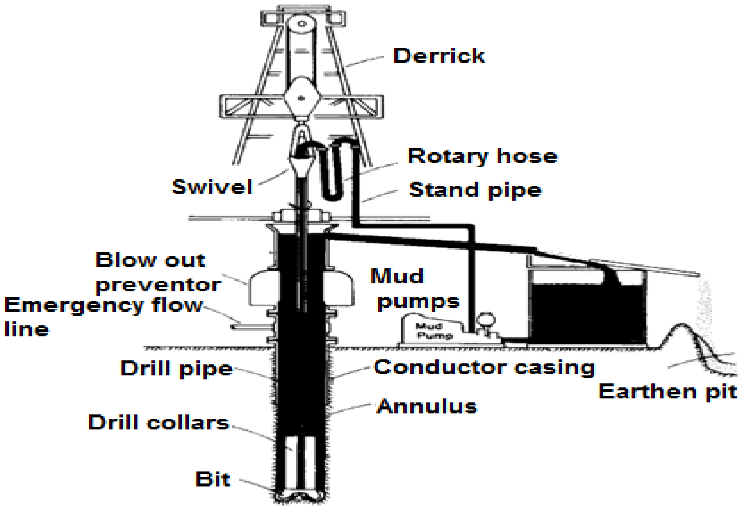

Figura 3- Basic drilling rigs equipments (Applied Drilling Engineering, 1986).

4. Drilling operations

4.1. Drilling fluids

Drilling fluids are complex mixtures of solids, liquids and gases, consisting of a disperse phase and the other dispersed. According to the American Petroleum Institute, 1991, the term drilling fluid can be, defined as a circulating fluid used to make viable, the drilling activity. Must be, designed and formulated for an efficient performance under changing conditions of the well. A drilling fluid system properly designed and formulated performs the following functions:

• Remove and transport the cuttings from the well to the surface, as well as ensuring its suspension during the interruption of a circulation;

• Support and stabilize the walls of the well;

• Allow to cool and lubricate the drill bit and the drilling string;

• Coat the walls of the well with a mud cake that acts as a waterproof seal on the permeable formations;

• Prevent or minimize damage to the production formations;

• Allow to obtain maximum possible information about the formations traversed;

The main criteria for the classification of the drilling fluids is, based on the primary contributor of the continuous or dispersant phase. In this criteria, fluids are, classified as being water-based mud (fresh or salt), oil based fluids, air fluids and synthetic base fluids. The oil-based fluids have a large environmental impact and as the water-based fluids and synthetic have less environmental impact, they are currently the most used. The gas-based fluids are, used only in special circumstances.

4.2. Cementation

As it is not possible to formulate a fluid that meets all the needs of the well, during drilling, the well passes through a casing process in which casings with decreasing diameters are introduce and cemented at various depth intervals. The dimensions of the well (casing) depends on several factors, including the depth of the well, temperature and pressure formation, type of formation, among others. The cementation is the main operation involved in the casing process of a well and can be, classified into two types: primary cementation and remedial cementation. The primary cementation is the work of the cementing casing strings, conducted shortly after the fall of these into the well, being the main operation for its structure. The cement is, pumped through the interior of the casing string and then is, shifted to the annular space between the walls of the well and the casing, through cementing mechanisms mounted onto the well. In figure 4, the main equipment used in primary cementation is illustrated.

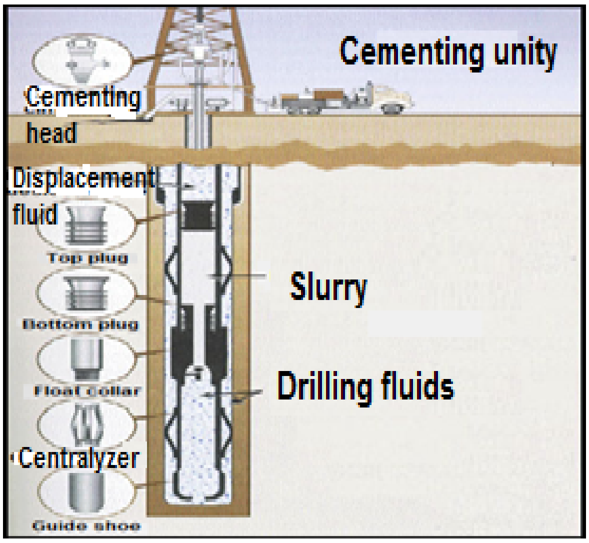

Figura 4 - Primary cementing equipment.

The drill string is, removed from the well and, once the cement paste is, prepared, all the equipment is, installed and the cementing team, then, launches the bottom plug into the casing. Immediately afterwards, the cement paste is pumped and the bottom plug separates the drilling fluid from the paste. As the cement slurry is pumped to high pressure, it pushes the bottom plug down until it rests on the float collar. The bottom plug has a hollow membrane at its centre, and when it rests over the float collar, the membrane ruptures due to continuous pressure of the pump in the cement paste, allowing the cement to pass through it and through the guide shoe going to the annular space. The cement continues to enter, and when it is all pumped, the team releases the top plug, pushing it, under the casing by a displacement fluid which is pumped immediately afterwards, allowing the remaining cement to be pushed to the annular space. The top plug wipes the remaining cement in the interior of the casing, and separates the cement from the displacement fluid. The top plug is, pushed until it rests on the float collar, on top of the bottom plug. Because its inside is massive, it prevents the passage of fluids, giving a rapid pressure increase in the pump, thus, signalling to the operator that the job is completed and turning it off. As the pressure in the annular space is greater than the pressure inside the casing, the cement tends to return to the interior of the casing, so, a valve in the guide shoe acts to keep the cement in the annular space, preventing its return to the interior of well. Depending on the conditions of the well and the type of cement used, generally, the cement paste hardens within 12 to 24 hours.

The main objectives of a primary cementation are: 1)To seal and provide additional support to the column casing and to the walls of the well, preventing the formation to collapse throughout the drilling process; 2)Prevent the flow formation fluids into the well, that is, isolate the well from the formations; 3)Provide separation of formations behind the casing, preventing or restricting intercommunication of fluids between them; 4)Quickly form a layer that prevents the loss of circulation; 5)Protect the casing and slow corrosion by minimizing contact between this and corrosive formation waters; 6 Prevent contamination of freshwater zones.

Generally, secondary cementation is, performed to correct problems in a primary cementation. The decision as to whether or not correct a primary cementation, is, a task of great responsibility, which, requires so a lot of technology, engineering and operational experience. As to the primary cementation, it is, often performed when conditions are not well known. When there is no control of the well, or, when the lost time in the rig or increased costs, force economic decisions of high risk (drilling handbook), especially in the case of offshore wells, in which the daily cost of a probe is quite high.

4.3- Coring

Coring operations are, designed to obtain representative testimonies of formations. According to the API, its main purpose is to obtain information to evaluate the potential production of the well. In the oil industry there are two methods of coring: coring while drilling (bottom coring), and after coring drill (sidewall coring). At the bottom coring, the procedure is similar to a normal drilling, but instead, in the drill bit, fits a crown coring, which, as it drills, lets a formation cylindrical buffer to pass inside it. This buffer is, housed in a space sampler connected to the drilling string and subsequently retrieved at the surface. The rod sampler consists of a sampler, which is a steel tubular device, comprising an inner tube suspended by, a swivel, assembly within an outer tube connected to the drilling string at its upper and a crown or coring drill at its bottom. The inner tube has at its lower end, a mechanism for retaining the sample, the core catcher, which houses the sample.

A sidewall coring is performed using tools (Figure 5) lowered into the well (usually by means of cables), which allow drilling the formation walls and sample with hollow projectiles. The samples are, embedded in the projectile, which are stored in a main device. To make its recovery, the tool is, pulled to the surface. This type of coring has, been developed with the aim to obtain well samples previously drilled. The selection of a particular method will depend on the formation, hiring, and the objectives outlined in the coring program.

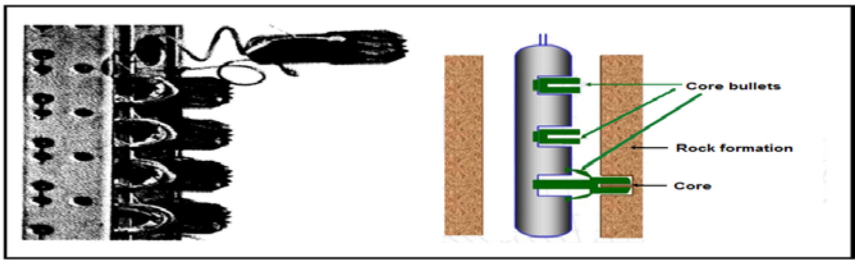

Figure 5 - Sidewell *coring* device. (Adapted from http://www.spec2000.net/09-corepore.htm).

4.4. Well completion

The completion is the process of transformation of the well in a production unit. Its classification is, based on the arrangements made. From this criterion, the methods of completion are, classified as the production casing (interface between the column and the reservoir) and the number of zones completed. Regarding the production casing, the completions can be at an open well, with, a perforated casing and with a torn liner or perforated. As for the number of zones completed, they can be simple completions, double or selective. This last rank refers to the number of zones obtained and the quantity of production columns that are lowered into the well. The decision to opt for the production of more than one reservoir at a time can be, taken due to the economic comparison of the various alternatives. Thus, when finishing the drilling process, the formation is tested and evaluated to determine if the well is viable or not. If it is, then it is, completed for production. If not, the well is prepared for abandon. With some differences between onshore and offshore wells, the completion of an oil well involves the following phases:

1) Installation of safety surface equipment

This phase aims to ensure access to the interior of the well safely, installing the necessary equipment to perform the following steps. The head of production and the blow out preventer are, installed at the wellhead. In offshore exploration, the completion may be, dried, when the wellhead is, mounted on the surface, or wet, when the wellhead is at the seabed. When completion is wet, the probe is, connected to the well on the sea floor through pipes called risers.

2) Conditioning the well

At, this stage the production conditioning of the casing and the replacement of the fluid that is inside the well occurs, by a completion fluid, through, a work string, a drill and a scraper, which, are lowered into the well to clean the removing cement left by the cementation production casing. The completion fluids are special salt solution fluids, nitrogen gas or oil. Immediately before and after the conditioning of the well, pressure tests are carried out on the production casing, through own procedures to verify its tightness. If there is no stabilized pressure test and leaks are detected (holes, casing connections, etc.), a procedure to locate and correct the problem is, taken.

3) Evaluation on the quality of cementing

Tests are performed at this stage of evaluation, to infer the quality of cementation from the production casing. It is important to note that the production casing has as it, main objective, to provide a hydraulic seal between the various producer intervals, preventing the migration of fluids, extremely important factor for the production operations. There are various methods to evaluate the quality of cementation, being the most used the acoustic or ultrasonic profiles. The most common profiles are the sonic profile CBL (cement bond log) / VDL (variable density log), and the ultrasonic profiles. The physical principle involved is essentially the emission of a sound wave and its capture by a receiver and subsequent measurement. Depending on the interpretation of profiles obtained, we can decide whether there is a need for correction of cementation.

4) Perforating

After confirmed the existence of an effective hydraulic isolation between intervals of interest, the following step is the drilling of these ranges by the casing. This drilling process is, called perforation. The perforation process consists on a perforating production casing in front of the producing formation, with the aid of explosive charges, creating flow channels in the liner and the cement. It is through these channels that the drainage of the fluid is processed, contained in the reservoir, allowing oil to pass through the cement paste around the existing casing as well as its metal walls and flow into the well to be produced.

5) Evaluation of formations

At this stage, to confirm the presence of hydrocarbons and make an assessment of their productive potential, usually, the well is, put on stream, allowing data to be, obtained on the flow conditions of the producing intervals. From all the tests done, the most complete one is the formation test, from the lined well (TFR), in which, a special column is lowered into the well, composed mainly by pressure and temperature recorders, samplers, valve for closing the well at the bottom and valves for circulation. The well is usually isolated just above the interval to be, assessed by means of a packer and is then, placed in flow through the interior of the column. On the surface, the variables needed for the evaluation are measured.

6) Wellhead´s Equipment

At this stage, the production column is lowered into the well and the Christmas tree installed, which, may be conventional (ANC) or wet (ANM), depending on the type of completion. The production column is the pipe through which the oil is, produced, which, main functions are to conduct optimally and safely, produced fluids to the surface and protect the coating against aggressive fluids and high pressures. The Christmas tree is a set of gate valves installed on top of the wellhead. (The equipment from the wellhead includes head coverings and a production head). It is the device responsible for supporting the weight of the column of production, sealing the annular space between the production column and the production casing to the surface and control the flow of oil produced. Thus, as the well produces, the flow rises up the column and into the production tree, which allows control of production, opening or closing the valves.

5. Case of study: AC1 well field Piriquito, Brasil

The parakeet field accounts until today with three producing wells, of which, the first two started production in 2011. The well AC1 is a development well that aims to prove continuity northeast, from the sandstone reservoirs of the oil-bearing formation from Do Chao, and further confirm the actual seismic interpretation which reflects a slight high structural that extends NE. The target reservoirs are below Alter Formation, located at an average depth of 465m from the Do Chao formation. The Alter formation consists essentially of outcropping limestone and has an average thickness of about 269m. In table 1, we can see the geological predictions.This drilling and completion program was, divided into three phases:

In phase 1 (drilling with a root-pneumatic probe) the well is drilled to about 20m before entering the Do Chao formation. As the alter formation rocks are very hard, at an initially phase, it is not possible to put enough weight on the drill with a rotary rig, making drilling inefficient. Then, taking advantage of the characteristics of shallow reservoirs and oil (shallow reservoirs, hydrostatic pressures and dead oil), we opted for the use of a root-pneumatic probe in this first phase. Then, the well is, drilled and the conductor casing and the casing surface are lowered and cemented. After the alter formation is traversed in phase 2 (rotary drilling rig) a root-pneumatic probe is replaced by a rotary rig and the well is drilled to an expected final depth. The well is then, conditioned and a conventional profiling is performed as well as formation tests to evaluate the presence of ranges of interest. If you prove the presence of the intervals of interest, the production casing is, lowered into the well and cemented. Otherwise, the well is, conditioned for abandonment. In table 2, we can observe a summary of the design of a well casing.

Listostratigraphy Unity	AC1 TVDSS(m)	Correlation Pits	
		AC3 TVDSS(m)	AC1 TVDSS (m)
Fm. Dochao	Surface (+77,4)	Surface (+79)	Surface (+81)
Fm. Alter	-191	-191.8	-192
Mb. Alter 3	-249	-248.8	-249
Production zone Top	-387.5	-388.5	-387.2
Mb. Alter 2	-412	-413.1	-410.8
Final Deph	-460	-457	-684.5

After the cementation is, terminated, the well and its location are prepared for the next stage. Therefore, in phase 3, the well is completed and assessed following all procedures for the completion of a well, and all the equipment is installed that will ensure safe production. Finally the well is completed with tube 2 7/ 8 " (BCP progressive cavity pump). In Figure 6, we can observe the end of the well completion.

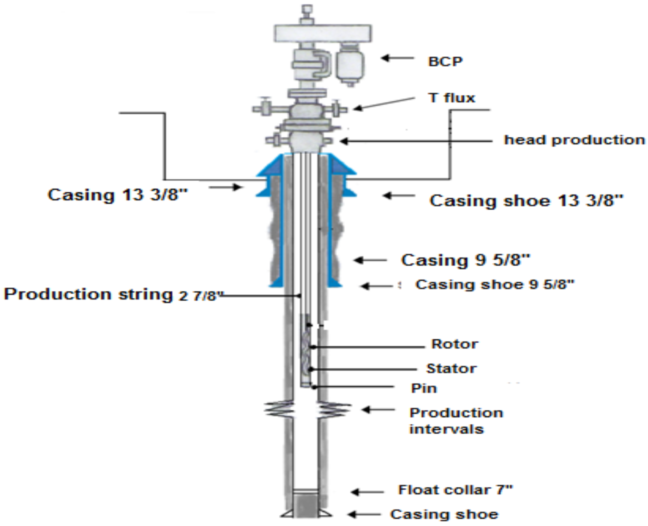

Figure 5 - *Esquema do poço no final da completação.*

8) Conclusion

Since the successful drilling of a well is, conditioned by how drilling operations are, scaled and performed, the analysis of these operations is extremely important for the oil industry. Drilling fluids are a vital part of the perforation. Are responsible for the stability of the well, and serve as a source of indication of the conditions in which it is, found. For successful cementation, apart from the well conditions, two factors should be, considered: the composition of the cement and how it is, placed in the well. The completion is crucial to the success of the production. Therefore, in the drilling of a well:

- Properties such as depth, temperature and pressure, influence the scaling operations.
- All operations performed must be, considered as critical and accomplished, taking into account, the issues of safety and in accordance with local regulations.

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