COMPARATIVE STUDY BETWEEN HYDRAULIC AND ELECTRIC BOP REGARDING RELIABILITY

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Abstract: The oil well drilling process is subject to unpredictable flows from inside the well, known as blowout. The Blowout Preventer (BOP) is a safety device used to seal the well if a blowout occurs, in order to ensure the safety and isolation of the well. This equipment works through a set of valves with hydraulic or electro-hydraulic actuation and failures are very common. Electric-drive BOPs are recent bets to improve the performance of BOPs. This work makes a comparative study of the performance of hydraulic (BOPh) and electric (BOPe) BOPs, focusing on the reliability analysis.

Keywords: Electric BOP; Reliability; Hydraulic BOP.

ESTUDO COMPARATIVO ENTRE O BOP HIDRÁULICO E ELÉTRICO QUANTO À CONFIABILIDADE

Resumo: O processo de perfuração de poços de petróleo está sujeito a fluxos imprevisíveis de dentro do poço, conhecido como *blowout*. O *Blowout Preventer* (BOP) é um dispositivo de segurança utilizado para vedar o poço caso o *blowout* ocorra, visando a garantir a segurança e o isolamento do poço. Este equipamento funciona por meio de um conjunto de válvulas com acionamento hidráulico ou eletro-hidráulico, e é muito comum ocorrerem falhas. Os BOPs com acionamento elétrico são apostas recentes para melhorar o desempenho dos BOPs. Este trabalho faz um estudo comparativo do desempenho dos BOPs hidráulico (BOPh) e elétrico (BOPe), com foco na análise de confiabilidade.

Palavras-chave: BOP elétrico; Confiabilidade; BOP hidráulico.

1. INTRODUCTION

Oil is formed from fossils that were deposited over millions of years in sedimentary rocks, both marine and terrestrial. After discovering a new oil reserve, a series of surveys is initiated in order to locate promising basins and study the best location for drilling. Then, exploratory drilling begins with the objective of locating hydrocarbons in the subsoil and, once commercial possibility has been proven, the production development phase begins. It is at this stage that the facilities are designed and built. After this step, the oil is extracted together with water and gas and, after a fluid separation process within the platform itself, it is transported to the refineries where it is later transformed into various derivatives such as gasoline, kerosene, diesel, asphalt, rubber, plastics, among others. In this way, it is possible to see the dimension of the importance of oil in society and the enormous financial value moved by this industry, which leads to a great dispute for its reserves.[3]

As the demand for new reservoirs grew, the need to study the safety of wells increased, since the fluids resulting from the reserves are highly flammable and, in addition, the drilling of oil wells also involves environmental risks resulting from the leakage of the oil.

Several accidents have already occurred in the oil industry, either due to human error or equipment failure, which are usually on account of a sequence of human failures, such as the Deepwater Horizon disaster in the Gulf of Mexico (2010), or the terrible Piper Alpha accident (1988), in which a massive explosion caused the death of 167 men. [1] The same error occurred on August 16th, 1984, when the lack of maintenance on the BOP caused the equipment not to work to prevent the death of 37 workers in the disaster at the Enchova Central platform, located in the Campos basin. [1]

The offshore oil industry is one of the areas with the highest risk of work-related accidents. The difficulty of access because it is at sea, in addition to the high risk of leaking flammable fluids, place this sector in this dangerous position.

After analyzing 20 articles focused on the study of accidents in the oil and gas industry, correlating the distribution of events to the type of installation, it was identified that oil platforms have the highest number of fatal occurrences (382), out of 9 events; then ships (204), with 2 events; and refineries (179), with 10 events. [2]

The oil and gas industry environment has characteristics that aggravate the complexity and increase the risk of lethality, such as excessive workload, noise, vibration, gases, acids, toxic and flammable vapors, (...) and, beyond that, there is the possibility of explosions, caused by gas leaks, fires, blowout (increased and uncontainable leakage of oil and gas that can occur during the well drilling), which can lead to a devastating explosion – as in the case of the Deepwater Horizon, cited above – (...), structural collapse etc. [6]

When starting the well drilling operation, it is necessary to properly use safety equipments to avoid the possible accidents mentioned above. One of the most important pieces of equipment for the safety of well drilling operations is the Blowout Preventer (BOP), a device placed at the wellhead and responsible for preventing blowout (uncontrolled fluid flow) during the drilling process.

The BOP is composed of a set of valves known as an annular preventer and slide preventer which, whenever a kick occurs (undesirable flow of fluid contained in a formation into the well), [3] acts to seal the well, preventing, this way, the occurrence of blowout. This equipment is mostly found with its hydraulic drive system. This type of drive has characteristics that are considered critical, such as: high complexity in operations, high failure rate, delay in response time, low reliability, robust and heavy model, and low availability due to frequent failures or time of maintenance.

Technological alternatives are more recently being introduced, based on an all-electric BOP control system, promising to significantly improve the safety of drilling operations [7]. The electric BOP is presented as a revolutionary proposal in which the increase in reliability and the reduction in the number of failures are the pillars of this new operating model for the equipment. In addition, complexity in operations is expected to decrease, as well as better operational security, less downtime due to failures or maintenance, faster response time, and a more compact and lightweight model.

The objective of this research is to study the impacts of this new technology, observing its improvements with focus on new reliability parameters and comparing the results of the new electrical operating principle with the traditional method used, the conventional BOP (hydraulic).

2. METHODOLOGY

Initially, a study was carried out on the operation system of the conventional BOP and the electric BOP, through review articles, research articles and patents in available databases. Then, an attempt was made to list the accidents involving the hydraulic BOP as well as the hybrid BOP, raising the main causes of failure, in addition to an analysis of the equipment's reliability.

In a later step, we aim to study the reliability methods, including: MTTF – Mean Time To Failure, MTTR – Mean Time To Repair, MTBF – Mean Time Between Failures (Average time between two failures), FMEA – Failure Mode and Effect Analysis and Functional Analysis. After this survey, it is expected to be able to propose possible improvements for greater reliability and safety of this equipment.

3. RESULTS AND DISCUSSION

When drilling a well, a slurry is injected in order to contain the pressure of fluids coming from the reservoir. For this slurry to play its role correctly, it needs to be properly calculated because, if the fluid pressure is greater than the injection pressure of the slurry, the well may collapse or fluids may emerge uncontrollably (blowout). If the pressure of the drilling fluid (slurry) is much higher than that of the well, its weight can fracture the well structures. The BOP is a safety system capable of sealing the well in the event of a blowout.

The Lower Marine Riser Package (LMRP), the structure that houses the annular preventer, is the upper part of the BOP. When the mud cannot control the flows coming from the well, resulting in the kick, the LMRP has the role of controlling the flow through the pressure exerted by the sealing rubbers in the riser, the piping through which the fluids circulate. In this way, the pressure exerted by the mud will be equal to the pressure in the formation well. As a redundancy system and for communication and commands coming from the platform to the annular preventer, two pods are placed on each side of the structure. A pod is nothing more than an electro-hydraulic subsea control. According to API 2012, every BOP must contain 2 pods, one on each side, capable of performing all BOP functions. [8]

When the annular preventers are not able to contain these flows, the second part of the BOP is triggered. It is popularly known as the BOP stack. The BOP stack is composed of a set of valves and drawers that have the function of sealing the well and, if necessary, definitively cutting the connection with it. The tube drawer has the function of closing the space around the drill string. The blind drawer closes this space when there is no drill string. The shear drawer is intended to cut large diameter tubes. Finally, we have a blind shear drawer that, in addition to cutting the pipe, seals the well. In short, the sealing process using the BOP stack consists of positioning the drawers towards the tube, crushing it and then shearing, breaking the contact with the well. [11]

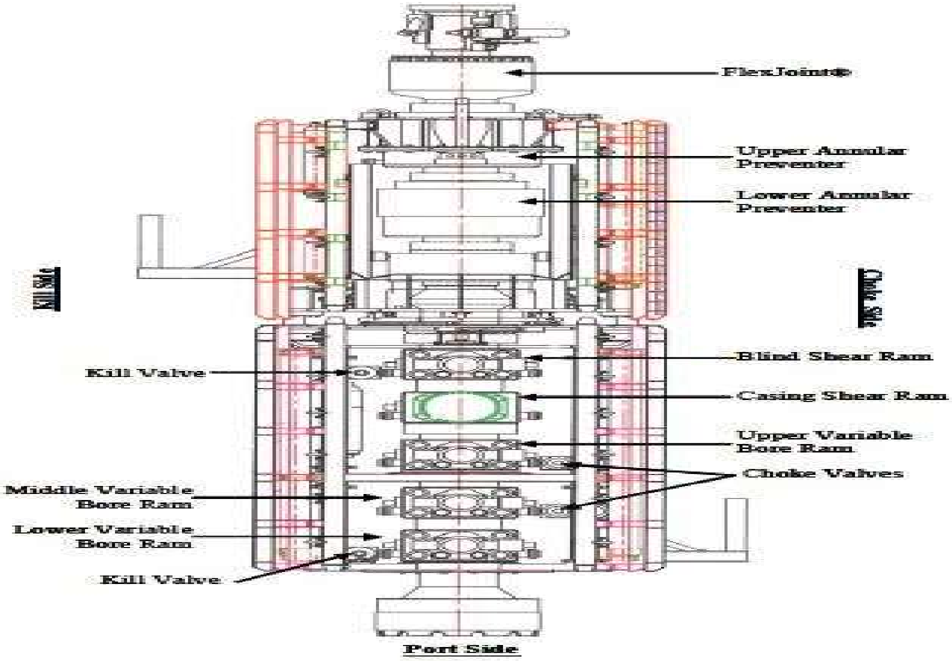
The accumulators have the purpose of supplying the drawers through hydraulic fluids with the necessary force to close them. According to API STD 53 and API RP16E standard, the minimum acceptable of the Annular BOP Control System is 60s and all units must operate within the maximum period of 45s. [9,10]

The Control System is managed by a BOP operator. The control panel is usually located in the Platform's control room. In case of failure, the equipment can be activated through the ROV or through the acoustic control. [8]

This equipment is mostly found with its hydraulic operating system, which brings with it some key points that affect its performance, such as: high complexity in operations, high failure rate, delay in response time, low reliability, robust and heavy-duty design, and high downtime due to failure or maintenance. These equipment, which act based on total or partial hydraulics, are unable to meet the API STD 53 and API RP 16E standards, on account of the long communication path of the hydraulic fluid between the offshore platform and the BOP stack at high depths.

Figure 1 shows how the hydraulic BOP structure is divided [13]:

Figure 1 Blowout Preventer



These operations involve a lot of complexity, risk and cost. An error or failure, whether caused by the equipment or by human action, can lead to successive failures, causing a major disaster to occur. For this, the BOP has redundancy systems in order to guarantee the success of the operation. However, many equipment do not work according to what their structure foresees.

After analyzing about 48 drilled development wells, it was found that more than 50% of the BOP failures came from the Main Control System and about 7 to 11% of the failures are caused by the connector, the preventers and the entire System that compose it. Another point that the article addressed is that many BOPs, culturally, operate at the System's edge. For example, from the BOPs that were evaluated, 26 had only one annular preventer in operation, while the norm foresees that the two annular preventers must operate. [12]

With the electric BOP, instead of using hydraulic accumulators to provide the necessary torque to actuate the drawers, electric actuators powered by a battery bank do this job. One of the benefits of accumulators is the ability to transmit large amounts of torque, as the equipment requires.

With the advancement of technology and through sealed packages capable of withstanding high pressures, it is totally possible to size and produce actuators and their battery bank capable of producing the necessary force to make the drawer operate. This set can be external to the BOP, connected only by an electrical connector already easily found on the market, making possible the reality of a less robust, lighter and, consequently, cheaper equipment. In addition, it will provide a much faster response and improve safety for underwater drilling. [8]

Alternatives to electro-hydraulic preventer technology have been developed, based on a fully electric BOP drive. The objective is to increase reliability and reduce the number of failures, and these are the pillars of this new model of equipment operation. Also, it is expected that the complexity in operations will decrease, as well as better operational security, less downtime due to failures or maintenance, a faster response time and a more compact and lightweight model.

Table 1 shows some comparative parameters between the electrical and hydraulic system:

Table 1 - Synthetic comparison between hydraulic BOP and electric BOP.

Hydraulic/Hybrid BOP (BOPh)	Electric BOP (BOPe)
Hydraulic working principle	Electrical working principle
High complexity in operations	Less completeness in operations
High failure rate	Less prone to failure
High downtime	Less downtime
High response time	Fast response time
Low reliability	Greater reliability
Robust and heavy model	More compact and lighter model

In addition, the application of this new technology will bring security and functionality that BOPh has not been able to bring during all these years. Operations such as maintenance and repairs on the hydraulic BOP can lead to stoppages that can last for months, due to the difficulty in emerging the equipment due to its weight, as well as a difficulty in repairing due to the high structural complexity of the equipment. The communication and hydraulic drive path usually suffer losses, which results in a delay in the response time, implying in non-compliance with the maximum operating time stipulated by the regulations. With this, the chances of failures increase drastically, thus increasing the risk of an accident involving human, animal and environmental life. [12]

The reduced size and weight, as well as the communication channel and electrical drive efficiently alleviate these problems. Advances in technology have allowed the production of motors capable of producing large amounts of force, which means that the drawers are activated in a time shorter than the normal limit.

The electrical working principle brings with it numerous benefits for the industry. It is known that well drilling operations involve a great risk, whether human or environmental. BOPe has the ability to follow all the technological evolution that industry 4.0 brings nowadays. The ele8ctrical concept opens a wide range for a much more effective backup and redundancy system, making it possible to apply the idea, for example, of the IoT (Internet of Things), which would allow the activation of the equipment from anywhere.

The new electric actuator should reduce the number of failures, response time, maintenance cost, energy losses and consumption, weight and volume and the environmental impact that the hydraulic system produces. In addition, it should increase the interval between maintenance and system reliability, increasing the competitiveness of industries that will use this equipment.

Based on tests and published literature, it is possible to affirm that the BOPe is a revolutionary investment, making it necessary, in view of all the dangerous and risky scenarios found involving the BOPh, and effective for the oil industry.

4. CONCLUSION

In this work, a study was carried out on the operating characteristics of conventional and electric BOP. For this, articles were raised in the literature that address the functioning of the BOPs under study, as well as the main reasons that lead to failure, in addition to the systematic analysis of the reliability of the equipment involving the analysis of downtime, as well as reliability parameters.

It is intended, at a later stage, to carry out a study on the reliability of the electric BOP so that, then, these data can be compared with the data obtained on the conventional BOP and, based on the results, it will be possible to define which one has the best reliability in operations.

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