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Optimization of well design and bit selection to reduce drilling cost and improve efficiency

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Abstract

Drilling oil and gas well at the lowest possible cost has always been paramount to drilling engineers in order to achieve their company's objectives. However, in most cases, this is not attained because of the problem associated with the drilling bit selection, drilling design and drilling parameters. As it is a fact that the large chunk of the cost of bringing oil and gas to the surface is always incurred at the drilling/completion stage. In this study, data were gathered from selected 5 Niger Delta wells and were analyzed. These data were used to calculate the costs of drill bits and the bits with lowest costs. The drilling cost was studied and optimization procedure employed to select the best bit from well data obtained. Bits RSS1, RSS2, RSS3, RSS4, GX1 and BX1 that were used to drill, were select for this study. Drilling cost relation was to ascertain the most cost-effective one. Drilling with bit RSS1 showed the lowest cost possible, therefore RSS1 was said to be optimized. In consideration of the drill bit specific energy (SE) with respect to the ROP, RSSI showed a low value, indicating minimal energy requirement for the successful drilling operation.

Conclusively, the SE is a function of ROP and ROP was highest at the minimum SE. Optimized where the drilling cost was minimum.

Keyword: Drilling Cost; Design; Specific Energy; Drilling Parameter; Cost-Effective; Completion

1. Introduction

As the search for oil and gas moves from shallow waters to deep and very deep waters, the cost of drilling a well and in vestigating reservoirs has gone up significantly. To provide investors more confidence to boost output and satisfy our energy demands, there has been a daily increase in demand for more cost-effective well design and operation in terms of choosing the correct tools and equipment. Therefore, the majority of businesses today have always sought to identify deep areas for improvement, which helps to position them as concerned partners in the larger endeavor of constructing a route from the earth's surface to the targets underneath it. There is a persistent demand to reduce expenses without compromising the caliber of services provided in the field. There are a number of ways to do this, but for the purposes of this project, we'll focus on one of the most important approaches, which begins with planning, to reduce drilling costs. This can only be accomplished by examining the most economical and efficient method of drilling a well. This entails, for the oil sector, lowering the possibility of exceeding budget because of "unforeseen events," subpar operations, or inadequate protocols, as well as, of course, refraining from risky behavior.

The overall cost of the well is significantly influenced by the well's design. At this point, competence is required to examine all the elements involved in obtaining a well-crafted technical proposal and a well-executed well plan. Furthermore, a thorough grasp of a formation's geology can aid in improving well design by identifying the safest route to the desired destination and easing the financial and safety load on the client. The horizontal well, which helps to

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maximize exposure by penetrating the target from the reservoir's heel to its toe, is one of the priciest wells available today. This kind has very high related costs, such as longer drill pipes, longer strings, the potential need for electronic instruments, longer rig days, larger footage, higher cementing operation costs, etc. By optimizing horizontal well design, costs can be significantly decreased by having shorter footage and arriving at the shortest pathway, which lowers the well's cost per foot [4]. The same well design expertise should be applied to deviated wells so that the trajectory's kickoff-point and other significant points are as efficient as possible [1]. In order to satisfy the customer, the Bottom Hole Assembly should be suggested. Additionally, the well survey program should be as precise as possible in order to provide a small

Drilling must be done in a cost-effective manner in order to develop an oilfield [8]/ Oilfield drilling operations will therefore have to overcome obstacles in order to lower total costs, improve performance, and lower the likelihood of running into issues. Drillability of rock is seen to deteriorate as hole depth increases in oil well drilling [2] Since variations in differential pressure have a substantial impact on drilling rate, the increasing complexity of drilling operations has led to a number of issues and crucial cost considerations [7,9]

These days, drilling operations employ a variety of techniques from several disciplines to produce well construction that is economical, safe, and environmentally friendly [8].

The study area of optimization of well design and bit selection for drilling cost reduction and improved efficiency in the Niger Delta region involve various aspects of oil and gas exploration and production. For this project, the focus is on Assa North and Gbetiokun area of Niger Delta.

2. Methodology

Well data were gathered from some drilled wells in Niger Delta in Nigeria thus, the names of the fields are:

2.1. Assa North Field

The Assa North field, also known as Ohaji South, is situated in the northeastern region of SPDC-operated OML-21 and crosses over into neighboring, non-SPDC-operated OML 53. The distance from Port Harcourt is 70 kilometers to the northwest. ASSA-001 made the discovery of the field in 1961, and since then, five further wells (ASSN-001, ASSN-002, AGGA-002, OHAS-001, and OHAS–002) have been drilled into the structure. The field is made up of a series of stacked reservoirs with shoreface and channel deposits in them. Nine of these reservoirs—found in the D02, H, and E sands—are hydrocarbon-bearing. H1000X and H4000X are the primary reservoirs, containing more than 80% of the hydrocarbon volume in the field. Six development wells will be drilled in the first phase, two in the H4000X reservoir and four in the H1000X reservoir. One of the two crestal wells intended to develop the H4000X reservoir is the H4D1 well. Anticipated ultimate recovery from the H4D1 (ASSN 003) well is estimated to be 152 Bscf of gas and 29 MMstb of condensate, with an estimated well potential of 70 MMscf/d. Drilling has already taken place on ASSN 004, 005, and 006, and ASSN 006 is currently being completed for production (SPDC End of Well Reports).The Assa North and Ohaji Southfields are expected to contain reserves of 4.3 trillion cubic feet (Tcf) of gas in addition to 215 million barrels (Mmbbls) of condensate (NS Energy, 2023).

2.2. Benisede Field

Nigeria's Bayelsa state is home to the Benisede Upstream Field. Nigerian Agip Oil Co Ltd (5%), NNPC Ltd (55%), The Shell Petroleum Development Co of Nigeria Ltd (30%), and Total E&P Nigeria Ltd (10%) are the owners of the upstream field. The Shell Petroleum Development Co of Nigeria Ltd. is in charge of running it. Operations for the project began in 1976 (NNPC Archives, 2015). Name, resource type, asset status, stage, owner and equity stakes, operator, product specifications (gravity, CO2, sulfur), location, and key operational data (production, start and end years, reserves, and capital and operating costs) are among the fundamental details included in the Benisede Upstream Field profile. Along with pertinent news, agreements, and contract information, we also offer proprietary estimates of production, capital and operational expenses, and other important economic indicators.

2.3. Gbetiokun Field

OML 40 is situated southeast of Gbetiokun Field. Gbetiokun-1 found the field in 1987; SPDC drilled it; and four wells—Gbetiokun-2 (SPDC), Bime-1, and Bime-2 (Chevron)—drilled in 1990–91, further evaluated the field. With the re-completion of the Gbetiokun -1 well by Elcrest/NPDC JV, the Gbetiokun field produced its first oil in July 2019. Between 2019 and 2021, seven more wells (Gbetiokun-3 to 8) were drilled in the field, bringing the asset's output from zero to an all-time high of 17,000 bopd in December 2021. By the end of 2021, cumulative production is expected to be 6.36

MMbbls. The 22,000 barrels per day early production facility processes crude into a storage vessel. It is then evacuated by shuttle barge to the Benin River Valve station, where it is pumped into the export pipeline to the LACT Unit in Otumara, and from there to the FOT.

2.4. Drilling Cost Optimization

2.4.1. Cost Per Foot Method

The cost per foot technique was adopted to ascertain the most effective bit used as seen in equation 1. However, the impacts of weight on Bit (WOB), revolution per minute (RPM), and rate of penetration (ROP) on bit selection were ignored and instead rely on the bit cost, total drilled footage, trip time, and rotating time. The secondary data were inputted in equations 1 and 2 to calculate the cost per foot of each bit used.

$CPF=CB+CR\ (T+tr)/F$ (1)

Where:

CPF: cost per foot \$/ft.

CB: bit cost \$.

CR: Rig cost \$/hr.

T: Total rotating time hr.

tr: trip time hr., t= RIH time+ POOH time (2)

RIH: Running in hole

POOH: Pull Out of hole

F: Total footage drilled

Given: Trip time = 8hrs, Cost of the rig = \$500/hr

Table 1 Drilling Cost Parameter

Bit	Bit Cost (\$)	Rotating Time (hr)	Connection Time (hr)	Mean Penetration Rate (ft/hr)
RSSI	2,000	12.45	6.00	20.50
RSS2	8,000	10.70	16.00	11.20
RSS3	7,000	16.00	13.00	17.00
RSS4	9,400	20.60	7.00	10.00
BX1	3,500	15	8.40	16.00
BX2	4, 000	10.2	18.5	12.50

3. Results

3.1. The Relationship between the Rate of Penetration (ROP) and Specific Energy (SE) in Bit Selection

The relationship between ROP and SE in a drilling bit selection at different depth was shown in the figures 1 - 6.

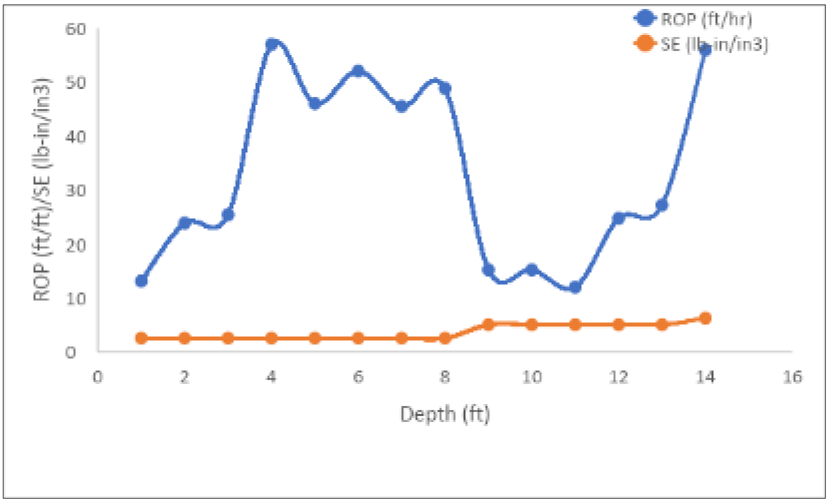

Figure 1 Relationship between ROP and SE for Bit RSS1

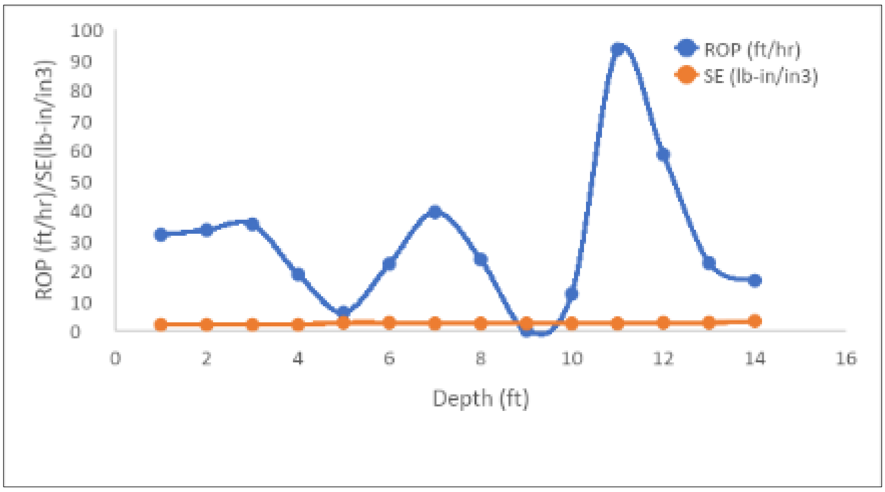

Figure 2 Relationship between ROP and SE for Bit RSS2

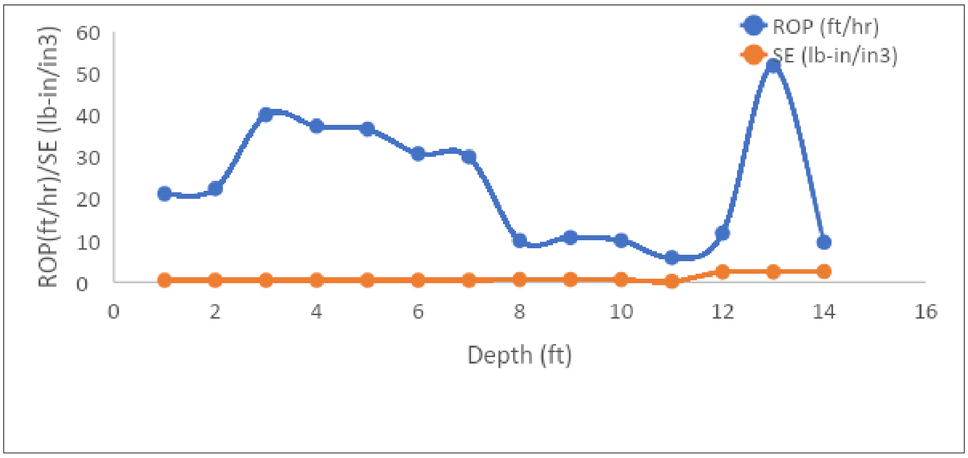

Figure 3 Relationship between ROP and SE for Bit RSS3

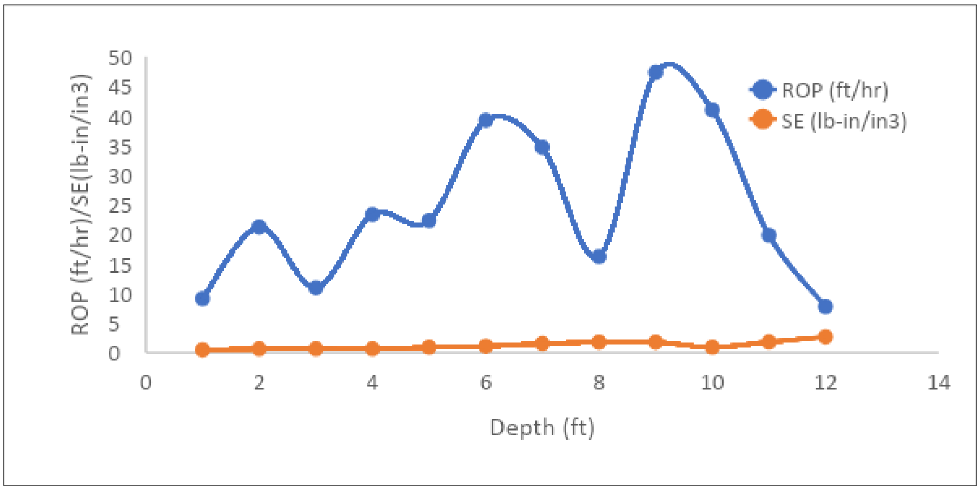

Figure 4 Relationship between ROP and SE for bit RSS4

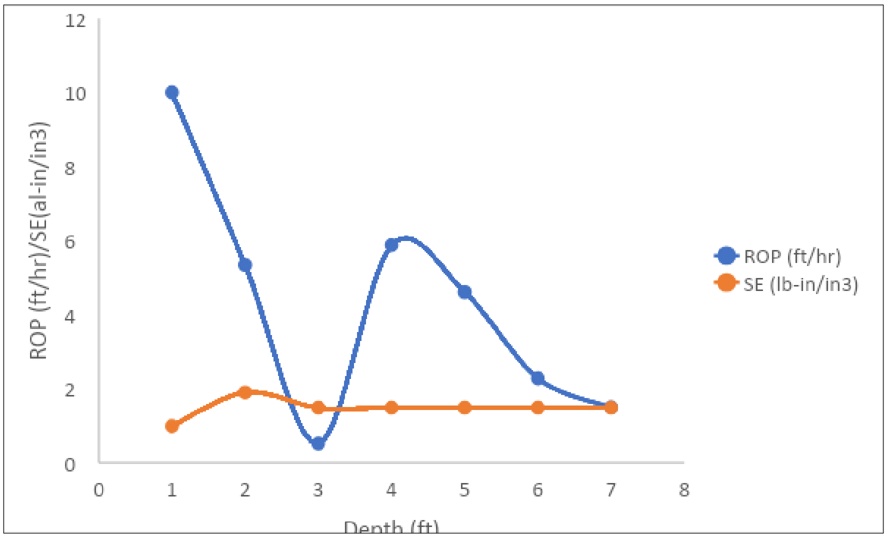

Figure 5 Relationship between ROP and SE for bit BX1

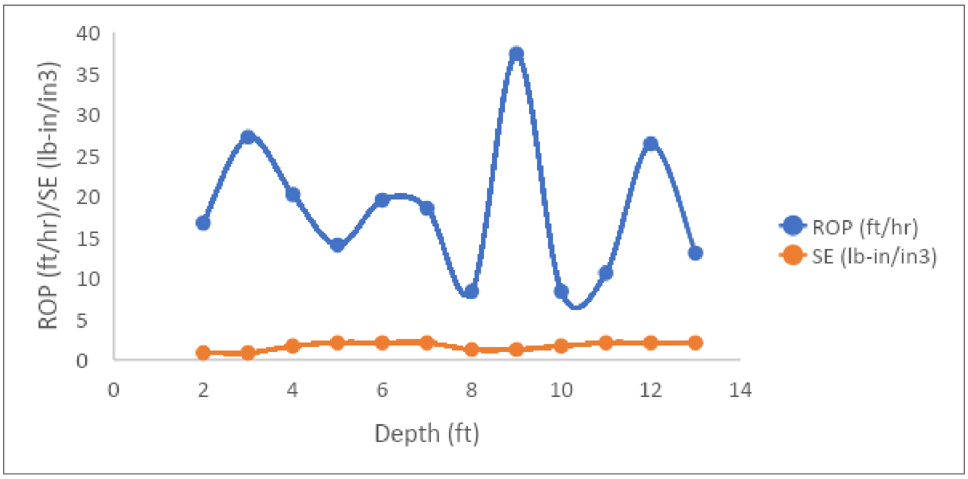

Figure 6 Relationship between ROP and SE for bit GX1

3.2. Analysis of Different Bits in Relation to the Cost per foot drilled

Figure 7 showed bits and cost per foot

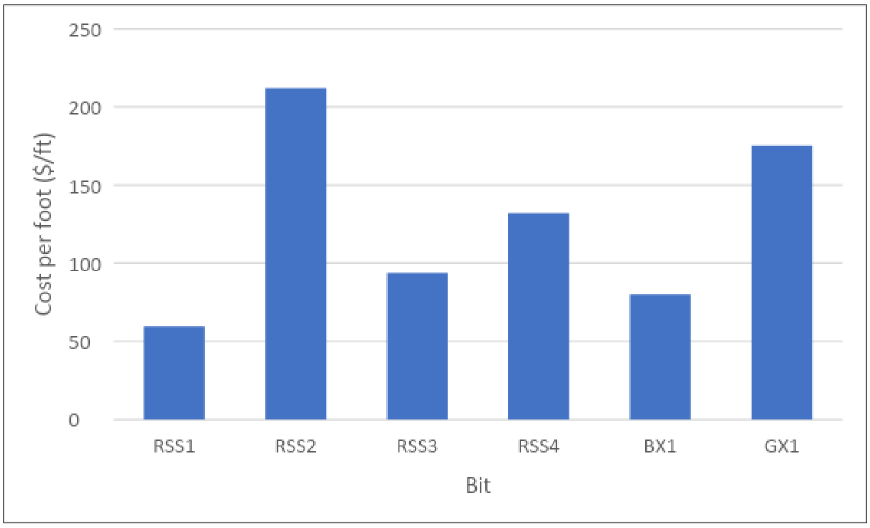

Figure 7 Bit and Cost Per Foot

4. Discussion

4.1. The Relationship between the Rate of Penetration (ROP) and Specific Energy (SE) at Different Depths

The effects of rate of penetration (ROP) and weight on bit (WOB) on the specific energy (SE) which is one of the yardsticks for measuring the performance of a drill bit during drilling operations have been reported in previous works. It was from the graphical presentation of the results of the research that the lower the SE, the higher the rate of penetration. In figure 6, it was shown that at the depths the SE was minimum, the ROP was maximum and vice versa for bit RSS1. The result showed an inverse relationship between the ROP and SE. This is in consonance with the findings of Harmer [6] which stated that optimum bits have low values for SE. However, bit RSS2 (Figure 2) showed some of abnormality because it had low SE and ROP. Other factors such as high torque and drag, sloughy shale and others could be responsible. Figure 3 showed that as the SE was decreasing, the ROP was increasing for bit RSS3. However, both the ROP and SE decreased alongside which could be traced to some drilling problems as mentioned earlier. Bits GX1 and BX1 as shown in figures 5 - 6 showed optimum bit selection because the SEs of both bits were low while their ROPs were high.

4.2. Validation of Results

Researchers have done several works on bit selection criteria. It was gathered that bits are said to perform optimally if they drill at low specific energy [6]. It reported by Rabia [3] that changeable in the value of weight on bit (WOB) and revolution per minutes (RPM) lead to change in the value of rate of penetration (ROP), and that effect on the value of SE. The results of this study (figures 1 -6) illustrated a condition where the ROP did not vary inversely as the SE as supported by Rabia [3]. From the drilling and bit design sheet obtained as a source of data for this study, it was observed that the specific revolution per minutes (SRPM) and WOB are kept constant in most cases, resulting in little or no change in SE. The trends of the graphical representation of the relationship between the ROP and SE (figures 1 - 6) are in tandem with the previous work done in this area.

4.2.1. Drilling Cost Optimization

One important performance metric for assessing the overall effectiveness of the drilling operation is the rate of penetration, or ROP. A greater ROP indicates that the formation is being drilled at a faster pace, saving rig time and indicating a more efficient operation when compared to similar "offset" runs drilling through equivalent formations and application. To differentiate between a high "overall" and high "instantaneous" ROP, one must exercise caution. For the simple reason that such high immediate ROP may not be maintainable, drilling with blazingly fast instantaneous ROP on the dial may not be the best course of action. The drilling cost was optimized by calculating, comparing, and selecting the bit that drilled a well at the lowest possible cost. Drilling cost is said to be optimized if a well is drilled safely at the lowest possible cost. The cost is usually considered of terms of dollars spent in drilling one foot down the formation. In this study, drilling cost parameters were obtained from five wells and drilling cost relation was used to compute the drilling cost per foot for each bit. The results obtained showed that the cost per foot incurred drilling with bit RSS1 was $59.65, $212.17 for bit RSS2, $93.75 for bit RSS3, $132.03 for bit RSS4, $80 for bit BX1 and $175.29 for bit GX1. It was deduced that bit RSS1 was optimized as it was used to drill the safely and at the lowest possible cost.

5. Conclusions

- The result showed that drill bit performance depends on RPM and WOB.
- There was an inverse relationship the specific energy (SE) and ROP whereas ROP depends on RPM and WOB.
- There were depth intervals where the SE and ROP were decreasing simultaneously indicating drilling problems such as axial vibration, which was gathered from literature that it was cause of WOB value variation drilling operations.
- The effects of drilling parameters such RPM, WOB and ROP greatly reflected on the SE of the selected bits.
- Bit RSS1 was selected as having the best bit design because the ROPs at different drilling depth were very high at lowest specific energy, and in addition, having the lowest cost in comparison with other drill bit design.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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