

Optimization Drilling Parameters Performance During Drilling in Gas Wells

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Abstract: The objective of the present work is to optimize drilling parameters such as WOB, ROP, RPM, flow rate and drill diameter of hole. The research contribution to investigation and analysis field data. This paper focuses on the optimization of drilling parameters. Drilling optimization is very important during drilling operation, to save time and cost of operation thus increases the profit. The result from analysis is used to determine optimum, RPM, ROP, flow rate, to give optimum drilling performance. Optimization the drilling parameters for depth at 11778.79 ft, weight on bit between 33000 lbs to 44000 lbs and rotary speed range between 50 to 80 rotation per minute, flow rate is 356.67 gallon /min, Optimize value of weight on bit per inch diameter of bit 8 1/2" in range 3882.35 lbs /in to 5176.47 lbs/in, The productive time for drilling is 60.5%. from total time of operations.

Keywords: Drilling, Rate of Penetration, Rotary Speed, Weight on Bit, Optimization, Parameters Drilling, Gas Well

1. Introduction

Future oilfield resource developments are subject to drill wells in cost efficient manners. For that reason future management of oilfield drilling operations will face new hurdles to reduce overall costs, increase performances and reduce the probability of encountering problems. Drilling wells for energy search from the ground has shown considerable technological advances in the recent years. Different methods from different disciplines are being used nowadays in drilling activities in order to obtain a safe, environmental friendly and cost effective well construction.

Communication and computer technologies are among the most important disciplines which can contribute to drilling optimization. Large amount of data could be piped through different locations on the planet in reliable and time efficient manners. Advanced computer technologies are now being used in storing large amounts of data, and solving complex problems.

From the very early beginning of the drilling campaigns the operators have always been seeking to reduce the drilling costs mainly by increasing the drilling speed.

In the drilling industry, the first well drilled in a new field

(a wildcat well) generally will have the highest cost. With increasing familiarity to the area optimized drilling could be implemented decreasing costs of each subsequent well to be drilled until appoint is reached at which there is no more significant improvement [1]. The relationship among drilling parameters are complex, the effort is to determine what combination of operating conditions result in minimum cost drilling [2]. The generally accepted convention for a proper planning of any drilling venture is to optimize operations and minimize expenditures [3]. Another essential aspect of the optimization is to enhance the technology and make the system effective [4]. Recently environmental friendly activities have also started to be common practice in certain locations, which in turn could be achieved by means of reducing the risks associated with having technical problems.

In recent years the increasing emphasis that is being paid by the oil and gas field operator companies towards working much efficiently at the rig sites are based on some important reasons. The most important of all are: cost and trouble free operations. During a peak in the cost of hydrocarbon resources, the rig supplier and oil field service provider contractor charges are increasing, pushing operators to work efficiently.

Due to the complexity of the activities being offshore

and/or being in the form clusters operators restraining themselves from causing a damage, which may result in destruction of more than one well due to their proximity between each other being very close. Directional techniques allowed drilling multiple wells from one location, thus eliminating construction of expensive structures for each well [5]. Due to the drilling requirements similarity of the wells located at close distances, collecting past data, and utilizing in a useful manner is considered to have an important impact on drilling cost reduction provided that optimum parameters are always in effect.

Major drilling variables considered to have an effect on drilling rate of penetration (ROP) are not fully comprehended and are complex to model [6]. For that very reason accurate mathematical model for rotary drilling penetration rate process has not so far been achieved. There are many proposed mathematical models which attempted to combine known relations of drilling parameters.

The proposed models worked to optimize drilling operation by means of selecting the best bit weight and rotary speed to achieve the minimum cost. Considerable drilling cost reductions have been achieved by means of using the available mathematical models.

It is important to bear in mind that formation properties, which are uncontrollable are one of the most critical factors in drilling performance determination. Drilling fluid properties and bit types, though controllable are not in good drilling practice to 3 change in ordinary bit runs. However, hydraulics, the weight applied to the bit and bit and rotary speed are among the controllable factors.

2. Objective of This Study

The optimization of rate of penetration for the drilling activities is going to have direct effects on the cost reduction, together with elimination of problems. It has-been reported that drilling optimization should be based on the accumulated and statistically processed empirical data rather than working with implicit relations [7]. The scope of this study is to make use of the data from rig sites. The data available to the drilling engineer is mainly sourced from Mud Logging Units (MLU).

It is also known that recently manufactured rigs are being equipped with powerful data import capabilities that make connection to third-party Well site Information. Transfer Specification (WITS) data simple and reliable [7]. WITS is a communications format used for the transfer of a wide variety of well site data from one computer system to another. It is a recommended format by which Operating and Service companies involved in the Exploration and Production areas of the Petroleum Industry may exchange data in either an online or batch transfer mode. New generation tool is Well site Information Transfer Standard Markup Language (WITSML) which is the standard transmission of well site data in a consistent form which would enable the integration of information from different suppliers [8].

The data could be piped in real-time, be processed and interpreted such as to recommend the optimum drilling parameters back in real-time as well [9].

This cycle is easily achievable in today's technology by means of using advanced communication systems, and innovative computer technologies. In order to understand what has been done so far in regards to drilling optimization it is very important to see what has been performed in the recent history.

3. Drilling Data Used for the Analysis

Necessary analyses for this research study performed using data belonging to Horizontally drilled wells in RISHA GAS area [10, 11, 12]. The wells were horizontally drilled from in three locations the drilling objective was to reach production target levels with relatively high inclinations. Figure 1 gives brief information of horizontally wells processed for real-time drilling optimization. Results belonging to three wells profile have been presented in the study.

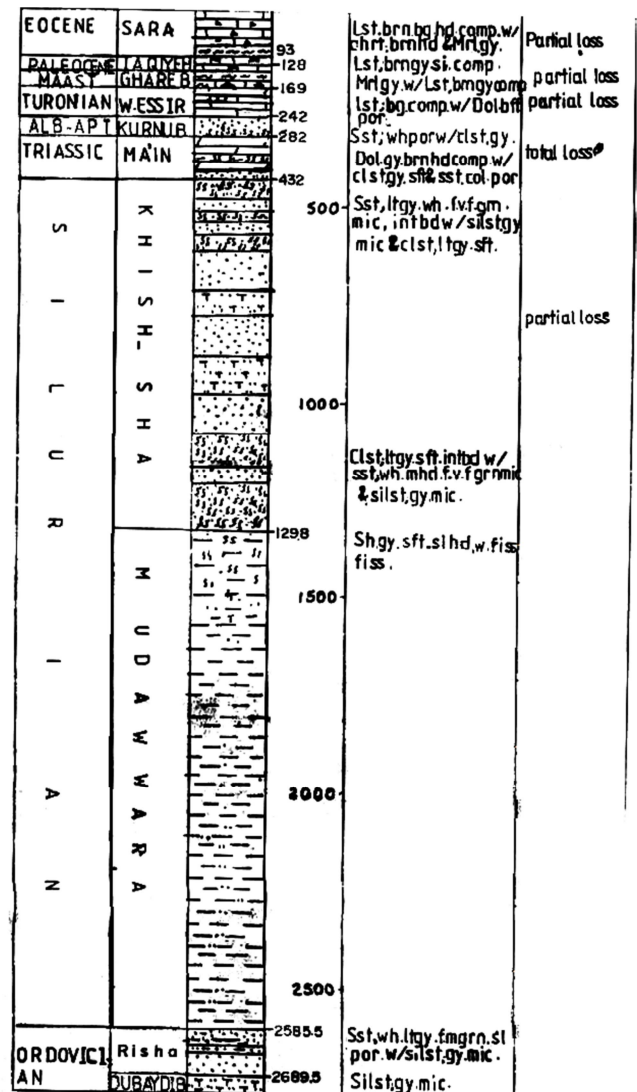


Figure 1. Cross Section Of Formation.

Table 1. Wells Summary Information.

| NO. Well | Well 1 | | | | Well 2 | | | |
|----------------------------------|-------------------|-------------------|------------------|-------------------|------------------|------------------|-------------------|-------------------|
| Well Total depth, ft TVD | 8711.053 | | | | 8934 | | | |
| Total depth, ft MD | 9655.98 | | | | 9655 | | | |
| Trajectory | Deviated | | | | Deviated | | | |
| RT elevation, ft | 3016.87 | | | | 3016 | | | |
| Drilling Unit type | National & IDECO | | | | National & IDECO | | | |
| Drilling time days | 52.65 | | | | 75.6 | | | |
| Hole Section, In | 17 ^{1/2} | 12 ^{1/2} | 8 ^{1/2} | 6 | 6 | 8 ^{1/2} | 12 ^{1/4} | 17 ^{1/2} |
| Hole section Inclination, degree | 0.25 | 1.5 | 66.7 | 89 | 86.54 | 39.48 | 1.5 | - |
| Hole section Depth, ft | 1251 | 43330 | 8799 | 10016 | 8934 | 8760 | 4216 | 36 |
| Casing Size, In | 4 ^{1/2} | 7 | 9 ^{5/9} | 13 ^{3/8} | 4 ^{1/2} | 7 | 9 ^{5/8} | - |
| Casing shoe depth, ft | 9954 | 8796 | 4327 | 1213 | 8930.8 | 8750.4 | 4209.5 | - |
| Drilling Fluid type | KCL | KCL | Water Based Mud | Spud | KCL | KCL | Water Based Mud | Water Based Mud |
| Drilling fluid Max density, ppg | 8.57 | 10.82 | 8.74 | 8.57 | 8.57 | 10.91 | 8.57 | 8.57 |
| KOP, ft | 7874 | | | | 8202.5 | | | |

Table 1. Continued.

| NO. Well | Well 3 | | | |
|----------------------------------|------------------|-------------------|------------------|--------------|
| Well Total depth, ft TVD | 3125 | | | |
| Total depth, ft MD | 3366 | | | |
| Trajectory | Deviated | | | |
| RT elevation, ft | 831.5 | | | |
| Drilling Unit type | National & IDECO | | | |
| Drilling time days | | | | |
| Hole Section, In | 26 | 12 ^{1/4} | 8 ^{1/2} | 6 |
| Hole section Inclination, degree | - | 1.25 | 36.98 | 44 |
| Hole section Depth, ft | 156.5 | 4193.11 | 8409.2 | 10253.12 |
| Casing Size, In | 20 | 9 ^{5/8} | 7 | - |
| Casing shoe depth, ft | 154.2 | 4189.83 | 8405.92 | - |
| Drilling Fluid type | Water Based Mud | Water Based Mud | KCL. polymer | KCL. polymer |
| Drilling fluid Max density, ppg | 8.57 | 8.58 | 10.45 | 8.57 |
| KOP, ft | - | - | 7710.35 | |

Drilling data available for the study was acquired from a field located in the Risha Area. The lithological specification of the formations is mainly dominated by means of limestone, clay, shale and sandstone. The detailed for the formations Lithology description limestone white, dolomite medium to hard, sandstone partly coarse grained, clay stone with shale, sandstone fine to very fine grained medium to hard siliceous cemented. Sandstone soft plastic with siltstone medium hard, with streaks of shale dark grey, siliceous cemented, sandstone white light grey, medium grained to fine, micaceous siliceous cemented.

Actual data is the only source of information to make are recommendation to optimize the drilling operations. The parameters those of which could be collected from a drilling activity are as listed in Table 2 Each parameter to be collected from the rig site is going to have an impact to the overall optimization process [17].

Data reliability and accuracy is very important, all of the data collecting sensors should be accurately calibrated and be signaling the correct magnitude of measurement. The success of drilling optimization is closely related with the quality of the recorded drilling parameters.

Table 2. Parameters from a drilling activity.

| | |
|-----------------|---------------------------|
| WOB | Drill string properties |
| RPM | Casing details |
| Pump parameters | Drilling fluid properties |
| Depth Torque | Hook-load |
| Inclination | Torque |
| Azimuth | LWD |
| ROP | MWD |

The parameters recorded for drilling optimization are critically important to be representative of data they are meant to reflect.

Factors Affecting Rate of Penetration

The factors known to have an effect on rate of penetration are listed under two general classifications such as controllable and environmental. Controllable factors are the factors which can be instantly changed such as weight on bit, bit rotary speed, hydraulics.

Environmental factors on the other hand are not controllable such as formation properties, drilling fluids requirements. The reason that drilling fluid is considered to be an environmental factor is due to the fact that a certain

amount of density is required in order to obtain certain objectives such as having enough overpressure to avoid flow of formation fluids. Another important factor is the effect of the overall hydraulics to the whole drilling operation which is under the effect of many factors such as Lithology, type of the bit, down hole pressure and temperature conditions, drilling parameters and mainly the rheological properties of the drilling fluid. Rate of penetration performance depends and is a function of the controllable and environmental factors. It has been observed that the drilling rate of penetration generally increases with decreased Equivalent

Circulating Density (ECD). Another important term controlling the rate of penetration is the cuttings transport.

Ozbayoglu et al. 2004 [13], conducted extensive sensitivity analysis on cuttings transport for the effects of major drilling parameters, while drilling for horizontal and highly inclined wells. It was concluded that average annular fluid velocity is the dominating parameter on cuttings transport, the higher the flow rate the less the cuttings bed development. One of the most important considerations in order to have an efficiently cuttings transported hole is to take into account the factors given in Table 3 [14].

Table 3. Factors for efficient hole cleaning.

| | |
|---|--|
| 1 Hole angle, degree | 1.25 to 1.50 |
| 2 Fluid Velocity, ft/min, for three wells | 414.17 to 581.24 |
| 3 Fluid Properties (rheological properties and density) | Vis=45-ta as, p.v=12, PH=10, 8.57ppg, 8.74 ppg |
| 4 Cuttings Size, shape, and concentration | Coarse medium and fine grained |
| 6 Rate of pipe rotation and pipe eccentricity | 80, 90, 100, 125 |
| 7 Fluid flow regime (laminar or turbulent) | Turbulent flow |

Table 4. Performed data runs for Well-1 12 1/4" Hole Formation Khisha and Mudawrah.

| No. Well | Well 1 | | |
|------------------|-----------------------------------|-------|-------|
| Formation | Khisha and Mudawrah | | |
| Bit Size, In | 12 1/4 | | |
| Bit type | GTX33, 3Js, H77F, S44, M4NE, S86F | | |
| Inc. min, degree | 0.25 | | |
| Inc. max, degree | 1.50 | | |
| M. W. min, ppg | 8.57 | | |
| M. W. max, ppg | 8.74 | | |
| Start, Ft, TVD | 1250.06 | | |
| End, ft, TVD | 4330.92 | | |
| WOB min, lb | 4400 | 8800 | 13200 |
| WOB max, lb | 15400 | 17600 | 19800 |
| N min rpm | 50 | 60 | 70 |
| N max, rpm | 80 | 90 | 100 |
| ROP, min, ft/hr | 10.17 | 10.99 | 12.56 |
| ROP, max, ft/hr | 14.63 | 19.68 | 19.68 |

Table 5. Performed data runs for Well-1 12 1/4" Hole Formation Khisha and Mudawrah.

| No. Well | Well 2 | | |
|------------------|---------------------|-------|-------|
| Formation | Khisha and Mudawrah | | |
| Bit Size, In | 12 1/4 | | |
| Bit type | HP53AJ, H77F, S86F | | |
| Inc. min, degree | 0.7 5 | | |
| Inc. max, degree | 1.50 | | |
| M. W. min, ppg | 8.57 | | |
| M. W. max, ppg | 8.74 | | |
| Start, Ft, TVD | 36. 09 | | |
| End, ft, TVD | 4216.06 | | |
| WOB min, lb | 15400 | 17600 | 19800 |
| WOB max, lb | 22000 | 24200 | 26400 |
| N min rpm | 80 | 80 | 90 |
| N max, rpm | 90 | 90 | 100 |
| ROP, min, ft/hr | 5.90 | 7.21 | 7.87 |
| ROP, max, ft/hr | 8.53 | 9.51 | 11.81 |

Table 6. Performed data runs for Well-1 12 1/4" Hole Formation Khisha and Mudawrah.

| No. Well | Well 3 | | |
|------------------|---------------------|-------|-------|
| Formation | Khisha and Mudawrah | | |
| Bit Size, In | 12 1/4 | | |
| Bit type | J33, H77F, S44, | | |
| Inc. min, degree | 0.2 5 | | |
| Inc. max, degree | 1.25 | | |
| M. W. min, ppg | 8.57 | | |
| M. W. max, ppg | 8.74 | | |
| Start, Ft, TVD | 119.75 | | |
| End, ft, TVD | 4196.39 | | |
| WOB min, lb | 6600 | 11000 | 13200 |
| WOB max, lb | 15400 | 17600 | 19800 |
| N min rpm | 75 | 80 | 80 |
| N max, rpm | 90 | 125 | 125 |
| ROP, min, ft/hr | 5.67 | 6.75 | 8.23 |
| ROP, max, ft/hr | 8.79 | 10.79 | 11.74 |

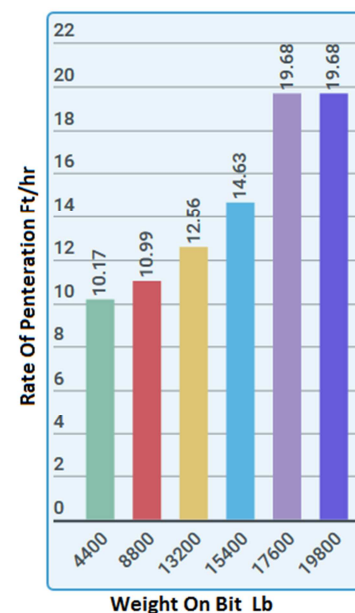


Figure 2. The Effect Of Bit Loading On penetration Rate For various Rocks.

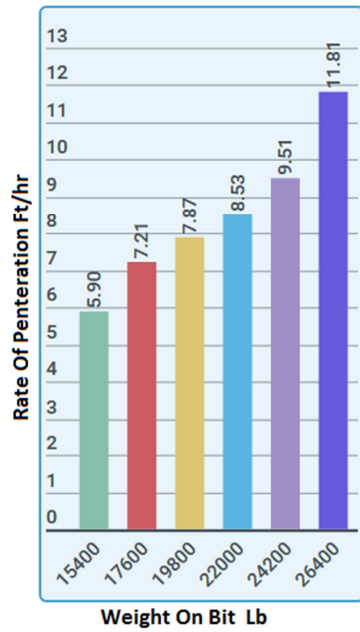


Figure 3. The Effect of Bit Loading On penetration Rate For various Rocks.

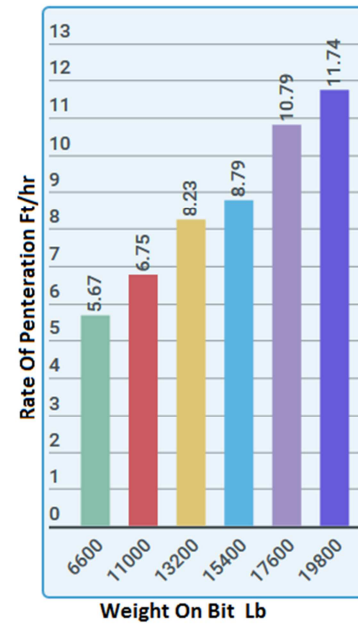


Figure 4. The Effect of Bit Loading On penetration Rate For various Rocks.

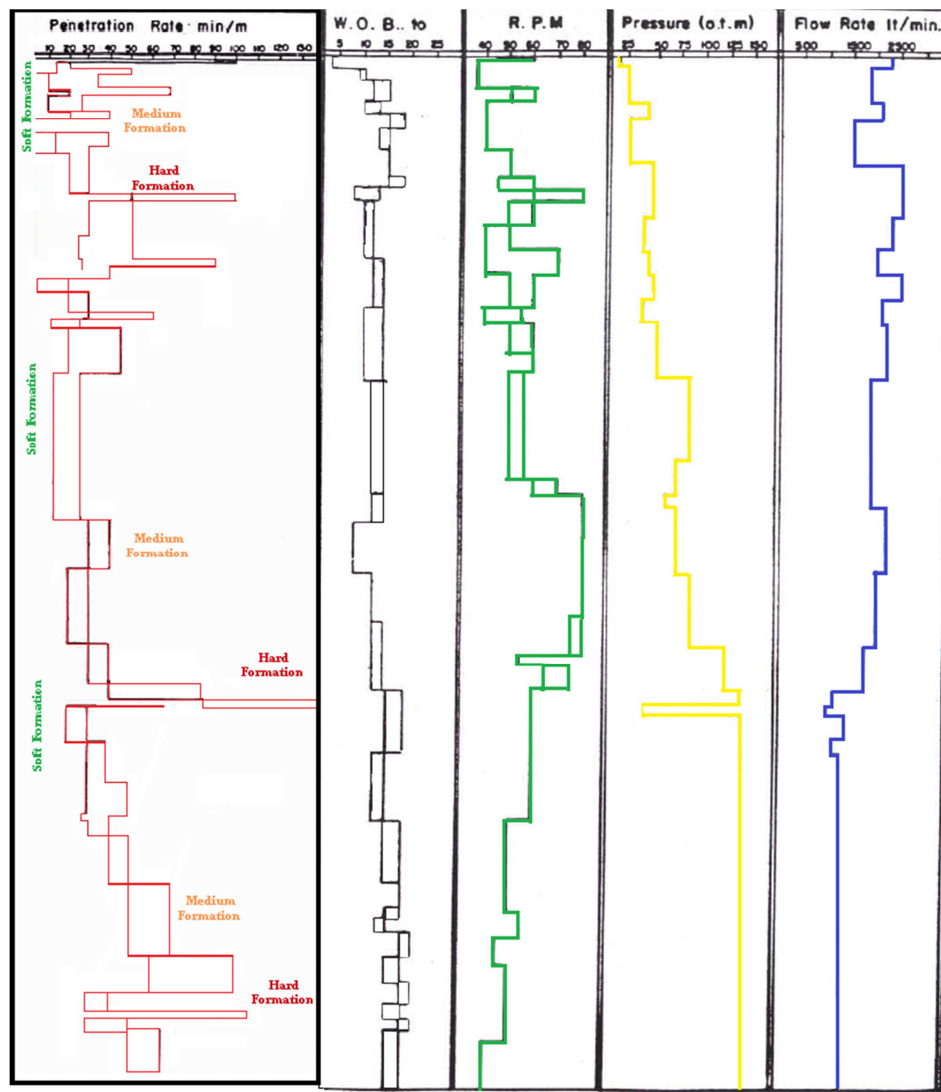


Figure 5. Drilling Parameter According The Lithology.

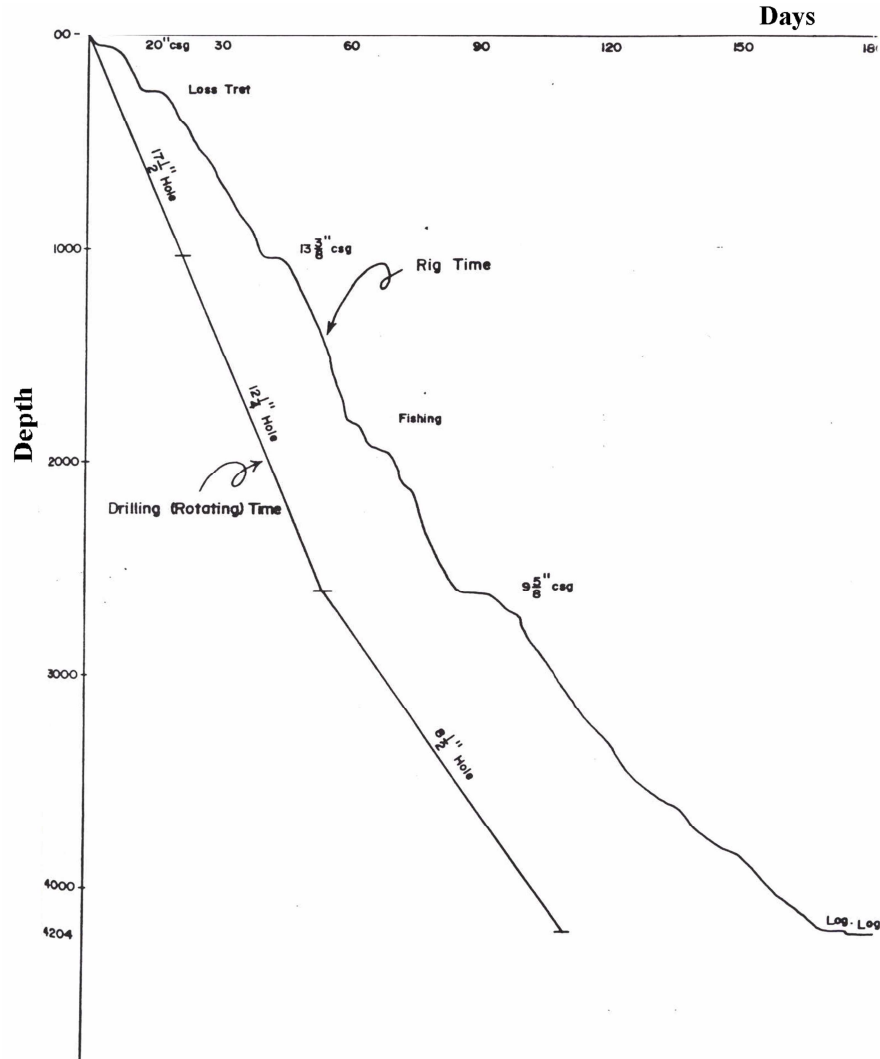


Figure 6. Operation performance Chart 'Rig Time + Actual Drilling Time.

Table 7. Time Break Down.

| No | Operation | Total Hours | Days | Percent- age |
|----|---|-------------|------|--------------|
| 1 | Drilling | 2633.15 | 60.5 | |
| 2 | Reaming | 174.50 | 4.0 | |
| 3 | Trips | 507.45 | 11.7 | |
| 4 | Mud conditioning | 31.00 | 0.7 | |
| 5 | Circulation | 114.15 | 2.6 | |
| 6 | Deviation survey | 20.20 | 0.5 | |
| 7 | Coring | 35.35 | 0.8 | |
| 8 | Logging | 87.55 | 2.0 | |
| 9 | Standby | 12.00 | 0.3 | |
| 10 | Run casing | 47.15 | 1.1 | |
| 11 | Cementing | 16.25 | 0.4 | |
| 12 | Waiting on cement | 41.35 | 1.0 | |
| 13 | Nippling BOPS | 33.15 | 0.8 | |
| 14 | Loss treatment | 285.45 | 6.6 | |
| 15 | Evaluating test | 3.00 | 0.07 | |
| 16 | Drilling cement | 23.55 | 0.5 | |
| 17 | Maintenance | 45.25 | 1.03 | |
| 18 | Building or Laying down drilling string | 68.25 | 1.1 | |
| 19 | Fishing | 19.45 | 0, 4 | |
| 20 | Operation with no charge | 153.50 | 3.5 | |
| 21 | Total hours | 4355.30 | 100% | |

4. Results & Discussion

The results for different optimization runs are as summarized in the following sections. The runs were individually performed for the same formation types, and provided that the data were belonging to equally sized bit diameters.

4.1. Presentation of the Results

The details of the performed data runs are as summarized in Table 1, such as wellbore deviation, drilling fluid density, type of fluid, hole section diameter, casing size, casing set depth, kick off point, drilling times in days. The given dataset are belonging to Well 1, well 2, well 3. well 1 objectives is to delineate and explore the gas bearing reservoir of Risha Formation, the well is anticipated to horizontally (max inclination 89 degrees) penetrate Risha Formation at True Vertical Depth (TVD) of 2655 m (GL) with vertical displacement of 550m.

The parameters those of which could be collected from a drilling activity are as listed in Table 2. Each parameter to be

collected from the rig site is going to have an impact to the overall optimization process [16]. Data reliability and accuracy is very important, all of the data collecting sensors should be accurately calibrated and be signaling the correct magnitude of measurement.

One of the most important considerations in order to have an efficiently cuttings transported hole is to take into account the factors given in Table 3 [14]. It was concluded that average annular fluid velocity is between 414.17 to 581.24 ft/min, dominating parameter on cuttings transport, the higher the flow rate. Another important factor is the mainly the rheological properties of the drilling fluid such as $\text{Vis}=45\text{--}50$ s, $\text{P.V}=12$, $\text{PH}=10$, M.W 8.57 ppg to 8.74 ppg.

Rate of penetration performance depends and is a function of the effect of the overall hydraulics to the whole drilling operation which is under the effect of many factors such as lithology, Type of the bit and nozzles, Downhole pressure and temperature conditions.

It is clear that Fluid flow regime is turbulent flow which better for bed development prevention for efficient hole cleaning.

4.2. Factors Affecting Rate of Penetration

Performed data runs for Well-1, 12 1/4" Hole, Formation Khisha and Mudawrah. The details of the performed data runs are as summarized in Table 5 such as wellbore deviation is between 0.25 to 1.75 degrees, the minimum drilling fluid density is 8.57 ppg and the maximum drilling fluid density is 8.74 ppg, the weight applied to the bit and the rotation speed. The given data set are belonging to Well 1 and Khisha & Mudawrah Formation. The Bit type in use was a milled tooth in type H77F, J33, HP53GX, and insert in type S86F, S44.

The general operating parameters for minimum weight on bit magnitudes are between 4400, 8800, 13200 lb. and the maximum weight on bit are 15400, 17600, 19800 lb, and 50 to 100 RPM for rotary speed [10, 11].

4.3. Rate of Penetration

Optimization of drilling operation can be obtained by increasing drilling speed (Moses and Egbon, 2011, 2012) [17, 18]. After obtained the data, the rate of penetration was collected from the field data. In Figure 2 shows the value of penetration rate increase when increase weight on bit.

However, as more data are obtained, the values of rate of penetration become more accurate.

This data is shown in Figure 2 illustrate the simulation of weight on bit with penetration rate for depth 4330.02 ft, Table 4.

Rate of penetration increase at moderate values from 10.17 to 19.68 ft/hr with increasing weight on bit from 4400 to 19800 lbs, and weight on bit per inch was 1077.55 lbs/in.

The optimum value of 13200 lbs or 1077.55 lbs/in of weight on bit can be used to have optimized drilling operation. This is valid as increasing weight on bit will increase rate of penetration but only to some value where after that, subsequence increase in bit weight causes only

slight improvements in penetration rate.

Based on the graph obtain in Figure 3 shown the penetration rate for depth 4216.06 ft Table 5 increase from 5.90 to 11.81 ft/hr with increasing weight on bit.

However after that, rate of penetration increase slowly. Although the weight on bit has increase from 15400 until 26400 lbs, and weight on bit per inch was 1706.12 lbs/in, rate of penetration still in the range of 11.81 ft/hr.

Based on the graph obtain in Figure 4 indicates the value of weight on bit with penetration rate for depth 4196.39 ft. Table 6 Rate of penetration increase at small ranges from 5.67 to 11.74 ft/hr with increasing weight on bit.

However after that, rate of penetration increase slowly.

Although the weight on bit has increase from 6600 until 19800 lbs, and weight on bit per inch was 1137.41 lbs/in, rate of penetration still in the range of 11.74 ft/hr. The optimized weight on bit is 13200 lbs or 1077.55 lbs/in during drilling operation, penetration rate for depth 4330.02 ft is suitable due to formation that is may be high in strength.

Figure 5 Shows the drilling parameters performance to be determined according Lithology and hole condition [19, 20]. The 17 1/2 hole Contains intercalation of limestone, dolomite, chert, sandstone and claystone soft to medium formation, the weight on bit was medium (26000 lb to 33000 lb) the penetration rate 10.33 ft/hr increase, the flow rate is 607 gallon /minute to clean the hole from cuttings. The 12 1/4 hole, contains the sandstone and shale. The negative effects from shale on drilling operation, Sloughing and swelling of shale are the major problems encountered when drilling a well. Shale make up of the drilled formations it means instability problems some shale sections contains hydrotatable clays, which continually absorb water and swell and slough into the hole. These formations, known as heaving shales, may result in high cost of drilling the hole and also cause other hole problems like pipe sticking, excessive solid build up in the mud hole bridging. the penetration rate is 7.44 ft/hr with moderately weight on bit and flow rate 475 gallon /minute. The 8 1/2 hole contains the sandstone and siltstone hard formation, the rate of penetration is decrease with increase the weight on bit 33000 to 44000 lb and decrease in rotation per minute 50- 80 RPM, the flow rate is decrease to 356 gallon /minute.

Figure 6 Show Operation performance, Rig Time and the Actual Drilling Time.

Table 7. show the time breakdown. The productive, non-productive and lost time are distributed.

The Rig spent 181.47 days on the location including. Following is the time spent per hole phase: Performed data runs for Well-4, 17 1/2" Hole Formation Khisha and Mudawarra, 35 days were spent to drill this hole, problems with losses, treatment by cement plugs. 12 1/4 hole takes 44 days, we phase the problems of sloughing and caving shale we spent time for treatment by increasing mud weight and more times for conditioning mud and circulation to keep the hole stability. 8 1/2 hole formation Dubeidib, sandstone white, light grey fine medium grained and siltstone grey slightly medium hard micaceous the interval was 1614 m

takes 79 days for drilling and other operations.

5. Conclusion

Main problems in this area partial loss circulation and Severe total loss of circulation occurred at different depths in the 17 1/2" holes, The loss zones were treated by pumping cement plugs, mud plugs, gunk plugs and by dropping other various materials such as balls of mixed of bentonite and Loss of Circulation Materials (LCM) in addition to the special-Net product to seal the loss zones..

The results of optimization show the significance of this study. Determination of optimum weight on bit is very important in drilling operation as this parameter can be change during drilling operation. The optimization of weight on bit with rotary speed per minute will optimize the whole drilling operation as a whole. Increasing rate of penetration will reduce the time need for drilling those reduces the cost for drilling operation.

Optimization drilling parameters such as weight on bit found that for depth at 11778.79ft, optimize weight on bit are 33000 lbs compared to 44000 lbs, with decrease the rpm between 50- 80 rpm, the flow rate is 356.67 gallon /min to keep the hole clean from cuttings, optimize value of weight on bit per inch diameter of bit 8 1/2 " is between 3882.35 lbs/in to 5176.47 lbs/in.

The results of this study provide guidance for next drilling operation near the drilled well to reduce the spent time for drilling operations. The productive time for drilling operations was 60.5%.

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