The Selection of Optimized PDC Bits in the 12 ¼” Hole Section (Upper Part) of Gas Fields

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Abstract—Selection of the optimized bit is the most important factor to prevent the high Cost per meter and approaching the long interval drilling and ROP. The goal of this paper is to investigate the PDC bit performance in the 12 ¼” hole section from Hith-Eva.B for one of the gas fields in Iran. The interval is mainly composed of thick white anhydrite beds, dolomitic streaks and limestone. It was also observed traces of cherts in the layers of gray claystone throughout the interval. At this interval, the optimized one is PDC with 8 blades of 13mm cutter size, Nozzle Quantity: 8 and 30.7 square inches Junk Slot Area. The average $/m is good amount and ROP for this bit is 12 m/h respectively for drilling 4 various wells. The most important feature for this bit is related to hard formation with high compressive strength. The recommendations that must be noticed for this bit are manufactured based on matrix body with heavy cutter layout density, Force balanced design ensures less vibration while drilling, Special enhanced gauge protection and dynamic flow simulating technology is used for hydraulic design to ensure optimum bottom hole flow pattern and anti-balling and benefit for increasing ROP.

Index Terms—PDC bit, optimization, cost per meter, rate of penetration, bit nozzle

I. INTRODUCTION

The South Pars gas field was discovered in 1990. It is located on the Qatar Arc in Iranian part of the Persian Gulf approximately 100Km from Assaluyeh, 105 km from Qatar and 330Km from Dubai.

The main Pars gas field is an anticline which its axis is elongated and curved from the North (in Qatar) to the Northeast. The flanks are dipping 0.5° to the Southeast and 0.6° to the Northwest.

The hydrocarbon reservoir of the Kangan and Upper Dalan Formations and equivalent to the Upper Khuff reservoir in the Arabian plate contain some of the most important gas reservoir in the Middle East region, as well as the world. They are Middle-Late Permian to Early Triassic in age and made up of cycles of carbonate-evaporite deposits [1]. The Kangan-Upper Dalan succeedings in South Pars Gas Field (and also in the North Field) include four reservoir units, respectively, K1, K2, K3 and K4 with increasing depth [2].

A. Geology

- **Hith Formation from 1706-1850 MD:** Hith Formation is mainly composed of thick anhydrite beds and thin dolomitic streaks. The age of this formation is Upper Jurassic. 13 ¾" Casing was set 10 meter Inside Hith Formation at 1716 meter.
- **Surmeh Formation from 1706-1850 MD:** Surmeh Formation is Middle to Upper Jurassic in age and divided into 9 members as following:
  - **Upper Surmeh Member from 1850 to 1974 MD:** This member is mainly composed of light brown dolomite and white amorphous anhydrite. The Upper Surmeh Member is Upper Jurassic in age.
  - **Upper Dolomite Member from 1974 to 2081 MD:** This member is predominantly composed of limestone and dolomite. There were also observed some anhydrite at the top of this interval. The Upper Dolomite Member is Upper Jurassic in age.
  - **Upper Limeston Member from 2081 to 2272 MD:** This member is Middle Jurassic in age and is composed of light cream to off-white limestone inter-bedded with hard dolomite.
  - **Cherty zone Member from 2272 to 2422 MD:** This member is Middle Jurassic in age and was entirely composed of white to off-white limestone inter-bededded with hard dolomite.
  - **Middle Limeston Member from 2424 to 2594 MD:** This member is Middle Jurassic in age and was entirely composed of limestone inter-bededded with some dolomitic streaks. It was also observed some black spots in lower part of this formation.
  - **Mand Member from 2594 to 2776 MD:** Mand Member is Middle Jurassic in age. It is entirely composed of limestone inter-bededded with some gray to light gray dolomitic streaks in the lower parts.
Lower Limestone Member from 2776 to 2959 MD: The age of Lower limestone Member is Middle Jurassic. It is composed of light gray to cream limestone and minor light brown to cream dolomites in the middle part.

Lower Surmeh Shale Member from 2959 to 3075 MD: Lower Surmeh Shale Member is Middle Jurassic in age. It predominantly is composed of off-white to gray limestone inter-bedded with argillaceous limestone, minor gray dolomite and gray to dark gray elongated shale. Traces of pyrite have been observed in some interval.

Lithiotis Member from 3075 to 3122 MD: The age of Lithiotis Member is Middle Jurassic. It mainly consists of light cream to light gray dolomite with sucrosic texture. It was also observed some white to off-white limestone and gray to dark gray claystone.

Neyriz Formation from 3122 to 3162 MD: Neyriz Formation mainly consists of gray to light cream dolomite inter-bedded with thin streaks of limestone and minor claystone. The age of this formation is Lower Jurassic.

Upper Dashtak Member from 3162 to 3294 MD: Upper Dashtak Member mainly consists of crystalline dolomite inter-bedded with white to gray argillaceous limestone. It was also observed some white anhydrite in lower part and some gray claystone in upper and lower parts of the member.

Evaporate B from 3294 to 3466 MD: Evaporite B mainly consists of anhydrite with thin dolomitic beds which becomes locally argillaceous towards the base.

II. MATERIAL AND METHODS

This paper is to investigate and Compare the PDC bits configuration and performance in the 12 ¼” hole section From Hith till Eva.B (upper part of 12 ¼” section) for one of the gas fields in South of Iran.

To achieve this approach, we will evaluate and select the appropriate bit for the related hole section (12 ¼”, upper part) first and then the results of experimental data (bit records) are shown at the second level.

A. For First Approach (Theorical Approach)

Bits were selected with systematic approach from data of original wells.

- Each selection was evaluated in terms of lithological characteristics by use of master, Sonic, Gamma Ray logs when available [3].
- Rock Mechanics characteristics, such as porosity, abrasiveness, hardness, compressive strength, plasticity were analyzed [2].
- We used the mud logging data of another phase that logs specifications are similar to considered (papered) phase and import these data to Rock Strength Analysis Software (ROCKY3.3) for selecting the PDC bit generally.
- Instantaneous ROP, weight on Bit, Speed, Torque and other drilling parameters from bit records were correlated with lithology.
- Dull bits were analyzed [4]
- Mud programs, casing programs and rig systems were evaluated to improve performance.

The analysis technique was effective. Because the bit design was not altered significantly after the original wells were drilled.

B. For Second Approach (Experimental Approach)

After selection the appropriate PDC bit, the running operation was started and bit records were registered. The characteristics of PDC bit selection are listed below:

- Bit size: 12 ¼”, 8 Blade 13mm Cutter
- Bit Specification: Number of Blade: 8, Primary cutter size (mm): 13, Nozzle Quantity: 8, Junk Slot area (in²): 30.7, Body Material: Matrix
- Bit size: 12 ¼”, 7 Blade 16mm Cutter
- Bit Specification: Number of Blade: 7, Primary cutter size (mm): 16, Nozzle Quantity: 7, Junk Slot area (in²): 35.7, Body Material: Matrix

At these bit records, various parameters are mentioned such as Depth in, Depth out, Drilling Meters, Drilling hours, Rate of Penetration, Drive procedure, Cost per meter and the related formation.

Cost per Meter, a primary factor in comparing bit performance in an unconstrained environment, becomes only an indicator in today's constrained drilling market [5].

The typical cost-per-Meter formula used to compare the efficiencies of drilling operations is:

\[ C = \frac{C_b + C_{tc} + C_r(t_d + t)}{L} \]  

At the above formula:

- \( C \) : Cost per Meter
- \( C_b \) : Bit Cost
- \( C_{tc} \) : Tools Cost
- \( C_r \) : Rig rate per hour
- \( t_d \) : Drilling time
- \( t \) : Trip Time
- \( L \) : Footage Drilled

During this investigation it was note that rotational method (i.e., conventional rotary, Positive Displacement Downhole Motor) had a significant impact on cost per meter and drilling performance. The frequency and severity of downhole problems, such as inadvertent pack offs, stuck pipe and twist offs, tended to be functions of certain bit/motor combinations. Historical drilling data were used for optimal pairing of the rotational technique with the proper bit type to achieve minimal cost per meter [6] [7].

III. RESULTS

A. Results of First Approach (Theorical Approach)

We entered logging data including sonic data, Gamma ray and formation density of another phase that similar to
the planned phase into Rock Strength Analysis software (Rocky 3.3) and related results were received. The considered interval depth is based on 1500m–2750m. As you see at the rock strength analysis report, the UCS (unconfined strength) of rocks for this interval is approximately between 17000–28000 psi. For these quantities of Rock UCS, regarding to the bit selection standards, we should select a PDC bit that appropriate with hard formations and equal or more than 8 blades regard to 13mm or 8 mm cutters size. At the next page, you can mention the UCS, lithology, Sonic data and Gamma ray diagrams from Depth of 2300m till 2500m that Max. amount of the UCS are considered at this interval.

B. Results of Second Approach (Experimental Approach)

For concerned 6 wells (Directional wells), according to offsets and our analysis, we used 2 types of PDC bits (item1 and item 2) and the result of bit running operation is explained and shown at Table I-Table IV (Both bits have been run with motor (7:8) lob configuration, same BHA, same hole deviation and drilling parameters):

At starting of section 12 ¼” drilling operation, for one well from Hith-Eva.b, we use PDC bit (Item 1). The related record is shown at Table I (dull condition: lost in Hole, because of BHA failure):

For second well from Hith-Eva.B, we used PDC bit (item 2). The related record is shown at Table II (dull condition: 5-3-BT-N-X-I-LT-PR):

Regard to the above records, the PDC bit with 8 blade of 13mm cutter (item1) is better than one (item 2). But for more investigation about the PDC bit with 7 blade of 16mm cutter, we used new one again for another well and the below records are mentioned at Table III (dull condition: 1-3-CT-G-X-1/16-PN-HP):

Regard to comparison of the above records, the performance of the PDC bit (item 1) such as ROP, Cost per meter are better than performance of PDC bit (item 2). In this reason, for the rest of wells from Hith-Eva. B, we used PDC bit (Item 1). The records are shown at Table IV

Dull conditions of above items are explained below [4]:

(*)&: 4-1-BT-A-X-I-CT,RO-DTF
(**************************************************************************): 3-4-CT-A-X-I-BT-BHA
(***************************************************************************): 6-4-RO-A-X-I-PN,LT-PR

The below Diagrams (Fig. 1) show the brief of above bit record for 6 various wells with lithology from Hith-Eva. B (Hole 12 ¼”, Upper section):
The destination of this paper is to investigate and compare the PDC bit configuration and performance in the 12 1/4” hole section from Hith till Evaporate B (Top Section) for one of the gas fields in South of Iran. The interval is mainly composed of thick white anhydrite beds, cream to off-white dolomitic streaks and white to off-white limestone. It was also observed traces of cherts in the middle and layers of gray claystone throughout the interval. The paper has two approaches. The first one is related to theoretical strategy that related data were calculated by Rocky 3.3 and the bit design estimation was considered regard to standard bit design and selection procedure. The second approach was related to experimental data that we used 2 types of PDC bits at 6 wells.

At this interval, the optimized one is related to PDC bit with 8 blades of 13mm cutter size, Nozzle Quantity: 8 and 30.7 square inches Junk Slot Area. The average Cost per Meter is good amount and Rate of Penetration (ROP) factor to prevent the high Cost per meter and approaching the long interval drilling and Rate of Penetration (ROP). The results showed that, this bit is a good selection for drilling the related interval (Upper part). The results for 6 different wells are shown below in the graph.

**IV. DISCUSSION**

selection of the optimized bit is the most important factor to prevent the high Cost per meter and approaching the long interval drilling and Rate of Penetration (ROP). The optimized PDC bits in the 12 1/4” Hole section of gas field for one of the phases in the south of Iran is 8 blades of 13mm cutter size, Nozzle Quantity: 8 and 30.7 square inches Junk Slot Area.

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**REFERENCES**