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Optimizing Drilling Using Managed Pressure While Drilling Technology

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ABSTRACT: The narrow operating window between pore pressure and fracture pressure makes drilling difficult in some operations. A feasibility study of managed pressure drilling (MPD) is carried out on Iran Lovan oil field. The previous wells drilled in this field showed that mud returns were lost during drilling Gadvan formation. This project work addresses this problem by utilizing **Managed Pressure Drilling (MPD)** technology through surface back pressure application in Lovan oil field. The methodology employed in this study is based on hydraulic analysis calculations and comparative drilling operation pressures. The DZxION MPD software performs hydraulic analysis using the API RP 13D rheological model and calculates the annular pressure drop and equivalent circulating densityto compare the pressures and the required back pressure, if needed. This project is based on hydraulic analysis calculations and comparing the drilling operation pressures in Lovan oil field. For analyzing the pressure regimes throughout the well, DZxION Managed Pressure Drilling software performs hydraulic analysis. By using this method to drill the well, some advantages were gained: the mud weights used to drill the well, the number of casing strings, and the number of changing mud weights were reduced.

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I. INTRODUCTION

Drilling operations exist in a world limited by high and low pressures. The unexpected appearance of either can lead to delays, increased costs and even to failure. With increasing frequency, operators are arming themselves against the consequences of pressure-related surprises with techniques different from those used in the past. One such departure from tradition is called managed pressure drilling [MPD]. The pressure range above pore pressure and below fracture initiation pressure is the drilling margin, or pore-pressure-fracture-gradient window. If at any point the ECD goes outside these bounds, operators must set casing and begin drilling the next, smaller hole size. The practice of maintaining a borehole pressure that exceeds the pore pressure gradient is called overbalanced drilling [OBD].

Operators encountered various pressures – associated challenges while drilling these wells, including well-bore instability and well control problems. Efforts to overcome these challenges gave rise to the development of MPD. MPD is used primarily to drill wells that do not lend themselves to either conventional overbalance or under balance methods, such as in areas where flaring is forbidden, or while drilling through high-permeability formations. MPD is a new technology that enables a driller to more precisely thereby controlling annular pressures in the wellbore to prevent these drilling related problems. The depletion of current reserves has necessitated the drilling of reservoirs that are deeper and more complex. MPD is a new technology that uses tools similar to those of underbalanced drilling to better control pressure variations while drilling a well. MPD allows for drilling into narrow pressure margins in a safer and more cost effective manner while mitigating drilling hazards and thereby reducing Non-Productive Time (NPT).

II. METHODOLOGY

The Lovan oil field lies in the eastern banks of the Karun River in an area about 45 km of the northwest of Abadan, Iran. It is 29 km long and 15 km wide, elongated in northern-southern direction. For the scope of this study, the main source of offset data will be well LV No. 4 and all the wells in the field, in particular, well LV No. 2. The target reservoir was the carbonate sequence of Fahliyan formation within the so called Khami group (lower Cretaceous) found oil bearing by the exploration well LV No. 2 and the first appraisal well LV No. 4. The top of the reservoir is at 13290 ft TVD. The high reservoir pressures and the sour nature of some of thefluids dictate special care and attention during drilling through the cap rock and reservoir sequences to avoid potential drilling hazards (ENI AGIP Co. 2005) It is decided to use the constant bottom hole pressure variation of managed pressure drilling technique to stay close to an agreeable pressure profile using surface backpressure. This variation is closely related to the enhanced kick and loss detection category of MPD. DZxION MPD CSM was used in order to perform offline hydraulic analysis and calculations (SagarNauduri, A.S. 2009). The software can act as a preliminary screen to determine the utility of MPD for the potential MPD candidate wells. For calculating the annular and pipe pressure drop, it follows API RP 13D rheological model. Essential input parameters for this software are as follows:

1. Pp and F_p data
2. Drill string and BHA-OD's lengths
3. Set of rheology data
4. Mud weight, circulation rate
5. Wellbore profile (if the well is directional)
6. Casing and open hole details (IDs and ODs)

The hydraulic calculations cannot be performed without the required input parameters mentioned above. Following the basic hydraulic analysis and calculations, it would help sssss.to make a better engineering decision in deciding whether to use MPD or not for a given prospect. In the method selected to perform the feasibility study of the LV No. 5 well of Lovan field, the hydraulic calculations using API RP 13D model are performed. This can determine the ECD of each mud weight. By determining ECD and having pore pressure and fracture pressure in hand, it is possible to choose which technology is suitable for drilling the well, namely conventional drilling or managed pressure drilling.

So the first input data is the casing and drill pipe data set. The drill pipe length depends on which section of the well is to be simulated. The next step is to enter the formation pressure regime. By using overburden pressure gradient, pore pressure gradient, and Poisson's ratio in Eaton's equations, the fracture pressure gradient is obtained. The obtained fracture pressure gradient and pore pressure gradient are input to the software in pound per gallon unit. The calculated equivalent circulating density by the software is compared with the pore pressure/ fracture pressure window. Drilling fluid properties, mud rheology data, and the BHA details are next.

This is how the software determines whether this window is acceptable or not. If both the hydrostatic and dynamic pressures in the well are between the pore pressure and fracture pressures, the well does not need the MPD. If these pressures (hydrostatic of mud and dynamic pressure when pumps are on) fall below the pore pressure or exceed the fracture pressure, the software calculates the required mud weight and amount of back pressure. Afterwards, the software decides whether the MPD is applicable or not. The next section refers to the pressure gradients using the actual drilling data from well LV No. 4 and all the important and valuable information from the offset wells. Well LV No. 4 still remains as the reference well, though.

FRACTURE PRESSURE AND PORE PRESSURE

The overburden gradient was calculated using the sonic log data of well LV No. 4. The bulk density has been calculated using AGIP default formulas. The default values in the formula such as matrix bulk density, pore fluid density, and average matrix transit time were modified according to the local conditions, although there was no sufficient data. The bulk density was then integrated to calculate the overburden gradient. The fracture gradient is calculated as a function in the estimated pore and overburden gradient of the area. Depending on lithological type encountered, the K constant (a function in Poisson's ratio) has been defined maintaining ENI AGIP strict policy operating in an unknown new area. In well LV No. 4, all the tests were conducted as formation integrity test (FIT). Therefore, the fracture gradient curve illustrated in the gradient forecast graph was constructed using the theoretical formula using the basic rules as stated in ENI AGIP policies and manuals. The fracture pressure prediction strategy was also developed by Ben Eaton in 1975. The data required are formation overburden stress, pore pressure, and Poisson's ratio of the formation. The resulting overburden pressure gradient is integrated from the bulk density of the well LV No. 5 and is represented in pound per gallon unit of depth. The main source of the actual pore pressure data above the reservoir section is the well LV No. 4. In the reservoir section, the actual bottom hole formation pressure from the DST tests has been used to update the pressure gradient data from the offset wells.

DRILLING OPERATION WINDOW

As it can be seen in Figure 6, from surface to Pabdeh formation at about 7382 ft TVD and in the whole Fahliyan formation, there is no serious drilling problem (through the 24", 17 ½", and 8 ½" hole section) due to the wide pressure margin figure 1 illustrates the drilling operation window of Lovan field. A significant loss has been observed during drilling lower 12 ¼" hole that has marginal pressure. Thus, the focus of this study is only on this section.

III. STEPS OF THE STUDY

The steps involved either candidate selection or a feasibility study that can be divided into the following main categories: defining the purpose, procuring information, performing hydraulic analysis, and selecting the method (Rehm,B. et al. 2009). First of all, establishing the purpose of the study has a higher precedence compared to the remaining steps. Heavy losses occur during drilling the lower 12 ¼" hole section; thus suggesting a way soing this drilling problem seems satisfactory. Therefore, curing the loss of circulation through that way provides advantages, including cost effectiveness (due to less mud loss) and eliminating excess casing string and saving time (because of fewer drilling problems and less rig cost).

All available data from the well being drilled (such as pressure regimes, drill string and BHA details, mud weight and rheology, and well bore geometry) are used in this study. Tables 1 to 7 are the input data of the software.

By using API RP 13D rheological model, the annular frictional pressure, ECD changes, and the required mud weight are calculated. The feasibility of the option, hydraulic analysis, constraints of the rig, and availability of the equipment assist choosing the best method along the different MPD variation.

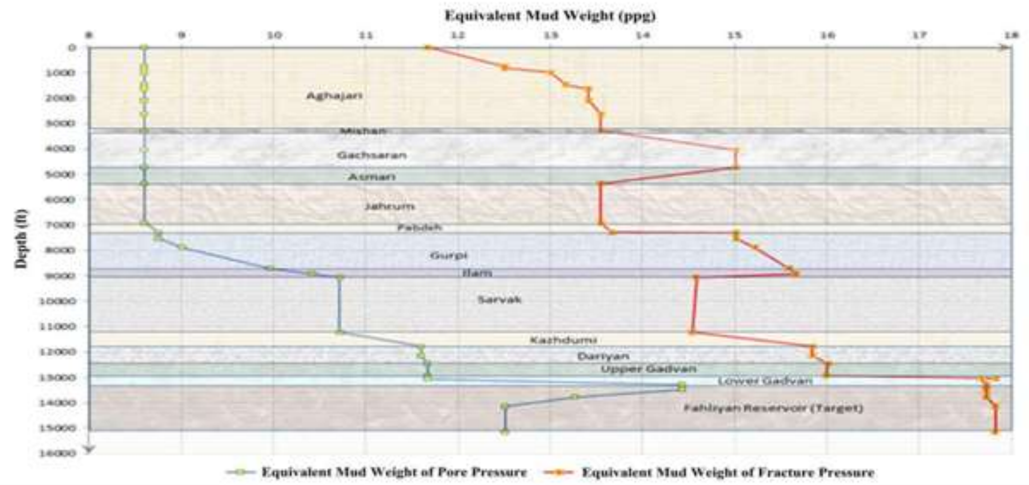

Fig.10: Pore pressure and fracture pressure profile of Well LV No. 5

Table 1: Input data, drill string and BHA details, used in Fahliyan formation

Drill String Description (From Bit to Top)	Inner Diameter (Inches)	Outer Diameter (Inches)	Length (feet)	Distance from Bit (feet)
DC	2.81	8.00	30.80	30.80
St. Stab	2.81	12.25	4.82	35.62
DC	2.81	8.00	62.73	98.35
St. Stab	2.81	12.25	5.41	103.76
DC	2.81	8.00	180.90	284.66
Jar	2.81	8.00	16.53	301.19
DC	2.81	8.00	30.80	331.99
HWDP	3.00	5.00	460.78	792.77
DP	4.27	5.00	12511.00	13304.50

Table 2: Input data, casing design data

Description (From Bottom to Top)	Hole Diameter (Inches)	Casing Outer Diameter (Inches)	Casing Internal Diameter (Inches)	Depth From (Ft)	Depth To (Ft)
Open Hole	12.25	9.625	8.535	7382.25	13304.45
Surface Casing	17.50	13.375	12.415	0.00	7382.25
Conductor Casing	24.00	18.625	17.755	0.00	820.25

Table 3: Input data, drilling fluid and circulation data

Rotational Speeds	Fann Viscometer Dial Readings
θ_3	2
θ_6	3

θ_{100} θ_{200} θ_{300} θ_{600}	20 30 40 60		
Parameter	**Min**	**Increment**	**Max**
Circulation Rate (gpm)	707.0	10.0	767
Mud weight (ppg) used in Lower 12 ¼" hole	14.22	0.03	14.31

Table 4: Input data, formation data

Formation Description	TVD (feet)	Pore Pressure (ppg)	Fracture Pressure (ppg)
Aghajari	0.00	8.60	11.67
Aghajari	820.2	8.60	12.51
Mishan	3281.0	8.60	13.55
Gachsaran	4035.6	8.60	15.01
Gachsaran	4727.9	8.60	15.01
Asmari	5367.7	8.60	13.55
Jahrum	6922.9	8.60	13.55
Jahrum	7287.1	8.75	13.67
Pabdeh	7290.0	8.75	15.01
Pabdeh	7533.1	9.00	15.01
Gurpi	7874.0	9.96	15.59
Gurpi	8697.9	10.42	15.22
llam	8924.3	10.72	14.59
llam	9058.8	10.72	14.59
Sarvak	11224.3	11.60	15.54
Kazhdumi	11782.0	11.60	15.84
Dariyan	12139.7	11.60	15.84
Upper Gadvan Lower Gadvan	12943.5 13051.0	11.67 11.67	16.00 17.84
Lower Gadvan	13288.0	14.43	17.73
Fahllyan Reservoir	13304.4	14.43	17.73
Fahllyan Reservoir	13780.2	13.26	17.73
Fahllyan Reservoir	15151.6	12.51	17.83

Table 5: Input data, used mud systems (ENI AGIP, 2005)

	Mud System	Density range (ppg)	Mud volume (ft^3)
24" hole section at 820 ft	Fresh water , bentonite (FW-GE)	8.75-9.17	17700
17 ½" hole at 7382 ft	Salt water, polymer-lignosulfonate system (SW-PO-LS)	9.17-11.5	17700
12 ¼" hole at 13304 ft	Salt water, polymer-lignosulfonate system (SW-PO-LS)	12.5-14.7	47700

Table 6: Input data, mud characteristics (ENI AGIP, 2005)

		Hole Phases		
		24"	**17 ½"**	**12 ¼"**
Mud Type	Units	FW-GE	SW-POL-LS	SW-POL-LS
From	ft	0	820	7382
To	ft	820	7382	13304
Mud Density	ppg	8.75–9.17	9.17–11.5	12.5–14.7
Viscosity	Sec^{-1}	70	50 - 60	50 - 60
PV	cps	15-20	15-20	15-20
YP	lb/100 ft^2	61	18-22	19-25
Gel 10"	lb/100 ft^2	NA	2-4	2-4
Gel 10'	lb/100 ft^2	NA	4-6	4-6
PH	-	9.5-10	9-10	9-10
Filtrate API	cc/30'	NA	<8	4-6
Pm	cm^3 0.02N H_2SO_4	NA	1	1
Pf	cm^3 0.02N H_2SO_4	NA	0.7	0.7

Table 7: Hydraulic program, 17 ½" section from 820 to 7382 ft RKB

	Pump data		**Bit Data**

Depth (ft)	MW (ppg)	Flow Rate (gpm)	Pressure (psi)	Force (HHP)	Annular Velocity (ft/sec)	Nozzles (1/32 in)	TFA (in^2)	Pressure at bit (psi)	% Pressure at bit	Jet velocity (ft/sec)	Pressure (HHP/in^2)	Impact Force (kg)
1640	9.2	898	1251	662	1.306	3*18+ 1*16	0.941	793	61.0	305	1.7	594
3821	10.1	898	1507	792	1.306	3*18+ 1*16	0.941	867	55.0	305	1.8	648
4921	10.2	898	1678	886	1.306	3*18+ 1*16	0.941	867	49.6	305	1.8	648
7218	10.2	898	2361	1241	1.306	3*18	0.745	1381	56.0	387	2.9	820
7382	10.2	898	2446	1288	1.306	3*18	0.745	1381	54.0	387	2.9	820

CONVENTIONAL DRILLING

When a MW of 14.68 ppg is used, there is no other way to reduce loss amount and stop it, even if the pump is turned off. Thus this mud weight is rejected. By using a MW of 14.45 ppg, the circulation is lost under dynamic conditions using a pump rate of 767 gpm. The only way to eliminate the problem in this situation is to reduce the pump rate to about 545 gpm; nevertheless, this rate might increase the risk of undesirable hole cleaning. It generates excessive frictional pressure of the cuttings, compensates for the pump rate reducing action, and might increase the ECD greater than that of the 767 gpm condition. Therefore, this mud weight could not treat loss of returns. These results make the use of a lower mud weight.

CONSTANT BOTTOM HOLE PRESSURE SOLUTION

In the simulator, a MW of 14.31 ppg is used to drill this section. It is obvious that this mud is about 0.12 ppg lower than the pore pressure of the Gadvan formation at 13304 ft TVD. The static BHP of this mud is 9900 psi, while the pore pressure is about 9983 psi. The well will certainly flow during drilling and connection, and thus the minimum 83 psi back pressure should be exerted at surface through choke manifold to compensate for the BHP. When the bit is reaming the formation at a pump rate of 767 gpm, the pressure throughout the wellbore is in a margin of safety and kick or loss scenario does not happen. The main issue is when a connection is to be made and the mud pumps are to be turned off. This is called the transition from dynamic to static condition.

IV. RESULTS

All the data mentioned above were input to the software. After running casing 13 3/8” to 7382 ft TVD and cementing, drilling continued with a 12 ¼" bit without major kick or loss problems according to the planned mud weight (ENI AGIP, 2005) (ENI AGIP Co. 2005).When the bit reaches 13181 ft TVD (lower 12 ¼" hole section), the operator changes the MW from 13.34 ppg to 14.68 ppg because of high pore pressure expected in Gadvan. This is continued to the planned 9 5⁄8 " casing setting depth (13304 ft TVD). Fig. 11 illustrates this procedure. According to Fig. 11, the pore pressure at 13304 ft TVD is about 9983 psi, and the column pressure of 14.68 ppg of mud is 10156 psi. When circulating the mud at 767 gpm, the BHP increases to 10259 psi. Although the well does not flow, as it generates positive differential pressures of 173 psi and 276 psi in static and dynamic conditions respectively, mud returns are lost throughout the Sarvak formation during drilling and making connection. It is critical to reduce the mud weight so as to possibly cure the problem. The minimum mud weight that can be used to drill this interval (about last 123 ft of Gadvan formation) is an EMW of 14.43 ppg. For safety reasons, a mud weight of 14.45 ppg was used to drill this section. Hence a little overbalanced was expected at the bottom of the hole; however, when the pump turned on at 767 gpm, the mud returns could be found in Sarvak formation.

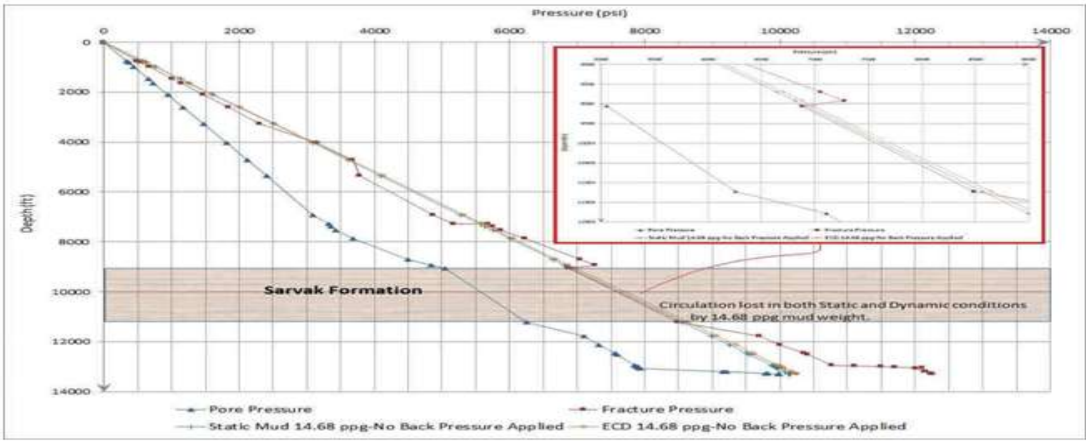

Fig. 11: Operation window, static and dynamic BHP using a MW of 14.68 ppg at a pump rate of 767 gpm.

V. CONCLUSION

The DZxION MPD software performs hydraulic analysis using the API RP 13D rheological model and calculates the annular pressure drop to compare the pressures and the required back pressure, if needed. Using a mud weight of 14.31 ppg and exerting 100 psi static back pressure, the wellbore pressure profile got slightly overbalanced. When the mud pumps are in service, no back pressure is required. The problem is resoed and no kick or loss is observed using a MW of 14.31 ppg and a static back pressure of 100 psi. As a result, the managed pressure drilling technology is useful in Iran Lovan oil field through using a lower mud weight in order to overcome the circulation loss in Sarvak formation.The feasibility study of implementing CBHP variation in Lovan oil field was done. It was more challenging when the hole was simultaneously exposed to Gadvan formation with a pore pressure very close to the fracture pressure of the other exposed formation (Sarvak). A MW of 14.68 ppg induced circulation loss in Sarvak; A MW of 14.45 ppg lowered the differential pressure and possibly brought formation fluid into the wellbore when the mud pumps were on; By using the MPD software, a MW of 14.31 ppg was selected to drill the bottom 12 ¼" hole section; Under static conditions, applying a surface back pressure of 100 psi by following the scheduled pump rate-choke opening eliminated the problem.By using this method to drill the well, some advantages were gained: the mud weights used to drill the well, the number of casing strings, and the number of changing mud weights were reduced.

VI. RECOMMENDATIONS

MPD improves the economics of drilling wells by reducing drilling problems. Further economic studies are necessary to determine exactly how much cost savings MPD can provide in certain situation. Further research is also necessary on the various MPD techniques to increase their effectiveness.

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