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Evaluating Cutting Transport on 12 ¼" Section Well TM-1

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ABSTRACT

Mud hydraulics on a 12-1/4" section needs to be planned properly. Mud hydraulics design on a 12-1/4" section includes determining mud density, flow type, pressure loss, pump specifications, bit hydraulics and cutting lifting design. The purpose of bit hydraulics design is to determine the optimum flow rate. Mud hydraulics optimization is carried out using methods the Bit Hydraulic Horse Power (BHHP), Bit Hydraulic Impact (BHI) and Jet Velocity (JV) methods, where the analysis is in the form of graphs. The graph is analyzed by using a trial and error method to obtain the recommended flow rate so as to provide good cutting lifting. where the expected recommendation analysis are Cutting Transport Ratio (Ft) > 90%, Cutting Concentration (Ca) < 5%, and Carrying Capacity Index (CCI) > 1. The analysis results from the graph show that for the hole 12-1/4", it is recommended to use an optimum flow rate of 626.6 gpm with minimum value of Ft is 90.01%, Ca is 0.87% and CCI is 1.95. These values are stated to be good by using 15-15-16 nozzle bit combination. The Flowrate value can be increased up to 785 gpm by using 18-18-20 nozzle bit combination.
Keywords: Hydraulic Mud Planning, Optimum Flow Rate, Cuttings Removal.

I. INTRODUCTION

The "DZ" field is located within the operational area of the Selat Malaka block and falls within the Tertiary stratigraphy of the Central Sumatra Basin. Within this field, drilling operations are planned for field development by adding an infill well, namely "TM-01," with reference data taken from offset well "SDP-28." The drilling program for well "TM-01" is scheduled to reach a depth of 2300 ftMD, targeting the sihapas formation, which consists of sandstone. This development well is designed as a vertical well.

Based on information from the reference well, the stratigraphic structure of this field is predominantly shale with hydrophilic mineral content and is also dominated by sandstone. Therefore, to facilitate an efficient and effective drilling process, the proper planning of hydraulic mud is essential to ensure optimal removal of cuttings from the wellbore.

The hydraulic mud planning for well "TM-01" is intended for two trajectories, namely the 12-1/4" and 8-1/2" trajectories. The planning process involves several stages, including data collection, data processing, planning, optimization, and evaluation. The ultimate objectives of this hydraulic mud planning are twofold. Firstly, it aims to determine the optimum flow rate values and identify the optimal nozzle size combinations suitable for the geometrical conditions of each trajectory. Secondly, it aims to achieve good hole cleaning criteria after optimizing hydraulic mud, taking into consideration the cutting transport ratio (Ft) above 90%, cutting concentration (Ca) below 5%, and carrying capacity index (CCI) above or equal to 1 (Wastu et al., 2019).

If the minimum criteria for these three parameters are met, it can be concluded that the level of cuttings removal after hydraulic planning is considered satisfactory. Improved hole cleaning directly impacts the rate of penetration (ROP), which in turn enhances drilling efficiency by reducing drilling time.

II. METHODS

The research methodology employed in the study of Hydraulic Mud Drilling Planning for Well "TM-01" in the "DZ" field encompasses several phases. These include data collection and processing from the offset well 'SDP-28,' encompassing data such as pore pressure fracture gradient, hole diameter geometry, depth, drill string diameter and length, casing design, drilling parameters such as Rate of Penetration (ROP), Rotation Per Minute (RPM), offset well flow rate, mud data such as density and cutting size, Plastic Viscosity (PV) dan Yield Point (YP).

The determination of mud density for each trajectory based on the drilling window of the reference well. This phase is carried out by plotting the formation pressure and formation fracture pressure values against drilling depth on a single graph to ascertain the upper and lower boundary safety factors for establishing the safe mud weight for each trajectory for well "TM-01." Determining the type of mud flow occurring within the drill string and annulus for each trajectory. To ascertain whether mud flow will be laminar or turbulent, various parameters, including dial readings from the viscometer (θ600, θ300, θ200, θ100, θ6, and θ3), are necessary to obtain PV and YP. Additionally, data on flowrate, inside and outside drill string diameters, and length of the offset well's drill string significantly influence the determination of mud flow type.

This analysis will utilize a modified-power law or Herschel-Buckley fluid model, as employed in the offset wells. Determining the magnitude of parasitic pressure loss occurring within the drill string and annulus for each trajectory and subsequently planning the bit pressure loss, which is then added to the parasitic pressure value to determine the pump pressure required for mud circulation. Planning pressure loss is crucial for establishing the pump pressure specification that aids in optimizing hydraulic mud. Determining the pump specifications capable of meeting the required pump pressure. In this phase, the required pump specifications include maximum HP pump, maximum pump pressure, and displacement pump. Determining the maximum flow rate as the upper limit to prevent mud turbulence. The determination of the maximum flow rate is calculated based on the pump specifications that will be used, considering parameters such as horsepower, pump pressure, and utilized flow rate. This implies that the maximum pump capacity will provide the required maximum flow rate without inducing turbulence.

Determining the minimum flow rate as the lower limit for cutting suspension. When establishing the minimum flow rate, values for annular velocity and slip velocity are obtained, closely related to how mud can suspend cuttings to prevent settling when mud is in dynamic conditions. Additionally, parameters such as cutting concentration and minimum velocity also influence the determination of the minimum flow rate. Planning hydraulic mud optimization to maximize mud flow rates based on the BHHP, BHI and JV methods, resulting in optimal flow rates and nozzle combinations. Through these three methods, various optimal flow rates with suitable nozzle combinations are determined. For BHHP, it maximizes the surface power potential used by the bit. For BHI, this method maximizes the impact potential of the mud exiting the nozzle against the rock. For jet velocity, it maximizes the nozzle jetting potential by maximizing the surface pump rate, thereby achieving maximum bit rate. Analyzing the success rate of hole cleaning after obtaining the optimum flow rate using several cuttings removal methods such as Cutting Transport Ratio (Ft), Cutting Concentration (Ca), and Carrying Capacity Index (CCI). According to (Al Rubaii, 2018), cuttings removal analysis can be conducted through three methods: cutting transport ratio (Ft) with a value exceeding 90%, cutting concentration ranging from 5-8%, and carrying capacity index with a value of 1.

III. RESULTS AND DISCUSSION

This drilling operation is conducted for field development by adding an infill well, namely "TM-01," utilizing reference data from the offset data well "SDP-28." The drilling program for well "TM-01" is planned to reach a depth of 2300 ft-MD, targeting the Sihapas Formation, which comprises sandstone reservoirs. This development well is of the vertical well type. By conducting hydraulic mud planning based on the reference well, it is expected that the planning results will positively influence cuttings removal and wellbore cleaning by meeting hole cleaning parameter criteria such as Ft, Ca, and CCI. For the 12-1/4" trajectory, drilling commences from a depth of 155 ft-MD and will penetrate through shale layers until casing installation of 9-5/8" from the surface down to a depth of 1250 ft-MD to isolate these shale layers.

Further data required for hydraulic mud drilling planning includes bit data, Bottom Hole Assembly (BHA) data, and drill string data. For well 'TM-01,' a Polycrystalline Diamond Compact (PDC) type bit will be utilized with specifications as outlined in **Table 1**. BHA and drillstring configurations will be based on reference data from well 'SDP-28.' There are two types of BHA and drillstring configurations, each for the 9-5/8" and 7" trajectories, generally consisting of drillstring equipment such as drillpipe, Heavy Weight Drill Pipe (HWDP), drill collar, drill jar, crossover sub, stabilizer, and bit sub. The drillstring data tabulation is provided for the 12-1/4" trajectory.

After conducting calculations for the 12-1/4" trajectory in well "TM-01," it was found that the cuttings removal results using the optimum flow rate based on the actual nozzle configuration were not entirely optimal. Therefore, a trial and error approach was employed to determine the optimum flow rate from the results of the optimization of three hydraulic bit methods through graphical plotting. The ultimate goal is to provide recommendations for the nozzle and the optimal flow rate range that meet the minimum criteria of the three cuttings removal methods: Ft, Ca, and CCI. For the 12-1/4" trajectory, it is recommended to use the optimum flow rate with a minimum cuttings removal value considered good at 626.6 with a bit nozzle combination of 15-15-16. The flow rate can be increased up to 785 gpm with a nozzle combination of 18-18-20. It is also known that using the actual nozzle results in poor cuttings removal. The "DZ" field is located in the working area of the Malacca Strait block and is still within the tertiary stratigraphy of the Central Sumatra Basin. In this field, drilling will be carried out for field development by adding an infill well, namely "TM-01," using reference data from the offset well "SDP-28." This development well is of the vertical well type.

Table 1. Tabulation of BHA Data for the 12-1/4" Trajectory

BHA 12-1/4"					
No.	Description	OD	ID	Length, ft	Total Length, ft
		in	in		
1	5" DP CSG	5.00	4.28	155.00	155
2	5" DP OH	5.00	4.28	684.82	839.82
3	5" HWDP	5.00	3.00	30.95	870.77
4	5" HWDP	5.00	3.00	31.10	901.87
5	5" HWDP	5.00	3.00	30.83	932.70
6	5" HWDP	5.00	3.00	30.95	963.65
7	5" HWDP	5.00	3.00	31.07	994.72
8	5" HWDP	5.00	3.00	30.84	1025.56
9	6-1/2" DC	6.50	3.00	30.75	1056.31
10	6-1/2" DC	6.50	3.00	28.84	1085.15
11	6-1/2" Drill Jar	6.50	3.00	31.97	1117.12
12	6-1/2" DC	6.50	3.00	30.02	1147.14
13	6-1/2" DC	6.50	3.00	29.98	1177.12
14	8" X/O	8.00	3.00	1.64	1178.76
15	8" DC	8.00	3.00	31.07	1209.83
16	12-1/4" Stab	12.00	3.00	5.18	1215.01
17	8" DC	8.00	3.00	30.74	1245.75
18	8" Bit Sub	8.00	3.00	3.00	1248.75
19	12-1/4" PDC bit	12.25		1.25	1250.00
BHA TOTAL				410.18	

Table 2. Bit Data

Bit					
Bit Size	Casing Size	Merk	Type	*Nozzle*	d *Nozzle* (in/32)
Driven	13.375		-	-	
12.25	9.625	NOV RH	PDC	7 x15	0.46875

Table 3. Drilling Powder Data

Data *Cutting*			
Hole	Diameter (mm)	Diameter (in)	Densitas (lb/gal)
12-1/4"	3.5	0.137795276	19.992

Table 4. Mud Properties Data 12-1/4"

12-1/4"							
θ600	θ300	θ200	θ100	θ6	θ3	PV	YP
63	43	27	13	6	4	20	23

The "DZ" field is located in the working area of the Malacca Strait block and is still within the tertiary stratigraphy of the Central Sumatra Basin. In this field, drilling will be carried out for field development by adding an infill well, namely

"TM-01," using reference data from the offset well "SDP-28." This development well is of the vertical well type. Preparations have been made for the drilling program, including hole geometry, casing design, and the drillstring to be used. Therefore, hydraulic mud planning is required for this well to facilitate a smooth drilling process. The drilling program for well "TM-01" is planned to reach a depth of 2300 ftMD, targeting the sihapas formation, which consists of a sandstone reservoir. This well will be divided into three trajectories: the 13-3/8" trajectory with conductor casing installation from 0 ftMD to 155 ftMD, the 12-1/4" trajectory with surface casing of 9-5/8" from 0-1250 ftMD, and the 8-1/2" trajectory with production casing of 7" from 0 to 2300 ftMD.

The planning of hydraulic mud is required for the 12-1/4" and 8-1/2" trajectories. This planning includes the determination of mud density, the determination of flow type, the determination of pressure loss, the determination of pump specifications, hydraulic bit planning to determine the optimum flow rate, and cuttings removal planning.

Data collection is carried out from the offset well 'SDP-28,' including well data such as depth and hole geometry. Drilling parameter data, such as the planned drillstring and BHA configuration, drillstring and BHA diameter measurements, pump data, bit data, pressure window data, and drilling mud data, such as mud properties like dial readings of θ600, θ300, θ200, θ100, θ6, and θ3, PV and YP values, density, and cutting diameter.

The first step in hydraulic planning is to determine the mud window, which aims to establish a safe mud weight that does not cause drilling problems. To determine the mud window, pressure window data such as formation pressure and fracture pressure are required. Since well "TM-01" is still within the same contour as the reference well, pressure data can be used as a reference for determining the mud window. Mud weight determination is carried out for two trajectories, 12-1/4" and 8-1/2". For the 12-1/4" trajectory, a mud weight of 9.6 ppg will be used, and for the 8-1/2" trajectory, a mud weight of 10 ppg will be used. These values include safety margins added to the formation pressure. At this stage, the Equivalent Circulating Density (ECD) magnitude is also determined, where the mud conditions, when dynamic and carrying cuttings, experience an increase in density. The determination of the ECD value is necessary for calculating the total annulus pressure loss, which reveals the increase in mud weight under static conditions. For the 12-1/4" trajectory, the ECD value ranges around 10.7 ppg, and for the 8-1/2" trajectory, it ranges around 10.9 ppg. These values remain below the fracture pressure, ensuring that the mud weight does not pose drilling problems.

Before determining the flow type, it is important to understand the rheology model of the drilling mud being used. In this well, the fluid model employed is Herschel-Bulkley after plotting shear rate against shear stress, obtained through dial reading on the viscometer. This fluid rheology applies to both trajectories. After determining the rheology of the mud, parameters derived from the Herschel-Bulkley fluid type, such as yield stress, Herschel-Bulkley flow index, and Herschel-Bulkley consistency index, are required to determine the flow type and other aspects. For the 12-1/4" trajectory, the yield stress ($\tau\gamma$) was found to be 2, with a flow index value of 0.5732 and a consistency index value of 574.50 cp. Once these parameters are obtained, the next step is to determine the flow type that occurs during circulation. The determination of the flow type is based on the critical Reynolds number (Nrec) value. If the Reynolds number (Nre) of a flow exceeds the Nrec value, the flow is considered turbulent. Conversely, if the Nre of a flow is less than the Nrec value, the flow is considered laminar. To calculate the Nrec value, values of γ and z, which are 0.0737 and 0.284, respectively, are needed. Thus, the Nrec values for the drillstring are 2338.67, and for the annulus, they are 4426.2.

The determination of the flow type will be divided into several sections, with each section having different borehole geometry conditions depending on the diameter of the mud flow. It was found that the Reynolds number along the flow inside the drillstring is turbulent, while the flow inside the annulus is laminar. This is considered favorable because within the drillstring, turbulent flow is necessary to ensure that the power delivered by the pump is not lost before reaching the bit, and turbulent flow exiting the bit can cause abrasion, preventing cuttings from settling. In contrast, laminar flow is desired in the annulus due to the borehole conditions that have not been cased, and the mud's function is to provide a mudcake on the borehole wall to withstand formation pressure. After determining the fluid flow type, the next step in mud hydraulic planning is to calculate the magnitude of pressure loss that occurs during mud circulation. The goal is to determine the value of equivalent circulating density and ascertain the pump pressure required at the actual flow rate. The calculation of the minimum pump pressure is identical to the calculation of pressure loss in the circulation system, except at the bit, which represents parasitic pressure loss. To determine the required pump pressure, the total pressure loss value is calculated. To obtain the total pressure loss, it comprises the sum of parasitic pressure loss and bit pressure loss. Parasitic pressure loss represents the total pressure loss that occurs in the drillstring except at the bit, both inside and outside the annulus. The parasitic pressure loss for the 12-1/4" trajectory is 484.28 psi. Once the parasitic pressure loss value is obtained, the next step in mud hydraulic planning is to determine the magnitude of pressure loss that occurs at the bit. In the 12-1/4" trajectory, a 12.25-inch PDC bit with a nozzle size of 7x15 is used. The nozzle Discharge Coefficient (Cd) is set at 0.95. To calculate the pressure drop at the bit, the area produced by the nozzle diameter is required. With the given nozzle diameter, the area of the nozzle is 0.5177 square inches. The pressure loss at the bit is found to be 1116.49 psi. Therefore, in the 12-1/4" trajectory, the total pressure loss amounts to 1600.787 psi. Therefore, a pump capable of providing a minimum pressure of 1600 psi is required.

Therefore, the pump selected for well 'TM-01' in the 12-1/4" trajectory is the Oilwell A600-PT, which is a triplex pump. Three pumps are employed, with two active pumps and one backup pump, configured in parallel, with a maximum HP of 1080 hp, a maximum flow rate of 849.6 gpm, and a maximum pressure of 1767 psi. Subsequently, the determination of the minimum flow rate is required to establish the minimum limit at which cutting can remain suspended in the mud. To calculate the minimum flow rate, the concept of Vmin or minimum velocity is utilized. During this stage, values for annular velocity, apparent viscosity, slip velocity, cutting velocity, minimum velocity, and minimum flow rate are determined. For the 12-1/4" trajectory, a minimum flow rate of 292.13 gpm is needed.

IV. CONCLUSION

Through the hydraulic design of well "TM-01" for the 12-1/4" trajectory, the hydraulic bit design using the actual nozzle configuration of 15-15-15 yielded an optimum flow rate of 600 gpm with cuttings removal results of Ft 89.6%, Ca 0.9%, and CCI 1.86. The cuttings removal is considered poor. In the course of planning the drilling of well "TM-01," various aspects of hydraulic mud have been meticulously considered. A safe mud weight has been determined, taking into account formation and fracture pressures, including the addition of safety margins. The type of mud flow in the well has been analyzed using the Herschel-Bulkley rheology model, resulting in turbulent flow within the drillstring and laminar flow within the annulus. Calculating pressure losses is essential to determine the required pump pressure, considering parasitic pressure and pressure loss at the bit. The precise selection of the Oilwell A600-PT pump is made to meet the minimum pressure requirements for mud circulation. Lastly, the minimum flow rate required has been calculated to ensure that cuttings remain suspended in the mud. With this thorough planning, it is anticipated that the drilling of well "TM-01" can be executed with maximum efficiency and safety to achieve the targeted depth.

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