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Maximizing Drilling Operations By Implementing An Advanced Drilling Fluid Technology

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Abstract

The drilling industry has developed and implemented tens of technologies in the last decade that have allowed operators and contractors to challenge and extend the technical limits that were once road blocks to advancement.[1,2]

A plethora of mechanical and electrical technologies have been introduced in the oil and gas industry that have extended reaches and depths once thought of as unattainable. As these reaches extend, so does the counter-culprit to these limits; friction. Several major oil and gas operators have proven an innovative environmentally safe advanced drilling fluid technology (ADFT) that is 100% compatible with most drilling fluid systems and mitigates the negative effects of surface and down hole friction as well as has shown to substantially improve operational efficiencies, resulting in more efficient drilling operations and lowering drilling costs. By mitigating inherent drilling friction major operators have seen faster rates of penetration, lower surface and down hole torque, lower pick up and slack off drag, lower ECDs and drilling pressures, lower down hole vibrations, reduced stick-slip, reduced equipment and material wear, longer bit life, faster trips, lower drilling fluid losses and the promotion of wellbore stability in directional, horizontal and ERD wells.

The Advanced Drilling Fluid Technology (ADFT) differs from conventional drilling fluid lubricants in that it does not alter the drilling fluid system rheology to attain the tremendous benefits seen in the field. The original concept behind this technology was to alter the conduit, (wellbore), rather than the properties of the drilling fluid. Additionally, ADFT has been proven by major oil and gas operators to stay in the system and maintain its effectiveness over time resulting in substantial time and cost savings.

Introduction

Over seventy percent of all energy that is delivered by a drilling rig and its surface and down hole equipment to drill a well is lost through friction[3]. In the drilling of directional, horizontal and extended reach wells, this friction energy loss can substantially limit the drillability of these wells.

Typically, companies do not have the financial resources to purchase the latest drilling equipment to overcome the negative effects of friction. This can result in the operators failing to meet their overall reservoir objectives and leaving untapped reserves behind. Standard friction reducers, or as there are commonly referred to in the drilling industry, “lubricants” can help in alleviating this friction. The three problems that are common with the use of standard lubricants are compatibility, effectiveness and environmental compliance. Although this ADFT meets all environmentally mandated discharge regulations throughout the world, both on land and offshore (i.e. LC-50, Microtox, etc.), this paper will focus on the operational successes major oil and gas operators have seen on numerous wells for compatibility and effectiveness.

Challenges of Wellbore Friction

Every well where the ADFT has been implemented, whether vertical or directional, was battling friction. The operators identified friction as the number one culprit to effectively drilling their wells. There are four main areas where wellbore friction has been hindering their operations: drilling torque, sliding friction in their laterals, flowing fluid pressures (SPP and ECDs) and wear. All four of these friction induced challenges come from the operating of standard mechanical surface equipment, through the down hole drilling tools-to-casing and down hole drilling tools-to- open hole contact and through the flowing of the drilling fluid in the drill string and wellbore. On every well where the ADFT was implemented, friction was reduced to a point where these challenges were effectively mitigated, thus allowing the operators to drill their wells efficiently.

Since the ADFT does not adversely affect drilling fluid properties[1] the operators were able to maintain their current drilling fluid systems without the addition of any new, special or incremental chemical additions into the system.

ADFT Development Background

Friction is the function of the reactive forces that are a result of two bodies rubbing against each other. This is the rubbing of wear components at the surface of the rig, the sliding and rotation of drill string components and casing against other casings or formation and the flowing of drilling fluid in the wellbore.

Surface friction is typically mitigated with the use of greases, oils and lubricants. These “lubes” ease the increase in friction that result as various surface equipment components churn to generate and transfer power to the drilling rig to drill and pump fluids. These lubes are typically in a non-diluted form and are applied directly to the component where the friction is being generated. The lower the friction, the more rig power can be transferred to the drill string and other drilling components to drill the well.

Down hole friction is polynomial where there are several drilling functions that can contribute to the increase in friction. The three main contributors (responsible for at least 95% of friction below the rotary table) are drilling torque, drilling drag and flowing pressure losses (i.e. equivalent circulating densities (ECDs)).

The drilling fluids that are used in the oil and gas industry are very complex and have various functions including cuttings transport, cooling and lubrication. Unlike closed systems such as engines and pumps, drilling fluid systems are not in a pressurized system and are subject to outside contaminants that are not seen in closed systems. Therefore the properties of the drilling fluids must be such that with the introduction of these contaminants (i.e. well bore fluids, drill cuttings, etc.), they do not adversely affect the primary functions of the drilling fluids.

A tremendous amount of research and development and field applications have been conducted in developing a drilling fluid lubricant (ADFT) technology that would have extremely high contact friction reductions and reduce ECDs all while maintaining drilling fluid properties and maintaining environmental compliance. By attaining these goals, not only can the fluid be utilized in the most demanding environments, but also allow for the optimization of drilling operations thus resulting in reduced overall drilling costs.

Laboratory tests and field applications have shown that this fluid technology not only yields higher friction reductions, but also maintains drilling fluid properties within the fluid’s original designed functions, and also reduces ECDs, wear and helps promote wellbore stability. All tolled, and when applied as prescribed, overall drilling operations can be optimized.

What makes this fluid technology different than typical lubricants is that it is a bonding lubricant rather than a flowing lubricant. Instead of altering the properties of the drilling fluid, it alters the flow boundary in which the drilling fluid flows by bonding to the surface of the drill pipe, casing and formation. By creating a bond with the surface, the eddy currents that are inherent in the flow boundary of the conduit are mitigated and thus reduce the effects of friction pressure. Couple this with the strong monolayer bonding and the lubricity characteristics of the lubricant, the metal-to-metal and metal-to-formation friction are mitigated thus yielding lower ECDs, lower torque and lower drag as well as reduced wear, lower vibrations and reduced stick-slip.

Laboratory Testing

The ADFT was tested on several types of friction measuring apparatus and with several different types of drilling fluids to determine its friction reducing capability.

The ADFT was tested for friction reductions at concentrations ranging from 2% to 6% v/v in varying mud weights and types. (Table 1) Although showing varying degrees of friction reduction, this fluid technology consistently showed higher reductions in friction than are typical for the industry. Compatibility tests of these treated drilling fluids yielded no detrimental affects to the drilling fluid properties with these concentrations of the ADFT . (Table 2)

In addition to contact friction testing, a fluid loop was constructed to determine the effects of the ADFT on ECDs. (Figure 1) Testing of both water based and oil based drilling fluids, at concentrations as low as 1% indicated a reduction if flowing friction pressure (ECDs) as high as 79%. (Table 3) For example, on a well where the static mud weight is 10.2 ppg and the ECD is 11.8 ppg, a reduction in ECD by 65% would yield an ECD with the treated drilling fluid of 10.76 ppg or a reduction of 1.04 ppg. In a well where the fracture gradient in the wellbore is questionable or low, this type of reduction could be the difference between losing fluid or breaking down the formation and successfully drilling the well.

Case Histories

Four case histories of the application of the ADFT will be presented in this paper. Two applications with the ADFT-A (for water-based drilling fluids) and two applications with the ADFT-NA (for oil/synthetic based drilling fluids) will be presented. All cases vary in application.

Middle East (Water Based System)

This first application was conducted in the Middle East where the operator was attempting to mill a section and drill a sidetrack. The issue that they were facing was that most of the well (>75%) was cased and the metal-to-metal contact prohibited them from maintaining tool face and sliding the well to drill it to total depth. (Figure 2)

The mud system was a standard water-based (potassium based) system. Prior to the addition of ADFT-A to the system, the well was drilling at less than 15 feet per hour (fph), and tool face to maintain directional control was difficult.

After the addition of 1 ½% ADFT-A into the system, the rate of penetration immediately increased to over 55 fph, the driller was able to maintain tool face and the well was drilled to total depth with no other issues. (Table 4)

Eagleford Shale (Oil Based System)

In this second application, the operator was having trouble with excessive torque, drag and drilling pressures.

This was limiting the lateral reach of the wells as well as requiring them to rotate their production casings and liners to total depth. Furthermore, prior to the application, it was indicated that they did not feel that they could improve on their rate of penetration (ROP) and they were "drilling as fast as they could".

As is shown in Table 5, in wells 1 through 6, the ROP was increased by an average of 122%, (114 fph), torque was reduced by an average of 49%, (9,450 ft-lbs), the SPP/ECD was reduced by an average of 40% (1,368 psi), and drag was reduced by an average of 14.4% (43k lbs).

Additionally the operator was able to run the production casing to total depth without rotation.

Another added benefit of the ADFT for these wells was that the operator experienced bit life increases of over 100% over offset wells, drilling over 10,000 ft per bit in areas where historically they had used two to three bits.

Eagleford Shale (Water Based System)

In this third application, the operator was wanting to explore the possibility of drilling the wells with water based drilling fluids versus oil based to cut costs, but still maintain the drilling performance of oil based drilling fluids.

As is shown in Table 5, in wells 7 through 10, the ROP was increased by an average of 161%, (153 fph), torque was reduced by an average of 50%, (9,450 ft-lbs), the SPP/ECD was reduced by an average of 40% (1,430 psi), and drag was reduced by an average of 15.1% (47k lbs).

Additionally the operator was able to run the production casing to total depth without rotation.

Eastern New Mexico (Water Based System)

In this fourth application, this operator was looking at making a step-change in their drilling operations to justify their drilling operations.

On these long horizontal lateral wells drilled in sandstone formations (see figure 9), the ADFT has proven to reduce drilling torque by up to 50%, reduced system pumping pressures by 50%, and increased the drilling rate by over 150%.

Additionally, the ADFT has promoted wellbore stability in the wellbores. In an area where the standard practice was to pick up a reamer and ream and condition the wellbore for three to four days before being able to run casing, the operator has eliminated the reaming run altogether thus saving them that reaming time.

An additional benefit that has been realized is that since some operators are choosing to reuse their drilling fluids from well-to-well, and since the ADFT maintains its full efficacy over time, they have been able to reduce their overall "lubricant" applications by one-half or two-thirds. By transferring the ADFT treated drilling fluid from well-to-well and regulating their lubricant additions to only new hole maintenance on subsequent wells, the overall cost to apply this technology has been less than other standard industry lubricants that do not have this efficacy benefit.

All tolled to date, on over 20 horizontal well applications in this sandstone formation, the operator has been able to save on average 4 days per well, and the associated daily operational rate and extend their horizontal reach by over 1,000 feet.

Conclusions

The Advanced Drilling Fluid Technology has successfully proven to effectively mitigate the negative effects of friction in numerous oil and gas wells throughout the world.

By mitigating the friction, oil and gas operators have been able to improve their operational efficiencies by an average of 25% thus allowing them to drill faster and further, with less energy as well as has helped them to reduce the overall cost of drilling their wells.

Nomenclature

Define symbols used in the text here unless they are explained in the body of the text. Use units where appropriate.

BHA = *Bottom hole assembly*
ROP = *Rate of Penetration (fph)*
PU = *Pick Up (lbs)*
SO = *Slack Off (lbs)*
ECD = *Equivalent Circulating Density (ppg)*
SPP = *Stand Pipe Pressure (psi)*
GPM = *Gallons Per Minute (gpm)*
BRU = *Bead Recovery Unit*
NPT = *Non-Productive Time (hours)*
ADFT = *Advanced Drilling Fluid Technology*
FPH = *Feet Per Hour*

References

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2. Walker, M.W., Veselka, A.J., Harris, S.A.: "Increasing Sakhalin Extended Reach Drilling and Completion Capability" SPE 119373-MS, SPE/IADE Drilling Conference and Exhibition, Amsterdam, March 17-19, 2009.

3. Dunn, M.D., Crane, L.R. and Thomas, R.L.: "North Slope Drilling Practices – Ever Adapting to New Challenges." AADE-05-NTCE-07, AADE National Technical Conference, Houston, April 5-7, 2005.

Table 1 – Laboratory Testing for Friction Reduction

		OBM/SBM Concentration of ADFT-NA % v/v				WBM Concentration of ADFT-A % v/v		
Testing Apparatus	MW-ppg	3	4	6	MW-ppg	3	4	6
Baroid Lubricity Meter	11.2	78%	82%	85%	12.5	82%	87%	87%
Falex Pin & Vee Block	11.4	26%	28%	36%	10.5	54%	57%	62%
Lubricity Evalulation Monitor	12.2	48%	50%	57%	11.5	56%	60%	64%
OFITE Lubicity Tester	10.9	39%	43%	52%	9.8	67%	75%	77%

Table 2 – Fluid Compatibility Testing (example)

TEST DESCRIPTION	Base	3% ADFT				
MUD WEIGHT PPG	12	12				
FUNNEL VISCOSITY (SEC/QT)						
RHEOLOGY @ 600 RPM @120°F	59	60				
300 RPM	38	38				
200 RPM	29	29				
100 RPM	18	20				
6 RPM	4	4				
3 RPM	3	3				
PLASTIC VISCOSITY (cP)	21	22				
YIELD POINT (LB/100 SQ FT)	17	16				
GEL STRENGTH 10 SEC / 10 MIN	5/8/18	6/8/16				
API W.L. (ML/30 MIN)						
HPHT @ 250 (ML/30 MIN)						
CAKE THICKNESS (32nd)						
SOLIDS % BY VOLUME						
OIL % BY VOLUME						
WATER % BY VOLUME						
MBT (PPB EQUIV.)						
pH STRIP/METER	9.1	9.0				
ALKALINITY (Pm)						
ALKALINITY FILTRATE (Pf)						
ALKALINITY FILTRATE (Mf)						
CHLORIDES (ppm)						
CALCIUM (ppb)						
GARRETT GAS TRAIN						
POTASSIUM						
EXCESS LIME						
LGS %						
STATIC SHEEN						

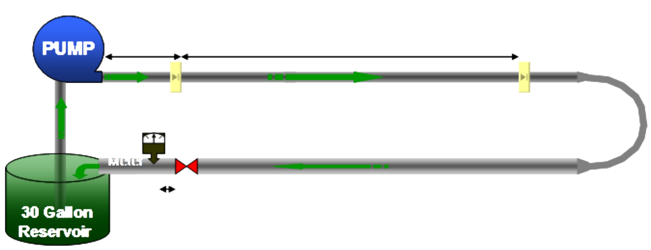

Figure 1 – ECD Flow Loop Testing Apparatus

Table 3 – ECD & Pressure Flow Loop Test Results

Test No.	% ADFT	Avg Temp (C)	Flow Rate (gpm)	Pressure Drop (psi)	Comments
1	0	33.54	8	5.34	10.4 ppg WBM baseline
2	0	33.33	8	5	11.2 ppg OBM baseline
3	1	33.68	8	1.68	10.4 pg WBM - 68% Drop
4	1	34.23	8	2.24	11.2 ppf OBM - 55.2% Drop
5	4	32.57	8	1.32	10.4 ppg WBM - 75% Drop
6	4	34.43	8	2.18	11.2 ppg OBM - 56.4% Drop
7	6	32.77	8	1.11	10.4 ppg WBM - 79% Drop
8	6	33.83	8	2.02	11.2 ppg OBM - 59.6% Drop

Figure 2 – Middle East Field Application

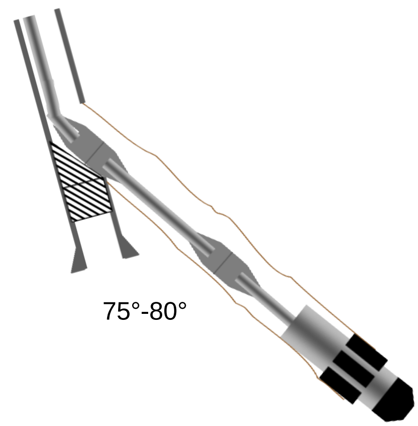

Table 4 – Middle East Field Application Results

% Additive	RPM	SWOB	Flow Rate	Drlg Torque	PU Torque	PU	SO	ECD	SPP on Btm	SPP off btm	ROP
		1000 lbs	gpm	1000 ft lbs	1000 ft lbs				psi	psi	ft/hr
0	0	5	500	22	24	320	185		2460		6.25
0	0	5	550	23	24	322	185		2440	1250	8.66
0	80	10	580	22	23	322	187		2460	1400	15.2
0	80	10	580	22	23	318	185		2460	1400	15
0.5	80	10	580	19	18	308	190		2220	1400	18.27
0.5	80	10	580	18	16	301	190		2200	1400	22.64
1	80	10	580	16	15	285	201		1800	1400	55.07
1	80	10	580	15	13	275	215		1770	1400	54.02
1	40	10	580	15	15	275	220		1700	1500	56.89
1	80	10	580	16	14	277	222		1700	1500	55.2
1	80	10	580	15	14	275	220		1700	1500	54.32

Figure 3 – Horizontal Wells in Eagleford Shale: Oil & Water Based Muds: Ten Well Application (No ADFT vs 3% ADFT)

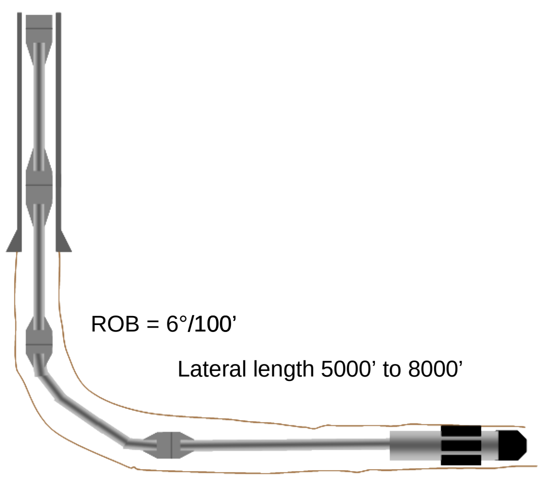

Table 5 – Eagleford Shale OBM and WBM Horizontal Well Applications (at 3% v/v ADFT)

Figure 4 – Horizontal Wells with Water based Mud – Sandstone Formations

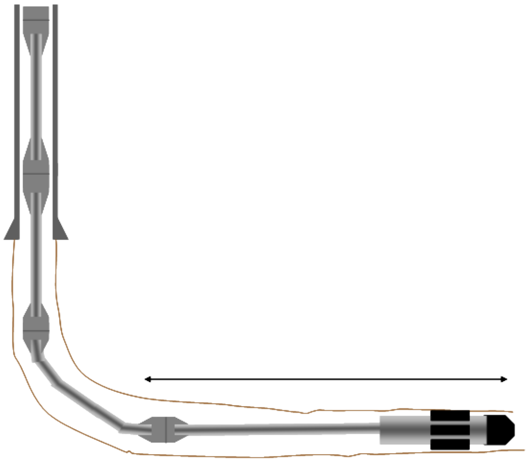

Table 6 – Sandstone Formations: Horizontal Wells Drilling Improvement (5 of 25 wells)

Well lengths ranged from 12,500 feet to 16,500 feet. Horizontal section lengths ranged from 3,000 Feet to 7,000 feet. WBM mud weight ranges were from 9.0 ppg to 11.2 ppg. All applications of the ADFT were at 3% v/v to the system.