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Navigating Hole Cleaning and Drilling Challenges in High-Angled Wells with D-Max Enhanced Water-Based Mud System: A Comparative Experimental Analysis

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Abstract: ***Effective hole cleaning is one of the biggest challenges faced in drilling operations all over the world, if a wellbore is not properly cleaned, it could lead to lots of hole problems, hole collapse, stuck pipe, mud losses, low ROP, casing issues, poor cementing etc. The impact of poor hole cleaning could lead to a ballooned well cost, in some cases, loss of the well and operator investment. Therefore, it is very imperative to carefully select drilling fluids system that will enable efficient hole cleaning for drilling activities.***

Selecting the appropriate fluid system that will guarantee effective hole cleaning requires a high level of engineering fluid designs and formulations.

Hole cleaning in highly deviated wells poses more challenges because drill cuttings can settle at these high-angled areas, forming cutting beds and restricting drill string movement. It is therefore very critical to design the drilling fluid to have the required carrying capacity to remove drill cuttings effectively from the well.

Emphasis on this work was to evaluate the effectiveness of D-Max system in optimizing rheological properties compared to other water-based mud system in the industry. Same concentrations of D-Max system components and two other WBM systems were formulated and pilot-tested in the laboratory, their rheological properties were obtained by conducting a barite sag test with model 900 viscometer to determine their YP and low shear rate viscosity that are responsible the carrying capacity of the fluid. From the result of the fluid designs, D-Max enhanced fluid systems provided a far better rheological and flow properties that enabled drilling of multiple highly deviated wells without issues.

I. INTRODUCTION

The D-Max enhanced water-based mud is a highly inhibitive, specialized system designed to provide stable wellbore conditions during drilling and completion activities. It does so through provision of high level of solids encapsulation and shale stability which prevents water interaction with formation and drill cuttings. It provides effective filtration control, reduces friction, and increases drill string lubricity thereby enhancing drilling ROP. The most important attribute of the D-Max system is the optimal rheological and flow properties that maximizes hole cleaning in high-angled wells. It is designed to also be environmentally friendly and offers a suitable alternative to oil-based mud systems. Laboratory and field application has proven that the D-Max system performs exceedingly well for different kinds of well trajectory.

Features of D-Max System

1) Low-Shear Rate rheology optimization
2) Very low filtrate invasion (thin and firm cake deposition)
3) Effective ROP enhancer
4) Enhanced solids encapsulation and shale stability
5) Advanced lubricity
6) Environmentally friendly
7) Effective carrying capacity

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II. LABORATORY FORMULATION & DESIGN

Objective: To determine the comparative advantage of D-Max system rheological & flow properties and its effectiveness in hole cleaning for high-angled wells.

For the lab work, formulations of D-Max system with the same concentration as two other independent water-based systems were pilot-tested, and a barite sag test conducted with a Viscometer (model OF 900) to determine the system with better rheological properties.

Product	Concentration	Unit
Fresh Water	0.87 bbls	bbls
Caustic Soda	0.6	ppb
Potassium Chloride	31.7	ppb
D-Max Viscoifier	1.3	ppb
D-Max Control H	3.0	ppb
D-Max Control L	2.0	ppb
D-Max Carb	2.0	ppb
D-Max- Inhibitor	7.0	ppb
D-Max Barite	120.0	ppb
D-Max Lube	3.0	ppb

Table 1.0: D-Max Fluid Formulation for 10.5ppg mud used for pilot testing

Model 900 Viscometer Data			
Sample Source	**D-Max System**	**Fluid 1**	**Fluid 2**
RPM	**Reading**	**Reading**	**Reading**
600	38.6	42.3	41.6
300	30.6	31.3	30.3
200	26.9	25.4	25.4
100	22.4	18.4	17.7
6	10.4	6.4	5.8
3	8.1	5.3	4.9
1	6.8	4.5	3.5
0.6	6.6	4.1	2.9
0.3	6.2	3.6	2.5
0.2	5.7	3.3	2.1
0.1	5.4	2.9	1.8
0.06	5.2	2.4	1.6
Plastic viscosity, cP	8.0	11.0	11.3
Yield point, lb/100 sq. ft.	22.6	20.3	19.0

Table 2.0: Model 900 Viscometer reading for mud formulations for D-Max System, Fluid 1, and Fluid 2

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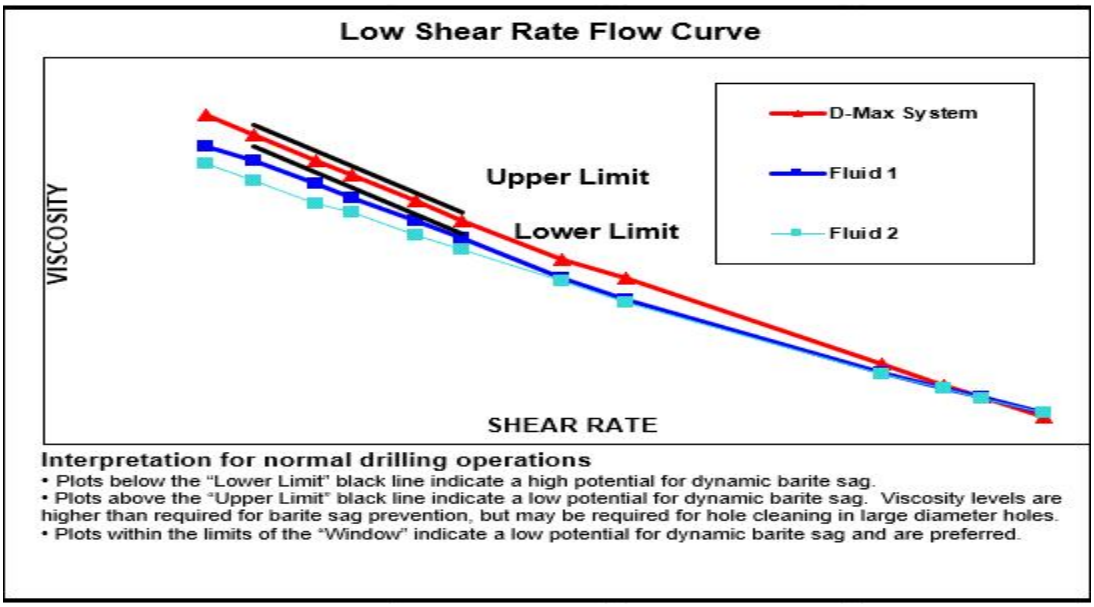


Fig.1.0: Low Shear Rate Flow Curve for D-Max System, Fluid 1, and Fluid 2

III. LABORATORY RESULT & INTERPRETATION

Based on the model 900 viscometer data for the three mud formulations, D-Max system produced the best low shear rate flow curve with low potential for dynamic barite sag which proves that the system has superior suspension and carrying properties thus providing better hole cleaning. For Fluids 1 & 2 with their low shear rate flow curve below the "lower limit" black line, they have high potential for barite sag which indicates weak suspension and carrying capacity.

A. Field Application

Although D-Max enhanced WBM has been successfully deployed for multiple high-angled wells including horizontal wells with 90 degrees inclination, for this paper we will limit the discussion to the execution of well in Fig. 2.0.

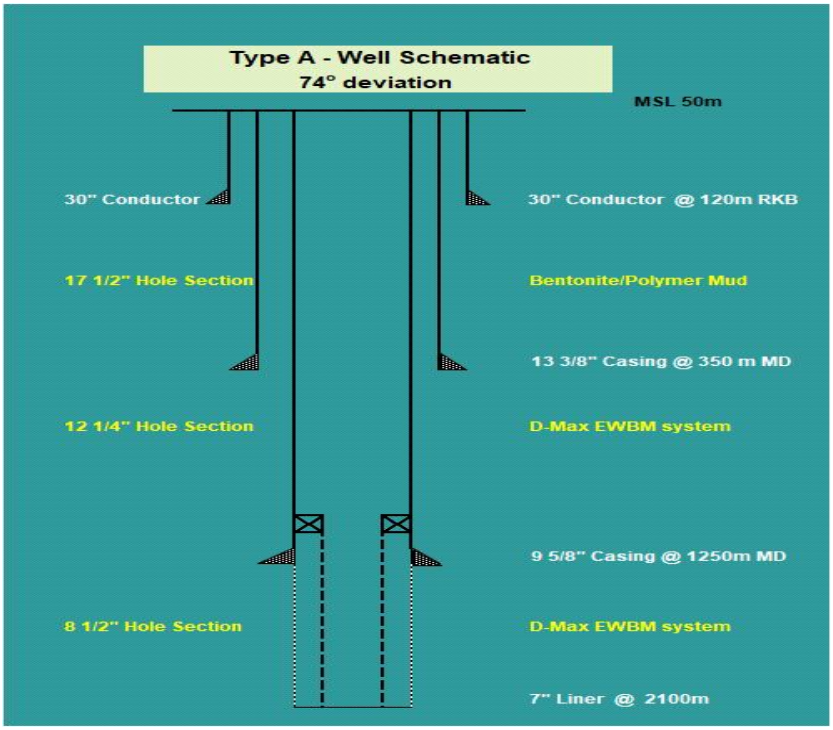


Fig.2.0: A typical well profile at 74^{o} inclination where D-Max EWBM was applied

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B. Well Discussion

The well was designed to be drilled at a 74° deviation. 30" conductor pipe was driven to refusal depth of 120 meters and the 17 ½" hole section was spudded with bentonite/polymer system and drilled to section total depth at 350 meters. 13 3/8" casing ran successfully to bottom and cemented in place. The bentonite/polymer mud was treated and converted to D-Max enhanced WBM system and was used to drill the 12 ¼" hole section to TD at 1250 meters. This D-Max system provided enhanced lubricity and proper hole cleaning while drilling this section, reason why only one BHA run was made to drill this section to TD. The well was left open for several days as the rig crew worked on a failed rig equipment. Nonetheless, 9 5/8" was successfully landed at bottom without issues which is testament of the excellent carrying capacity and suspension properties of D-Max fluid system. The fluid recovered from 12 ¼" section was reconditioned to optimize the rheological properties and was used to drill the 8 ½" hole section to TD at 2100 meters. At the end of the drilling activity, 18 hours reduction in drilling time was achieved compared to what was planned. There was no doubt from the operator that the application of D-Max enhanced fluid contributed immensely to the great achievement.

IV. SYSTEM COMPONENTS & FUNCTIONS

Components	Functions
Caustic Soda	pH Adjustment
Potassium Chloride	Adjustment of water salinity to prevent hydration of water sensitive shale and clay formations
D-Max Viscoifier	Provides required rheological properties of the fluid. Optimizes the carrying and suspension capacity of system
D-Max Control H	Controls fluid loss and filtrate invasion, supplements for fluid viscosity
D-Max Control L	Supplements for fluid loss reduction
D-Max Carb	Prevention of seepage losses and lost circulation
D-Max- Inhibitor	Provides drilling cuttings encapsulation and improved solids removal efficiency, it also functions for secondary lubricity.
D-Max Barite	Used for fluid density increase
D-Max Lube	Functions as anti balling and anti-accretion agent. Provides lubricity and maintains high ROP in sticky shale and claystone.

Table 3.0: D-Max high performance WBM components and their functions

V. CONCLUSION & RECOMMENDATION

The laboratory results and the success of the field applications has proven that D-Max fluid system is exceptional for hole cleaning in highly deviated wells. The fluid system has excellent low shear rate flow properties, provides enhanced ROP, optimizes drilling activity, and saves time and cost which are very valuable to the operator. The system is flexible, its components are compatible with most WBM systems, which is why is relatively easy to convert other WBM systems to a D-Max enhanced fluid. At a time regulators around the world are preventing the use of toxic chemicals in drilling fluids, D-Max is environmentally friendly and provides durable alternative to Oil-based mud systems.

A. Nomenclature

PPG = Pounds per gallon
WBM = Water-based mud
OBM = Oil-based mud
ROP = Rate of penetration
EWBM = Enhanced water-based mud
TD = Total depth
BHA = Bottom hole assembly
RPM = Revolutions per minute
MSL = Mean Sea level
YP = Yield Point

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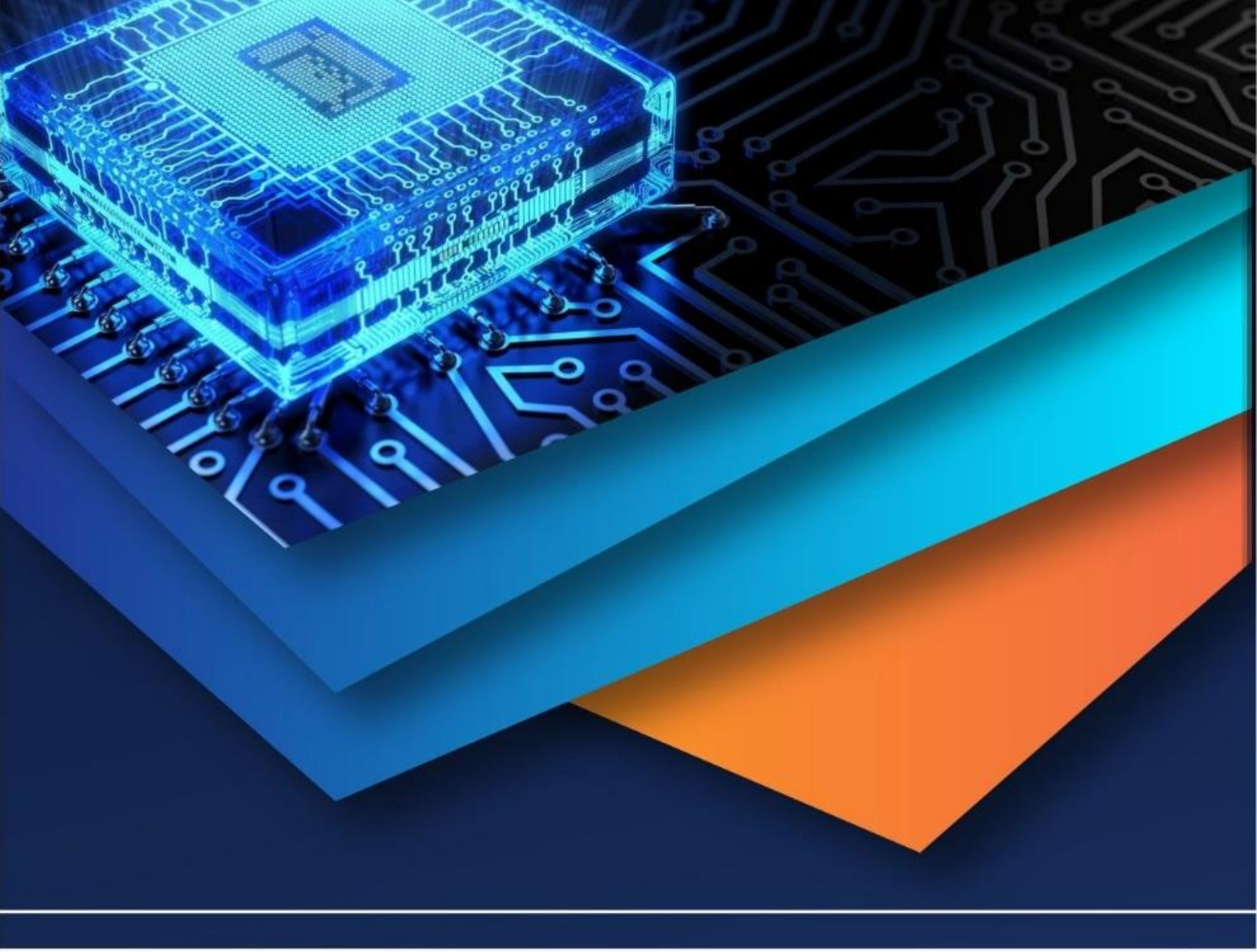
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