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Determination of Optimum Parameters of Aphron Fluid Using Design of Experiments with Taguchi Method and Laboratory Investigation of its Rheological Properties and Formation Damage

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Abstract

Recently, in consequence of the decrease in easy access to crude oil reservoirs, oil and gas industry has fouced on production from heavy oil and exhausted reservoirs (low pressure reservoirs). Drilling in low pressure reservoirs is associated with many technical and economical problems that occasionally make these fields economically unprofitable. Most of the problems include uncontrollable lost in fracture and formation damage in production zone. Drilling fluid plays a significant role in achieving the appropriate drilling technology as penetration of the drilling fluid in formation results in reducing the productivity of the well especially in depleted reservoirs. Multi-layer micro-bubble fluids or aphrons have been used in recent years as a part of water base and oil base drilling fluids. Their effect on reducing the formation damage has been observed in application. It should be noted that these fluids are suitable for drilling of depleted reservoirs because of their bridging properties. In this study, in order to determine the optimal stability conditions of factors such as: type of polymer, polymer concentration, surfactant concentration, pH, salinity, mixing time and RPM using Taguchi experimental design with L36 array (two parameters in two levels and five parameters in three levels) Were optimized. Then, the effect of the concentration of polymer and surfactant on rheological properties was studied and the optimal fluid was selected for damage testing, and the return permeability of the micro-bubble fluid was compared with the base polymeric fluid. A micro-bubble fluid with a concentration of 3 pounds per barrel of XG and 1 pound per barrel of SDBS showed the most stablilty and most stable rheological properties.Micro-buble fluid also showed a better performance in evaluating pressures in formation damage test in comparison with polymer base fluid both return permability wise and shut-off wise.

Keywords: Micro-bubble Fluid, Aphron Fluid Stability, Aphron Fluid Rheology and Formation Damage.

INTRODUCTION

Aphrons were first discussed by Sebba, who coined the term Colloidal Gas Aphron (CGA) and named the foam-like microbubbles with colloid-like properties as aphrons. Aphrons are small bubbles; they have a size range of 10-100 microns in diameter. Sebba noted that the most remarkable property of these microbubbles is their non-coalescing nature. The aphron-based drilling fluid combines certain surfactants to create aphrons or micro-bubbles. The aphrons are generated using conventional mud-mixing equipment, which entrains air up to level dictated by the concentration of aphron-generating surfactants. The surfactants in the fluid convert the entrained air into aphrons or highly stabilized bubbles. The aphrons are stable at downhole conditions, set up inner bridging in low-pressure formations, prevent uncontrollable fluid loss, and prevent formation damage. The surfactants in the fluid convert the entrained air into highly stabilized bubbles. However, in contrast to a conventional air bubble, which is stabilized by a surfactant monolayer, the outer shell of an aphron is thought to consist of a much more robust surfactant tri-layer. This trilayer is envisioned as consisting of an inner surfactant film enveloped by a viscous water layer; overlaying this, is a bi¬layer of surfactants that provides rigidity and low permeability to the structure while imparting some hydrophilic character. The most dominant characteristics of aphron drilling fluids are their rheology and the presence of bubbles [1-10].

The purpose of this study is to investigate experimentally the effect of salinity, polymer and surfactant concentration, pH, mixing time and mixing RPM on aphron stability by using Taguchi method as a design of experiment. The rheological and formation damage properties of aphron are also compared to the base polymeric fluid.

METHODOLOGY

The experiments conducted in this study are divided into two general categories. The first batch experiments were designed to verify the fluid stability and the second group was designed to investigate rheological properties and formation damage of aphron drilling fluid. To obtain the optimal conditions for the aphron fluid stability, a Taguchi design of experiment with L36 array (two parameters in two levels and five parameters in three levels) was used (Table 1), and fluid compositions were chosen based on this design of experiment. The aphron fluid was prepared by using a Hamilton Beach mixer, firstly, a polymer base fluid was prepared and then surfactant was added to it for aphronization. To study the stability of aphron drilling fluid, the drainage static test was used. Generated aphrons were immediately transferred into a 100 ml measuring cylinder and drainage time of one-tenth of the total volume was recorded. Rheological properties such as plastic viscosity, yield strength and apparent viscosity of aphron were measured by using Fann VG meter. FDS350 setup was used to study the diffusion of aphron fluid to porous media (5 carbonated plugs were used as porous media). At first, the permeability of each core was measured by FDS350 and then static and dynamic mud tests were performed about 6 hours for detecting aphron and base polymer fluid diffusion in porous media. The overbalanced pressure during the tests was set between 250 to 300 psi.

Table 1. Level of the design of experiment for stability

Parameter		Level	
Mixing time (min)	15	20	-
RPM	10000	14000	-
Polymer Type	XG	PAC-R	NG
Polymer Concentration (lb/bbl)	2	3	4
SurfactantConcentration(lb/bbl)	0.5	0.75	1
Salinity	No. salt	Half Saturated	Saturated
pH	9	10	11

RESULTS AND DISCUSSION

After preparation of aphron drilling fluids based on Taguchi design of experiment, their stability was measured carefully. The effect of different parameters on fluid stability was investigated by using Minitab software (Figure 1). Xanthan Gum polymer has a greater effect on the stability of aphron than other polymers and concentration of polymer and surfactant has a more important role on the stability. The rheological properties of aphron fluids were also measured using Fann VG meter. As the concentration of polymer and surfactant were increased, the viscosity of aphron was increased that is because of more surfactant activities in microbubbles of aphron drilling fluid.

Dynamic mud test at a rate of 5 L/min and an overbalanced pressure of 250-300 psi for each core was performed 3 hours across one face of core plug and then static mud test was done by stopping the circulation of aphron fluid at the same condition. Figure 2 shows the differential pressure across the core plug during dynamic and static mud test for aphron and base polymer fluids. According to Figure 2, more differential pressure is needed for diffusing aphron drilling fluid to core plugs, which is because of the presence of microbubbles in aphron fluids.

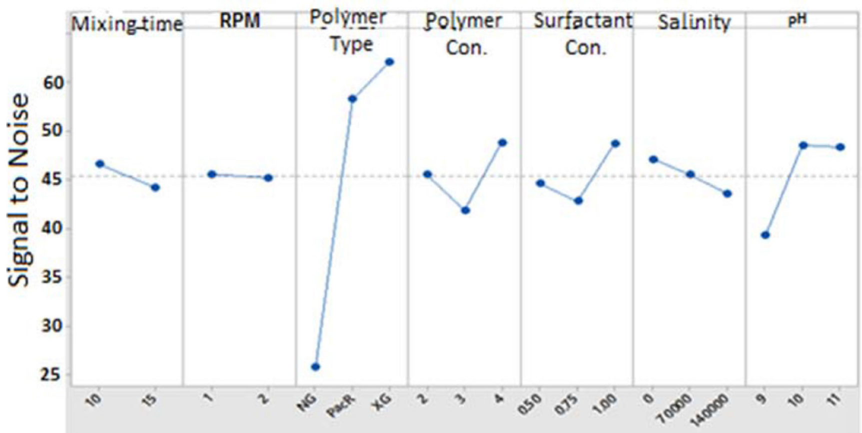

Figure 1: Effect of different parameters on the aphron stability.

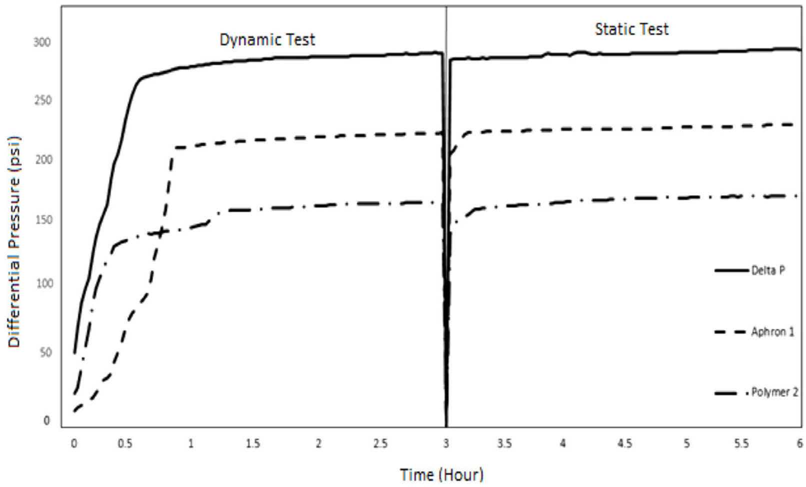

Figure 2: Differential Pressure vs. Time for First and Second Tests.

CONCLUSIONS

The results of the experiment showed that mixing time and mixing RPM had less effect on aphron stability. Salinity had a negative effect and pH of 10 and 11 showed the more stability of aphron.

The polymer concentration is the most important factor in controlling aphron diffusion and formation damage.

Increased polymer concentration resulted in the decrease of aphron's yield strength.

Permeability recovery of aphron was about 80 percent and for base polymeric fluid was about 50 percent.

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