

Experimental Investigation of Physical and Chemical Properties of Drilling Foam and Increasing its Stability

Soleymani, Mohammad*⁺; Kamali, Mohammad Reza

*Department of Research and Development in Upstream Petroleum Industry,
Research Institute of Petroleum Industry (RIPI), P.O.Box:14665-137Tehran, I.R. IRAN*

Saeedabadian, Yazdan

Petroleum University of Technology (PUT), Iran , Tehran, I.R. IRAN

ABSTRACT: *This investigation presents the effect of various parameters on foam stability and its rheological properties. The underlying idea of this experiment is generating of drilling foam with uniform bubbles. The main problem of foam using is controlling its stability during field application. The most important parameters which cause Instability in foam are gravity drainage, gas diffusion and bubble coalescence. Among these parameters gravity drainage has the highest effect on foam instability in field application. For measuring of drainage effect it is necessary to produce foam with uniform bubbles. This Experiment was performed with a specific foaming system which constructed in Research Institute of Petroleum Industry (RIPI) just for this point. This foam system consisted of an apparatus which injected nitrogen gas through a porous plate into the foam solution. In each test one parameter was variable and the effect of this variation was measured on foam properties. The main parameters which investigated in this experiment were temperature, foamer concentration, pH effect, stabilizers, and contaminants. Obtained results from testing of each parameter can be used simultaneously to improve the foam stability in elevated temperature. In this way by changing of physical and chemical properties of foam, it becomes more stable in real condition of wellbore.*

KEY WORDS: *Drilling foam, Foam stability, RIPI drilling laboratory, UBD foams.*

INTRODUCTION

For many years, drilling foam has been traditionally used in UnderBalanced Drilling (UBD). Using conventional drilling foam in UBD condition causes many problems like formation damage[1-3]. Drilling foam due to its special structure is thermodynamically unstable.

As soon as foam is created, it begins to degrade and gaseous and aqueous phases beginning to segregate. This segregation causes weakness in foam bubbles structure. The parameters which contribute in foam instability are gas diffusion, bubble coalescence and drainage (gravity segregation).

* *To whom correspondence should be addressed.*

+ *E-mail: soleymanim@ripi.ir*

1021-9986/13/3/127

6/\$/2.60



Fig. 1: Foam generation system.

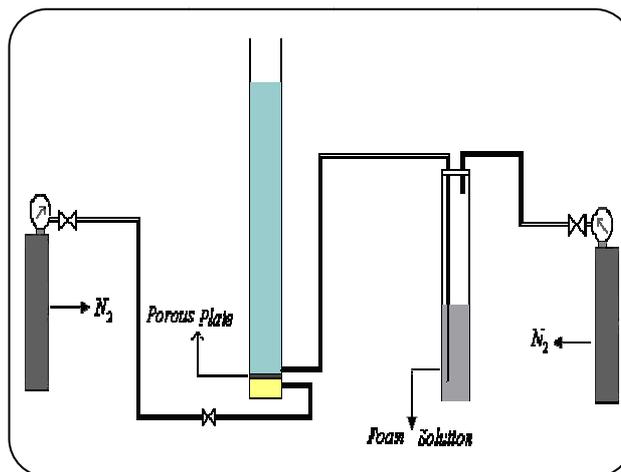


Fig. 2: Schematic diagram of foam generation system.

In condition of uniform bubbles, drainage acts as a main parameter in foam stability [4, 5]. During the drainage the liquid phase become thinner and bubbles touch each other and rupture easily. The rate of drainage increases dramatically by increasing of temperature. In elevated temperature the liquid film between bubbles vaporizes and wall of the bubbles become weak. Among the various method for decreasing of temperature effect on foam and increasing its stability, one of the best methods is finding the best range for physical and chemical properties of foam. These properties can be foamer concentration, water pH, foam quality, stabilizer agent and etc [6].

EXPERIMENTAL SECTION

Foam generator system

The foam generator system used in these experiments consists of a gas injection system which injects gas through a porous plate into the foam solution (Fig.1). Foam solution are placed in a cylinder and pushed into the main cylinder. The foaming system is a commercial one that is used on site for commercial drilling. The foam solution consists of 100 mL distilled water with pH 7 and foamer concentration of 2 mL. The foaming system is a commercial one that is used on site for commercial drilling.

The foam solution consists of 100 mL distilled water with pH 7 and foamer concentration of 2 mL. Fig. 2 shows the schematic diagram of foam generation system. Foam is produced by injection of nitrogen through the porous plate from an input under the plate and foam solution injected above the plate at the same time. By control of final foam volume, the gas volume is controlled.

Procedure

All parameters which contribute in foam stability have a certain range that in this range, foam has the highest stability compared to other range of that parameter [7, 8]. By definition of these ranges for all parameters and using them simultaneously, it will be possible to generate foam with higher stability than that foam which was produced in common way on site. In addition to stability, the volume of foam after agitation by mixer for 45 sec is measured as foam ability.

Temperature effect

For evaluation of foam stability in various temperatures, since the apparatus had not capability to heat the foam, moreover the stability of foam is not high to heat the foam for a few minutes, it is essential to use stabilizing agent to improve the half life time of foam. In this way, a certain type of stabilizer called PHPA was used.

In field experience, at the first, drilling foam was generated at surface and then sent to the well for cutting transport, therefore the foam generation temperature is ambient temperature and by sending to wellbore, it was heated gradually by increasing the depth [9].

In this experience the worst scenario was considered. In this way, the foam solution was heated to reach the purposed temperature then nitrogen was injected into the heated solution. By running some experimental tests, it is determined that the injection of nitrogen into foam solution caused a decrease in foam temperature around 15°C. Thus at the first, foam solution was heated

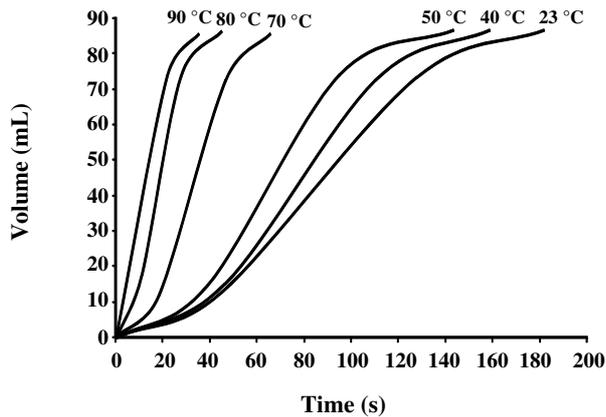


Fig. 3: Temperature effect on foam stability.

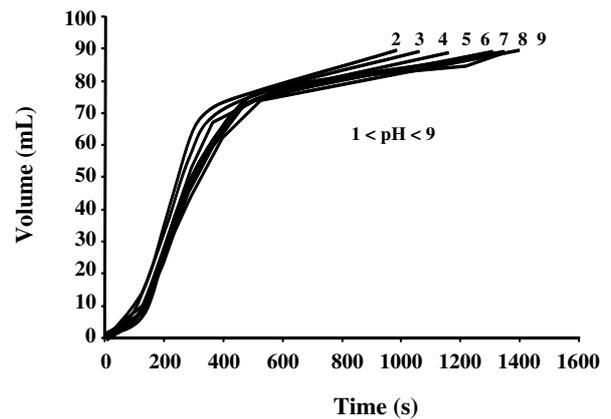


Fig. 5: Water pH effect on foam stability(1 < PH < 10).

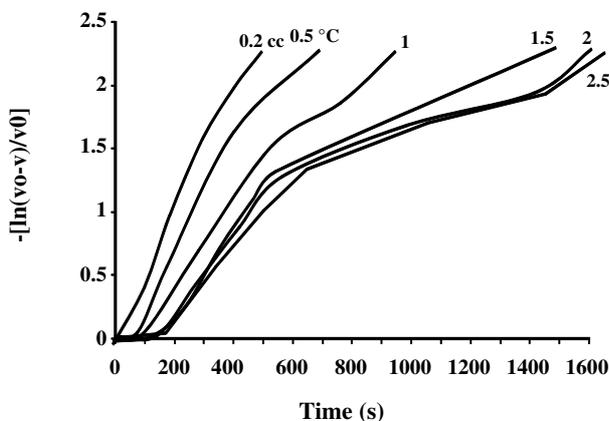


Fig. 4: Foamer concentration effect on foam stability in ambient temperature.

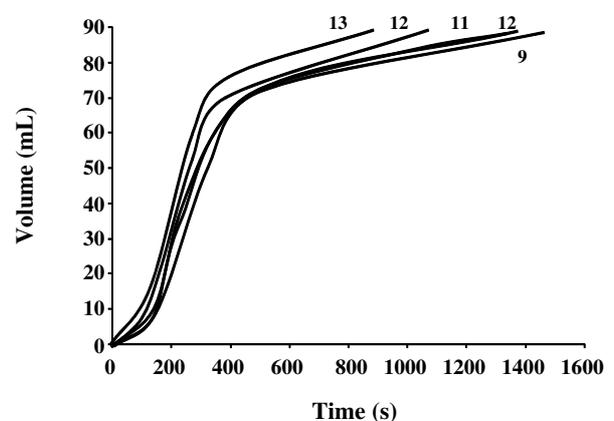


Fig. 6: Water pH effect on foam stability(8 < PH < 14).

15°C more than purposed temperature. By this procedure, tests and results became more reliable. After generation of foam, foam transferred into a container and put in a drying oven. Drying oven was set up in temperature exactly equal to the test temperature. From Fig. 3 it is obvious that temperature increasing has a detrimental effect on foam stability, especially when stabilizing agent is not used. In this way the temperature more than 50°C causes huge reduction in foam stability. In real application by increasing the depth of well, temperature increases gradually, so there is no escape from this phenomenon. Therefore the best way for reduction of temperature effect is changing the physical and chemical properties of foam.

Foamer concentration effect [10-13]

Fig. 4 illustrates the variation of foam stability with concentration for foam with quality around 90% and

in ambient temperature. Results show that increasing of foamer concentration causes an increase in foam stability. In low concentrations the rate of stability rising is high, but after a certain concentration (2 mL in this experiment) the stability of foam remains almost constant. From the Fig. 4 it is obvious that after the concentration of 2 mL adding additional foamer not only has not any effect on foam half life time but also increases the viscosity of the foam.

Water pH effect

Figs. 5 & 6 show the effect of water pH on foam stability. According to these graphs, increasing the water pH from 2 to 9 causes an increase in foam stability, but after pH 9, increasing pH causes a reduction in foam stability. This reduction is considerable for pH of 12 and 13. In terms of foam ability according to the Fig. 7 the acid range has a little effect on foam volume while in base range the volume of foam decreases dramatically.

Therefore it is evident that the best range for pH is between 8 and 10 in order to generation and 10 in order to generation of foam with acceptable properties.

Contaminant effect

Drilling fluid in wellbore may be contaminated by reservoir fluid or crude oil. Reservoir fluid usually composed of monovalent and divalent salts such as NaCl, KCl and CaCl₂ [14]. In this experiment the effect of these salts and three crude oils with different API numbers are tested on foam stability. Figs. 8 and 9 show that the half life time of foam in various concentrations of salts for three mentioned salts. Presence of salt in base foam solution is detrimental for foam half life even the concentration of salt is very low and the effect of divalent ion such as calcium on foam stability is more dramatic than monovalent ions like sodium and potassium. Between similar salt ions (monovalent or divalent), the one has higher molecular weight, has higher effect on foam properties.

Regardless to type of the salt, in high concentrations after a certain amount, foam solution become insensitive to further salinity. Therefore in real field application the foam solution must be monitored continuously and when salt observed in solution by adding special material, the ions of salt should be settled. Regardless to type of salt, in high concentrations after a certain amount, foam solution becomes insensitive to further salinity. The only effect should be considered in this condition is foam ability, since foam volume decreased with salt increase.

Figs. 10 & 11 illustrate the effect of crude oil on foam half life time. The crude oil used in this test had different API numbers (27.3, 35.5, and 43.5).

According to the graphs, oil contamination increases foam stability, and this increasing varies by different crude oils. The main parameter of crude oil which contributes in foam stability is its API number. Higher API number has lower effect on foam stability. Main reason for this trend is increasing of viscosity of crude oil. Increasing oil concentration after a certain amount shows an inverse effect and decreases foam stability because of foam fast decay.

Stabilizing agent effect

Evaluation of stabilizer agent effect on stability and rheological properties of foam, required to test various

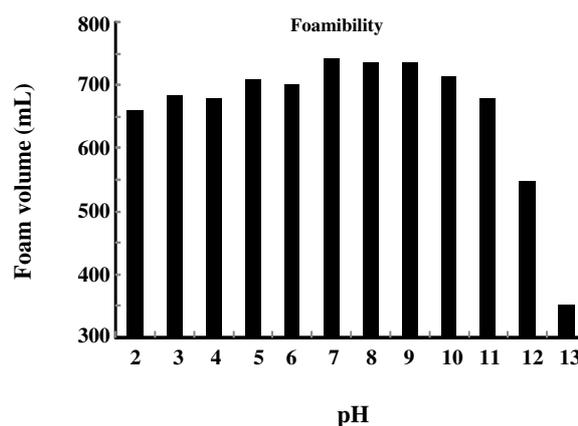


Fig. 7: Effect of pH on foamability.

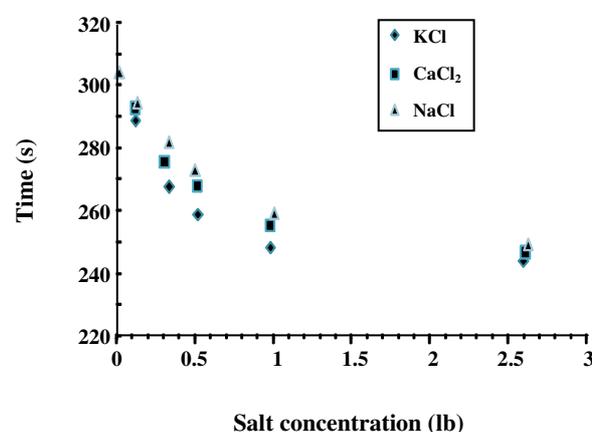


Fig. 8: Salinity effect on foam stability (<3lb).

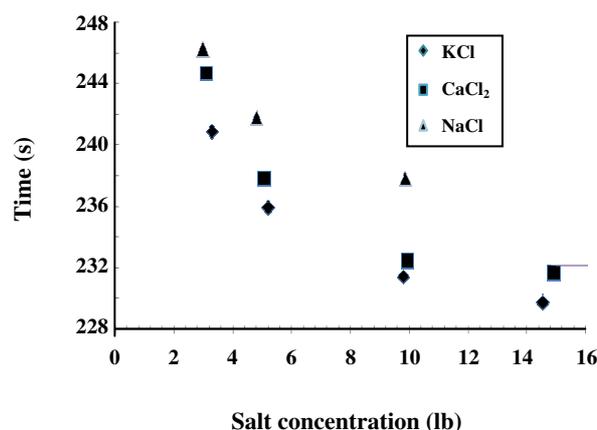


Fig. 9: Salinity effect on foam stability (>3lb).

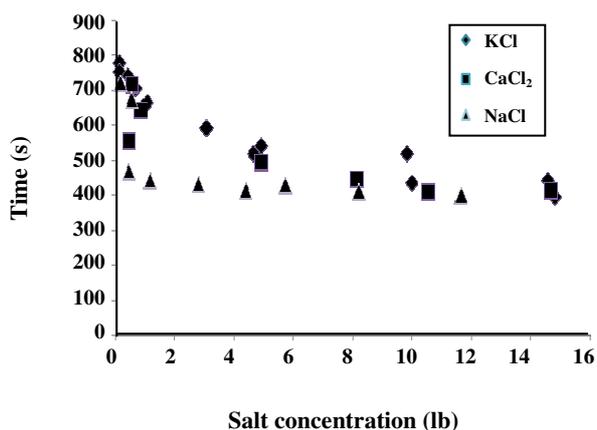


Fig. 10: Salinity effect on foamability.

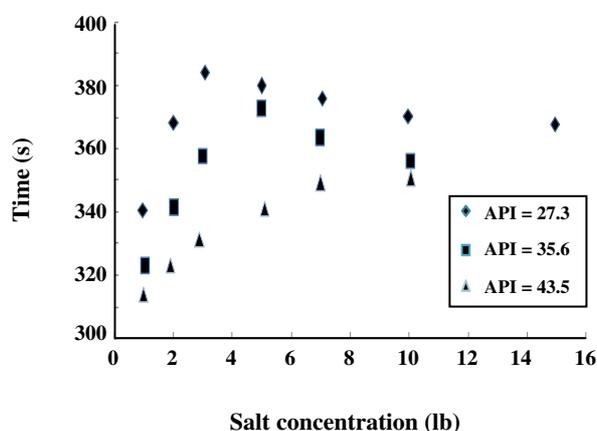


Fig. 11: Effect of crude oil on half life time.

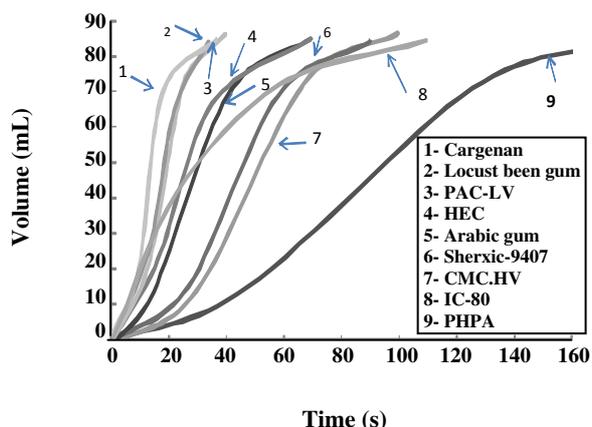


Fig. 12: Stabilizing effect on foam stability).

materials (natural and chemical) with different structure. These stabilizers should have some specifications such as water solubility; high molecular weight and they should increase the viscosity of base solution [14].

In this way the following material were used for stability and rheology test:

1. Partially Hydrolyzed Poly AcrylAmide (PHPA)
2. HydroxyEthyl Cellulose (HEC)
3. CarboxyMethylCellulose (CMC)
4. Carageenan
5. Locust bean gum
6. PolyAnionic Cellulose (PAC LV)
7. Arabic gum

Fig. 12 shows the effect of these stabilizers on foam stability. Between tested stabilizers, PHPA,CMC, Arabic gum and HEC showed acceptable half life time compared to other stabilizers. In terms of solubility, among these stabilizers, PHPA, CMC and Carrageenan and locust bean gum dissolved in water completely while CMC should be heated a little to dissolve in water and HEC required remaining in water for some minutes to dissolve completely. Locust bean gum and PAC LV had very similar stability properties.

Since stability and drainage rate are related to each other inversely, therefore Carrageenan, PAC LV and locust bean gum had higher drainage rate than others.

CONCLUSIONS

According to the results of test, it is obvious that by changing the physical and chemical properties of foam and identifying the best range of these Properties in terms of foam stability, it will be possible to increase foam stability without any additional treatment. Some important parameters that have serious effect on drilling foam properties and stability can summarized as :

- 1- Temperature increasing has a detrimental effect on foam stability, especially when stabilizing agent is not used. In this way the temperature more than 50°C causes huge reduction in foam stability
- 2- Results show that increasing of foamer concentration causes an increase in foam stability
- 3- Increasing the water pH from 2 to 9 causes an increase in foam stability, but after pH 9, increasing of pH causes a reduction in foam stability
- 4- Tthe effect of divalent ion such as calcium on foam stability is more dramatic than monovalent ions like sodium and potassium

5- Between tested stabilizers, PHPA, CMC, Arabic gum and HEC showed acceptable half life time .

Nomenclatures:

RIPi	Research Institute of Petroleum Industry
UBD	Underbalanced Drilling
NaCl	Sodium chloride
KCl	Potassium chloride
CaCl ₂	Calcium chloride
PHPA	Partially Hydrolyzed Poly AcrylAmide
HEC	HydroxyEthyl Cellulose
CMC	CarboxyMethylCellulose
PAC	PolyAnionic Cellulose
LV	Low Visvosity

Acknowledgment

The authors would like to extend their thanks to RIPi's Drilling Fluid Research Division for funding of the research discussed in this paper. We also express appreciation to the Research Advisory and laboratory staff, Mortazavi S.A., Modjtahedi S.j., Badamaki M.R., for their technical assistance , guidance and for providing some additives used in these studies.

Received : Apr. 3, 2012 ; Accepted : Jun. 17, 2013

REFERENCES

- [1] Martins A.L., Lourenço A.M.F., Sá C.H.M., Silva Jr. V., Petrobras: Foam Rheology Characterization as a Tool for Predicting Pressures While Drilling Offshore Wells in UBD Conditions. *SPE 67691* (2001).
- [2] Benjamin Herzhaft, SPE, IFP, Abdoulaye Toure, SPE, Cenergys, Fabrice Bruni, Cenergys, Stephane Saintpere, SPE, Totalfinaelf: Aqueous Foams for Underbalanced Drilling: The Question of Solids, *SPE 62898* (2000).
- [3] Bennion D.B., Thomas F.B., Jammaluddin A.K.M., Ma T., Agnew C., "Using Underbalanced Drilling to Reduce Invasive Formation Damage and Improve Well Productivity", Hycal Energy Research Laboratories Ltd (2000).
- [4] Dotchi exerowa-pyotr M. kruglyakov, "Foam and Foam Films (Theory, Experiment, Application)", Elsevier (1998).
- [5] Durian, D.J. and Weitz, D.A., Foams, in: "Kirk-Othmer Encyclopedia of Chemical Technology", 4th Edition, Wiley-Intersciences, **II**, pp. 783-805 (1994).
- [6] Affonso M. F. Lourenço, Stefan Z. Miska, Troy D. Reed, Mark B. Pickell, Nicholas E. Takach, Study of the Effects of Pressure and Temperature on the Rheology of Drilling Foams and Frictional Pressure Losses", *SPE 84175* (2003).
- [7] Jorge.H.B.Sampaio, Advanced Drilling Techniques", Curtin University of Technology (2006).
- [8] Adam T. bourgoyne jr, Martin E.chenevert, Keith k., Millheim F.S., Young jr., *Applied Drilling Engineering*, p.72 (2005).
- [9] Maini B., Ma V., Evaluation of Foam Stability at High Temperature and High Pressure, *Energy, Mines and Resources of Canada*, **25**(6) (1986).
- [10] Nikolov A.D., Wasan D.T., Huang D.W., Edwards D.A., The Effect of Oil on Foam Stability: Mechanisms and Implications for Oil Displacement by Foam in Porous Media, *SPE 15443* (1986).
- [11] Heller J.P. and Kuntamukkula S., "Critical Review of Foam Rheology Literature" *Ind. Eng. Chem. Res.*, **26**, p. 318 (1987).
- [12] Herzhaft B., "Rheology of Aqueous Foams: A Literature Review of some Experimental Works" *Oil and Gas Science Technology*, **587** (1999).
- [13] Argillier J-F., Saintpere S., Herzhaft B., Toure A., Nergys C., Stability and Flowing Properties of Aqueous Foams for Underbalanced Drilling, *SPE 48982* (1998).
- [14] Shih-Hsien Chang, Reid Grigg B., Effects of Foam Quality and Flow Rate on CO₂ Foam Behavior at Reservoir Conditions, *SPE 39679* (1998).