FOAM STABILITY CHARACTERIZATION AND PERFORMANCE IN THE PRESENCE OF SURFACTANT FOR GAS WELL DELIQUIFICATION

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ABSTRACT

In gas well deliquification, surfactant injection minimises liquid loading in mature gas wells, promoting a stable gas output. It is critical to evaluate the surfactant performance and produced foam stability. To this end, laboratory experiments are conducted to determine the surfactant's performance. This study focused on the characterisation study of foam stability and quantify the quantify the foam unloading capacity at different field formation water salinity, temperature, and field hydrocarbon ratios. The foam stability at different field hydrocarbon ratios reduces as the hydrocarbon ratio increases. At 15% and 50% hydrocarbon ratio, the full time collapse is at 203 seconds and 100 seconds. More stable foam is observed as the water salinity increases. It is recorded at 9.85 ppt, showing the full time collapse at 420 seconds, while at 6.31ppt, the full time collapse at 329 seconds. The increase in testing temperature to 90°C shows the lowest foam stability with 140 seconds of full collapse. At 4°C shows 450 seconds of full collapse. In conclusion, the more stable foam formed at higher water salinity. Adding hydrocarbon in the water ratio acts like defoamer agent to reduce the foam stability. At high temperature, foam collapse the fastest as compared to other parameters, with 70 seconds of full collapse at 329 seconds. Based on the unloading performance, at low hydrocatbon ratio, high salinity, and low temperature able have the excellent unloading performance as more stable foam able to entraine the fluids over the testing column.

ABSTRAK

Pengeluaran air didalam telaga gas bole dilakukan dengan, suntikan surfaktan bagi meminimumkan jumlah cecair dalam telaga gas matang. Untuk tujuan ini, eksperimen makmal dijalankan untuk menentukan prestasi surfaktan. Oleh itu, kajian ini tertumpu kepada kajian pencirian kestabilan buih dan mengukur kuantiti kapasiti mengangkat buih pada nisbah kemasinan air, suhu, dan peritus hidrokarbon yang berbeza. Kestabilan buih pada nisbah hidrokarbon medan berbeza berkurangan apabila nisbah hidrokarbon meningkat. Pada nisbah hidrokarbon 15% dan 50%, keruntuhan sepenuh masa adalah pada 203 saat dan 100 saat. Buih yang lebih stabil diperhatikan apabila kemasinan air meningkat. Ia direkodkan pada 9.85 ppt, menunjukkan keruntuhan sepenuh masa pada 420 saat, manakala pada 6.31ppt, keruntuhan sepenuh masa pada 329 saat. Peningkatan suhu ujian kepada 90°C menunjukkan kestabilan buih paling rendah dengan 140 saat keruntuhan penuh. Pada 4°C menunjukkan 450 saat keruntuhan penuh. Kesimpulannya, buih yang lebih stabil terbentuk pada kemasinan air yang lebih tinggi. Menambah hidrokarbon dalam nisbah air bertindak seperti agen penyahbuih untuk mengurangkan kestabilan buih. Pada suhu tinggi, buih runtuh paling cepat berbanding dengan parameter lain, dengan 70 saat runtuh penuh pada 329 saat. Berdasarkan prestasi pemunggahan, pada nisbah hidrokatbon yang rendah, kemasinan yang tinggi, dan suhu rendah mampu mempunyai prestasi mengangkat buih yang sangat baik kerana buih yang lebih stabil dapat memasukkan cecair ke dalam tabung ujian.

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INTRODUCTION

1.1 Background

In the form of mist stream, wet gas is produced from gas wells along with condensate and/or liquid water. Depleted reservoir pressure reduces gas flowrate consequently decreasing the gas transport capacity. Reduced gas flow rate is known to cause annular and slug flow which indicated the potential when the gas velocity drops to critical level. Therefore, the well will experience an effervescent flow regime and eventually the production will cease (Boyun Guo, 2014).

To overcome this problem, various methods are implemented. Water can be withdrawn from the well by reducing the surface tension as in a foam state. Install the narrower tubing or by ensuring lower wellhead pressure can create sufficient pressure drop for unloading water through artificial lifting like gas lift and pumping is a common practice (Boyun Guo, 2014).

The liquid carried by the gas may not able to reach the surface as the gas production decreases over time. Due to decreasing gas velocity. The significantly denser water drops out of the gas stream and accumulates at the bottom of well forming a liquid plug. Thus, back pressure in the formation increases as the pressure gradient in the tubing increases due to fluid build-up. (James F. Lea, 2003)

There are 4 signs to look for water loading such as onset of liquid slugs at the surface of the well, increasing differential between tubing and casing pressures over time, sharp gradient changes on a flowing pressure survey, and sudden decreases in a production decline curve

To prevent the water accumulation from killing the well, several method can be used to continuously remove water The gas velocity or siphon strings or well production performance in the tubing is depend on the size of the tubing through which the gas is produced (this could be the tubing or the casing-tubing annulus or simultaneous flow up the casing-tubing annulus and the tubing). Gas velocity is higher in smaller tubing (James F. Lea, 2003)

Technically at high gas velocity, the liquid is swept out from the well and tubing in the form of mist. Thus, this reduces the liquid accumulation and lowers the back pressure of fluids in the tubing. However, the smaller tubing size has its own draw backs. Apart of severely limiting the type and size of artificial lift equipment, smaller tuning size induced high friction losses and limit the gas production (James F. Lea, 2003).

Plunger lift is one of the artificial lift method that intermittently remove the accumulate liquid. Acting like a displacement piston, plunger lift depends on the gas pressure build up during the shut in period. Once the well is open to flow, the plunger will displace the accumulated liquid to the surface as the gas pressure pushing the plunger. The process will continue intermittently between well shut in and well flowing (James F. Lea, 2003).

The biggest challenge in using plunger lifts is that the automation and control the algorithms controlling the operation which require frequent operator intervention. The arrival of a dry plunger coupled with a damaged spring can result in a dangerous projectile and loss well control if it is not carefully control (A.V. Bondurant, 2007). Due to complexity of mechanical water removal approach, much simpler and straight forward method is investigated. With the ultimate objective is to reduce the water density, utilization of chemical foamer and gas lift is an practiced approach

Chemical foamer which normally consist of surfactant reduces the interfacial tension allowing the formation gas bubbles, which in turn reducing the water density. The reduction of water density lowers the back pressure on the formation and allowing more gas to flow and further reduces the water density. Once the gas exceeds the threshold critical velocity, the energy from the gas will force the foam to flow and carried the water to the surface (James F. Lea, 2003)

Various studies had been done to identify the effect of foam stability in various parameters. The effectiveness of the foam generated depends on many parameters including surfactant type and concentration, water salinity, temperature, agitation velocity and hydrocarbon fraction (Omrani et al., 2016a), (Omrani et al., 2016a), (Alyousef et al., 2019), (Almobarky, 2018)

1.2 Problem Statement

Successful gas well de liquification application may affect based on the produced water salinity. This needs to be considered as it related to the water ionic strength. As a result, it will decrease the electrostatic double layer forces and diminishing the surfactant solubility in brine. Most researchers did vary their water salinity based on synthetic brine make-up in laboratory. However, less reported by using field produced water at different salinity level.

Apart from that, the effect of hydrocarbon may also affect the foam stability. Most of the studies done by researchers concluded that, at high hydrocarbon percentage, foam stability is reduced drastically. However, they only focusing on percentage of hydrocarbon, but little reported on the effect of density and viscosity of hydrocarbon sample. It is literally a scars information to understand at different density and viscosity of field hydrocarbon sample towards foam stability.

Generally known that foam stability will decrease as the temperature increase and otherwise. Most of the Deepwater field flowing its production from the high reservoir temperature to a very low subsurface (wet tree) facility, up to the production riser. However, little has been identified for the foam performance at a very low temperature.

1.3 Objectives

(a) To investigate the foam characterization at different field formation water salinity, different temperature, and different field hydrocarbon ratio towards foam stability

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(b) To quantify the foam unloading capacity and the relation to its stability

1.4 Research Scope

(a) Foam stability characterization

Foam column laboratory method (modified ASTM D3519) will be used as to identify the foam stability performance against three Malaysia field formation waters at 1000ppm to 21,000ppm concentration, at testing temperature of 99^{o}C and 4^{o}C and using Malaysia field hydrocarbon sample at different density and viscosity will be used as experimental parameters. . There are two parameters that is important to be measure which are time to peak height half-life , time to full-life (expiration), and foam density

(b) Foam unloading performance towards foam stability

Foam column laboratory method (modified ASTM D3519) will be used as to identify the foam unloading performance against two Malaysia field formation waters. There are two important parameters quantify unloading performance which fluid carry over, %

1.5 Significance of Study

The correlation between temperature, salinity, hydrocarbon properties and foam stability present new findings in this study. The fundamental knowledge of gas well deliquification lead to develop a new approach in analysing the liquid loading treatment via chemical. A laboratory scale testing could be very useful to determine the chemical efficiency at different parameters and conditions. The unloading performance correlation with foam stability will be able to anticipate the fluid unloading application in the field

However, real field application will be more benefit in collecting additional information for making the chemical foamer application process more efficient and economic. This project could also contribute to better energy and natural resources management.

REFERENCES

Almobarky, M. (2018). Enhancing The Foam Stability Using Surfactants Mixtures. 23–26. http://onepetro.org/SPESATS/proceedings-pdf/18SATS/All-18SATS/SPE-192449-MS/1248685/spe-192449-ms.pdf

Alyousef, Z., Ayirala, S., Aramco, S., & Gizzatov, A. (2019). Evaluating Foam Stability using Tailored Water Chemistry for Gas Mobility Control Applications. http://onepetro.org/SPEADIP/proceedings-pdf/19ADIP/2-19ADIP/D021S055R002/1122325/spe-197407-ms.pdf

A.V. Bondurant, S. B. D. D. S. and P. O. O. (2007). Getting the Last Gasp: Deliquification of Challenging Gas Wells.

A.R. Kovscek, C.J. Radke Fundamentals of foam transport in porous media

L.L. Schramm (Ed.), Foams: Fundamentals and Applications in the Petroleum Industry, American Chemical Society, 1994 (2015), pp. 115-163

A.K. Vikingstad, A. Skauge, H. Høiland, M. Aarra Foam–oil interactions analyzed by static foam tests Colloid Surf. pp. 189-198

Boyun Guo, K. S. A. G. (2014). Well Productivity Handbook. Gulf Publishing Company.

Carrie. (2020, October 28). How to Reduce Friction Loss in Pipe Systems.

D. Myers Surfactant Science and Technology John Wiley & Sons, New Jersey (2005), pp. 253-261

James F. Lea, H. V. N. M. R. W. M. W. (2003). Gas Well Deliquification Solutions to Gas Well Liquid Loading Problems. Gulf Professional Publishing.

Joshi, S. 2015. Foamer evaluation by the sparging test method for application to gas well deliquification. MSc thesis, Delft University of Technology.

L.L. Schramm, F. Wassmuth L.L. Schramm (Ed.), Foams: Basic Principles, Foams: Fundamentals and Applications in the Petroleum Industry, ACS, 1994 (2015), pp. 3-45

Omrani, P. S., Shukla, R. K., Vercauteren, F., & Nennie, E. (2016a). Towards a Better Selection of Foamers for the Deliquification of Mature Gas Wells.

Omrani, P. S., Shukla, R. K., Vercauteren, F., & Nennie, E. (2016b). Improving the Foamer Selection Procedure for Gas Well Deliquification Application. 26–28.

R. Aveyard, B.P. Binks, P.D.I. Fletcher, T.G. Peck, C.E. Rutherford

Aspects of aqueous foam stability in the presence of hydrocarbon oils and solid particles Adv. Colloid Interface Sci., 48 (1994), pp. 93-1___

R. Farajzadeh, A. Andrianov, R. Krastev, G.J. Hirasaki, W.R. Rosse
Foam–oil interaction in porous media: implications for foam assisted enhanced oil recovery Adv. Colloid Interface Sci., 183–184 (2012), pp. 1-13

Shoeibi Omrani, P, Shukla, R.K, Vercauteren, F., Nennie, E. 2016. Improving the foamer selection procedure for gas well deliquification. SPE Annual Technical Conference and Exhibition, SPE-181592-MS.

W.D. Harkins A general thermodynamic theory of the spreading of liquids to form duplex films and of liquids or solids to form monolayers J. Chem. Phys., 9 (1941), pp. 552-568

Wang H., Wangbiao, Z, Chuanbao,W, Deming Z., Hanhui. (2017). Effect of Temperature on Foaming Ability and Foam Stability of Typical Surfactants Used for Foaming Agent. Journal of Surfactants and Detergents. 20. 10.1007/s11743-017-1953-9.