Experimental Investigation of Foam drilling fluid using Visualization Technique

Abinash Barooah[1, 2], Muhammad Saad Khan[3], Ahmad K. Sleiti[4], Motasem Abdelrazeq[4], Mohammad Azizur Rahman[1], Ibrahim Hassan[3] Rashid Hasan[2], Berna Hascakir[2]

[1]Petroleum Engineering Department, Texas A&M University at Qatar, Qatar.

[2]Petroleum Engineering Department, Texas A&M University College Station, USA.

[3]Mechanical Engineering Department, Texas A&M University at Qatar, Qatar.

[4]Department of Mechanical and Industrial Engineering, College of Engineering, Qatar University, Doha, Qatar

Abstract

Over the years, as the number of directional wells have increased to improve the productivity, it has been observed that cutting transport is more difficult in horizontal and directional well as compared to vertical wells. While the foam/aerated drilling fluid provides significant advantages over conventional drilling fluid such as higher rate of penetration and reduction in formation damage, however these advantages are reduced due to inefficient cutting transport to the surface.

This study investigates the effect of different parameters such as cuttings weight concentration, liquid flow rate and gas flow rate on cutting transport using foam/aerated drilling fluid. The liquid and the gas flow rate was varied between 219 – 380 kg/min and 4 – 6.5 L/min, while the gas input pressure was kept constant at 2 bar. An anionic surfactant was used to stabilize the foam with a stationary liquid density of 818 kg/m^3.

The results showed that increase in the liquid flow rate or Reynold number improved cutting transport, whereas increase in the gas flow rate and solid cuttings concentration decreased the cutting transport velocity by for a constant gas input pressure. A non-dimensional performance parameter was introduced, for comparison of the cutting transport efficiency of different fluids such as water, 0.05 wt. % and 0.1 wt. % bio-polymer concentrations. It was observed that foam fluid has the highest bed height, Reynold number and lowest solid velocity (Reynold number). Performance parameter indicates that foam fluid has a better cutting transport efficiency as compared to bio-polymer based drilling fluid for horizontal drilling.

This study can act as a guide to improve our knowledge of cutting transport and how cutting transport efficiency of different fluids can be compared using performance parameter.

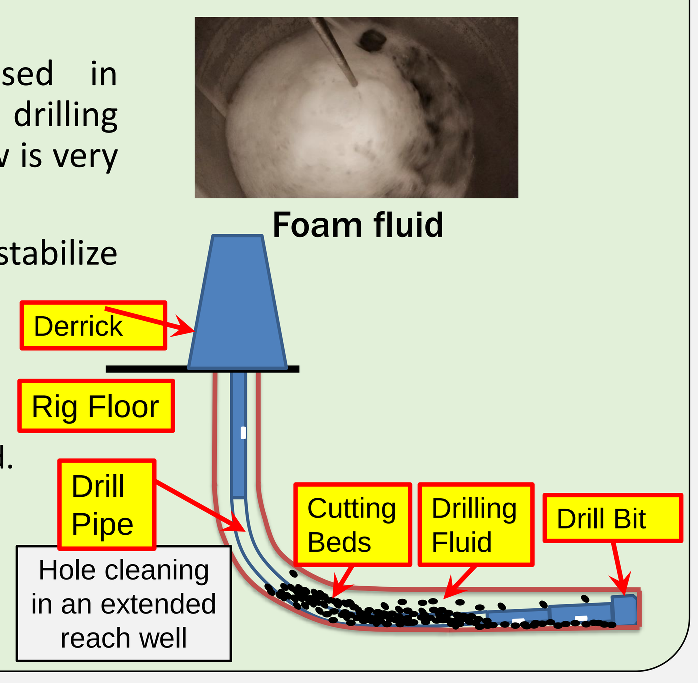
Introduction: Foam Drilling fluid

Foam fluids are generally used in underbalanced and deep water drilling where operating pressure window is very narrow.

A surfactant is generally used to stabilize the system.

Advantages:

- Very low density can be achieved.
- Reduced formation damage.
- Prevention of lost circulation.
- Significantly higher penetration rate



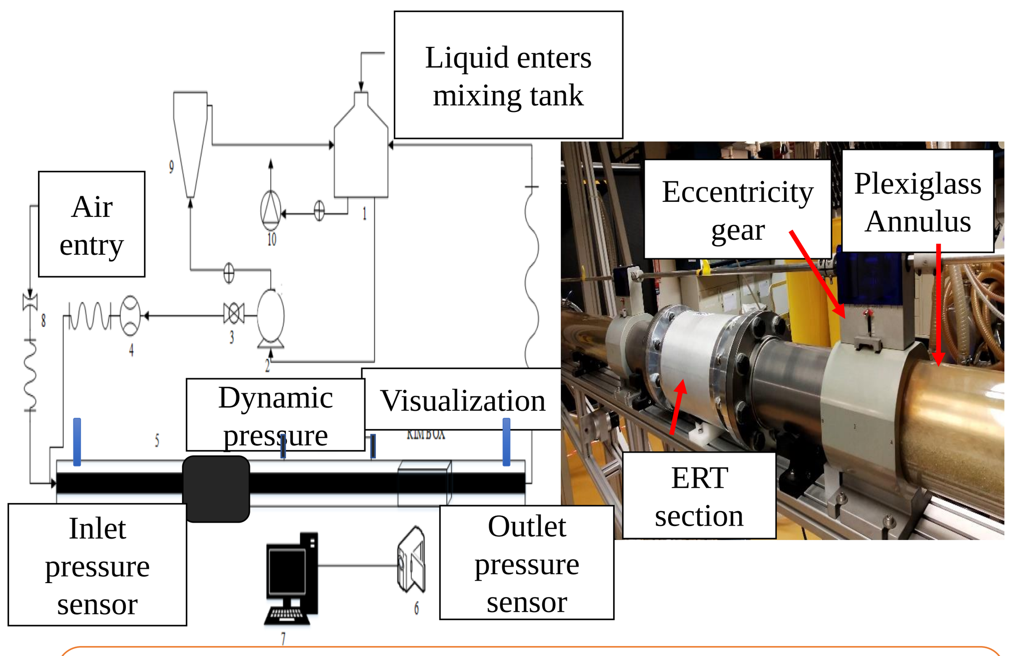
Experimental Procedure

Bed Height Measurement: The initial and final height of the sand dune was measured and the average value was taken for analysis purpose.

Velocity of dune: Time taken to travel through the visualization section of length 27.94 cm.

Visualization section Foam fluid

Set Up Description



The dune height and velocity was measured in the visualization section high a high quality DSLR camera.

1) Tank 2) Slurry pump 3) Ball valve 4) Slurry flow meter 5) Annulus 6) High speed camera 7) Computer 8) Air flow meter 9) Hydro cyclone 10) Drain pump

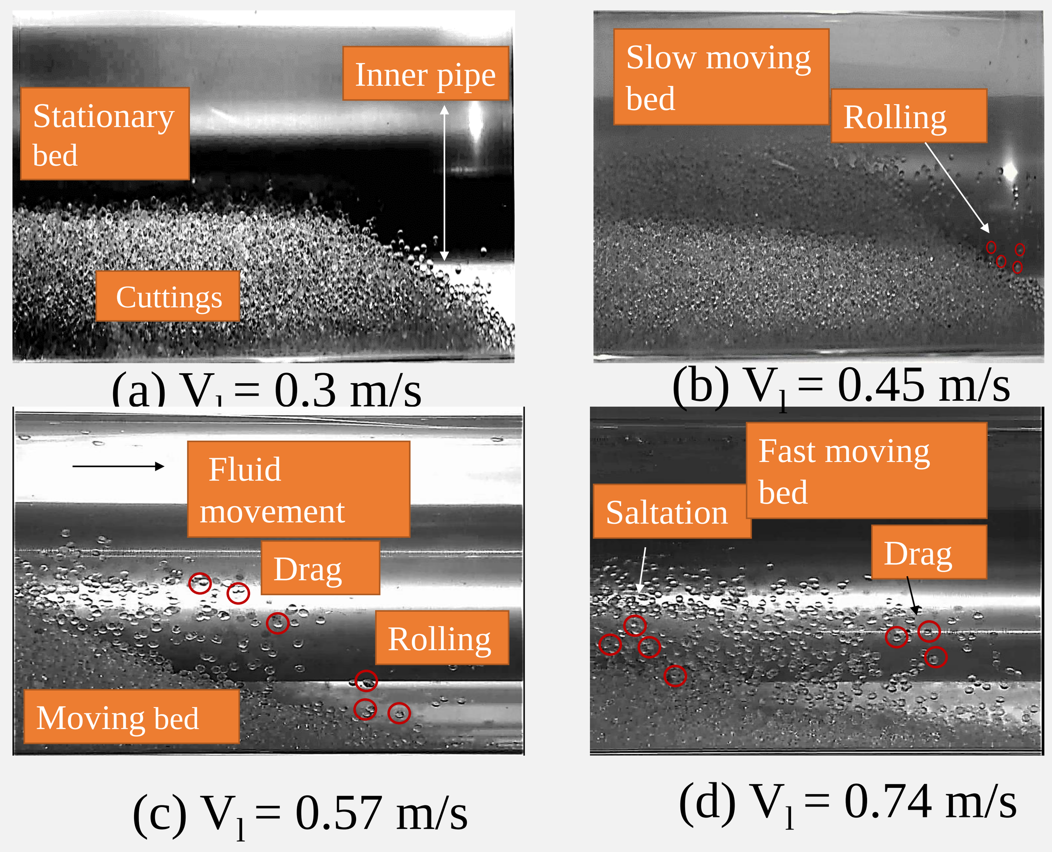
Schematic of the flow loop in TAMUQ

Parameters used

Hydrodynamic range	
Stationary liquid	818 kg/m^3
Density	6.5 – 7.06 ppg /
Circulating mixture density	793 – 838 kg/m^3
Viscosity	0.7 cP
Surfactant concentration (Wt%)	0.02
Cutting concentration (Wt%)	0,2,4
Operating range	
Liquid mass flow rate	219 – 380 Kg/min
Gas flow rate	4 – 6.5 L/min
Gas input pressure	2 bar
Drill pipe rotation	0 (Capacity: 0 – 120 RPM)
Eccentricity	0 (Capacity: 0 – 60%)
Inclination	0 (Capacity: 0 – 12 degree)

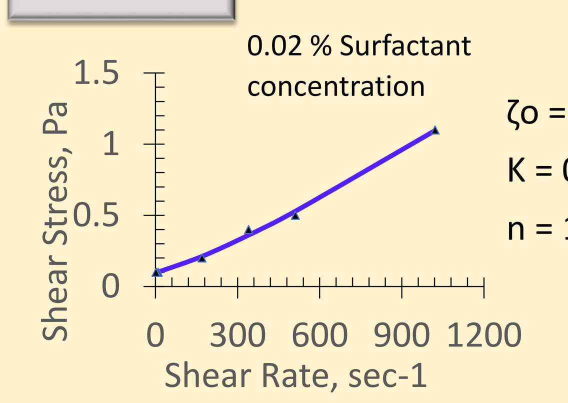
Summary of the experimental matrix

Surfactant : Petrostep ES-65-A (Sulfonate)



Types of flow regime observed

Results



ζo = 0.098
K = 0.00022
n = 1.21

Rheology of foam drilling fluid

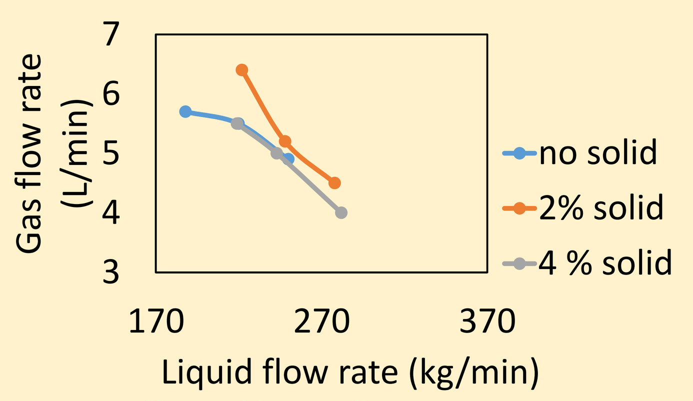
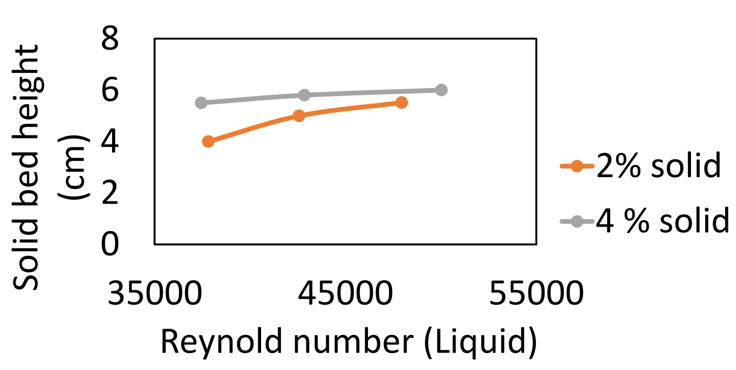


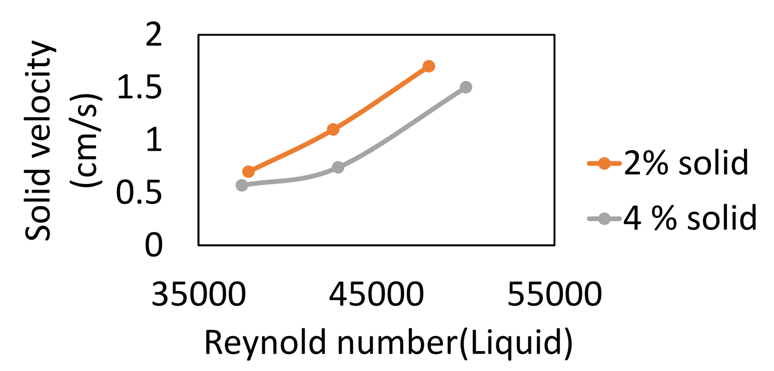
Figure: Effect of liquid flow rate on gas flow rate

- FANN VG meter was used for Rheology measurement
- Hershel Bulkley model given by the eq : ζ = ζ$_o$ + Kγ̇^{n}
- Shear thickening model

For maintaining a constant pressure gas input pressure of 2 bar, the gas flow rate decreases due to increase in liquid flow rate and vice versa.

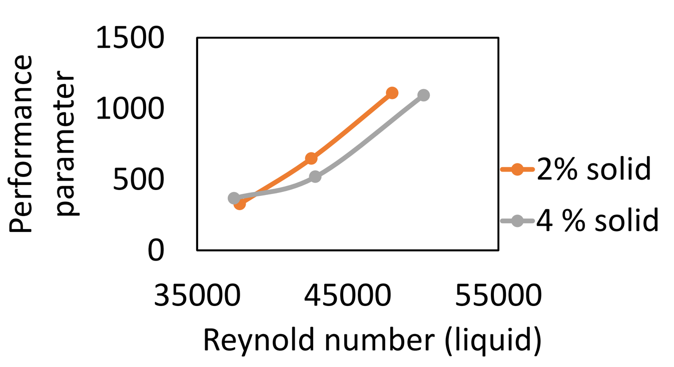
Results: Bed height and Solid velocity





- Increase of mass flow rate (Re) increases the solid bed height as well as solid velocity.
- Lower solid concentration has higher solid velocity and lower bed height.

Results: Performance Parameter



Performance parameter = (V$_s$ * BH)/ɲ

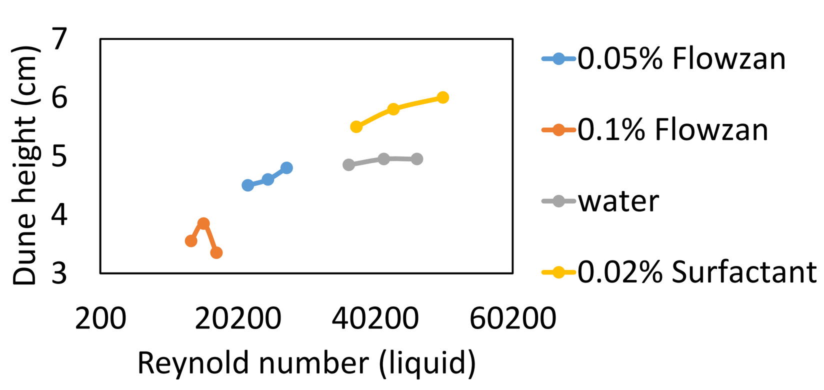
Vs = Dune velocity (m/sec)

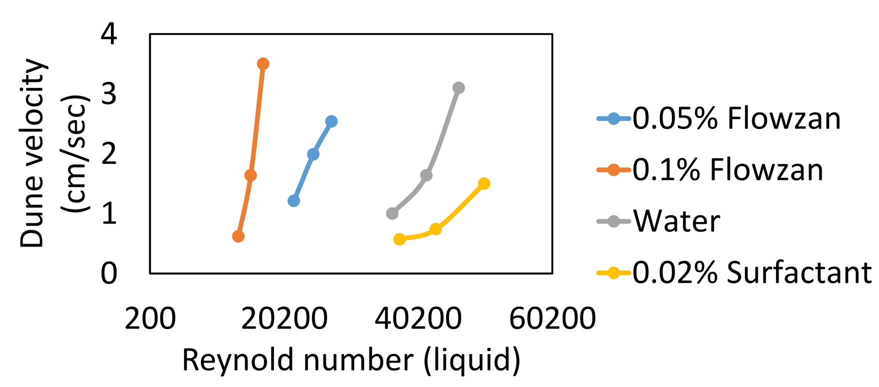
BH = Bed height (m)

ɲ = Kinematic viscosity (m^2/sec)

- Performance parameter indicates cutting transport efficiency.
- At higher Reynold number, performance parameter is higher due to higher liquid flow rate.
- Cutting transport is easier in case of lower solid concentration.

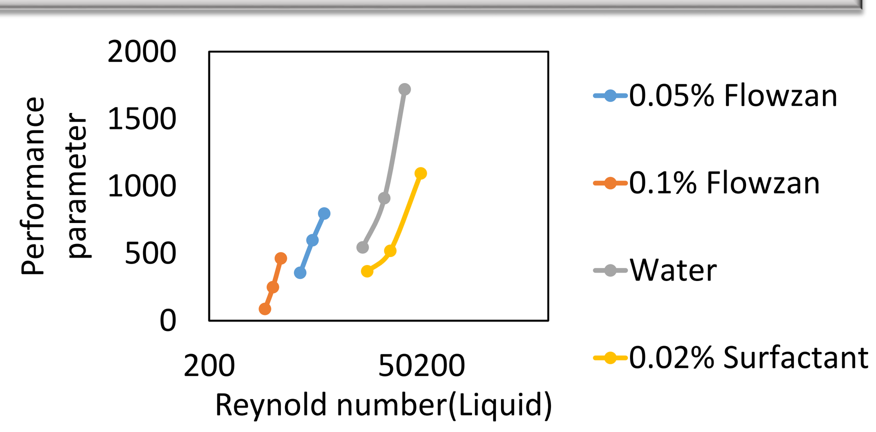
Results: Comparison of different fluid type





- Foam fluid has the highest solid bed height whereas the 0.1% Flowzan has the lowest solid bed height.
- Foam has lower dune velocity due lower liquid flow rate for the same pump output.

Results: Comparison of Performance parameter



Foam has better cutting transport as compared to Flowzan due to lower viscosity.

Fluid type	Viscosity (pa.s)	Density (kg/m3)
Water	0.00089	997
Flowzan (0.10%)	0.00254	1001
Flowzan (0.05%)	0.00153	999
Surfactant (0.02%)	0.0007	820 - 850

Conclusions.

- Solid bed height increases with the increase in liquid flow rate and decreases with increase in gas flow rate for a constant gas input pressure.
- For a constant pump output, foam fluid has the highest solid bed height and lowest dune velocity due to lower liquid flow rate.
- Performance parameter indicates that cutting transport efficiency of foam is higher than flowzan and lower than water.

Future Work and recommendations

Potential Customers/Market: oil and gas industry, process industry, and food industry.

Publications: Four conference paper published and three journal paper published and three submitted.

Student Professional Development/Capacity Building: The project contributed to the professional development of 2 PhD students.

Future Plans: Scaling-up the experimental results to the field cases using non-dimensional analysis and artificial intelligence.

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