Packing Free Gas Absorption Columns for Amine Scrubbing of CO_2

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Introduction

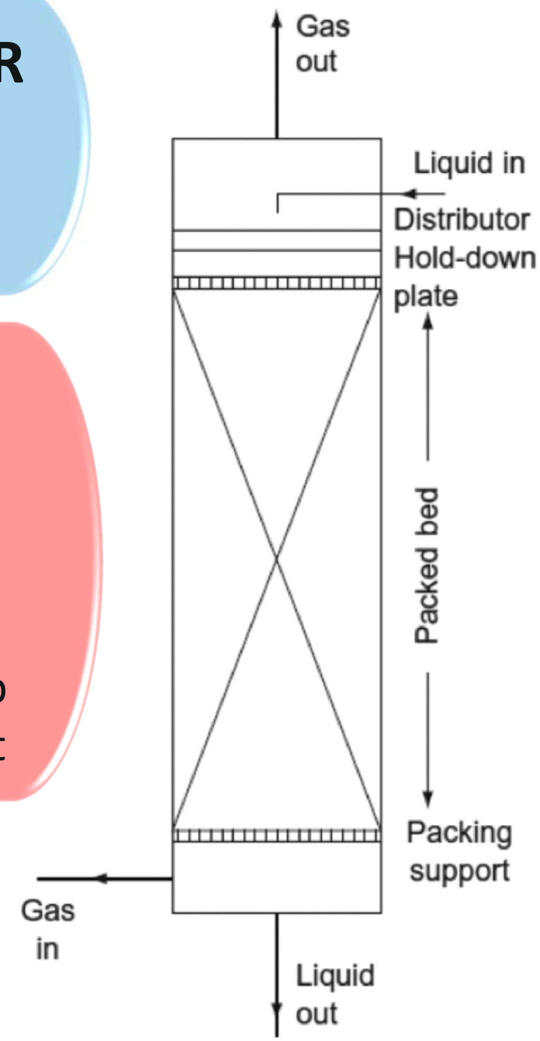
Post Combustion

Technologies
- Chemical Absorption
- Membrane (Gas Phase Separation)
- Cryogenic… etc

Research Area
- Solvent
- Process Technologies
- Energy Integration

PACKED TOWER FOR GAS ABSORPTION

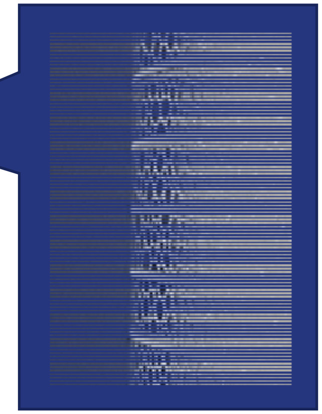
Limitations
- **High Capital Cost (65% of CC cost)**
- Energy Intensive
- Construction time
- High Pressure Drop
- Foaming of Solvent



Alternative Approach

~~Packings~~

Froth



Low Pressure Drop – Less *energy consumption*

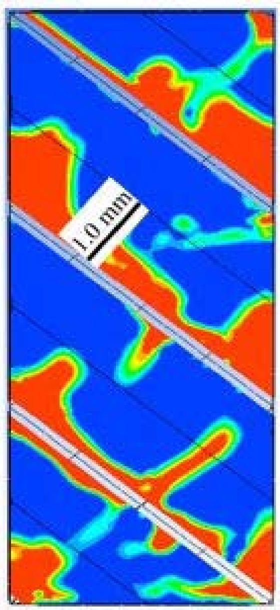
High Surface Area – High gas to liquid *mass transfer area*

Low Film Thickness – Lower *diffusion resistance*

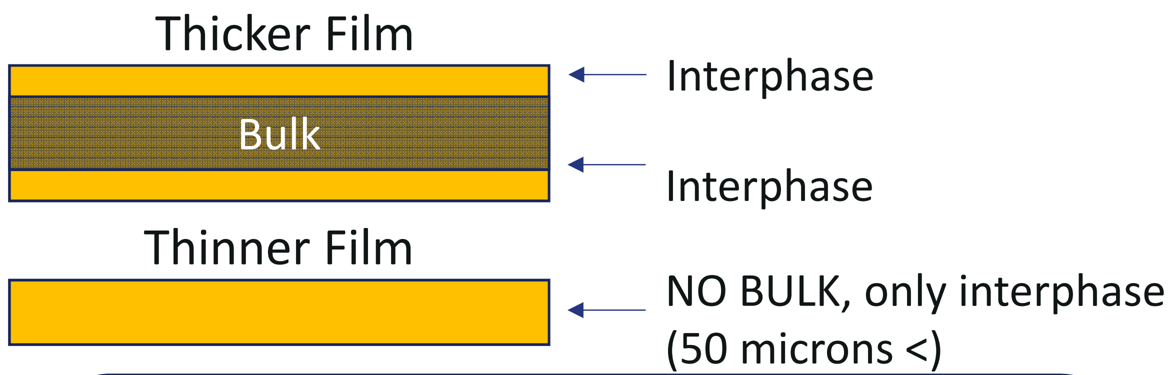
Froth structure

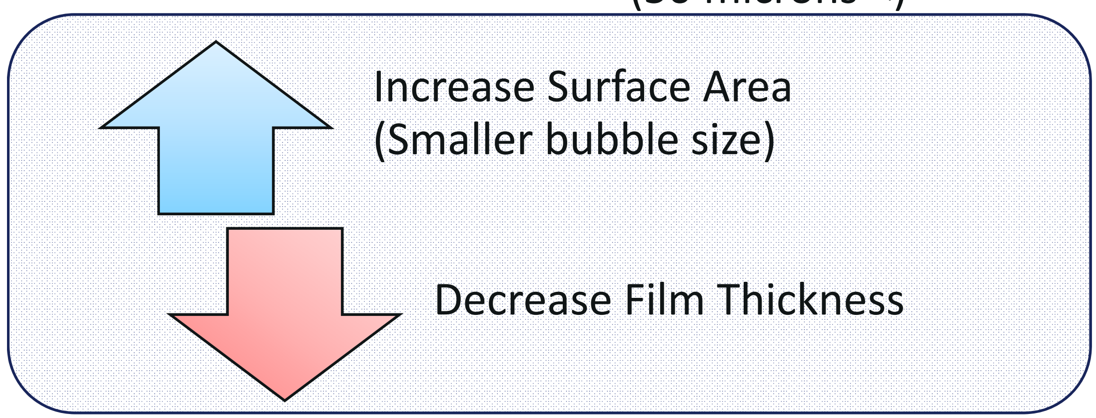
$$Rate\ of\ mass\ transfer\ = K \times a \times (Concentration\ difference)$$

Reactor Type	Specific Interfacial Area (m^2/m^3)
Packed Column	10-1700
Froth Column*	1105-3220



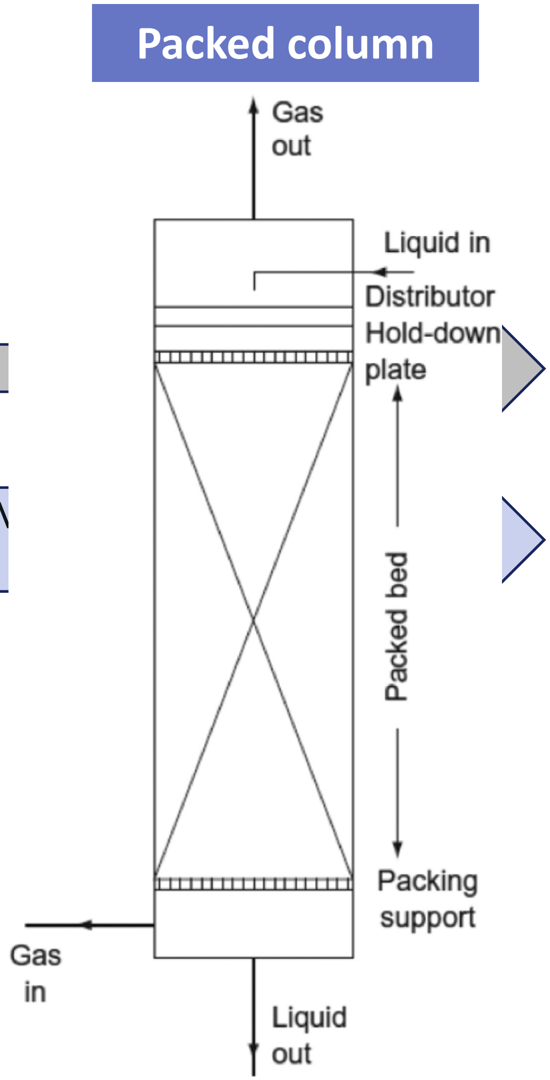
Liquid Film on Packing





* *Energies* 2018, *11*(11), 3103

Goal Summary



- Shorter Column
- Lower Capital Cost
- Less Construction Cost
- Packed with Froth
- Lower Pressure Drop
- Unstable Froth

High Mass Transfer Area and Diffusivity

How?

Unstable/Controlled Froth
- Froth Formation
- Froth Dispersion

Processes
- Coarsening
- Coalescence
- Drainage

Solvent Properties
- Surface Tension
- Bulk/Dynamic Viscosity
- Surface Visco-elastic Properties

Stage 1

Identify the Solvent/Solution Properties Favorable for Frothing
(Low Gas Velocity Frothing Studies)

Stage 2

Design the Column for Carbon Capture Process
(High Gas Velocity Application)

Amine based solution and additives

Solvent

- University of Kentucky Advanced Solvent (UKAS)
  - Rich condition (C/N > 0.4)
  - Lean condition (C/N <0.2)

Additives

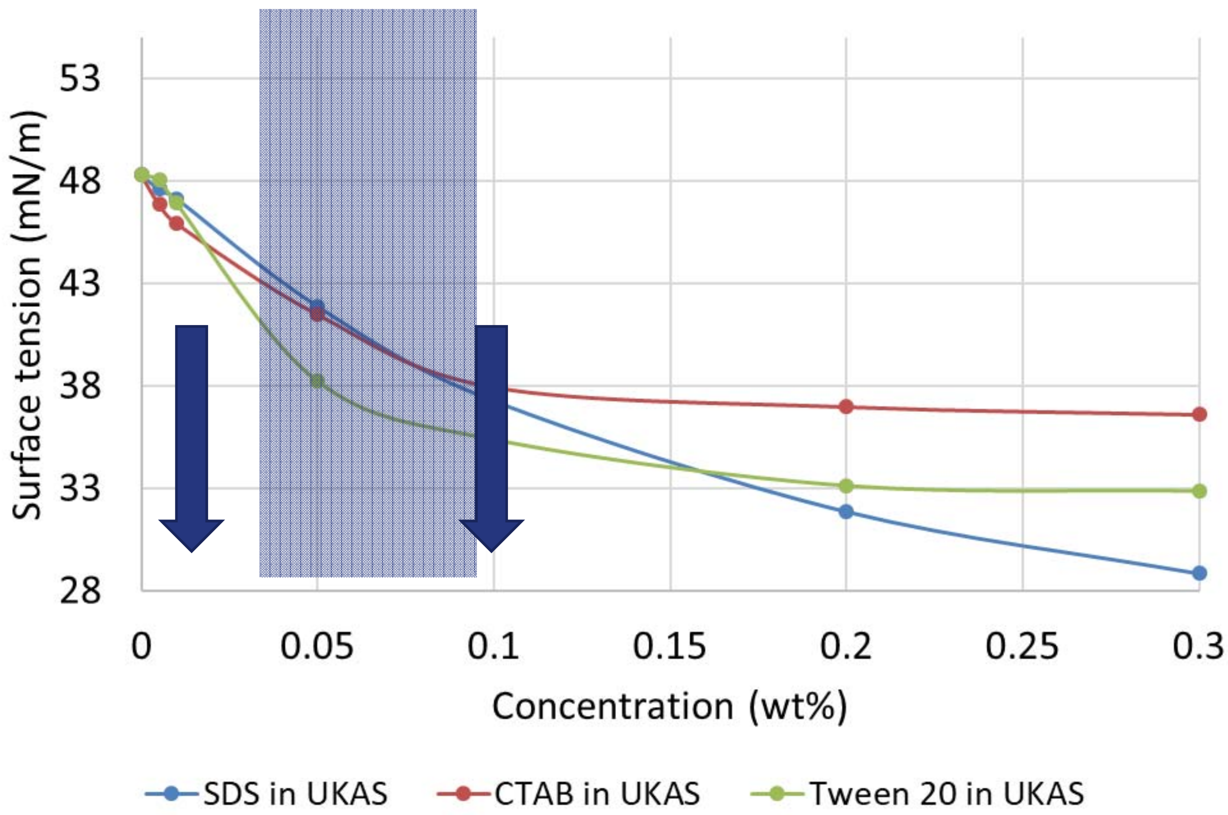
- Surfactants
- Corrosion Inhibitor[2]
- Degradation Products[1]

Surfactants

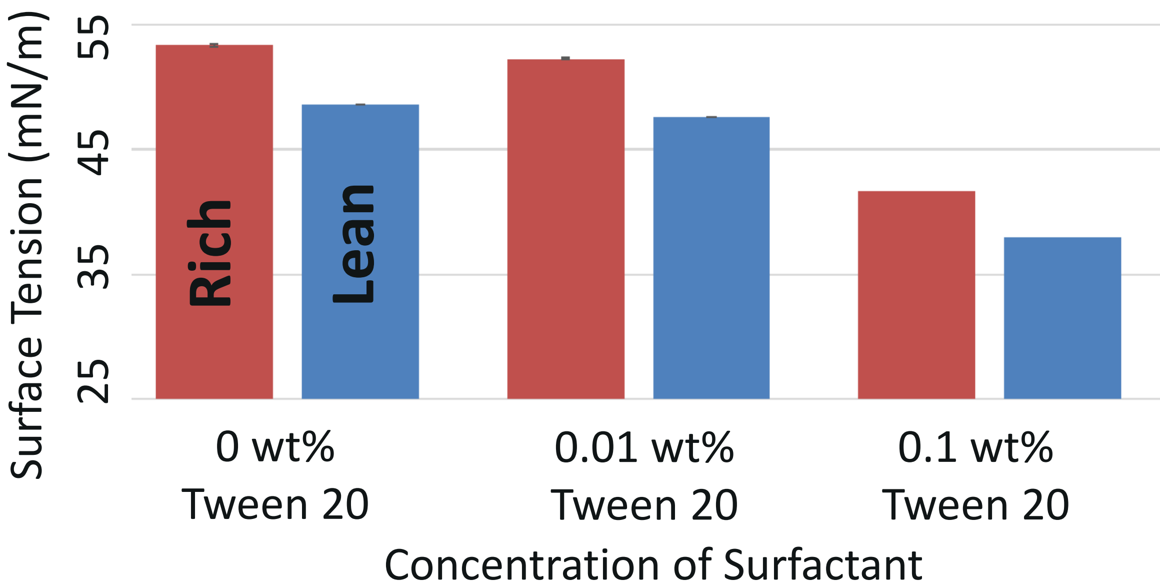
- Non-ionic (Tween 20)
- Cationic (Cetrimonium Bromide/CTAB)
- Anionic (Sodium Dodecyl Sulphate/SDS)

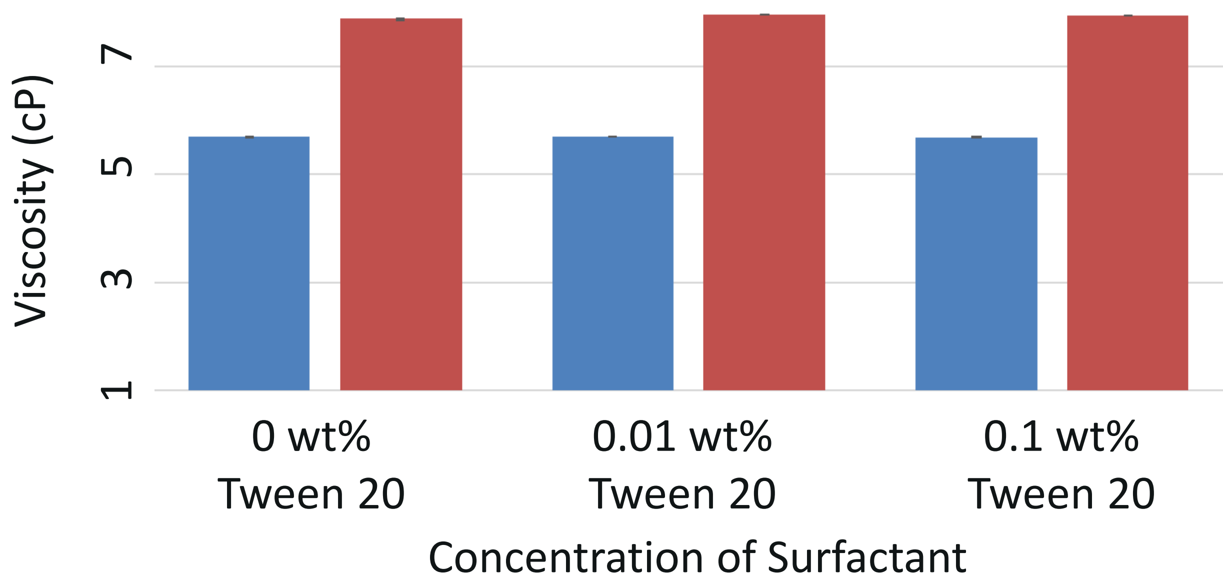
1. International Journal of Greenhouse Gas Control 60 (2017) 156–161
2. International Journal of Greenhouse Gas Control 5 (2011) 381–386

Critical Micelle Concentration



Surface Tension and Viscosity of UKAS





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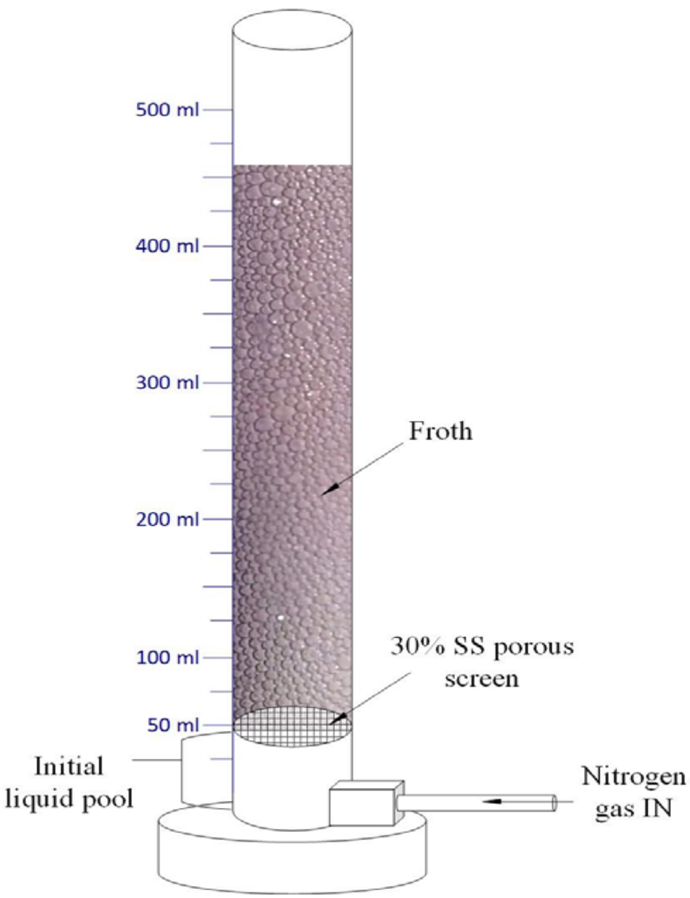
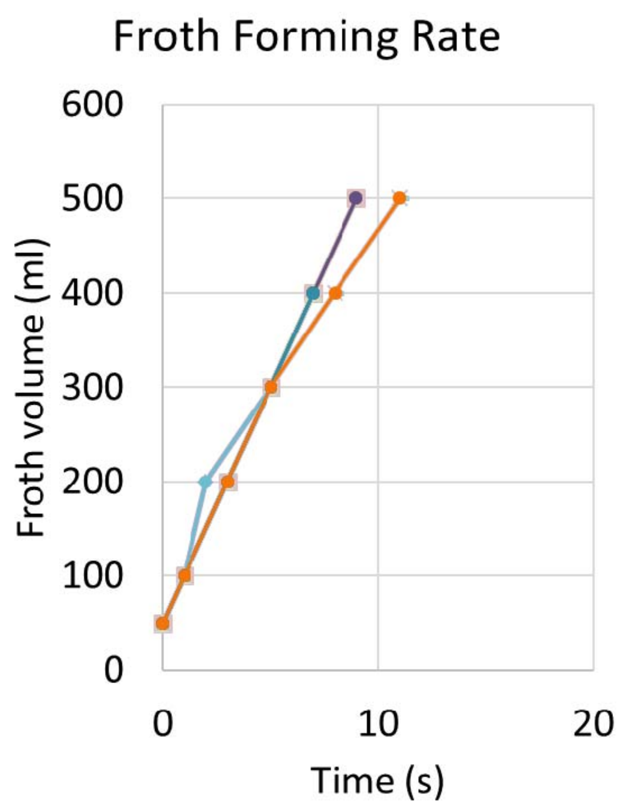
Froth Formation Rate

$G_V = 0.05$ m/s,
L = 50 ml



Experimental Setup

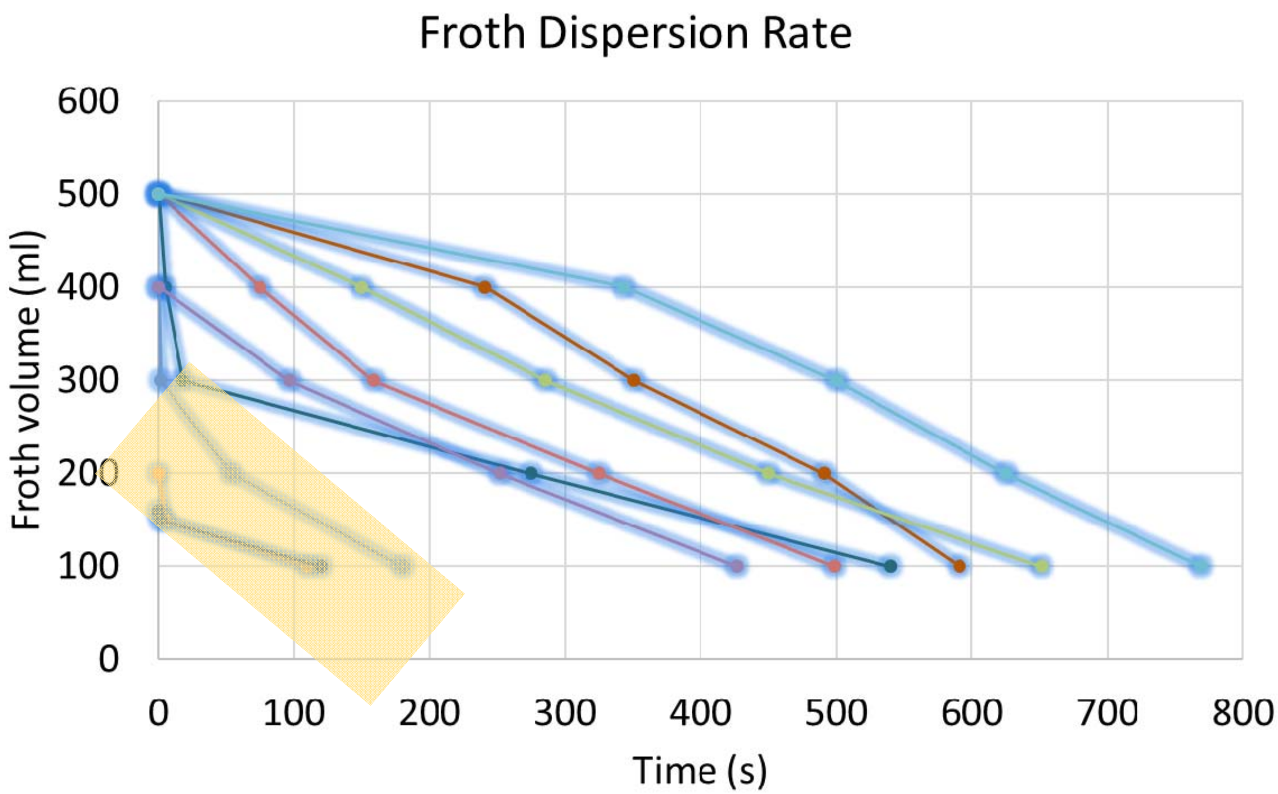


Froth Dispersion Rate

G_V = 0.05 m/s,
L = 50 ml

Fast Dispersion

Uniform Bubble Size



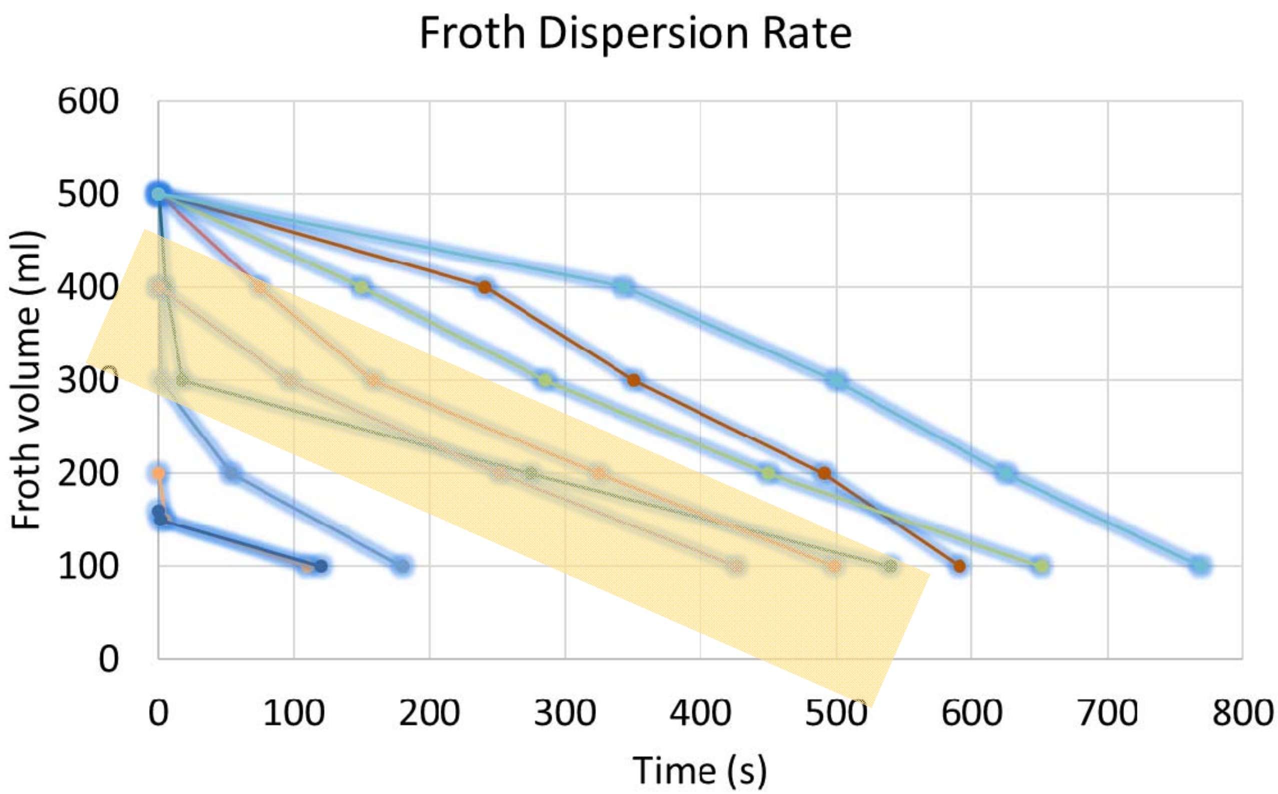
Lean – 0.1 wt% - Tween 20
Rich – 0.1 wt% - Tween 20
Lean – 0.01 wt% - SDS

Froth Dispersion Rate

$G_V = 0.05$ m/s,
L = 50 ml

Slow Dispersion

Non-uniform Bubble Size



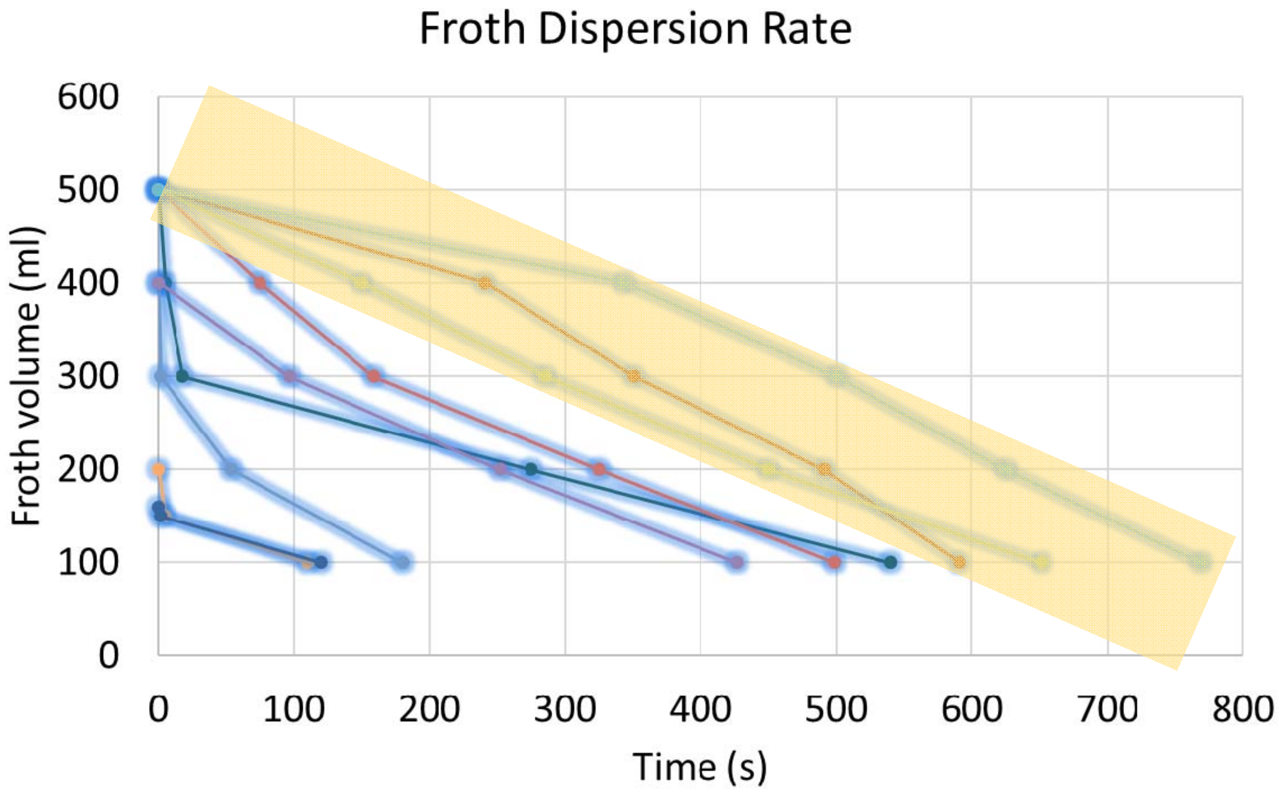
Rich – 0.01 wt% - SDS
Lean – 0.1 wt% - SDS
Lean – 0.01 wt% - CTAB

Froth Dispersion Rate

$G_V = 0.05$ m/s,
L = 50 ml

Very Slow Dispersion

Non-uniform Bubble Size and Plugs of Froth



Rich – 0.1 wt% - SDS
Rich – 0.01 wt% - CTAB
Lean – 0.1 wt% - CTAB

Conclusions

- Experiments were performed to understand the solvent properties favorable for unstable and controlled frothing
- UK Advanced Solvent has slow rate of froth dispersion even at lower ionic surfactant concentration due to its higher viscosity
- Ionic surfactants form very stable froth whereas non-ionic has high dispersion rate
- Higher concentration of surfactant forms smaller bubbles
- The overall rate of dispersion does not completely depend on either just surfactant or just solvent. But it is the combination of surfactant, solvent and CO_2 loading.
- The concentration of surfactant below and above CMC both formed froth but the stability depends on the other factors like the type of surfactant.

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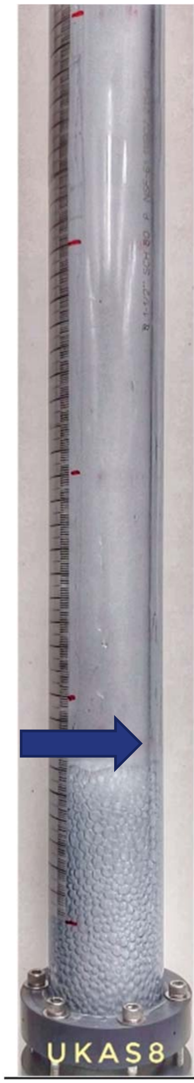
Acknowledgement

- Kunlei Liu and Heather Nikolic
- Power Generation Research Group
- Carbon Management Research Group (CMRG)

Froth Rheology

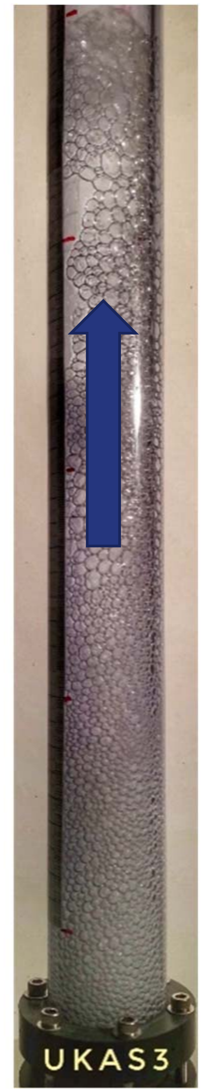
Structured and unstable



Structured and rising

Fast coalescing

Annular



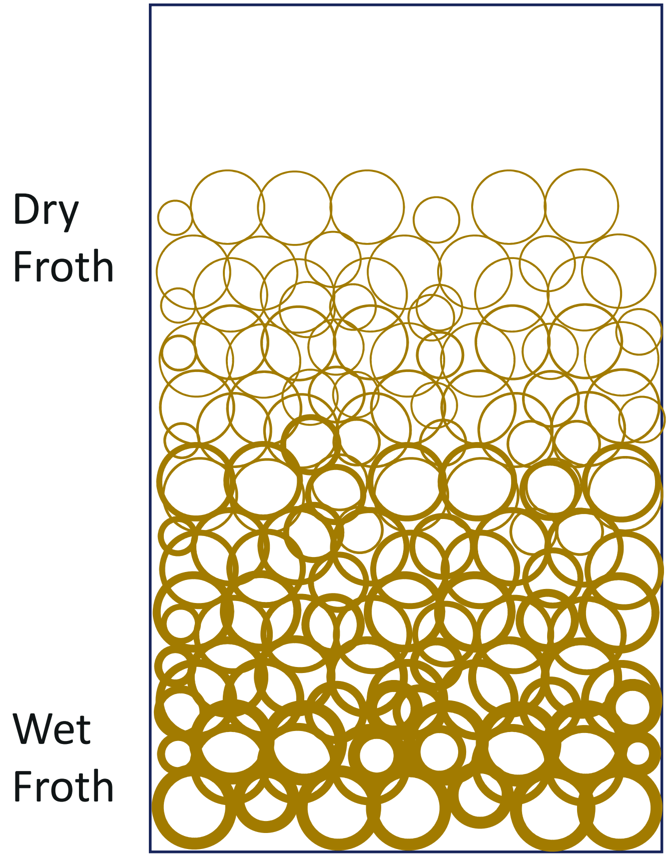
Plug flow

Froth Dispersion – Mechanisms of Froth Breakdown

Coarsening/Ostwald ripening – Transfer of gas from smaller bubbles to the bigger bubbles

Coalescence– Fusion of bubbles after rupture of continuous film phase between them

Drainage – Draining off of the liquid in the froth/bubble film due to gravity creating wet and dry froth



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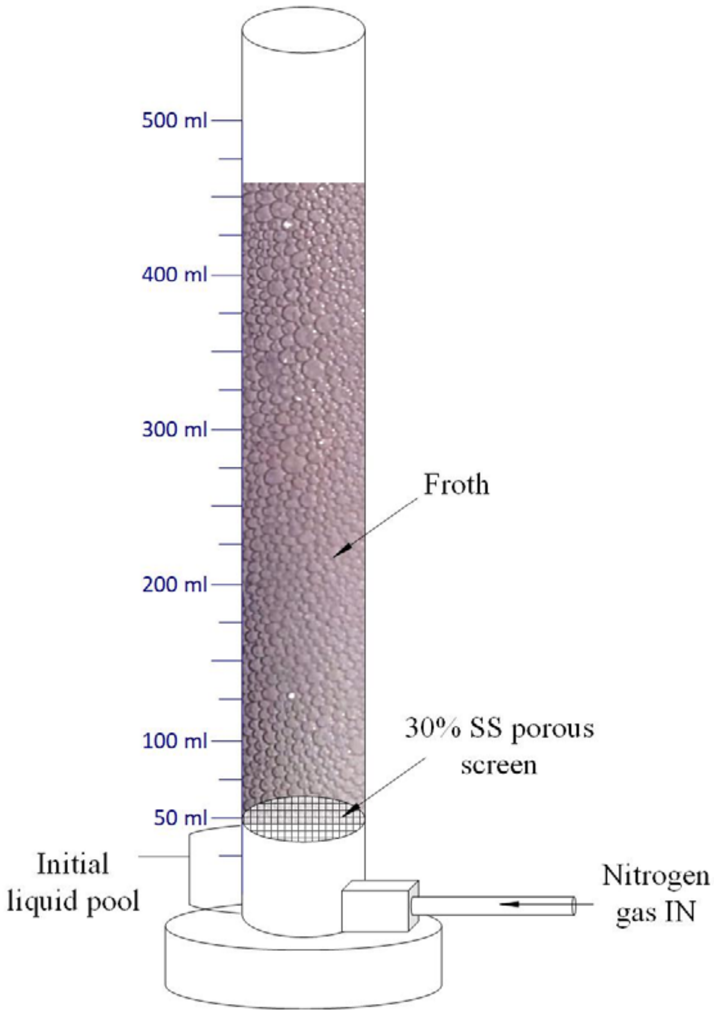
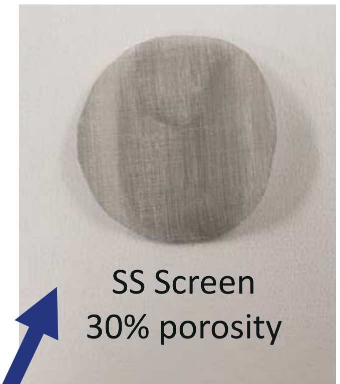
Experimental set up





- Ross – Miles method
- Waring Blender method
- Bikerman method
- Foam scan method
- Custom

Gas Distribution