

Effects of process conditions on foaming in stirred tanks

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Context

This work focused on gaining improved understanding of foam formation in chemical reactors, including the impact of operating conditions and equipment used. Further focus was placed on replicating foaming behaviour across scales to facilitate troubleshooting and foam mitigation in production.

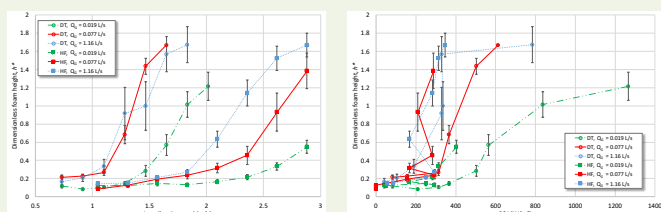
Objectives

- Investigate the effect of impeller type & speed (N) and gas flow rate (Q_G) on foam generation.
- Develop scale-up/scale-down guidelines for replicating foaming behaviour across scales.

Foam generation



- A** Large (~cm) bubbles
 - Foam unstable (disappears rapidly within 60s)
 - Occurs at low N & Q_G
 - B** Average (< cm) & small (mm) bubbles
 - Foam slightly stable (up to ~30 min)
 - Occurs at intermediate N & Q_G
 - C** Small (< mm) bubbles
 - Foam stable for hours
 - Occurs at high N & Q_G
- Foam type C created more often with turbine (higher P/V)



- Foam height increases sharply at a critical tip speed, which depends on impeller type and Q_G
- Foam height appears to correlate somewhat with P/V for intermediate and high Q_G
- N has a greater impact than Q_G on the amount of foam

Conclusions

- The hydrofoil impeller generates significantly less foam than the disc turbine at similar impeller tip speed & gas flow rate.
- Impeller speed has a more significant impact on the amount of foam generated than gas flow rate.
- Foam height correlates better with P/V than impeller tip speed when comparing impeller types at a single scale.
- However, scaling-up with constant P/V (and Na) results in excessive foaming at large scale.
- Constant Na as scale-up strategy for gas flow rate gave better results than U_G or Q_G/V , however it failed to reproduce the gas dispersion regime across scales and didn't replicate foaming at high impeller speed.
- Better foam replication across scales for this system was achieved by scaling-up with constant impeller tip speed (and Na).

Materials and method

Impeller types:

- Disc turbine
- Narrow blade hydrofoil

Tank sizes: 5 L, 171 L

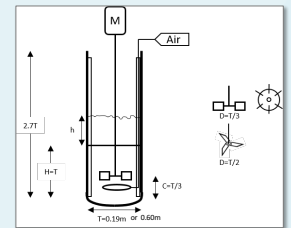
Fluids: Aq. solution of Tween® 20 (0.1 g/L) and air.

Impeller tip speed: 0.7-2.0 m/s (hydrofoil), 1.0-2.9 m/s (turbine)

Gas flow rate: 1.2-7 L/min (5L), 3.5-18 L/min (171L)

Foam measurement:

- Average of 4 diametrical line of sight measurements of highest foam height, h
- Dimensionless foam height, $h^* = h/H$



Scale-up strategies

Foam impacted by impeller type & speed, and $Q_G \rightarrow$ scale-up with geometrical similarity and constant parameters for:

- Gas flow rate: superficial gas velocity (U_G), Q_G/V or aeration number ($Na = Q_G/ND^3$)
- Impeller speed: V_{tip} , P/V, We or Fr

- U_G and Q_G/V always lead to excessive foaming; Na best replicates foam generation at low to intermediate impeller speeds (but not always at high speeds)
- P/V, Fr \rightarrow excessive foam formation at large scale compared with small scale; We \rightarrow very low N at large scale

Scaling-up using constant impeller tip speed & Na enabled replication of foam heights at both scales, particularly for the hydrofoil.

