Advancing Green Reactor Engineering by Fundamental Characterization of Multiphase Flows

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Green Engineering

Need:

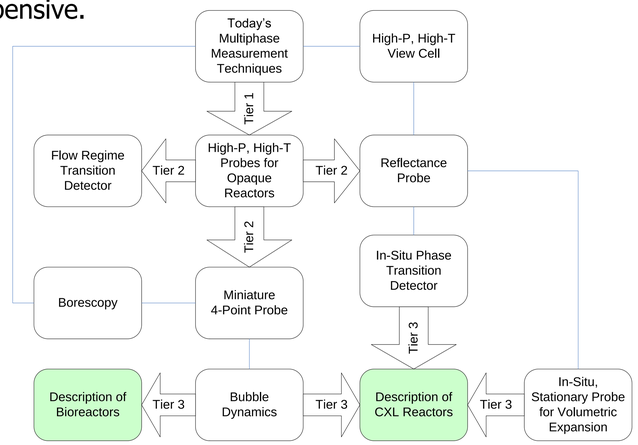
Develop environmentally friendly and cost effective processes

Possible Routes

- **Reduce** waste and pollution by increasing reactor performance and efficiency through better understanding of reactor design and scale-up
- Produce fuels and chemicals from **renewable** sources of energy
- Use carbon dioxide expanded liquids (CXLs) which can **replace** harmful solvents, such as volatile organic compounds (VOCs), with up to 80% (by volume) carbon dioxide

How does our research fit in?

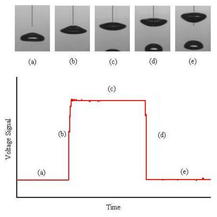
Emerging green processes show great potential; however, they are not well characterized - this limits their widespread implementation in industry. Our goal is to create novel fiber-optic measurement techniques that are used to quantitatively describe multiphase reactors (bioreactors and CXLs) at industrially relevant operating conditions where many current, experimental techniques cannot be used or are too expensive.



Research progression[1]

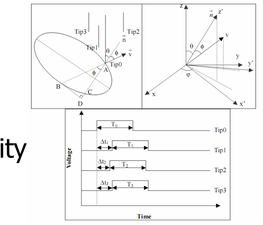
Fiber-Optic Probes

- Inexpensive compared to many of today's current measurement techniques
- Sense differences in gases and liquids at high-frequency (100 kHz) sampling rates allows for use as on-line process control tools
- Invasive technique allows investigation of opaque reactors operating at high pressures and temperatures



4-Point Mini-Probe

Improved working pressure and temperature of probe to 180 bar and 375 ºC and reduced size to 0.625 mm for characterization of smaller bubbles



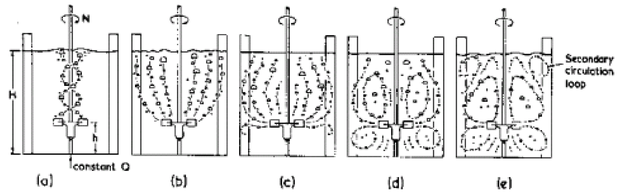
Detects

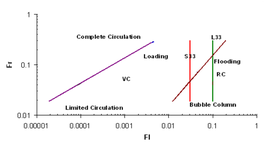
- Gas holdup
- Bubble velocity
- Bubble size
- Bubble surface area

for bubbles as small as 1 mm expected at higher P & T in CXLs and bioreactors

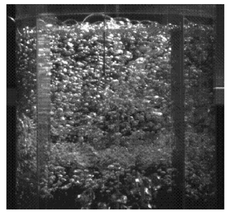
Flow Regimes in a Stirred Tank

The optical probe can also be used as a process control tool that monitors flow regime changes in an opaque stirred tank

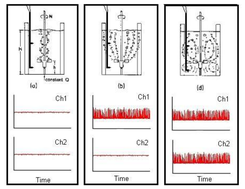


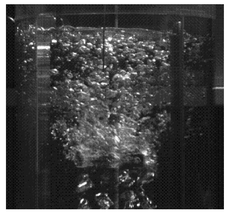


$$Fl = \frac{Q_G}{N \cdot D^3} \qquad Fr = \frac{N^2 \cdot D}{g}$$

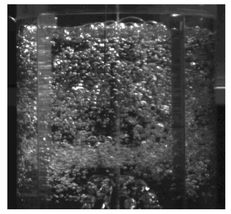


500 rpm & 12.5 L/min

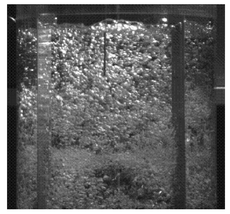




350 rpm & 8.7 L/min



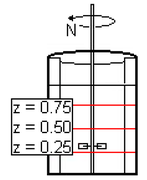
500 rpm & 8.7 L/min



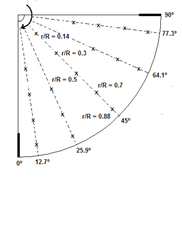
750 rpm & 8.7 L/min

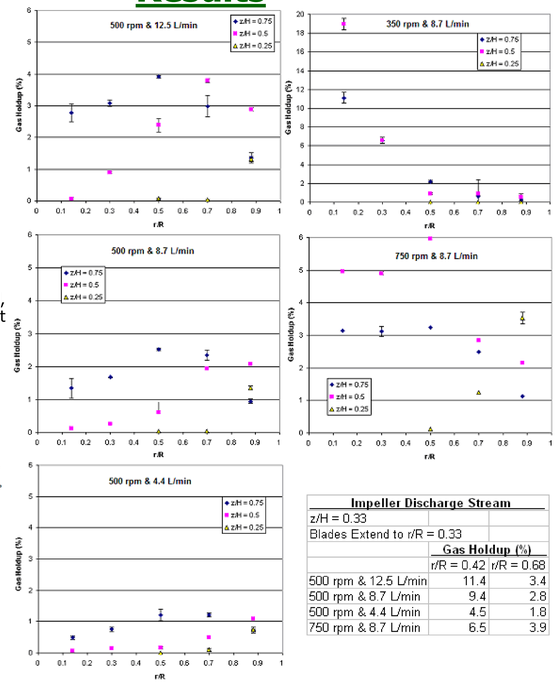
500 rpm & 4.4 L/min

Results



Local radial, tangential, and axial measurement positions



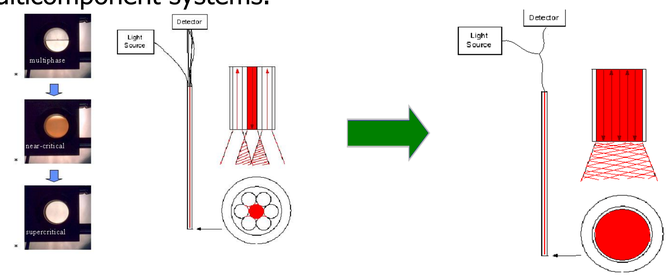


Impeller Discharge Stream		
z/H = 0.33		
Blades Extend to r/R = 0.33		
	Gas Holdup (%)	
	r/R = 0.42	r/R = 0.68
500 rpm & 12.5 L/min	11.4	3.4
500 rpm & 8.7 L/min	9.4	2.8
500 rpm & 4.4 L/min	4.5	1.8
750 rpm & 8.7 L/min	6.5	3.9

Optical probe accurately captures the complex 3D flow pattern in a multiphase stirred tank (local gas holdup, bubble size, bubble velocity vector, and specific interfacial area) and how it changes with operating conditions.

Critical Opalescence Probe

New design simplifies construction, improves signal/noise ratio, increases active sampling area, and eliminates dead space. These improvements allow this probe to track critical phase boundaries of complex, poorly described multicomponent systems.



References

1. "Advancing Green Reactor Engineering by Fundamental Characterization of Multiphase Flows", *CREL Annual Report 2009-2010*, Pages 46-50, (2010).

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