Fuel Cell Coolant Optimization and Scale-up

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FC077

Overview

Total project funding

- DOE share: $351K
- Contractor share: $88K
- Funding received in FY09: $0K

Timeline

- Project start date: 09-01-2009
- Project end date: 08-31-2011

Barriers addressed

- System thermal management

Interactions/ collaborations:

- Lehigh University (Subcontractor)

Background

The development of a nanoparticle-based coolant for application in PEM fuel cells began in 2004 with a SBIR grant from the DOE. The expectation of the coolant was to have a low electrical conductivity and exceptional thermo-physical properties in comparison with fluids of similar electrical conductivity. Proceeding through Phase I and Phase II of the research provided a good recipe for a coolant fluid that demonstrated low electrical conductivity as well as good thermo-physical properties. With the current grant from the DOE, scale up of the manufacturing of the coolant has taken center stage. Before the end of 2010 a pilot plant will be completed and production will begin on semi-large scale. The cost to produce the coolant is expected to reduce significantly.

Key Technical and Economic Questions to be Answered

- What effect will the impeller type, mixing speed, number of baffles in the reactor, temperature, and the recipe have on the nanoparticle properties?
- What filtration process could be used to remove unwanted chemical species from the nanoparticle slurries?
- How to blend the coolant in large quantities (thousands of gallons)?
- What are the quality control issues with the nanoparticle- based coolant and how to solve them?
- How will the large scale pilot plant production affect the cost of the coolant?

Characteristics of the Coolant

- The Complex Coolant Fluid consists of a base compound (glycol/water mixtures) and an additive package.
- The base compound mixture has a freezing point less than –40 ^{o}C, is non-flammable, and can be used at temperatures up to 122 ^{o}C.
- The additive package consists of corrosion inhibitors and ion-suppressing compounds to maintain the electrical conductivity of the coolant at a low level.

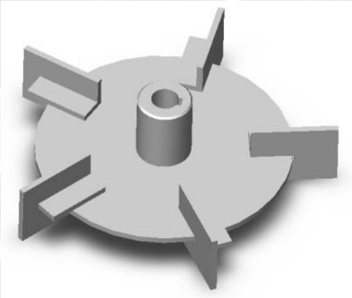
Optimization

Currently, two types of impellers are being examined, Rushton RT5 and Lightnin A310. They are being tested at various speeds and temperatures in a 2 liter reactor to determine which has better conversion rate with the least amount of power input.

Using the dimensionless variables above, different sizes and types of impellers can be compared. When scaling up to the next size reactor these equations can be used to predict the best type of impeller.

The next steps with the optimization are to see how a baffled reactor will compare with a non-baffled reactor and doing all the tests at larger scales such as 20 and 30 liter reactions.

Lightnin A310



Rushton RT5

$$Np = \frac{P}{N^3 D^5 \rho}$$

$$Nq = \frac{Q}{ND^3}$$

$$Nre = \frac{ND^2 \rho}{\mu}$$

Np = Impeller power number
Nq = Impeller flow number
N = Impeller rotational speed (1/sec)
Nre = Impeller Reynolds Number
μ = Viscosity in Pas
P = Impeller power (W)
D = Impeller diameter (m)
Q = Impeller primary flow (m^3/sec) (pumping capacity)
ρ = Fluid density (kg/m^3)

Parameter	Ratio
Speed	$\frac{Nq\ (2)}{Nq\ (1)}$
Diameter	1.0
Flow	1.0
Power	$\frac{Np1\ (Nq2)^3}{Np2\ (Nq1)^3}$
Flow/Power	$\frac{Np2\ (Nq1)^3}{Np1\ (Nq2)^3}$
Torque	$\frac{Np1\ (Nq2)^2}{Np2\ (Nq1)^2}$

Scale Up

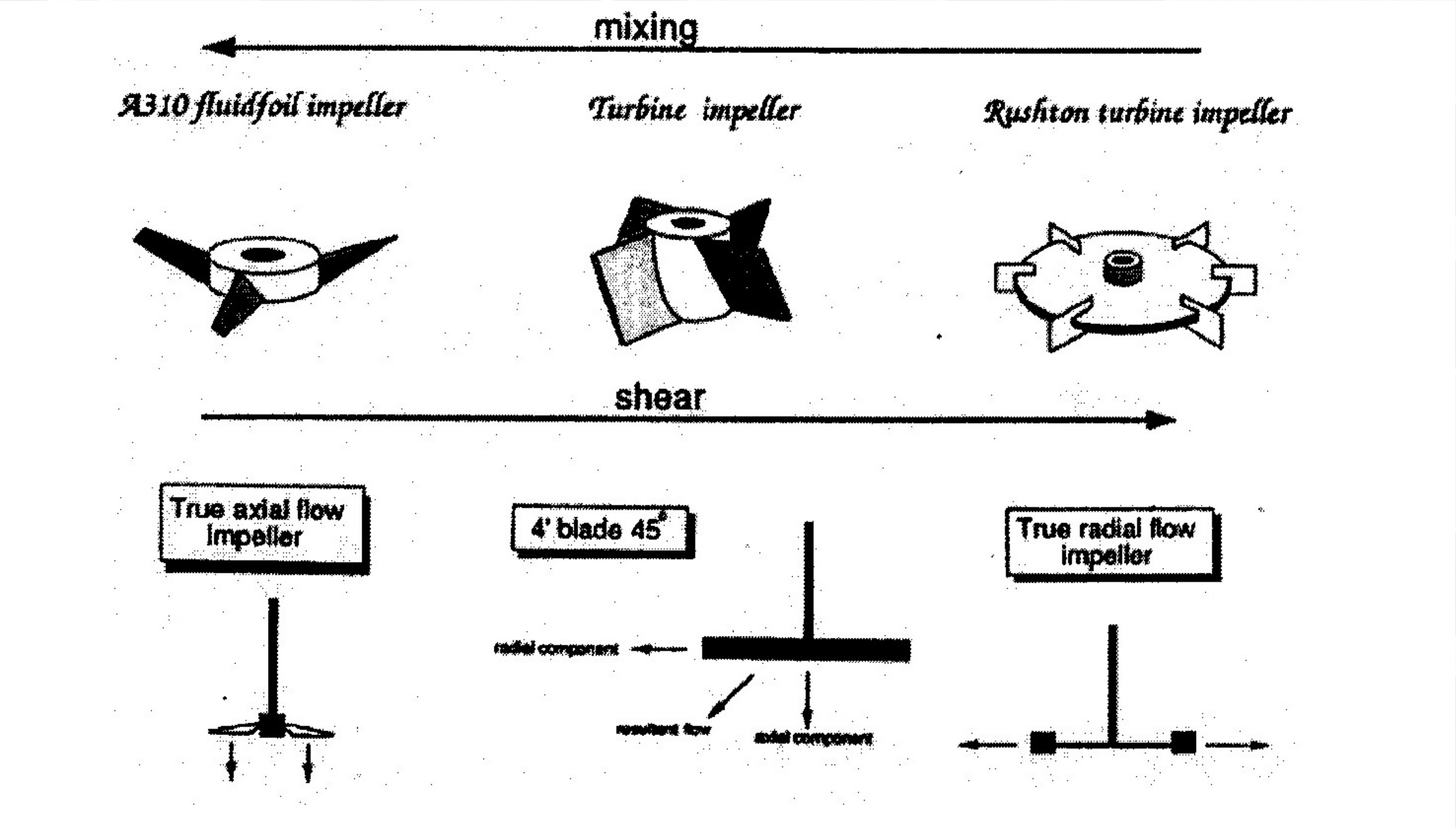
Scale Considerations

- Emulsion Polymer Development Bench Scale 1L-5L
- Pilot Scale 10L-100L
- Manufacturing Scale 4000L-25000L
- No Systematic Strategy for Scale-up (Heuristics: tip speed, P/V, etc.)

The Origins of Some Scale-Up Problems

- No attention given to agitation effects on the bench scale
- Can it be done?
  - What is the smallest scale?
- Proposed Approach
  - Empirical
    - Mixing, Shear Stress

Typical Impeller Types



Scale-up Effect on Agitation Properties

Property	Pilot 20 Gal	Plant Scale 2500 Gal			
P	1.0	125.0	3125.0	25.0	0.2
P/V	1.0	**1.0**	25.0	0.2	0.0
N	1.0	0.3	1.0	0.2	0.0
D	1.0	5.0	5.0	5.0	5.0
Q	1.0	42.5	125.0	25.0	5.0
Q/V	1.0	0.3	**1.0**	0.2	0.0
ND	1.0	1.7	5.0	**1.0**	0.2
ND2ρ/μ	1.0	8.5	25.0	5.0	**1.0**

Reactors

Picture show 0.5, 2.0, and 20 liter reactors

Picture show 10 and 100 liter reactors

Summary

Dynalene has procured 10 , 20 , and 100 liter reactors for the production and scale-up of nanoparticle to be used in the fuel cell coolant. The scale-up methods have been reviewed and certain criteria have been developed. Different types of agitators and baffles have been identified and their potential effect on the nanoparticle production have been investigated.

The site for the pilot plant is currently under preparation. The materials and components needed for the completion of the pilot plant are being reviewed and will be procured soon.

The pilot plant is expected to be finished by the end of August 2010 and research in the 10 L and 100 L reactors will resume soon after.

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