Agitator Design Principles for Biofuels

Who Should Attend

This is a course for people who must specify, purchase or optimize fluid agitation equipment used for Biofuel applications. Such applications include, for example, simple tanks containing solutions, broth and slurry tanks, compounding tanks and fermenters/bioreactors. The application technology ranges from simple to complex. A basic Introduction to general agitator design principles is given, but the focus is specifically on applications found in the Biofuels Industries.

Having a working knowledge of the terminology and technology used by agitator designers enables the attendee to assume a more active role in the purchase and operation of such equipment, instead of leaving everything in the hands of the vendors. The result can be a lower price paid by specifying clearly what is needed, while avoiding undersized or poorly designed equipment that can cause lost productivity. Principles of energy cost optimization are discussed. Senior management can see how proper agitator design can impact overall production and profit.

This course provided 1.2 CEUs or 12 PDH credits by Benz Technology International, Inc.

Learning objectives

Upon completion of this course, you will (day one):

- Be able to choose the right impellers for the job
- Understand how power and pumping are calculated
- Understand the basics of heat transfer
- Gain a familiarity with biofuel sizing guidelines

(day two:)

- Understand the principles and limitations of agitation scale-up
- Understand basic non-Newtonian rheology
- Learn how to use an agitator as a viscometer
- Learn how cellulosic hydrolysis reactor agitators are designed.
- See how CFD may be used to aid in process visualization
- Learn the differences between top tier and lower tier agitator suppliers
- See a few mistakes that have been made in agitator specification

Course Description

This course presents a rather intense introduction to the major principles of agitator process design, as applied to liquid, solid-liquid and fibrous slurries as commonly found in the Biofuel industries. A brief introduction is given to the basics of agitation theory as applicable, but the emphasis is on practical application of theory, rather than as an academic treatise. Specific guidelines are given for major industry applications. Considerable time is spent on scale-up, non-Newtonian rheology and the special characteristics of cellulose hydrolysis reactors and fermenters. Some practical time is devoted to the issue of how to choose equipment suppliers.

Course Agenda

Day One: Major Agitator Design Principles and Biofuel Applications

Agitator design basics

- Nomenclature
- Principal dimensionless numbers, correlations
- Impeller classifications
- Flow patterns
- Agitated heat transfer

Design for liquid motion

- Calculating pumping capacity
- Characteristic velocity
- Scale of Agitation
- Why power, rpm both important
- Sample problem
- Use of commercial software
- Comparing impeller performance

Starch-based ethanol application guide

- Typical flow sheets covered
- Slurry tanks
- Liquefaction
- Saccharification
- Fermentation
- Beerwell
- Stillage
- Other miscellaneous applications

Cellulosic ethanol application guide

- Pretreated biomass slurry tank
- Cellulose hydrolysis reactor basics
- Simultaneous saccharification and fermentation
- Other miscellaneous applications

Biodiesel application guide

- Esterification reactors
- Washing
- Storage
- Other miscellaneous applications

Day Two: Scale-up, Rheology, Cellulose Reactor design, etc.

Agitation Scale-up

- Goal of scale-up
- Process versus physical scale-up
- Single versus multiple scaling parameters
- Impact of scaling method on equipment size

Basic rheology for agitator design

- Discussion of major rheology types
- Limitations of conventional viscometers for fibrous materials
- How to use an agitator as a viscometer

Cellulose hydrolysis reactor design

- Reactor schemes: fed batch, continuous flow
- How to do the job with a turbine agitator
- How to design experiments to cover scale-up needs
- Sample problem

Use of Computational Fluid Dynamics in agitator design

- Flow around coils
- Velocity profiles
- Bubble size distribution
- Gas holdup distribution
- $k_l a$ distribution
- Blending simulation
- Reaction simulation

- Future technology

Choosing an Agitator Supplier

- Concept of top tier versus lower tier suppliers
- Detailed differences between top tier and low tier
- Historical mistakes in agitator specifications
- Practical tips

Summary

- What we have learned
- Future directions

Course Director

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<u>Publications of Gregory Thomas Benz, P.E.</u>

1) “Design and Scale-up of Agitators for Gas Dispersion in Fermentors”, R. Rautzen, G. Benz and D. Dickey, presented at Engineering Foundation Conference on Mass Transfer and Scale-up of Fermentors, New England College, Henniker, NH, July 1977

2) “Improved Starch Reactor Design”, G. Benz, Proceedings of 1990 Scientific Conference, Corn Refiners Association, Indianapolis IN, September 1990, pp121-136
3) “Computational Fluid Mixing for Corn Wet Milling Applications”, G. Benz and A. Bakker, Proceedings of 1994 Scientific Conference, Corn refiners Association, Oakbrook, IL, September 1994, pp 185-192
4) “Mixing in Industrial Fermenters”, A. Bakker, G. Benz, presented at Biotechnology Conference, Sydney, Australia, 1996
5) “A Comparative Study of Alternative Gas Dispersion Impellers”, K. Myers, A. Thomas, A. Bakker and G. Benz, presented at Gas-Liquid Systems Session. Mixing XVI, Williamsburg, VA June 1997
6) “ Proper Impeller Systems Insure Mixing Performance”, M. Reeder, G. Benz, Chemical Processing Magazine, July 1997, pp 63-64
7) “Enhancement of Fermentation with Effective Impeller Systems”, G. Benz, Proceedings of 2001 International Symposium “New Horizons in Microbiology and Biotechnology”, Seoul Korea, June 2001, pp 153-154
8) “Optimize Power Consumption in Aerobic Fermenters”, G. Benz, Chemical Engineering Progress, May 2003, pp 100-103
9) “Impeller Selection for Agitated Aerobic Fermenters”, G. Benz, Chemical Engineering Progress, February 2004, pp18S-24S
10) “Team Up with a Consultant for Equipment Selection”, G. Benz, Chemical Engineering Progress, August 2006, pp 50-51
11) “The G-Value for Agitator Design: Time to Retire It?”, G. Benz, Chemical Engineering Progress, March 2007, pp 43-47
12) “Selecting Agitator Seals for Bioprocessing Applications”, G. Benz, W. H.L. Teng, Chemical Engineering Progress, January 2008, pp 44-52
13) “Piloting Bioreactors for Agitation Scale-Up”, G. Benz, Chemical Engineering Progress, February 2008, pp32-34
14) “Agitation Challenges in Cellulosic Ethanol Production”, Ethanol Producer Magazine, March 2008
15) “Sourcing Equipment in Developing Countries while Minimizing Risk”, G. Benz, Ethanol Producer Magazine, August, 2009.
16) “Determine the Optimum Number of Process Trains”, G. Benz, Chemical Engineering Progress, January 2010, pp 50-51
17) “Agitation of Fibrous Materials”, G. Benz, Chemical Engineering Progress, June, 2010, pp 28-32
18) “Reduce Risk When Sourcing Abroad”, G. Benz and L. Du, Chemical Engineering Progress, October 2010, pp 32-36

Patents

U.S. # 6883960, “Mixing arrangement for tanks.” A non-rotating, sealless method of mechanically agitating tanks