1979 ENGINEERING FOUNDATION CONFERENCES

MIXING VII

New England College
Henniker, New Hampshire

August 12-17, 1979

PROGRAM

Sunday, August 12, 1979

3:00 p.m. - 9:00 p.m. REGISTRATION AND CHECK-IN

6:30 p.m. - 8:00 p.m. DINNER

Monday, August 13, 1979

9:00 a.m. - 12:00 Noon SESSION I: MIXING AND CHEMICAL REACTIONS

Session Chairman: H. L. Toor
Carnegie-Mellon University

"A Thinning Slab Model for Simultaneous Mixing and Chemical Reaction"

The alternative slab model of Mao and Toor is improved by allowing the alternative slabs of reactants to become thinner with time. The model gives more accurate predictions than earlier models when applied to non-premixed stirred tank data and data downstream of a multiple jet mixing head.

P. T. Palepu, R. J. Adler, R. V. Edwards
Case Western Reserve University

"Fast Reactions in a Vortex"

Reaction of a strong acid and base is generally so fast that the locale of reaction is a surface between solutions being mixed. The rate of reaction is not controlled by chemical kinetics but depends on diffusion to the reaction surface, which is expanding in time. A detailed description of this expansion for a model vortex eventually leads to predictions which are compared to an experiment for a reacting flow downstream of a mixing head.

William E. Ranz
University of Minnesota

"Mixing and Fast Chemical Reactions in Some Industrial Reactors"

Under certain circumstances one or more (fast) chemical reactions may be employed to decide if a mixture was molecularly homogeneous (micromixed) or if segregation was present during reaction. A convenient system of series-parallel test reactions has been developed and characterized, whereby the product distribution responds to segregation. Experimental data are presented and compared to a model in which diffusion and reaction take place in intially segregated parts of the fluid.

J. R. Bourne Techn. Chem. Laboratorium, Zurich

"The Effect of Agitator Diameter and Width on Resin Properties During VCM Suspension Polymerization"

Experimental runs are presented showing the effects of reactor agitation on resin polymer properties during vinyl chloride suspension polymerization. The effects of impeller diameter, width, and speed are correlated with resin properties using the Weber number. Results show that the relationship of particle size and distribution versus Weber number are parabolic, not linear as they are with simple dispersions. Relationships of the resin internal morphology with agitation are also presented.

Gary R. Johnson
Continental Oil Company

2:00 p.m. 5:00 p.m. AD HOC SESSIONS

7:30 p.m. SESSION II: MIXING OF PARTICULATE SOLIDS AND AGITATION OF LIQUIDS FOR PARTICULATE SOLIDS SUSPENSION

Session Chairman: D. S. Dickey
Chemineer Agitators

"The Suspension of Solids in Surface Agitated Aeration Basins"

Solids suspension in a small surface agitated, baffled aeration tank was investigated. Categories of suspension have been established and correlated against Froude number impeller and basin geometry. Actual full-scale plant data has been compared to this correlation.

D. L. Bennett
Air Products and Chemicals, Inc. Engineering Dept. Allentown Pa.

Monday, August 13, 1979 continued

"Relationship of Turbine Off-Bottom Clearance to Power Requirement for Solid Suspension"

Statistically significant correlation was found to exist between off-bottom clearance and power required for solids suspension. Clearances up to one turbine diameter for particles settling from 0.5 to 30 ft/min was studied.

L. V. Castro
Proquip, Inc.

"Flow, Particle Suspension and Mass Transfer in Contoured Bottom Tanks"

Experimental measurements in a constant cross sectional area, draft tube and contoured bottom tank showed equivalent performance and reduced power consumption compared to conventional tanks. Characteristics of flow, particle suspension and mass transfer could be scaled-up according to well defined rules.

J. R. Bourne
Swiss Federal Inst. of Technology, Zurich

"The Effect of Gas Sparging on Solids Suspension in an Agitated Tank"

A study of simultaneous gas dispersion and solids suspension in an agitated tank revealed a more dramatic interaction than anticipated by current design practice. A modified designed correlation is presented.

D. G. R. Short
E. I. duPont Company, Wilmington

"Improved Mixing and Bentomite in the Production of Taconite Concentrate Green Balls"

Excellent dispersion can be achieved with a fluidized bed mixer, which combines the high instantaneous materials contact and shear needed for breaking the bentonite pockets.

T. A. Resing
Littleford Brothers, Inc.

"Recent Developments in Solids Mixing"

Significant developments in mixing and blending of dry particulate solids will be reviewed. This review will cover the fundamental theories, mixing characteristics of mixers and other topics related to solids mixing.

F. S. Lai
U.S. Grain Marketing Research Center

L. T. Fan
Kansas State University

Tuesday, August 14, 1979

9:00 a.m. - 12:30 p.m. SESSION III: GAS-LIQUIDS DISPERSIONS AND MASS TRANSFER

Session Chairmen: Doug Leng
Dow Chemical Company

George Tsao
Purdue University

"Two Phase Hydrodynamics of Turbine Agitators and Its Relationship to Mass Transfer and Gas Hold-up"

Two different flow regimes for gas-liquid agitated systems are defined. Different holdup and mass transfer were found to depend on the regime and cavity formation. A tentative criterion is proposed to establish the occurrence of stable regimes.

M. G. Warmoeskerken and John M. Smith
Delft University of Technology, Holland

"The Influence of Very Small Bubble on the Dynamic $K_L A$ Measurement in Viscous Gas Liquid Systems"

A new phenomenon which influences the dynamic method for $K_L A$ measurment will be discussed. Correction factors may be calculated and can amount to values of 2 to 5.

Klass van't Riet and J. J. Heijnen
Gist-Brocades N.V., Delft, Holland

"Oxygen Absorption Mechanisms in Fermentors"

Oxygen concentration fluctuations near the free gas-liquid surface of a fermentor are measured using a unique microprobe. The technique can help with the interpretation of surface aeration and mixing length.

Y. H. Lee
Drexel University

"Agitated Gas Dispersion: Power Requirments, Flooding, Hold-up and Scale-up"

Data on flooding, holdup and dispersion on a large scale gas dispersion mixing facility of 2.6 m^3 will be reported. Conditions covers those commonly found in industrial practice. Scale-up is compared with methods proposed in 1977 at Cambridge, England.

D. S. Dickey
Chemineer Agitators

Tuesday, August 14, 1979 continued

"Sparged Agitated Vessels: Recent Work"

Experimental work on gas-liquid mixing is presented. An attempt is made to answer:

1. How much gas is recirculated through the impeller cavities?
2. How much gas is absorbed from the free surface?
3. What role do multiple impellers play in agitated gas-liquid systems?

A. W. Nienow
University College, London

2:00 p.m. - 5:00 p.m AD HOC SESSIONS

7:30 p.m. SESSION IV: LIQUID - LIQUID DISPERSIONS AND MASS TRANSFER

Session Chairman: J. B. Gray
E. I. duPont Company, Wilmington

"Drop Mechanics in Extraction Equipment"

How mixing affects overall extraction performance and capacity will be described for several types of equipment.

David B. Todd
Baker-Perkins, Inc.

"Drop Breakage in Liquid-Liquid Dispersions"

A method of predicting drop sizes in stirred liquid-liquid dispersions is described. A theoretical model based on Kolmogorov's local isotropy theory is experimentally confirmed.

G. Narsimhan
J. P Gupta

Doraiswami Ramkrishna
Purdue University

"The Effect of Dispersed-Phase Viscosity on Drop Breakup in Agitated Liquid-Liquid Systems"

Correlating equations are developed for predicting mean equilibrium drop size in dilute liquid-liquid dispersions under conditions where both surface forces and dispersed phase viscous forces are important.

Richard V. Calabrese
Pickard, Lowe and Garrick, Inc.

Tuesday, August 14, 1979 continued

"Oil-Water Dispersion Mechanisms in Agitated Vessels"

Dispersion of oil in water in agitated vessels was studied using stereoscopic movies. Two mechanisms were observed: (1) Shear flow stretching of oil drops into fine ligaments followed by fracture of the ligaments into smaller drops; (2) Turbulent breakup of large oil drops by vortices trailing behind impeller blades.

Gary B. Tatterson
University of South Carolina

"Simulated Behavior and Control of Liquid-Liquid Mechanically Agitated Reactors"

A previously developed model was used to calculate temperature and composition profiles along the circulation path in each phase for steady conditions and for step changes in these variables.

Dvora Barnea, Michael S. Hoffer, William Resnick
Technion-Israel Inst. of Technology, Haifa

Wenesday, August 15, 1979

9:00 a.m. - 12:30 p.m. SESSION V: MEASUREMENTS AND CHARACTERIZATION OF MIXING

Session Chairman: James Y. Oldshue
Mixing Equipment Company

"A Correlation - Tracking Technique for Shear Rate Measurement"

A cross beam laser technique, developed to measure particle fluid velocities in an agitated vessel, was extended to obtain shear rates. The estimation of the shear rates are useful in characterization of mixing operations.

H. H. S. Yuan and G. B. Tatterson
University of South Carolina

"Effect of Jet Flow Directed into a Mixing Impeller"

A study on the impact of side flow on both an axial and radial flow mixing impeller was made using a laser anemometer, fluid force instrumentation and a mini-computer. Simultaneous measurements of flow and fluid forces are found to be essential for precise scale-up of process and mechanical design.

R. N. Salzman
Mixing Equipment Company

Wednesday, August 15, 1979 continued

"Dead-Space, Spectra and Scale-up in Mixing Tanks"

The velocity was measured in water by using a hot-film anemometer in two geometrically similar tanks agitated by a six-blade turbine impeller. The turbulence spectra indicate that fundamental changes in the scale and character of the turbulence occur as the system volume is increased.

S. H. Luk and D. W. Hubbard
Michigan Technological University

"Geometric Effects on Blending Time with Anchor Agitators"

The effect of liquid height to agitator diameter, blade configuration, and the presence of baffles was tested over a wide range of Reynolds numbers. Blend time was observed on a batch and on a continuous basis.

L. J. Jacobs, Jr. and J. Y. Chen
Monsanto Company

"Controlled Back-Mixing for Activated Sludge System"

Dye tracer tests have been conducted to measure liquid mixing and to identify flow patterns in aeration systems. Various geometrical configurations and hydraulic conditions have been investigated. Operating data from full scale plant will be discussed.

S. N. Hong and M. S. K. Chen
Air Products and Chemicals, Inc.

2:00 p.m - 5:00 p.m. AD HOC SESSIONS

7:30 p.m. SESSION VI: MOTIONLESS MIXERS

Session Chairman: C. S. Wang
Syracuse University

"Convective and Flow Resistance Characteristics of a Range of Motionless Mixing Devices"

Not Here

Experimental studies have been made with four different types of mixing elements in circular duts. The convective enhancement for each device will be compared with that for the Kenics static mixer at similar values of pumping power.

W. D. Morris
University of Sussex, England

Wednesday, August 15, 1979 continued

"Gas Absorption and Aerosol Separation in A Motionless Mixer"

Performance data will be presented for a static mixer used as a scrubber to remove SO_2 and aerosol particles. A preliminary model has been developed for describing the performance of the mixer.

C. S. Wang
Syracuse University

"Heat Transfer Enhancement in Laminar Flow by a Static Mixer"

Heat transfer for vicous fluids in a Sulzer mixer can be predicted from a model using refreshment length and hydraulic diameter in the Leveque solution. The predictions are in good agreement with experiemental results.

C. J. Hoogendoorn and Van der Meer
Delft University of Technology, Holladn

"Mixing of Segregated Particle Systems"

Experimental results show that uniform mixtures of fines and grain were obtained after one pass through a six element motionless mixer. It was observed that segregation rates were accelerated with increase in size difference.

F. S. Lai
U.S. Grain Marketing Research Center

"Koch Static Mixing - Adapted Motionless Mixer Design"

Concentration distribution measurmenets with Koch-Sulzer static mixing units are described. Criteria for selecting the best mixing unit type are discussed and applied to the Koch-Sulzer mixing elements.

Chris F. Meyer
Koch Engineering Co., Inc.

"The Measurement of Mixing Efficiency in Inline Mixers"

A method based on tracer techniques has been developed for measuring the mixing efficiency of continuous mixers. Mixing in both axial and radial directions will be considered.

S. Lehtola and Knoppamaki
Finnish Pulp & Paper Tech. Rsch Ctr., Finland

Thursday, August 16, 1979

9:00 a.m. - 12:30 p.m. SESSION VII: NUMERICAL METHODS FOR SIMULATING MIXING

Session Chairman: G. K. Patterson
University of Missouri-Rolla

"Numerical Simulation of Flow Behavior and Heat Transfer in an Agitated Vessel"

A procedure for numericla simulation of flow and heat transfer in an agitated vessel is developed based on a two dimensional tangential flow model. The results explain the dependence of the velocity distribution on the Reynolds number in the turbulent flow regime, and the resultant turbulent diffusivity is in good agreement with experimental data.

S. Hiraoka and I. Yamada
Nagoya Institute of Technology, Japan

L. T. Fan
Kansas State University

"A Generalized Three-Environment Model for Unpremixed Stream Chemical Reactors"

A deterministic flow, stochastic micromixing, three environment model simulated by Monte Carlo techniques is developed to describe the effects of incomplete mixing on the performance of continuous flow chemical reactors fed separately by feedstreams which may have arbitrary flow rate and residence time distribution. The model is compared with published experimental data obtained from an experimental "jet stirred" reactor using a Michaelis-Menten reaction in the liquid phase.

B. W. Ritchie
University of Exeter, England

"Micromixing Effects on Continuous Sirred Tank Reactor Performance"

A model has been formulated to correlate the reaction and exit age data. A semilog relationship has been found relating the mass transfer terms to the total power input for the impeller agitator and the turbine agitator.

T. R. Hanley
Tulane University

Thursday, August 16, 1979 continued

"Mixing Effects on Complex, Multiple Chemical Reactions - Yield and Conversion"

Methods for modeling complex (multiple) reactions to predict yields in turbulently mixed reactors are only now being developed. Comparisons are made between methods based on rapid equilibrium, reandom coalescence-dispersion and "paired-interaction" closure, a new method under development by the author.

G. K. Patterson
University of Missouri-Rolla

2:00 p.m. - 5:00 p.m. AD HOC SESSIONS

7:30 p.m. NOVEL CONCEPTS IN MIXING

Session Chairman: E. B. Nauman
Xerox Corp.

"Mixing of Stratified Liquids by Vortex Rings"

Vortex rings are formed when a fluid is discharged impulsively from an orifice. They offer a novel approach to mixing in very large vessels.

M. H. I. Baird
McMaster University, Canada

"Mixing and Diffusion in Rotary Kilns"

Solids mixing, heat and mss transfer are all important in this common commercial device which has flow patterns reminiscent of those in a single screw extruder.

John Ferron
University of Rochester

"Triboelectricity as a Measure of Solids Mixing"

Charge develops when dissimilar materials are brought into rubbing contact. This, the basis for the xerographic process, provides a unique measure of solids mixing.

N. A, Cicciari
Xerox Corp.

" A Continuum Description of the Mechanical Mixing of Fluids"

When interpreted as the deformation of contact interfaces between materials, mixing can be describec in terms of continuum mechanics.

J. M. Ottino
University of Minnesota

Thursday, August 16, 1979 continued

"The Efficiency of Baffles in Mixing Tanks"

Experimental results are given for Pfaudler impellers, radial flow turbines and axial flow turbines.

C. Koen
Marill-Marly, France

"Plunging Jets in Practice: Scale-Up and Contamination Data"

Design data are provided for this novel appraoch to gas-liquid contacting.

J. Smith
T.H. Delft, The Netherlands

Friday, August 17, 1979

9:00 a.m. - 12:00 Noon

SESSION IX: MIXING IN/OF VISCOUS AND NON-NEWTONIAN MEDIA

Session Chairman: J. J. Ulbrecht
SUNY

"An Overview - What are the rheological complexities and how do we meet their challenges"

Jarda J. Ulbrecht
SUNY

"Mixing of Newtonian and Non-Newtonian Liquids with Helical Agitators"

A new model is developed based on a drag flow analysis and this will be supported by a new experimental evidence obtained with a number of Newtonian and Non-Newtonian liquids.

Pierre J. Carreau, W. I. Patterson
Ecole Polytechnique, Canada

"Power and Hold-Up in the Mixing of Aerated Highly Viscous Non-Newtonian Fluids"

Standard and pitched-blade turbines were used to disperse gas in two different types of rheologically complex liquids. Both the power and the gas hold-up were measured and correlated with the rheological parameters of the liquids used. Some qualitative observations about the gas bubbles' behavior will also be reported.

Aloin W. Nienow
University College, England

Friday, August 17, 1979 continued

"Nucleation and Bubble Coalescence Driven by Ultrasound in Viscous and Non-Newtonian Liquid Media"

Removing of residual monomer from highly viscous polymer syrups is one of the serious problems of the polymer industry. Dr. Prud'homme will suggest a technique on how to promote nucleation and coalescence in these systems.

R. K. Prud'homme
Princeton University

"Kinematics of Mixing"

A new model of mixing was developed based on the kinematics of flow. The role of shear and elongational deformation are compared and the conclusions are appled to proceses in extruders and motionless mixers.

L. Erwin
University of Wisconsin-Madison

"Lamellar Mixing Model for Analysis of Liquid-Liquid Mixing with Diffusion and Reaction"

The new lamellar mixing model provides for a unified treatment of fluid mechanics, diffusion, and chemical reaction in a mixer. The intermaterial area per unit volume and the striation thickness are the parameters of the model.

J. M. Ottino
University of Minnesota