CHALLENGE PROBLEM 2 WORKSHOP

CHAIRMEN:

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OBJECTIVES OF CHALLENGE PROBLEM 2

1) **Determine the Capability of Mathematical Models to Predict Axial and Radial Hydrodynamic Profiles in Circulating Fluidized Beds**

2) **Determine the Extent of Improvement of Models Since Challenge Problem 1 (May, 1995)**

- **Sent Problem to Approximately 100 People**

- **Received Predictions From 13 Respondents**

  Some (3) Modeled All of the Data
  Others (10) Modeled Only Part of the Data
  Data Set Most Modeled: FCC Catalyst w/Elbow at Riser Top

Table 1. List of Modelers

1.	Benyahia/Arastoopour (1)	Illinois Inst. of Technology
2.	Berruti (2)	Univ. of Western Ontario
3.	Gauthier (3)	Inst. Francais du Petrole
4	Gidaspow/Mostofi (1)	Illinois Inst. of Technology
5.	Guenther/Syamlal/O'Brien (1)	Fluent/Fluent/NETL
6.	Hjertager/Solberg/Ibsen (4)	Aalborg U./Telemark U.
7.	Huilin (5)	Harbin Inst. Of Technology
8.	Lattner (1)	U. of Houston
9.	Pugsley/Malcus/McKeen (2)	U. of Saskatchewan
10.	Salvaterra/Ocone (6)	Heriot-Watt U.
11.	Shadle/Monazam/Fout (1)	NETL
12.	Yang (1)	Siemens/Westinghouse
13.	Zheng/Wei/Liu (5)	Tsinghua U.

(1) = USA-6 *(2) = Canada-2* *(3) = France-1*
(4) = Denmark-1 *(5) = China-2* *(6) = U.K.-1*

A submission from BASF modeled only the fluid bed at the bottom of the riser.

CLASSIFICATION OF MODEL TYPES

- **Harris and Davidson Have Classified Models Into Three Groups:**

  I Models Which Predict the Axial Solids Suspension Density, but Not Radial

  II Models Which Predict the Radial Variation in Suspension Density by Dividing the Flow into Two or More Regions

  III Models Which Predict Hydrodynamics from Fundamental Equations

	Modeler(s)	Data Modeled	Model Type
1.	Benyahia/Arastoopour	10/24	Type III (CFD)
2.	Berruti	18/24	Type II
3.	Gauthier	3/24	Type II?
4.	Gidaspow/Mostofi	6/24	Type III (CFD)
5.	Guenther/Syamlal/O’Brien	6/24	Type III (CFD)
6.	Hjertager/Solberg/Ibsen	20/24	Type III (CFD)
7.	Huilin	3/24	Type III (CFD)
8.	Lattner	24/24	Type II
9.	Pugsley/Malcus/McKeen	13/24	Type II
10.	Salvaterra/Ocone	12/24	Type III (CFD)
11.	Shadle/Monazam/Fout	12/24	Type I
12.	Yang	24/24	Type II
13.	Zheng/Wei/Liu	24/24	Type III (CFD)

STATEMENT OF CHALLENGE PROBLEM 2

- **For Both Sand (d_{p50} = 178 μm, ρ_p = 2640 kg/m^3) and FCC Catalyst (d_{p50} = 67 μm, ρ_p = 1200 kg/m^3) Predict:**

1) Axial ΔP/L Profiles

2) Radial Mass Flux Profiles

3) Radial Particle Velocity Profiles: *NOTE: These data were not used because of problems with the particle velocity probe*

in a 20-cm-diameter riser, 14.2 m long for both a Blind Tee and an Elbow Riser exit at the Following Conditions:

FOR BOTH FCC CATALYST AND SAND

Solids Mass Flux, kg/s-m²

Riser Inlet Gas Velocity, m/s	*50*	*390*
12.0	X	X
3.7	X	

OVERALL ASSESSMENT

- **Models Still Need Substantial Development to be Able to Predict the Actual Axial and Radial Profiles Accurately**

- **Axial Profile Exit Effects ($\Delta P/Lg$) and the Correct Shape of the Radial Mass Flux and Particle Velocity Curves Are Still Not Predicted by Most Models**

- **Models Will Have to be "Calibrated" to be of Use in Serious Modeling**

- **It was Difficult to Compare Models Accurately Because Many Modelers Only Modeled a Small Portion of the Data**

- **The Per Cent Error Between the Model Predictions and the Experimental Data Was Calculated for Each Model for Both the FCC and the Sand Data**

- **This Was Often Not the Best Way to Compare the Model Predictions**

- **Sometimes the PerCent Error Was Low When the Shape of the Curve Produced by a Model Was Badly in Error**

- **However, the Models From the Researchers Having With Lowest PerCent Error Predicting *at Least Half* of the Data Are Listed. These Are:**

PerCent Error

Model	FCC	Sand	Total
Lattner	61	93	77
Hjertager/Solberg/Ibsen	138	67	103
Benyahia/Arastoopour	102	109	105
Berruti	71	172	122
Pugsley et al.	90	167	129
Zhang/Wei/Liu	87	177	132

Range of Total PerCent Errors: 77 to 334%
The Highest Individual Per Cent Error was 838%

- **We Also Looked at Predictions for Axial Pressure Profiles and the Radial Mass Flux Distributions for Both FCC and Sand, as Well as the Predictions by Exit Type**

- **The Following Areas Were Analyzed:**

  1. **FCC, Elbow**
  2. **FCC, Blind Tee**
  3. **Sand, Elbow**
  4. **Sand, Blind Tee**

  5. **FCC, ΔP/L, Elbow**
  6. **FCC, ΔP/L, Blind Tee**
  7. **Sand, ΔP/L, Elbow**
  8. **Sand, ΔP/L, Blind Tee**

  9. **FCC, Mass Flux, Elbow**
  10. **FCC, Mass Flux, Blind Tee**
  11. **Sand, Mass Flux, Elbow**
  12. **Sand, Mass Flux, Blind Tee**

- **For Each of the 12 Areas, Models Were Analyzed According to When They Had the First or Second Best Per Cent Errors**

- **The Models Which Had the Most First and Second Best Percent Errors in The Above 12 Categories Were:**

Lattner	**7/12**
Hjertager/Solberg/Ibsen	**5/12**
Yang	**4/12**
Benyahia/Arastoopour	**3/9**
Berruti	**2/9**
Zhang/Wei/Liu	**2/12**