#### Multiphase Flow & Reactors Engineering and Applications Laboratory (mFReal)



#### Benchmarking CFD Simulation in Multiphase Systems Using Advanced Radioisotope and Non-radioisotope Measurement Techniques

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University of Science & Technology





## Benefits of CFD

- •Minimize the effort required in the laboratory
- •Cut off unnecessary cost for lab/pilot experiments
- •Avoid Hazards in the lab/pilot
- •Better visualization and understanding
- Easy to do scale-up research

Validation is essential Lack of benchmarking data



#### Techniques in mFReal

- •Benefits of Computational Fluid dynamics (CFD)
- •Radioactive Particle Tracking (RPT) Technique
- •Gamma-ray Computed Tomography (CT) Technique
- •Gamma-ray Densitometry (GRD)
- •Four and Two Points Optical fiber probe
- •Advanced Fast-Response Heat Transfer Probe
- Advanced hybrid measurement probe
- •Two point optical probe for (gas-Solid system)
- •Hot wire anemometry
- •Gas Tracer Technique
- •Liquid Tracer Technique
- Pressure Transducer
- Mass transfer optical probe

#### AL-DAHHAN RECEIVES TOP HONORS

Dr. Muthanna Al-Dahhan, a member of the Missouri S&T faculty since 2009, recently was named Curators' Distinguished Professor by the University of Missouri System Board of Curators. The distinction is the highest and most prestigious academic rank awarded by the university and recognizes outstanding scholars with established reputations in their field of study.

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### Radioactive particle tracking







### Procedure of RPT





# Spline fitting algorithm Cross-correlation algorithm Monte-Carlo algorithm

local liquid and solid velocity fields
Turbulence Kinetics Energy
Reynolds Shear Stress
Eddy Diffusivity
Movement Trajectories

### **RPT** Applications







15 days

30 days

#### **RPT** Applications



Gas velocity 1 cm/sec (a) air-water-1day (b) air-water-15days (c) air-water-30days



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# Gamma-ray Computed Tomography







### CT for CFD validation



### CT applications



# Gamma Ray Densitometry (GRD)

- Pinpoint Flow Pattern (Regime)
- •Holdup profile
- Mal-distribution identification









## Two-Tip Optical Probe (TTOP)



# • Higher voltage when gas touches than liquid



## Signals from Two-Tip Optical Probe





**Raw Signal** 



#### **Filtered Signal**





#### **Normalized Signal**

#### Local Hydrodynamic Parameters

Voltage







- Phase saturation ۲
- Phase local velocity
- Extent of Local Back Mixing •
- Extent of Local Maldistribution •

### Four tip optical probe

- •Bubble local gas holdup
- •Bubble chord length
- Interfacial surface area
- •Bubble frequency









Radial dimensionless r/R (-)



#### Two point optical probe for gas-Solid system

- •Solid Holdup
- Particles Velocity
- •Bubble rise velocity
- •Bubble mean size
- Bubble frequency

Light receiver ┥	-
Light —	
Light receiver -	-
	Quartz glass window





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#### Mass transfer optical probe

1- An optical oxygen probe measures the local dissolved oxygen concentration in the liquid phase with a fluorescence mechanism.

2- By implementing a proper reactor model, the volumetric gas-liquid mass transfer coefficient, kla, can be determined.





Optical oxygen probe on 6" high pressure slurry bubble column



 Optical oxygen probe; 2. Optical fiber;
 Light source; 4. Spectrometer; 5. USB interface; 6. PC and software (Ocean Optics Inc.)



#### Advanced Fast-Response Heat Transfer Probe

**Different shapes** 















## Hot Wire Anemometry (CTA) Technique



















### Gas/liquid Tracer Technique



#### Pressure transducer

- Single Ended pressure transducer:
- •Up to 345 kPa.
- Differential pressure transducer:
- •Absolute pressure difference ranging from 0-102 kPa.



Flow Regimes and their Transition Velocities (Glass Beads)





Differential pressure transducer



Single-ended pressure transducer

# Thanks

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