Gas Phase Mixing in Bubble Columns with Internals

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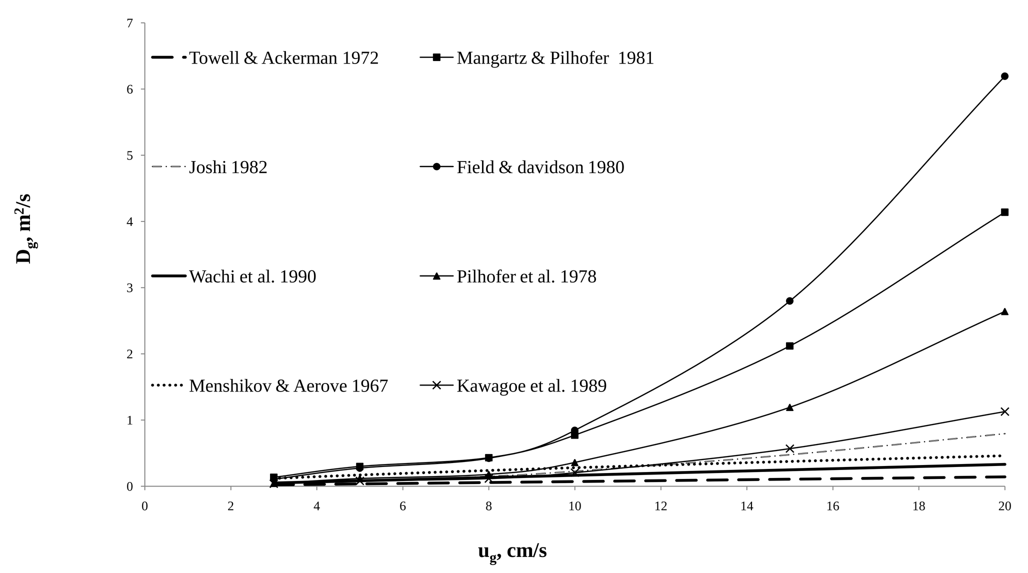
Introduction

• Gas phase mixing is one of the important hydrodynamic parameters to be considered in the scale-up of bubble column reactors since its extent influences the performance of bubble columns and can adversely affect the reaction rates and product selectivity

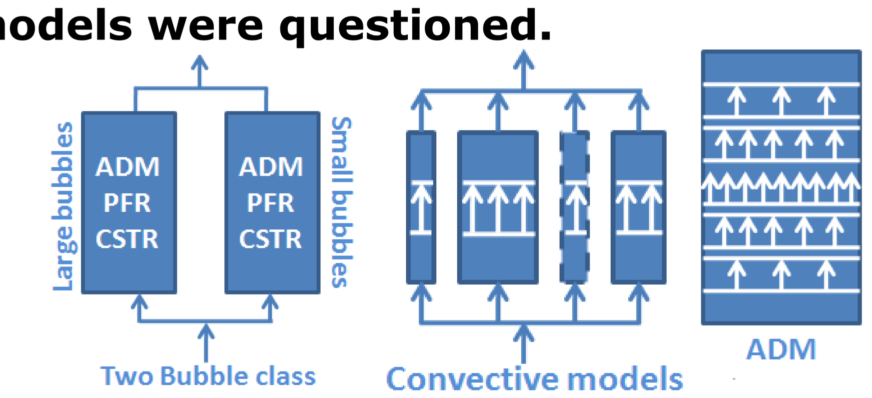
• The investigation of gas phase backmixing has not been well studied in literature due to problems involved in determining a reliable gas RTD data.

• The validity of published empirical correlations is limited to the experimental conditions of the particular studies



• Gas phase modeling studies used ADM, two bubble class models, and pure convective models: however the applicability of these models were questioned.

• In addition, all the reported models and correlations were developed for bubble columns without internals

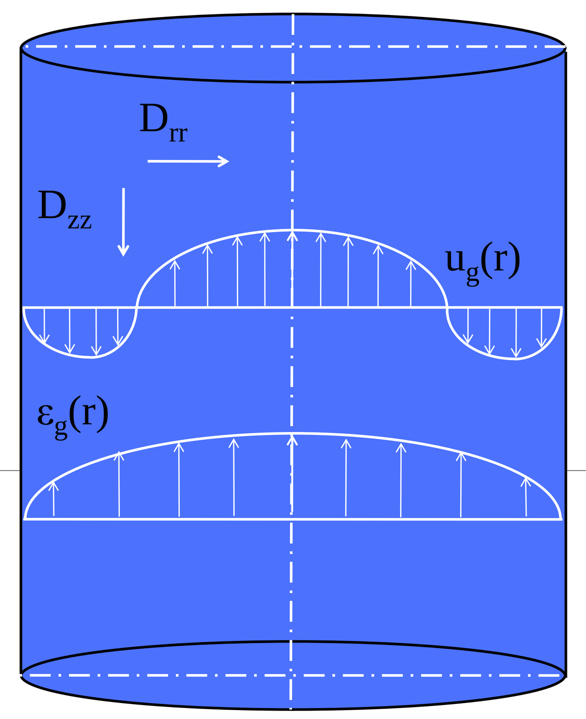


Proposed Model

• A Classical 2D Convection Diffusion model is proposed to model gas phase mixing in bubble columns:

$$\frac{\partial \varepsilon_g(r)c}{\partial t} = \varepsilon_g(r)u_z(r)\frac{\partial c}{\partial z} - \varepsilon(r)D_{zz}\frac{\partial^2 c}{\partial z^2} - \frac{1}{r}\frac{\partial}{\partial r}\varepsilon_g(r)rD_{rr}\frac{\partial c}{\partial r}$$

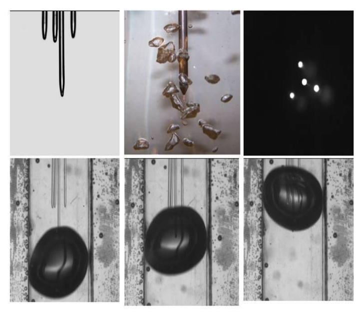
C(r,z): gas phase concentration
r: radial position
Z: axial position



Model parameters:

$\varepsilon_g(r)$: radial gas holdup profile
$u_z(r)$: radial gas velocity profile
D_{zz} : axial turbulent diffusivity
D_{rr} : radial turbulent diffusivity

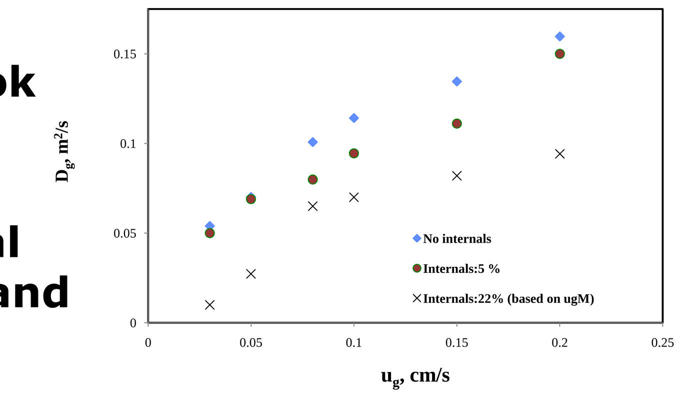
$\varepsilon_g(r)$ and $u_z(r)$: obtained from optical probe data



D_{zz} and D_{rr} : fitted by comparing model prediction with experimental data

Motivation

• Experimental data shows that the gas phase dispersion decreases in presence of internals

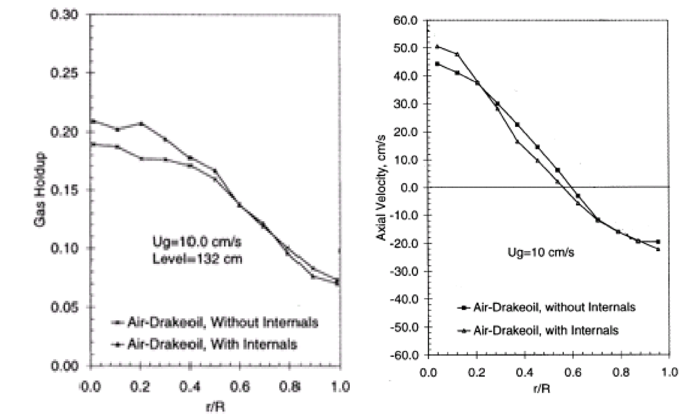


• To explain why this happens, one must look at the physical processes that control gas phase mixing:

1. Large scale recirculation (leading to axial dispersion) resulting from the upwards and downwards flow regions

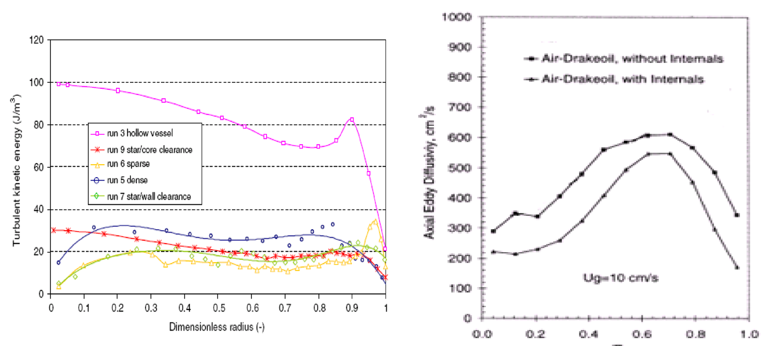
2. Turbulence or fluctuating velocity Contributes to both the radial and axial turbulent mixing

• On the one hand, reported data indicate that the presence of internals increases the steepness of the liquid gas velocity profile and gas hold holdup profile which suggests an increase in gas phase mixing



Chen et al. (1999)

• On the other hand, reported data indicate that the presence of internals decreases the turbulent dispersion parameters which suggests decrease in gas phase mixing

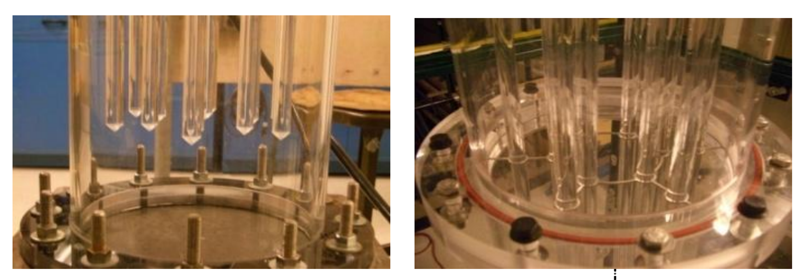


Larachi et al. (2006) Chen et al. (1999)

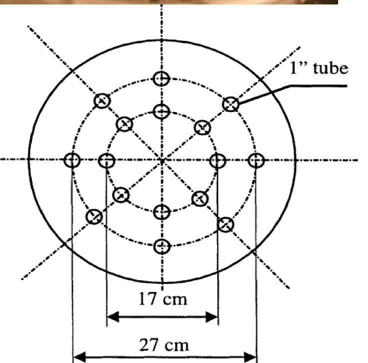
Experimental Setup

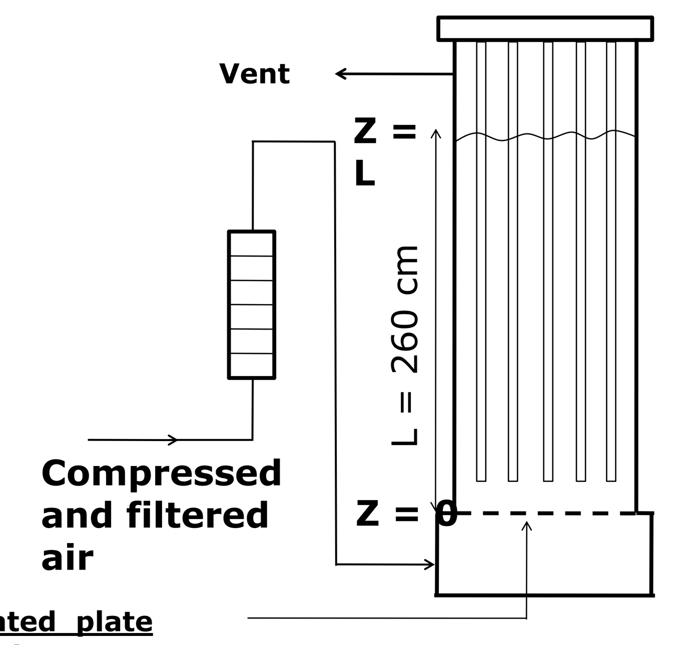
• A lab scale (8") and a pilot scale (18") bubble columns are used to study the effect of internals. This allows for the investigation of the effect of the scale in presence of internals

• Two configurations of internals
• are proposed:



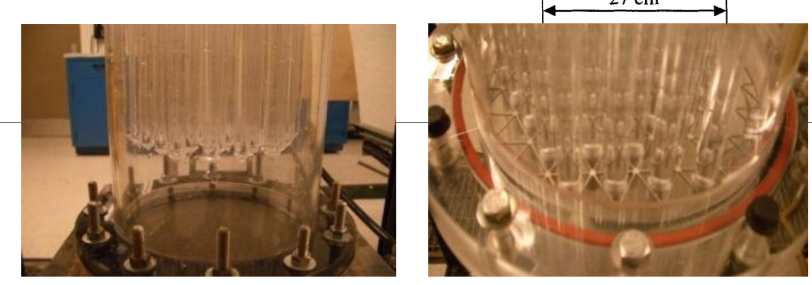
5% occluded area
(liquid phase MeOH synthesis)
Circular pitch: 2 concentric bundles of
17 and 27 cm diameter.
16 rods



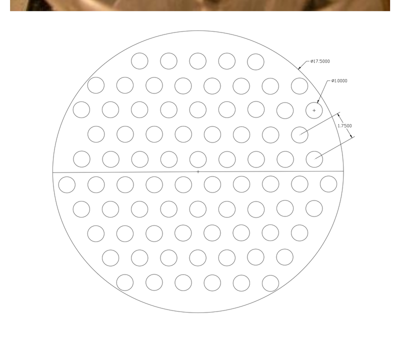


18" bubble column

Perforated plate distributor
Number of holes: 241
Size of holes: 3 mm
Layout: square pitch of 2.4 cm
Total free area: 1.09%



25% occluded area
(Fischer-Tropsch synthesis)
Triangular pitch = 1.75"
79 rods



Experiment Conditions
•System: Air-water
• Ambient temperature and pressure
• Dynamic height = 160 cm
• SGV: 3-45 cm/s
• Distributor Free area:1.09%
• Column diameters: 8" and 18"

Objectives

• Investigate the effect of superficial gas velocity , reactor diameter, and % internals on the radial gas velocity profile

• Develop a model that quantifies gas phase mixing by considering both the radial variations in the gas holdup and gas velocity profiles and the turbulent dispersion parameters.

• Use the developed model to study the effect on superficial gas velocity, reactor diameter, and % internals on the fundamental parameters that affect gas phase mixing, namely, the radial and axial turbulent diffusivities

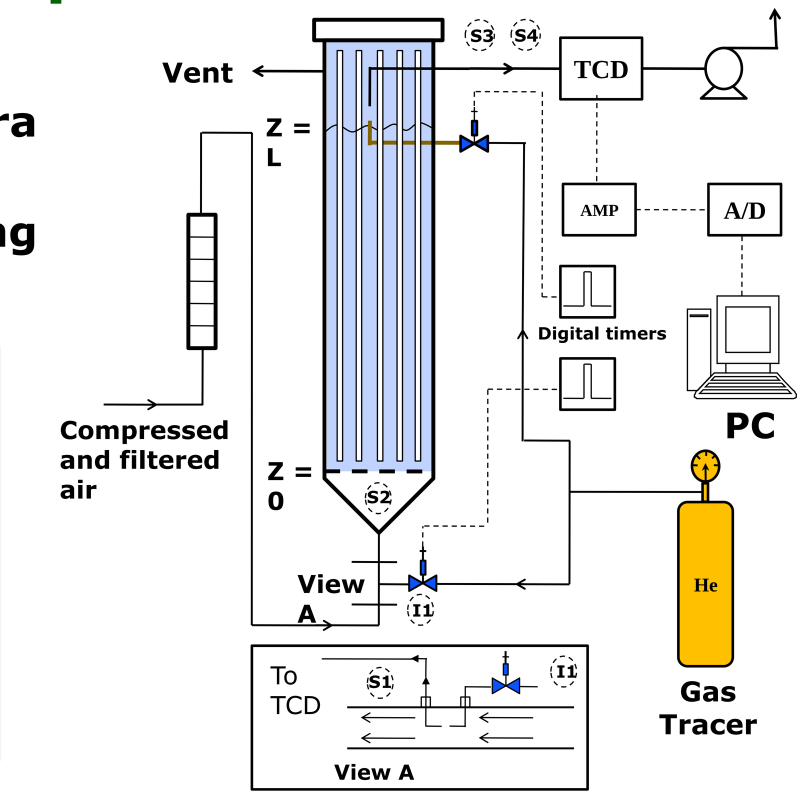
• Develop a model for predicting the gas phase mixing coefficient in bubble columns with internals using simple design parameters (superficial gas velocity, column diameter, diameter of internals, and inter tube gap.

Tracer Experiment

Developed gas tracer technique:
➢ Takes into account the extra dispersion in the plenum
➢ The dispersion in the sampling system is considered

The conducted tracer measurements for different zones

Measurement	Tracer injection	Sampling location
(i)	I1	S1
(ii)	I1	S2
(iii)	I2	S3
(iv)	I1	S3



Schematic diagram of experimental setup

➢ The plenum is assumed to be a continuous stirred tank reactor (CSTR):

$$C_{in} = e^{-t/\tau}$$

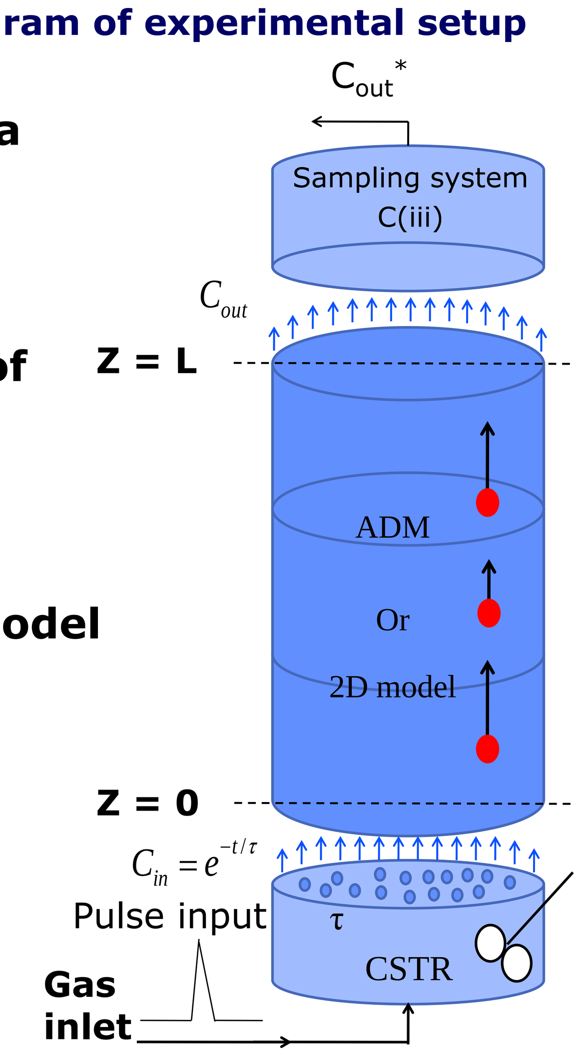
➢ Convolution of C_{in} for the regression of τ :

$$C_{in}^*(t) = \int_0^t C_{in}(t')\cdot C_{(i)}(t-t')\cdot dt'$$

➢ Axial dispersion model (ADM) or 2D model cab be assumed to obtain C_{out}

➢ Convolution of C for the regression of dispersion parameters:

$$C_{out}^*(t) = \int_0^t C_{iii}(t')\cdot C_{out}(t-t')\cdot dt'$$



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