BIOENERGY III

CHARACTERIZATION OF THE FLUIDIZATION AND MIXING OF BINARY MIXTURES CONTAINING BIOMASS

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May 2011

Introduction

Biomass Materials

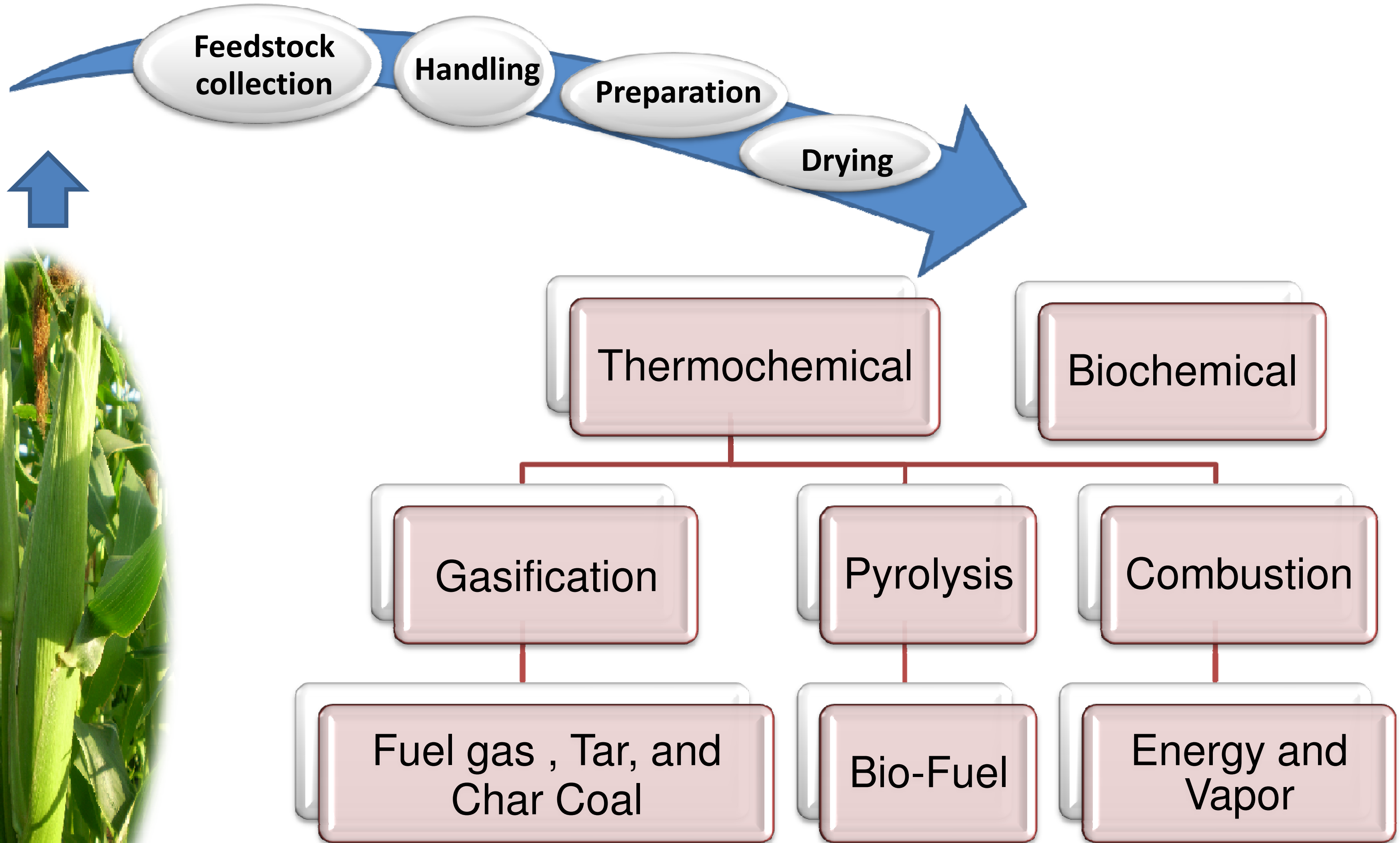
stand as the third energy resource after oil and coal due to their abundance and rapid replenishment.

Advantages of biomass as a sustainable fuel source

- An alternative source of renewable energy
- Minimal environmental impact and green-house gas emissions
- Generation of multiple-product streams: food, energy, hydrocarbons, plastics and pharmaceuticals
- Social and economic development of rural areas

Introduction

Biomass Conversion Processes



Fluidized beds play the key role in almost all of the biomass conversion processes

Introduction

Fluidization of biomass

Large in size

Biomass Particles

Low in density

Extreme in shape

Cumbersome fluidization of biomass particles

REMEDY

Adding inert materials such as sand or alumina

Introduction

Fluidizing biomass with the help of inert materials

Advantages

- Improving fluidization quality
- Improving heat transfer in the bed

Disadvantages

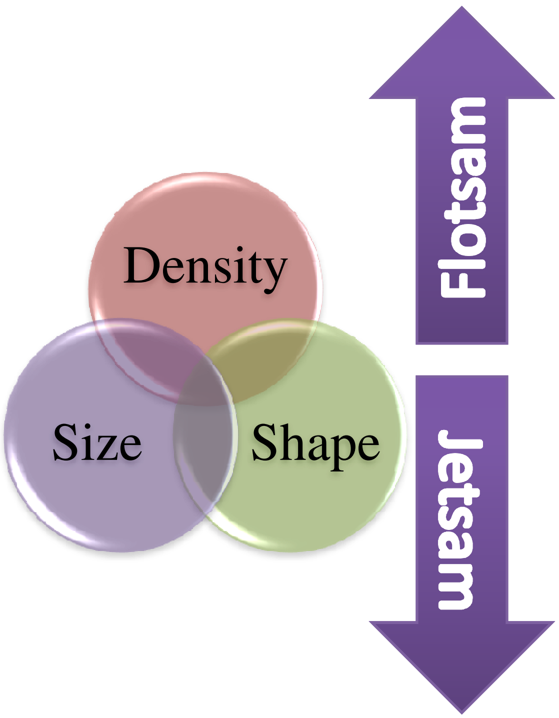
- Segregation of inert and biomass particles

Flotsam: **Particles migrating to the top of the bed**

- Light, small particles

Jetsam: **Particles migrating to the bottom of the bed**

- Heavy , large particles



Objectives

To scrutinize the binary fluidization behavior of a biomass and silica sand mixture at low superficial gas velocities

To find the impact of adding irregular particles on the fluidization characteristics of the common bed materials like sand.

To understand the mechanisms and parameters governing the mixing/segregation patterns before complete fluidization of the mixture

Methodology

Materials

Table 1. Properties of materials used

Material	*Shape*	*d_p(mm)*	*h_p(mm)*	*ρ_p(kg/m^3)*	*ρ_b(kg/m^3)*	*ε (-)*
Sand	Spherical	0.380 (0.1-1.0)	-	2650	1632	0.43
Wood Particle (W-P 1)	Cylindrical	*3.175*	6.350	670	332	0.50
Wood Particle (W-P 2)	Cylindrical	*6.350*	6.350	670	332	0.50

- *Type of wood: birch cylindrical rods*

Systems Investigated

Table 2. Properties of binary mixtures investigated

System	*Biomass type*	*Sand mass (kg)*	*Biomass mass (kg)*	*Wt.% of biomass*	*Vol.% of biomass*
System 1	W-P 1	5.363	0.282	5	20.58
System 2	W-P 2	5.364	0.282	5	20.55
System 3	W-P 1	4.365	0.485	10	35.36
System 4	W-P 2	4.367	0.484	10	35.33Z

Methodology

Techniques deployed:

1. Analyzing the global and local pressure signals corresponding to the whole, top and bottom of the bed
2. Analyzing the optical fiber signal

➢ *the height of the static bed was set at 225 mm (H/D=1.5)*

Procedure:

Starting from the well-mixed and fixed-bed state, the superficial gas velocity was quasi-steadily increased until it reached the desired value. Then, the bed was slowly defluidized until it returned to a fixed state.

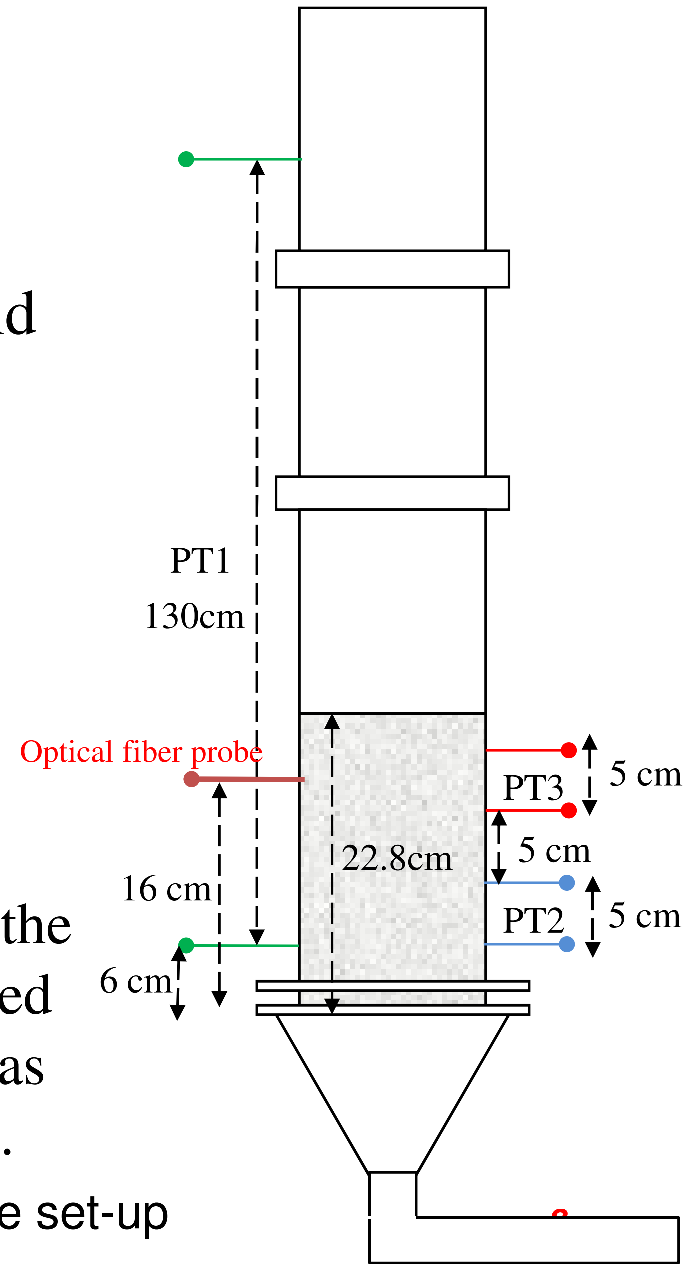


Figure 1. Schematic diagram of the set-up

Methodology

Parameters studied:

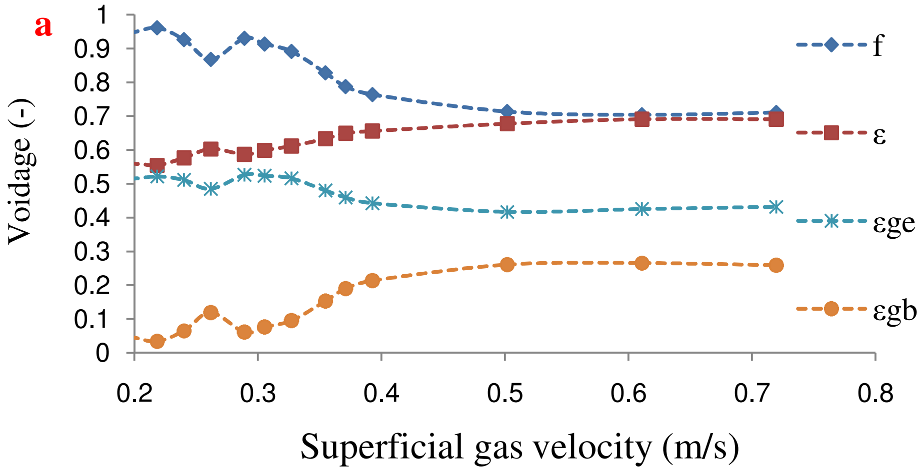
1. Static and dynamic pressure analysis
   - Time-averaged pressure values
   - Standard deviation of signals
   - Dominant frequency

2. Optical fiber analysis
   - Emulsion phase fraction (f)
   - Time-averaged voidage (ε)
   - Mean voidage of bubble and emulsion phases

Preliminary Results- Optical fiber data

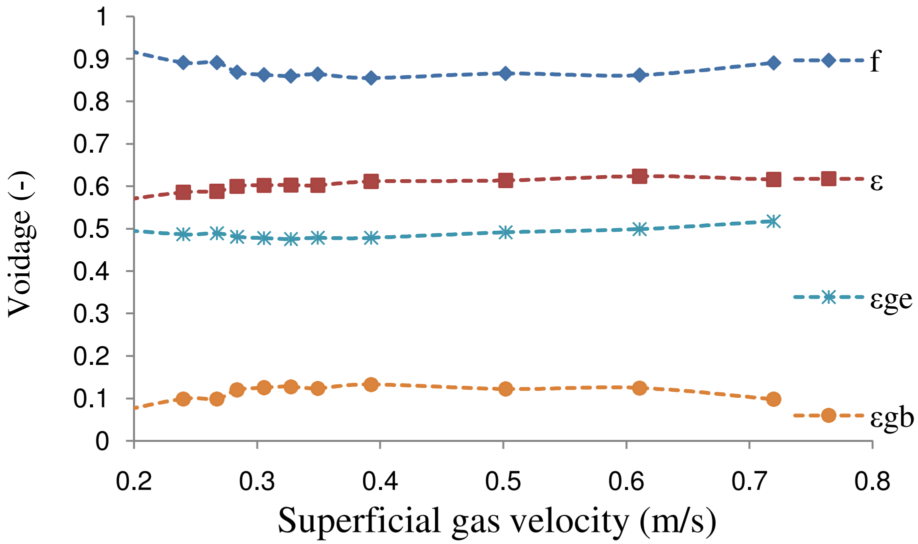
Impact of adding biomass particles on the fluidization of sand

a



Sand alone

b



W-P1:5%

f= emulsion phase fraction

ε= time-averaged voidage

ε_e= mean voidage of emulsion phase

ε_b= mean voidage of bubble phase

ε_{ge}= bed voidage of emulsion phase (f. ε_e)

ε_{gb}= bed voidage of bubble phase ((1-f).ε_b)

c

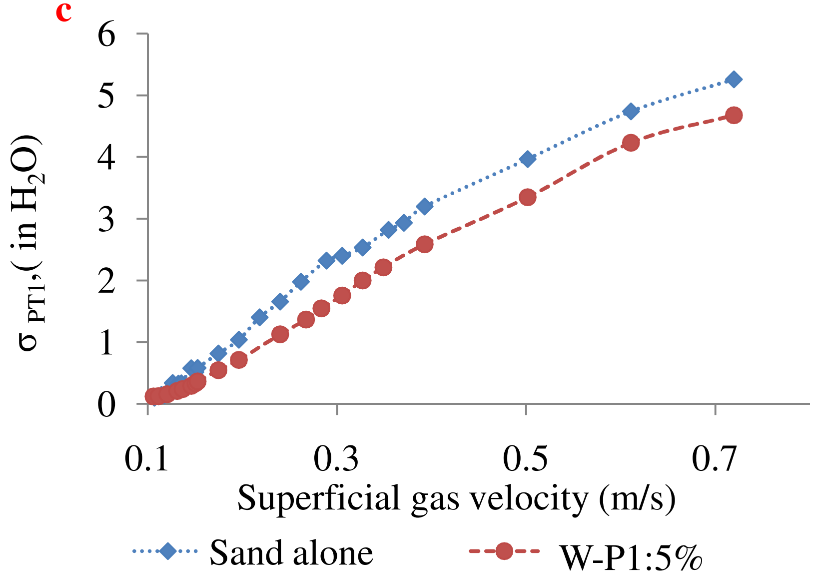


Figure 3. Comparing fluidization behavior of mixtures containing biomass with that of sand alone a,b: optical fiber analysis, c: standard deviation of global pressure along the bed

Preliminary Results- Optical fiber data

Impact of adding biomass particles on the fluidization of sand

Effects on the bubble phase

Decrease in the bubble size (Implied by the decrease in the standard deviation of the global pressure signal, Fig. 3 c)

No considerable change in the frequency of bubbling
(Inferred from pressure fluctuation and optical fiber signals)

Decrease in the bed voidage of bubble phase (ε_{gb})

(As shown in the Fig. 3a,b)

Preliminary Results-- Optical fiber data

Impact of adding biomass particles on the fluidization of sand

Effects on the emulsion phase

Increase in the emulsion fraction phase (f)

(As shown in the Fig. 3a)

Increase in the bed voidage of emulsion phase (ε_{ge})

(As shown in the Fig. 3a)

Preliminary Results

Characteristic Fluidization Velocities of Systems Investigated

U_{if} = Initial fluidization (Onset of deviation from fixed-bed situation)

U_{ib} = Initial bubbling (Onset of formation of bubbles travelling along the bed)

U_{cf} = Complete fluidization (Onset of full fluidization of total bed inventory)

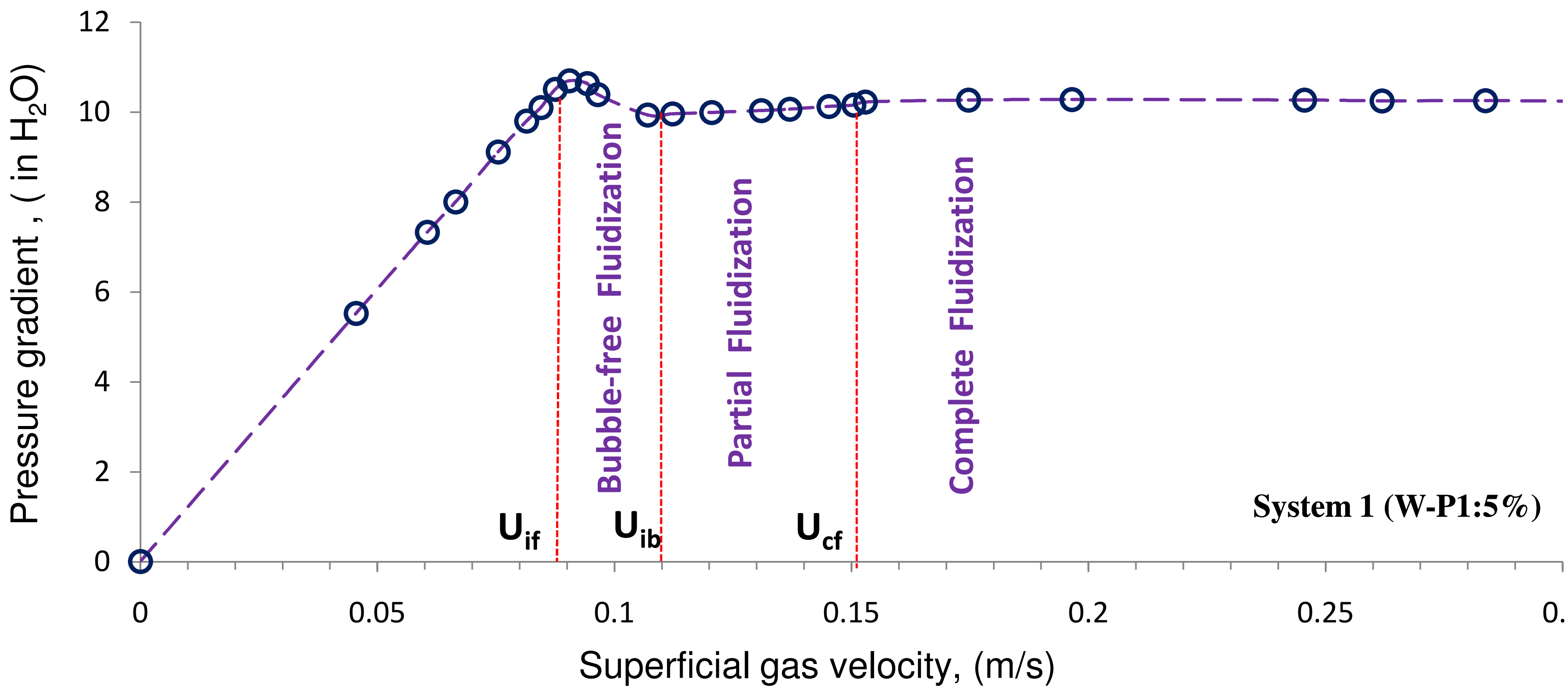


Figure 4. **Typical** curve of time-averaged global pressure drop during fluidization of **investigated binary mixtures**

Preliminary Results- Pressure transducers data

Effects of increasing the biomass content of the fluidizing mixture

•**Higher degree of segregation** (Implied by the increase in the discrepancy between up and down pressure drops, Fig. 5)

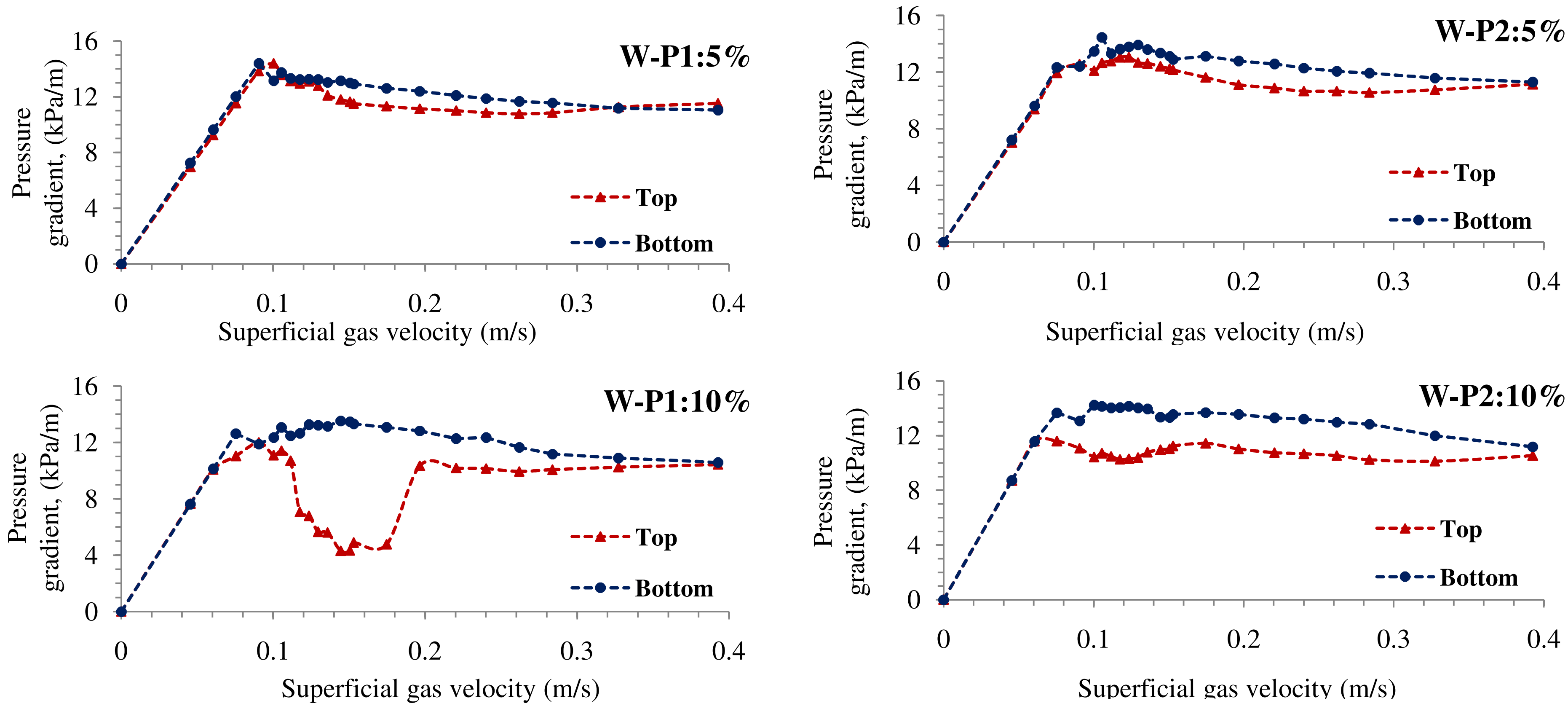
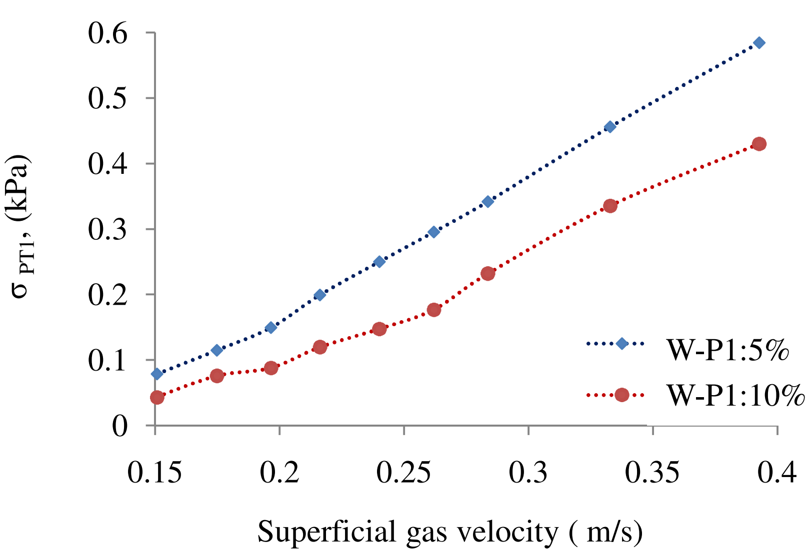


Figure 5. Bottom and top pressure drop gradients of systems investigated at increasing values of the superficial gas velocity

Preliminary Results-- Pressure transducers data

Effects of increasing the biomass content of the fluidizing mixture

- **Shrinkage of bubbles** (Implied by the decrease in the standard deviation of the global pressure signal, Fig. 6)
  - *the standard deviation of pressure fluctuations as a function of gas velocity correlates with the bubble diameter*
- **Delay in the bubble formation** (Implied by the delay in the occurrence of sudden change of the global pressure signal dominant frequency which is not shown here)



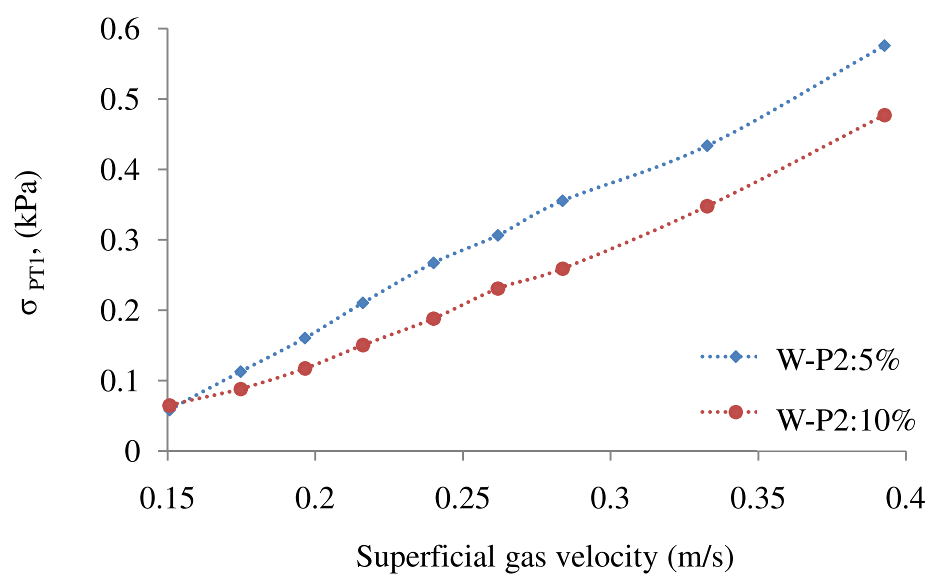


Figure 6. Comparison of standard deviation of signals representing the global pressure fluctuation in systems differing in mass fraction of biomass

Early Conclusion

Primary conclusions drawn via performing introductory experiments

Adding irregular particles like biomass may cause significant changes in the distribution of gas/solid between dilute and dense phases.

The presence of biomass particles reduces the fraction of bubble phase via shrinking bubbles without notably changing bubble frequency .

Since parameters such as the mass fraction and number of added biomass particles affects the formation and size of bubbles, they can influence the trend of mixing/segregation

Future Works

In Progress

The aforementioned conclusions will be verified through

1. Performing additional experiments at various operational conditions for different types of sand-biomass mixtures via using Optical fiber at different position of the bed.
2. Carrying out exhaustive Radioactive Particle Tracking (RPT) experiments to study
    - Time-averaged concentration and velocity profiles
    - Bubble properties such as size, velocity, and distribution
    - Hydrodynamic characteristics of the system
    - Axial and lateral mixing patterns of solids
    - Mixing/segregation intensity
    - Solids mixing dynamics
    - …

Thank You