Movement and mixing of biomass or coal particles in a fluidized bed combustor under high temperatures

Zhihao Yang, Lunbo Duan*, Lin Li, Daoyin Liu

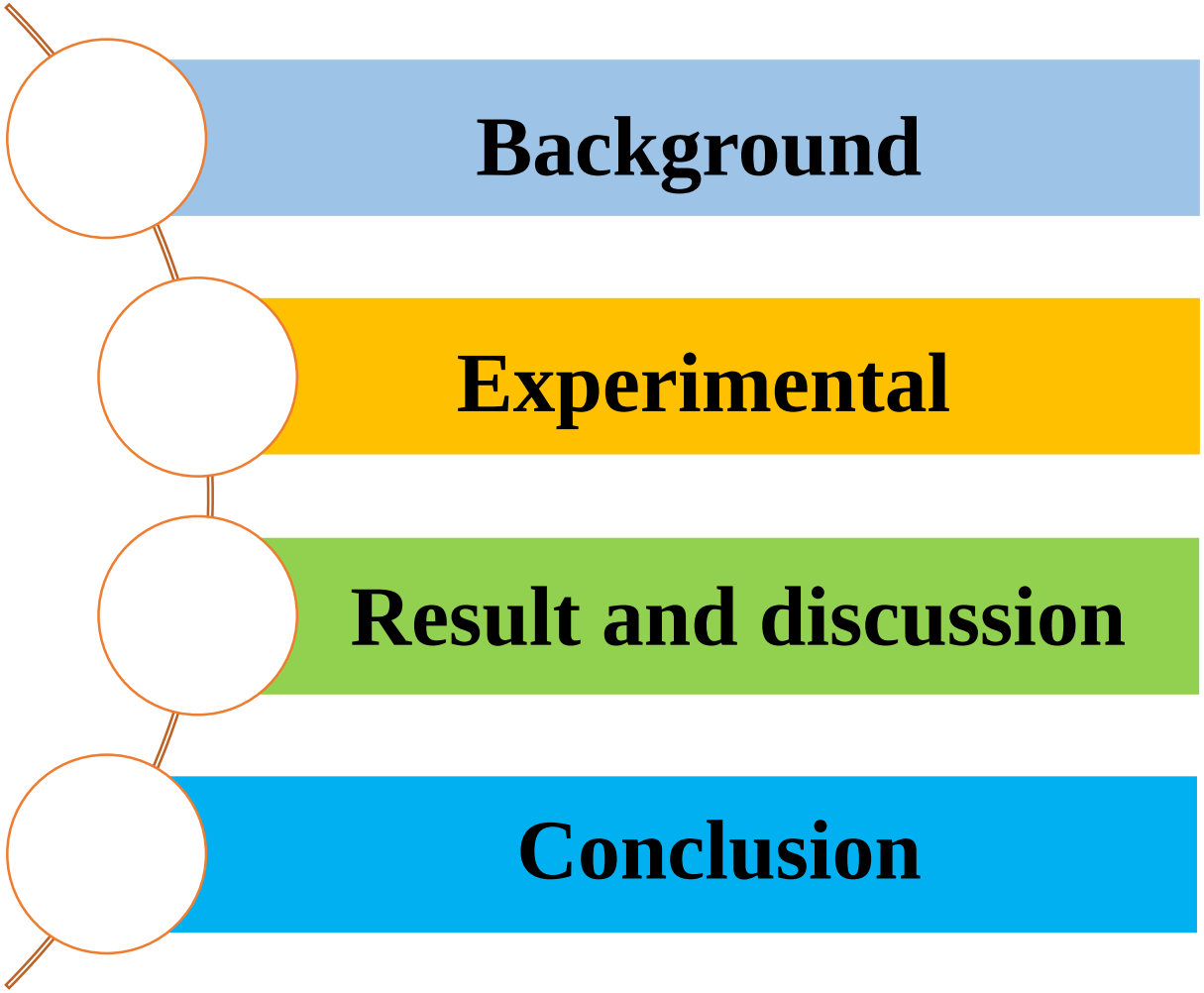
School of Energy and Environment

Southeast University

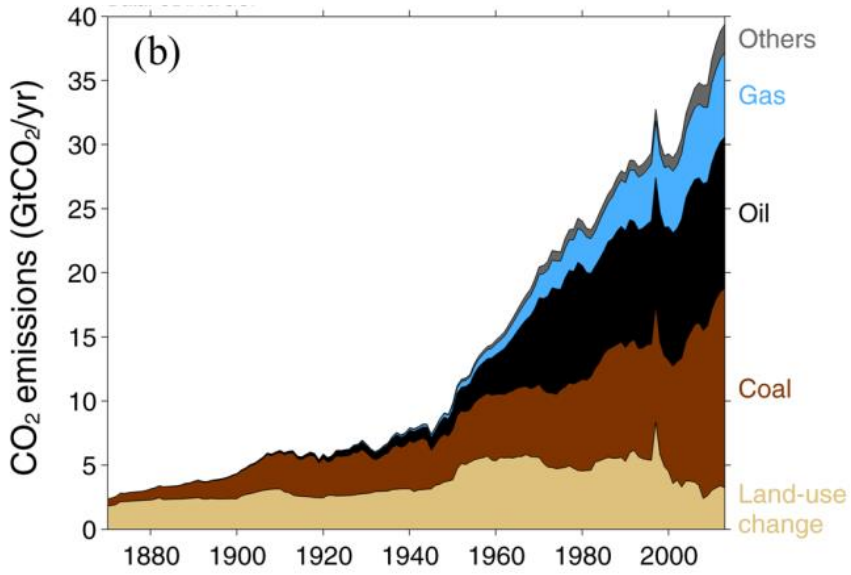


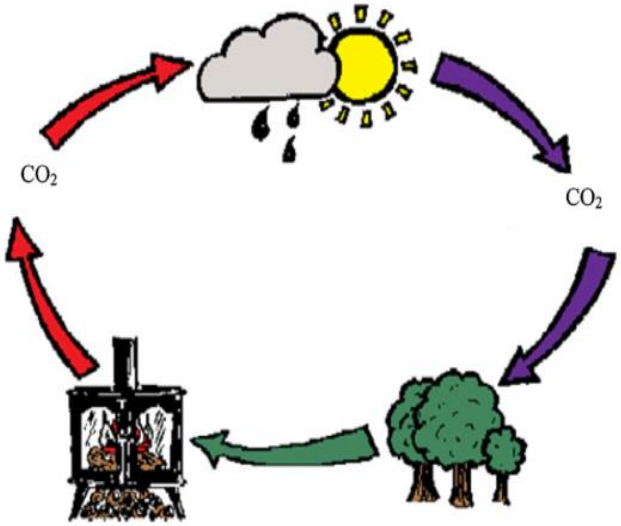


Outlines


Background
Experimental
Result and discussion
Conclusion

Background





- **Coal combustion is the largest source of CO_2 emissions**
- **Biomass is seen as the most promising energy source to mitigate CO_2 emissions**

fluidized bed combustor

- flexible furnace temperature control
- fuel flexibility
- low environment impact

low quality
high ash content
low calorific value

Background

irregular size

density

shape

biomass particles

assist biomass fluidization

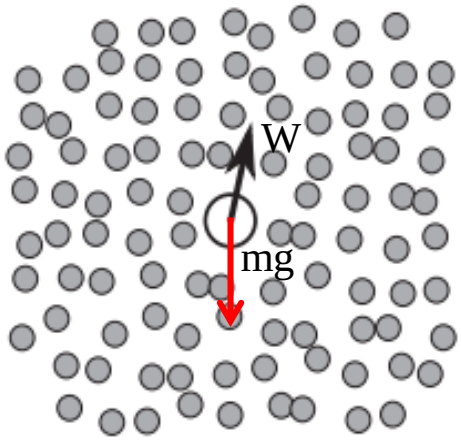
size, density

segregation

inert material

segregation is strongly coupled with thermochemical reactions and bed hydrodynamics.

Particle is larger but less dense ?



Single particle immersed in a fluidized bed of other particles.

In order to answer this question we can set the force balance on that particle under simplified conditions.

gravitational force ⟺ hydrodynamic interaction

comparison

the size and density of the particle and fluidization velocity.

buoyancy

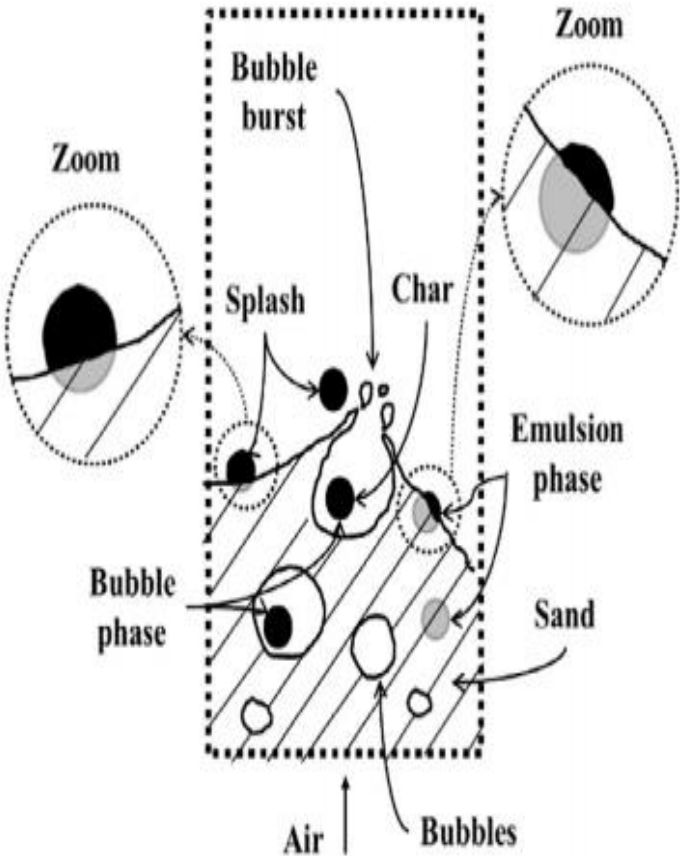
drag force

$\frac{\pi}{6} d^3 \rho_p g$

$\frac{\pi}{6} d^3 \rho_f g$

$C_D \frac{\pi d^2}{4} \frac{\rho_f u^2}{2}$

Background



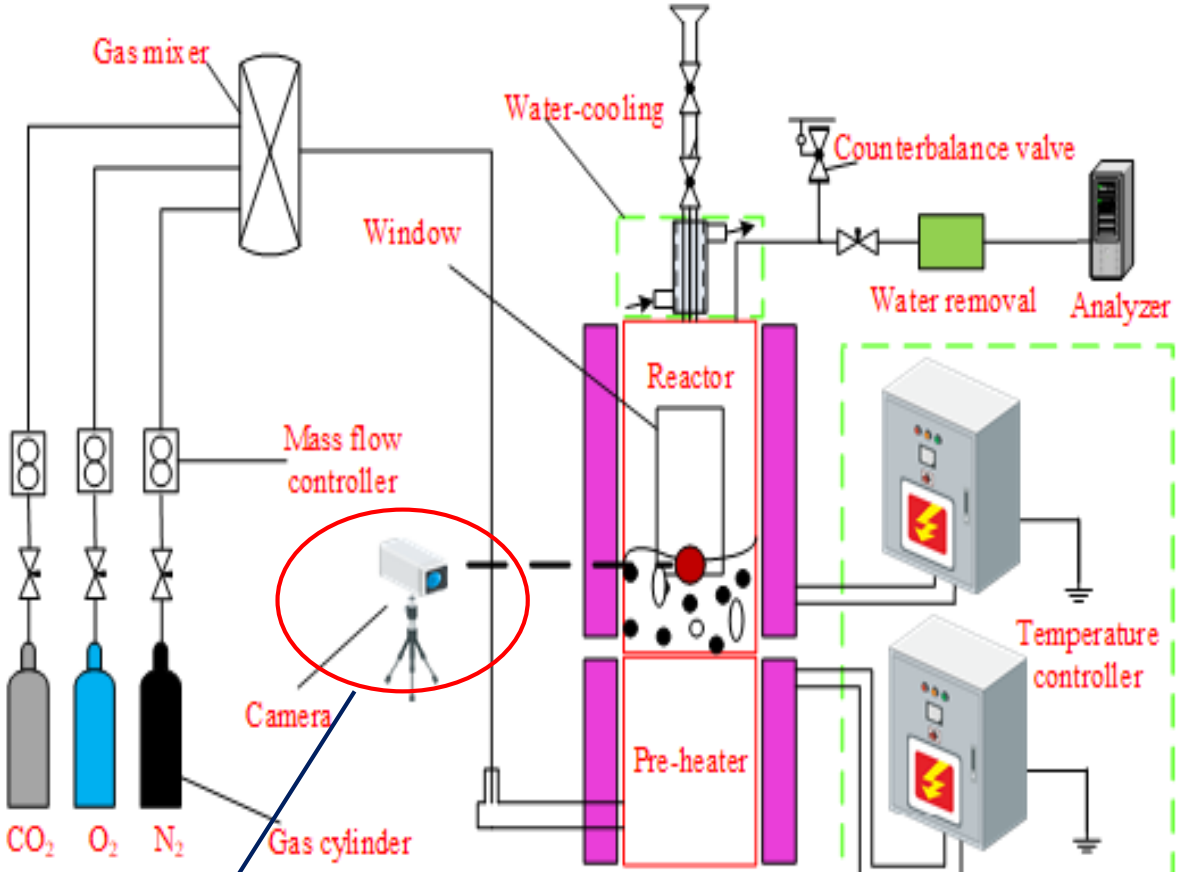
gravitational force > hydrodynamic interaction , particle sink towards the bottom of the bed; then by the action of the bubble, particle may be raised to the surface of the bed or be thrown into the splash phase.

hydrodynamic interaction > gravitational force ; the particle tend to float on surface of the bed and will be thrown into the splash phase by bubble.

The effects of particle density, shape, size and gas velocity on particle position distribution have been studied in cold state.

However, the physical properties of the particle will change during combustion, so the cold state experiment can not truly reflect the position of particle in the furnace.

Experimental



Two-dimensional FB：
200×34×400 mm,
Window:
100 mm × 200 mm

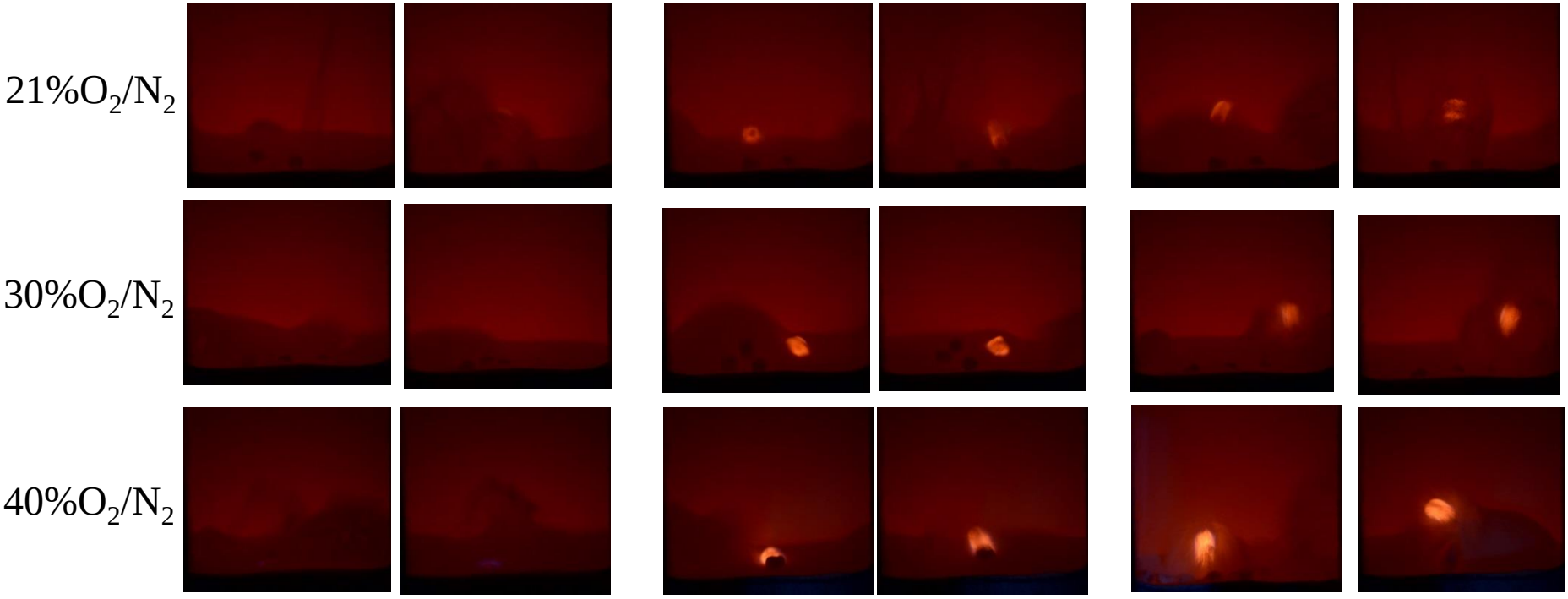
Bed materials：Silica sand
Size：0.3-0.35 mm
Density： 2560 kg/m^3

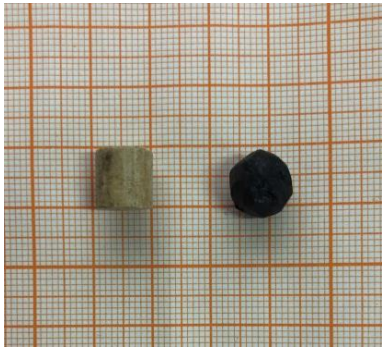
Particle position

30 frames/s

Experimental

Particle position





rice hull：cylindrical，diameter：8 mm；high：10 mm
lignite：spherical，control the same mass (800 mg)

Experimental

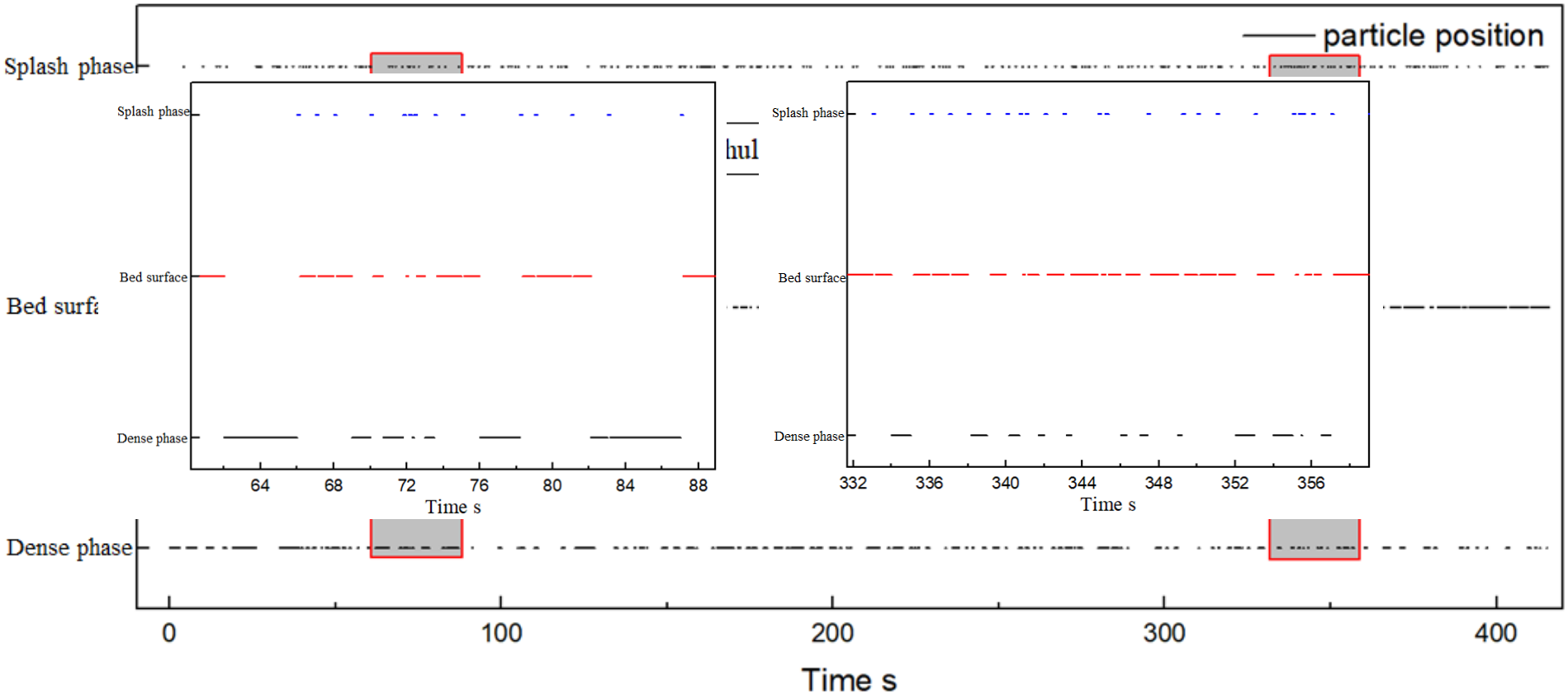
Fuel	Proximate analysis, wt% (as received)					Ultimate analysis, wt% (dry and ash-free basis)				
	Moisture	Volatile	Fixed carbon	Ash		C	H	O[a]	N	S
Lignite	16.17	35.53	39.18	9.12		67.11	4.23	25.07	1.45	2.14
Rice hull	9.31	61.72	14.20	14.77		49.74	5.78	43.72	0.68	0.06

Condition	Fuel	Atmosphere	Fluidized velocity	Condition	Fuel	Atmosphere	Fluidized velocity
1	rice hull	$21\%O_2/79\%N_2$	$5\ u_{mf}$	7	lignite	$21\%O_2/79\%N_2$	$5\ u_{mf}$
2	rice hull	$30\%O_2/70\%N_2$	$5\ u_{mf}$	8	lignite	$30\%O_2/70\%N_2$	$5\ u_{mf}$
3	rice hull	$40\%O_2/60\%N_2$	$5\ u_{mf}$	9	lignite	$40\%O_2/60\%N_2$	$5\ u_{mf}$
4	rice hull	$21\%O_2/79\%CO_2$	$5\ u_{mf}$	10	rice hull	$21\%O_2/79\%N_2$	$7\ u_{mf}$
5	rice hull	$30\%O_2/70\%CO_2$	$5\ u_{mf}$	11	rice hull	$21\%O_2/79\%N_2$	$9\ u_{mf}$
6	rice hull	$40\%O_2/60\%CO_2$	$5\ u_{mf}$				

Temperature： 1073 K

Result and discussion

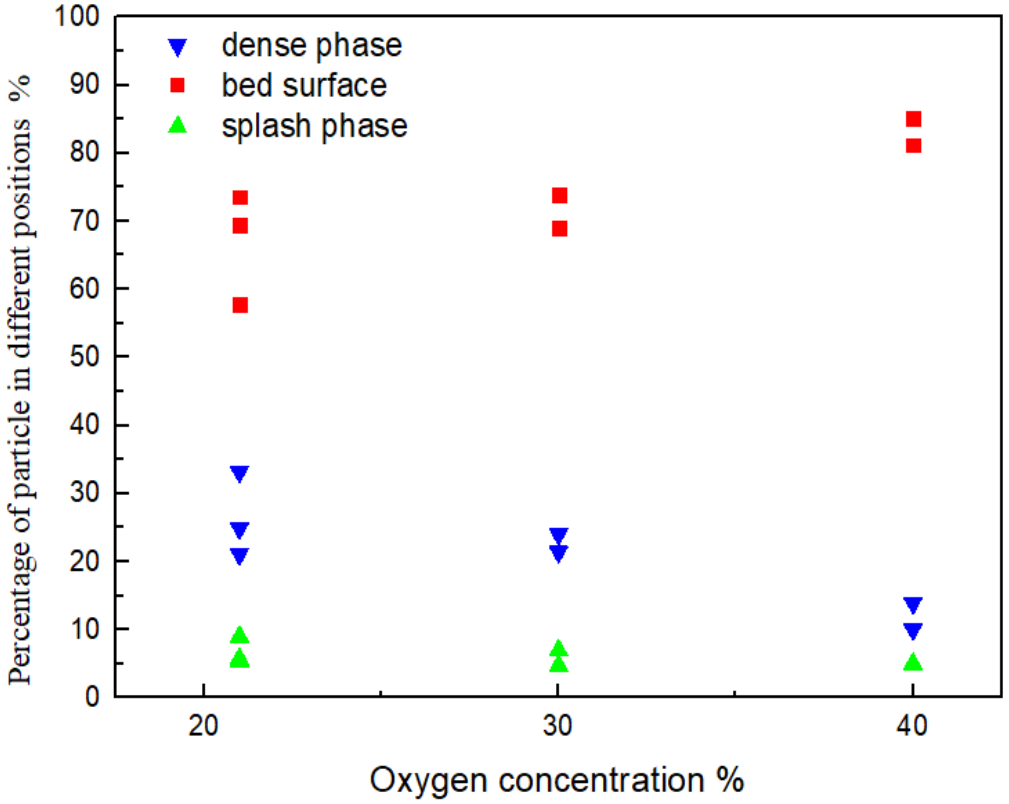
Position of the particle during combustion



The rice hull particle tend to be in the dense phase at the start of the experiment and then change to float on surface of the bed as the reaction progressed.

Result and discussion

Effects of Oxygen concentration



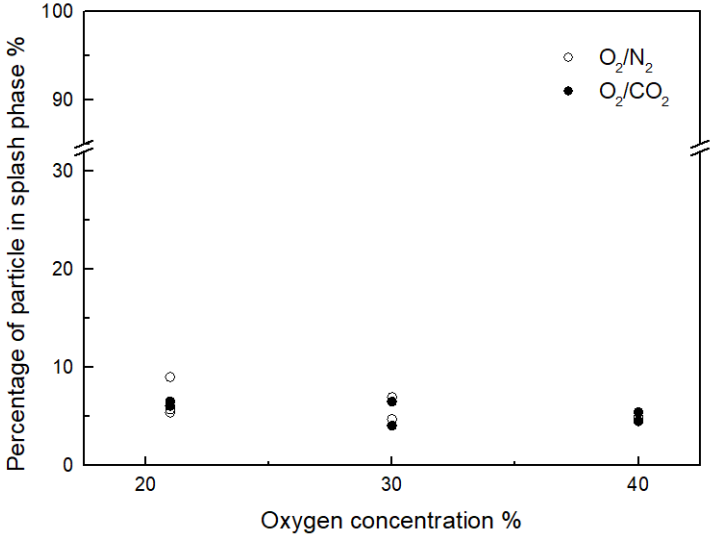
With the increase of the oxygen concentration, the percentage of particle in dense phase decreases and the percentage of particle in bed surface increase.

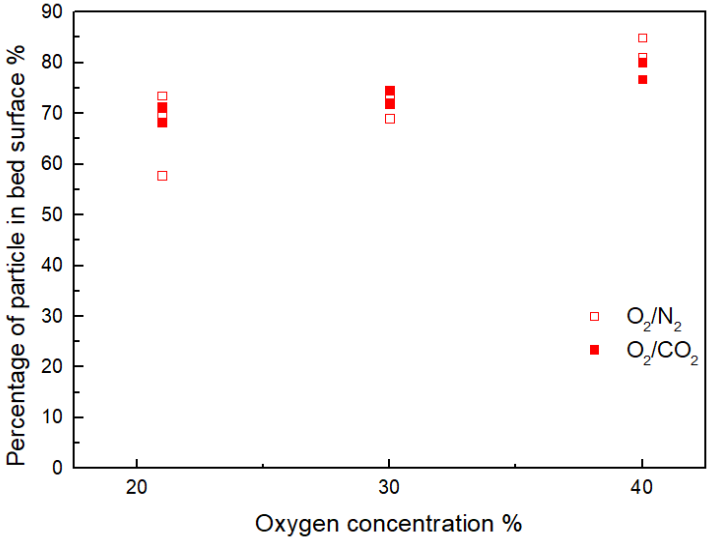
$$\frac{\pi}{6} d^3 \rho_p g$$

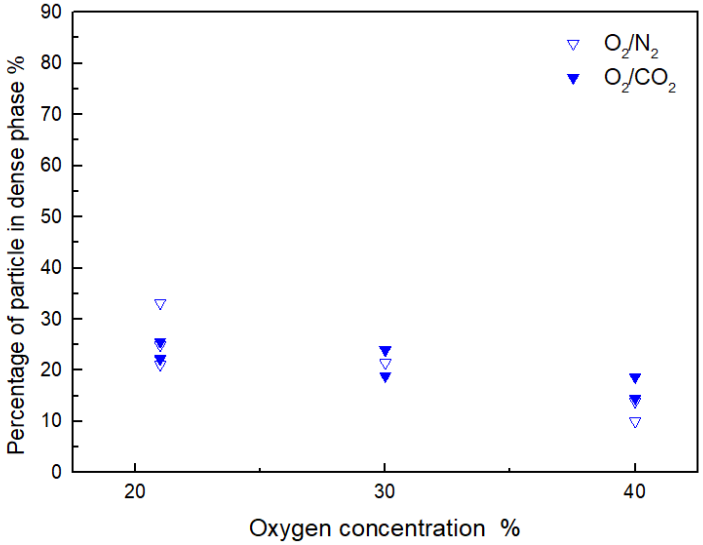
With the increase of the oxygen concentration, particle density and gravity are decrease, so the particle is more likely to float on the surface of the bed.

Result and discussion

Effects of atmosphere



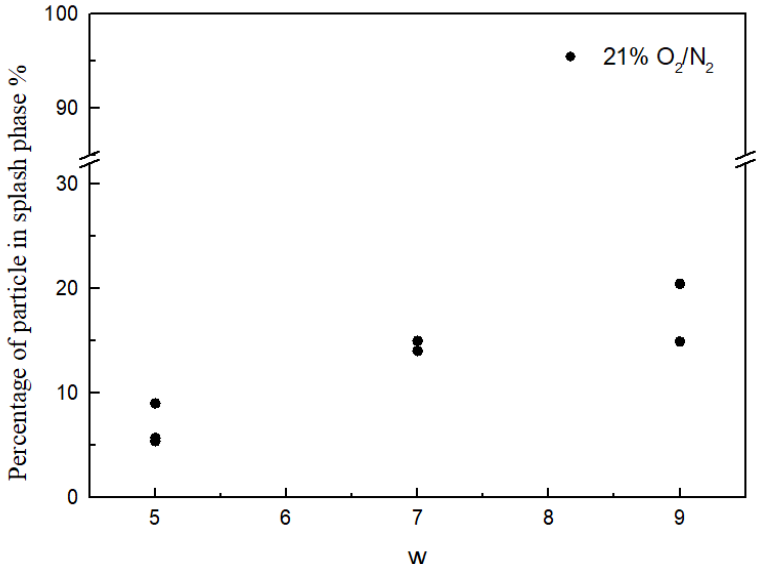


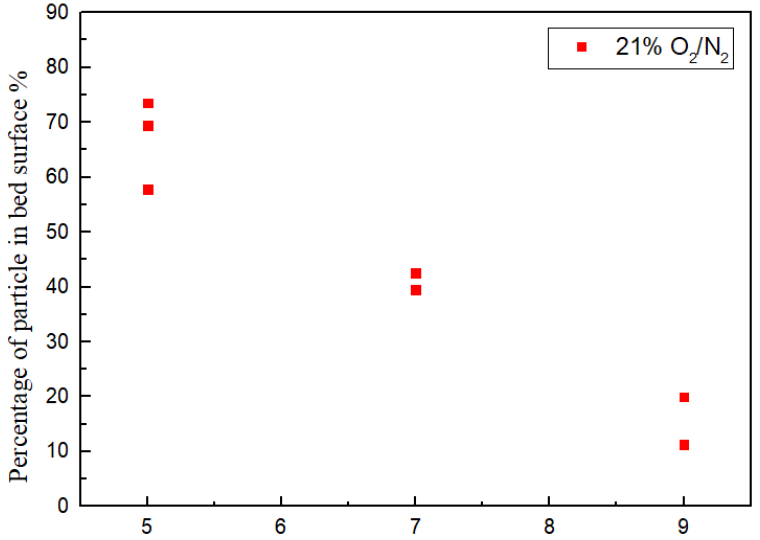


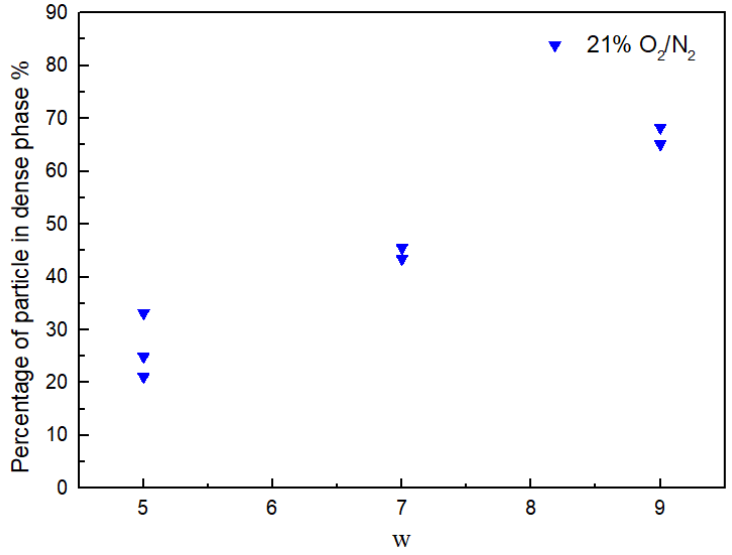
When the N_2 is replaced by CO_2, the percentage of particle in different positions don't have significant change, and has the same trend with the increase of the oxygen concentration.

Result and discussion

Effects of the fluidization velocity







Voidage(ε) of the bed increase with the increase of the fluidization velocity, so ρ_f and hydrodynamic interaction decrease. Therefore the particle is more likely to be in the dense phase .

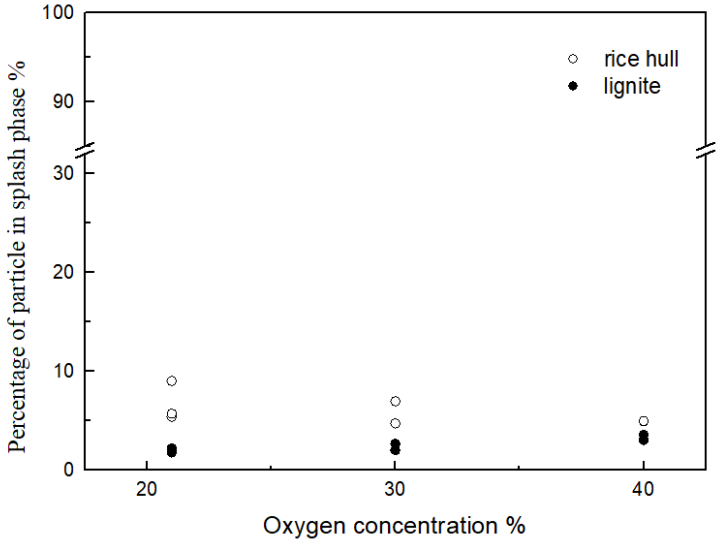
$$\frac{\pi}{6}d^3\rho_f g \qquad C_D\frac{\pi d^2}{4}\frac{\rho_f u^2}{2}$$

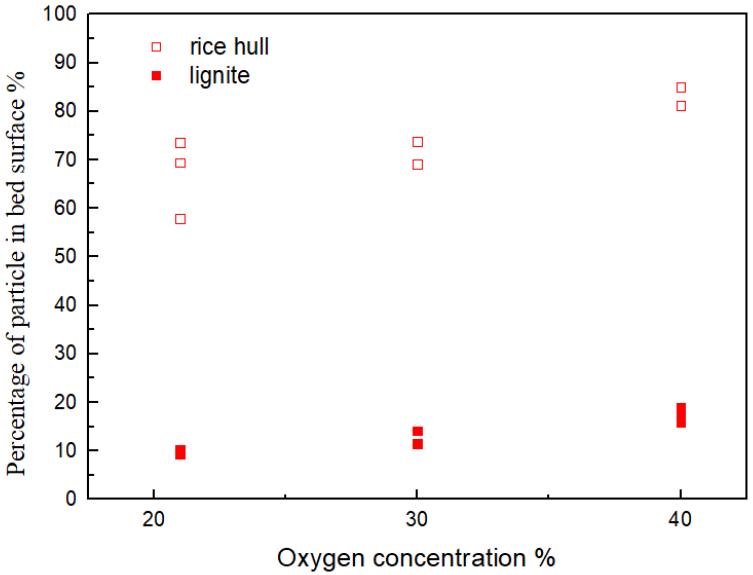
$$\rho_f = (1-\varepsilon)\rho$$

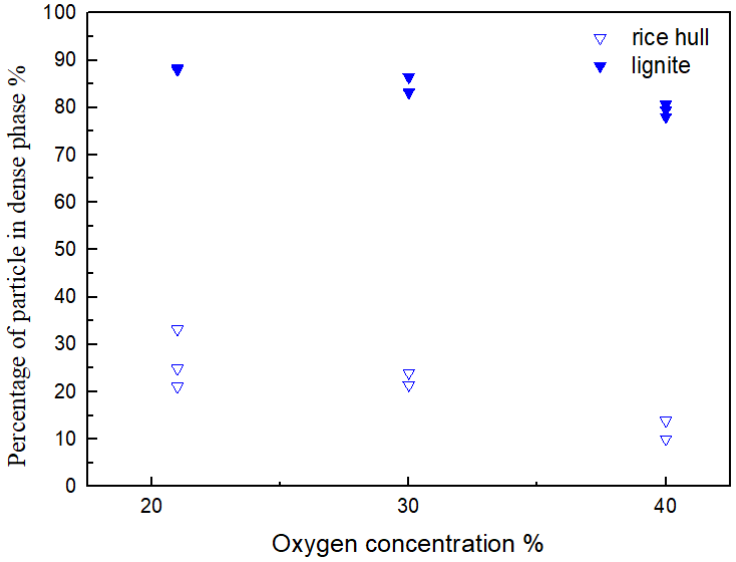
The bubble frequency increases with the increase of w, so the particle is more likely to be thrown into the splash phase by the bubble.

Result and discussion

Compare with the lignite coal







Due to the different of the density during combustion, rice hull is more likely to float on the surface of bed than lignite.

Compare with the rice hull, lignite has the same trend with the increase of the oxygen concentration.

Conclusion

- The rice hull particle tend to be in the dense phase at the start of the experiment and then change to float on surface of the bed as the reaction progressed.
- With the increase of the oxygen concentration, the particle is more likely to float on the surface of the bed.
- With increasing the fluidizing velocity, the percentage of the particle in the dense phase and splash phase are both increase.
- The percentage in the dense phase of lignite particle is longer than that of rice hull particle.

Thanks for your time and attention!

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