Gas/solid flow characteristics in a gas–solid cyclone reactor based on Euler/Lagrange approach

Fluidization XVI

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Contents

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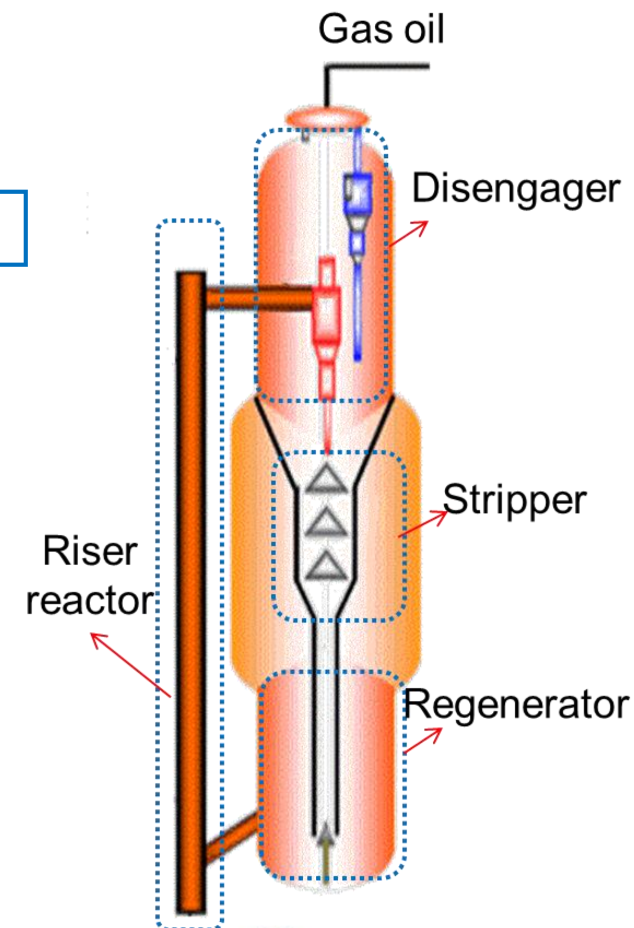
INTRODUCTION

Fluid catalytic cracking (FCC) is an important primary conversion in the oil refining industry.

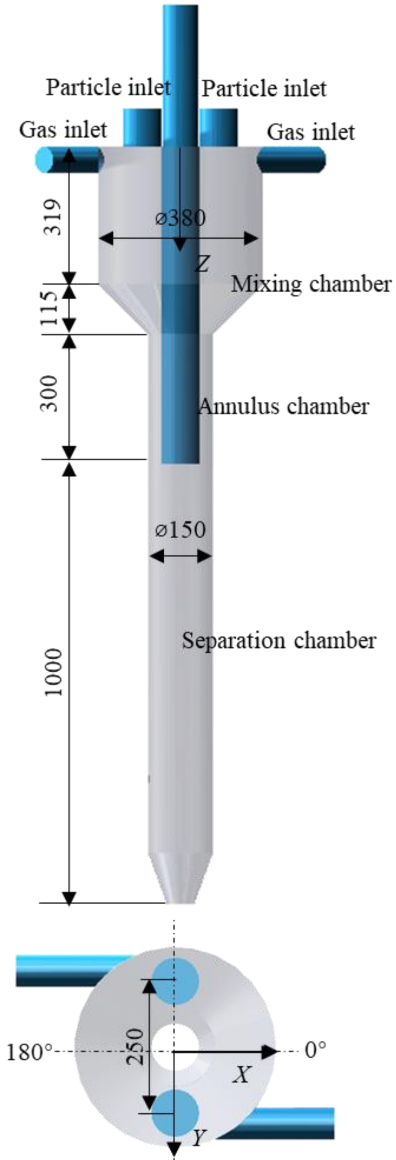
Shortcomings of riser reactors

- Particles backmixing
- Overlong reaction time
- Products over-cracking

A downward gas-solid cyclone reactor was developed for conquering side reactions.



INTRODUCTION



- Gradient distribution-avoid the deep cracking
- Primary separator-separate gases and particles in real time

Research method

Experiment

The complex flow field in cyclone reactor restricted most of the experimental research

Simulation

CFD models play an increasingly important role in process design, and control and/or optimization of complex multiphase systems

Contents

EXPEIMENT

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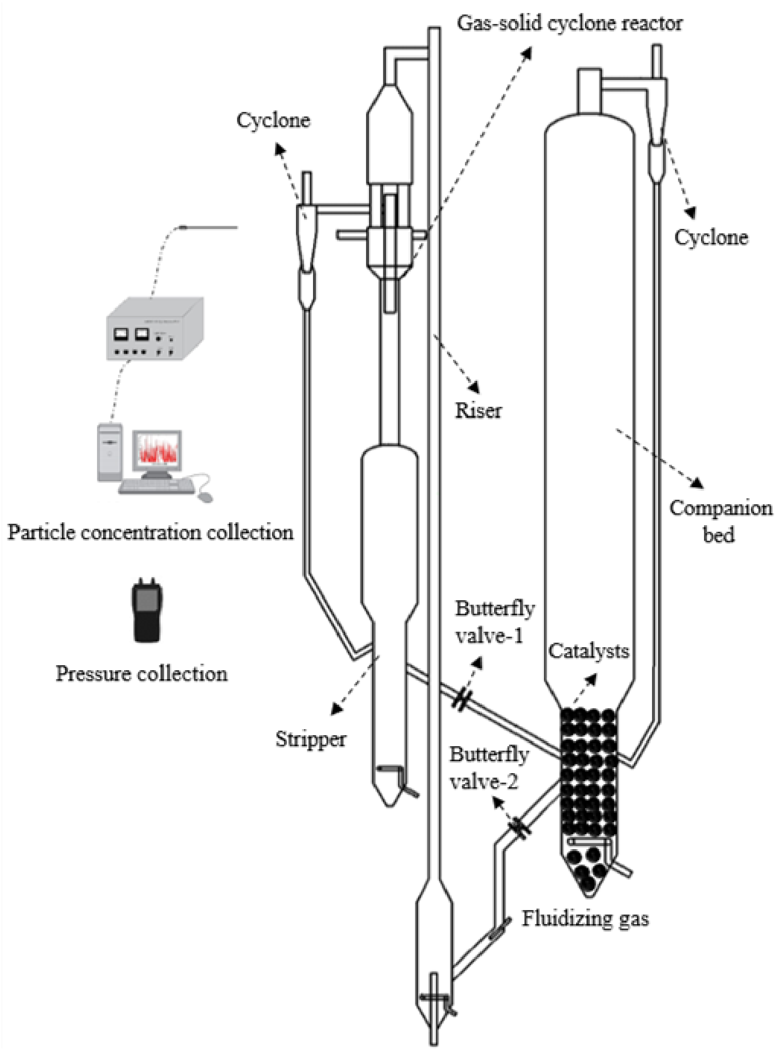


- Catalysts supply module
- Catalysts transport module
- The cyclone reactor
- The stripper
- The data acquisition module

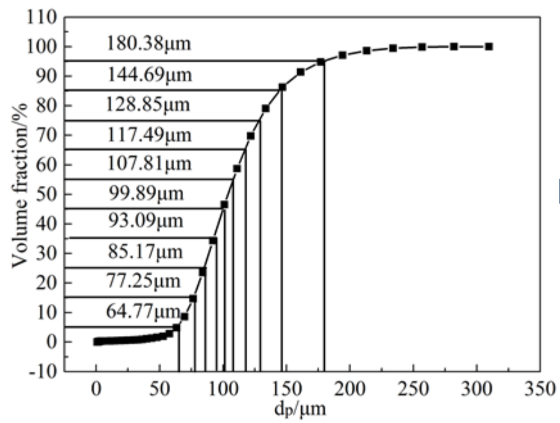
Table 1–Detail sizes of the cold-model experimental system

Item	Height (m)	Diameter (m)
Companion bed	11.4	0.5-0.8
Pre-lifting section	2.0	0.3
Riser	14.2	0.1
Stripper	4.8	0.5-0.8
Cyclone	1.3	0.17

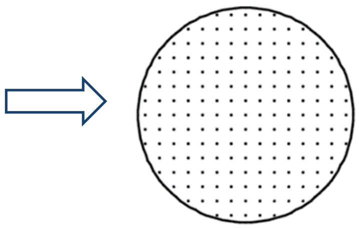
Contents

SIMULATION

- **Model:**
  - RNG k-epsilon model
  - Eulerian–Lagrangian approach
- **Inlet boundary:**
  - Gas velocity: v_g=13.76 m/s
  - Particle: v_p=4.15 m/s
  - Particulate loading: 0.31 $\beta_s = \dfrac{m_s}{m_g}$
- **Outlet boundary:**
  - Gas: pressure outlet
  - Catalyst: trapped and escaped
- **Wall boundary:**
  - No-slip conditions
  - Different coefficients of restitution



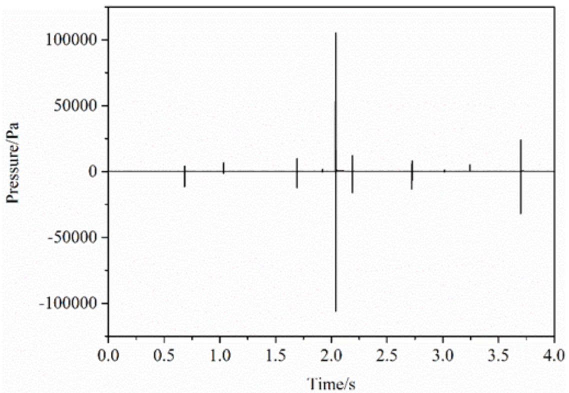
Particle inlet



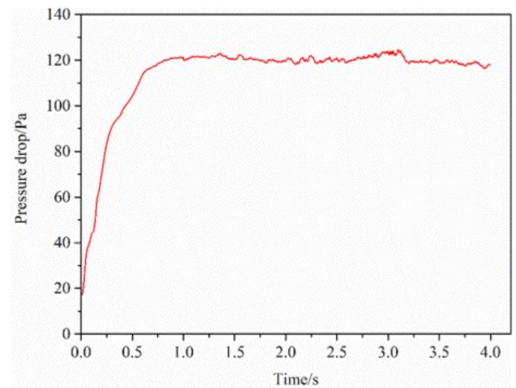
The particle diameter corresponding to the volume fractions 5%, 15%, . . . , 95% are assigned to the arranged parcels. And each incident parcel contains only one particle size.

SIMULATION

- The validation of the simulation

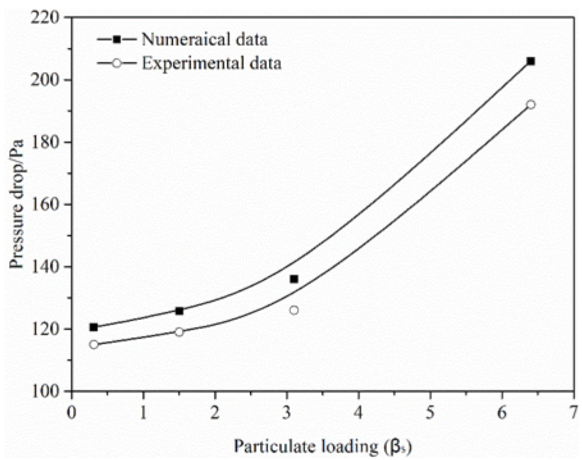


DPM method



DDPM method

The pressure drop calculated by DDPM is more reasonable.



A satisfactory agreement has been achieved.

Contents

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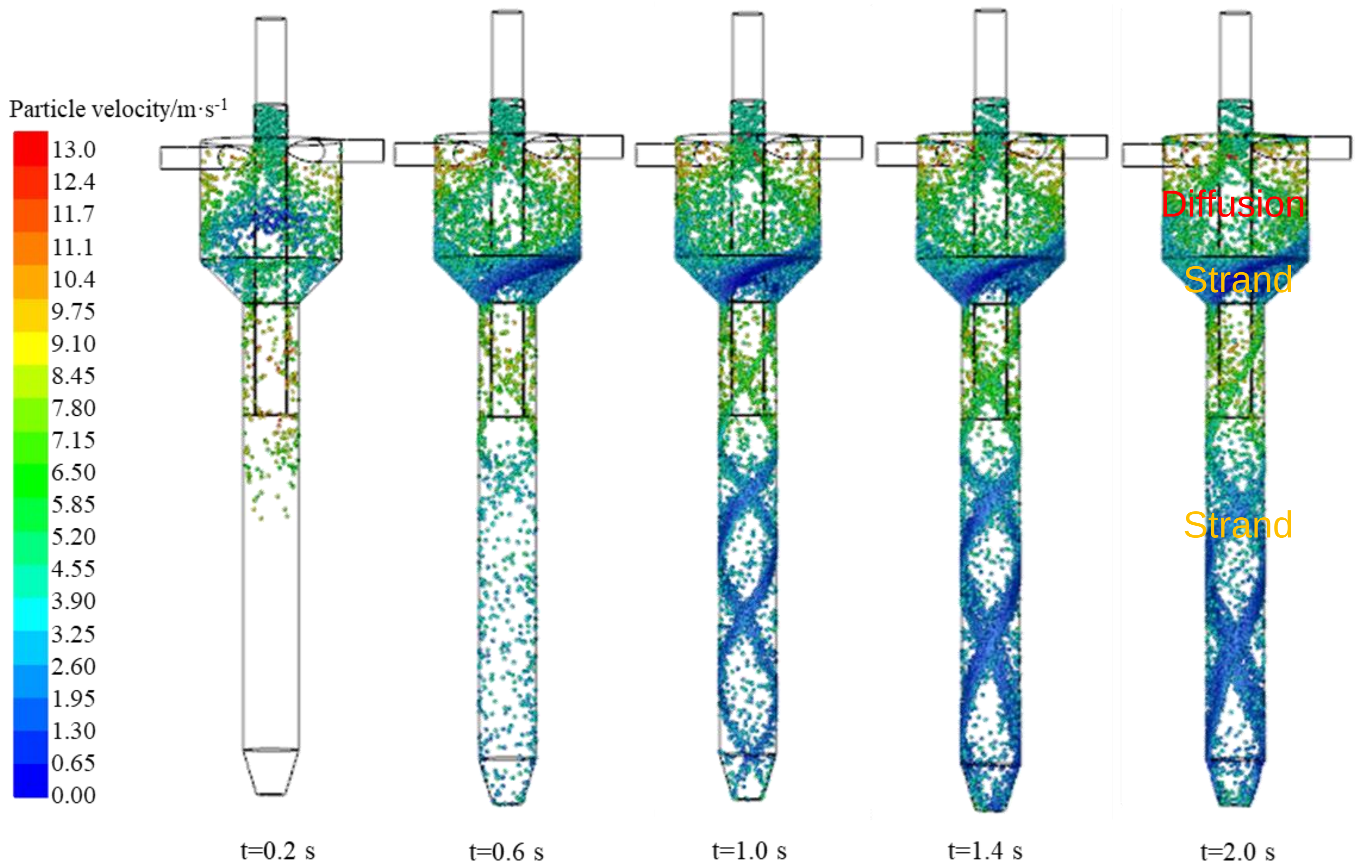
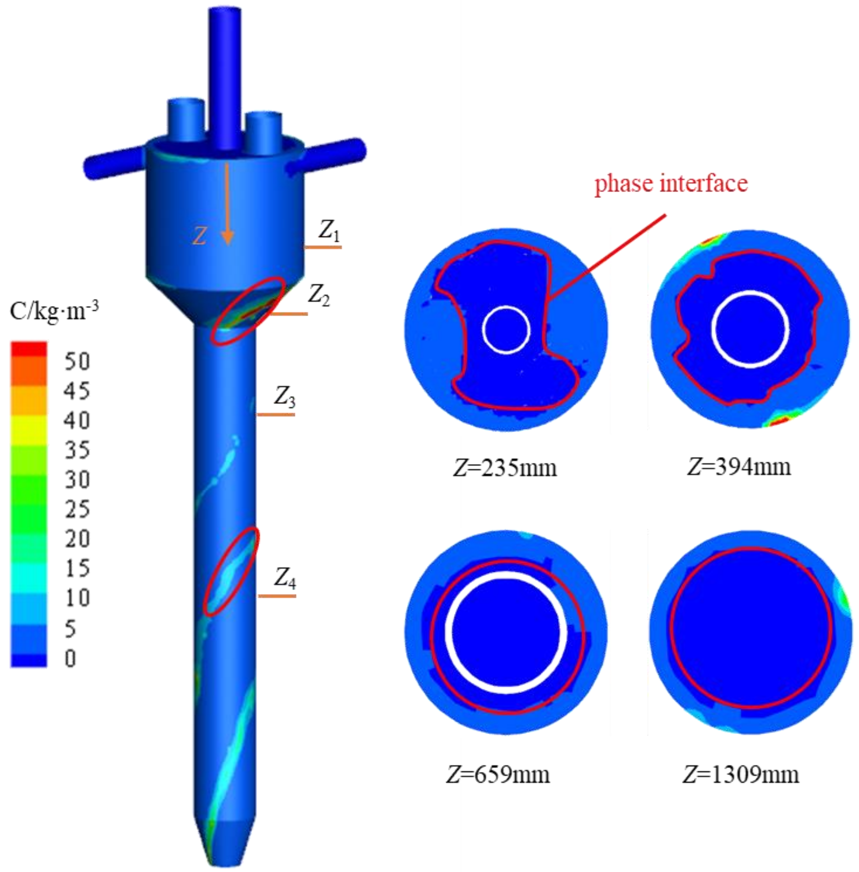
RESULTS AND DISCUSSION

➢ Dynamic flow of particles



RESULTS AND DISCUSSION

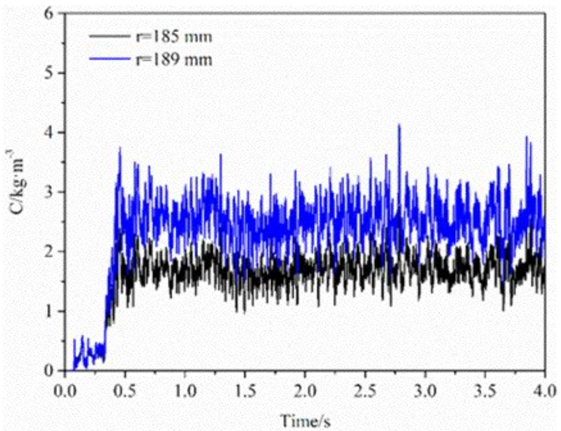
➢ Particle concentration



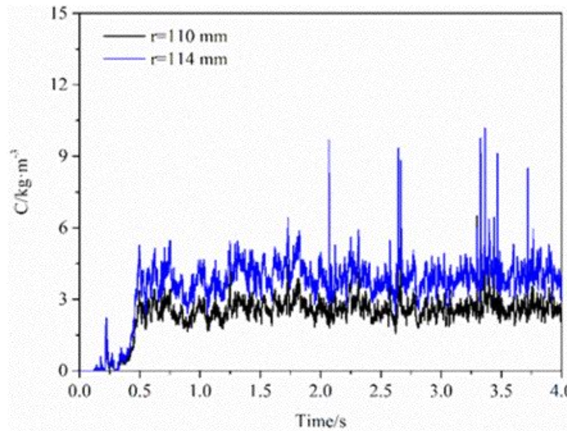
- Solid concentration is higher in strands.
- The phase interface structure composed of internal pure gas and external mixtures can be observed.
- The phase interface structure can prevent lights gas products from overcracking.
- The shape of the interface tends to be more circular.

RESULTS AND DISCUSSION

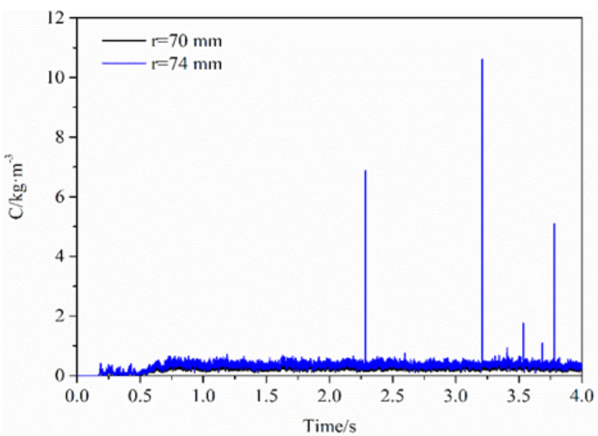
➢ Particle concentration



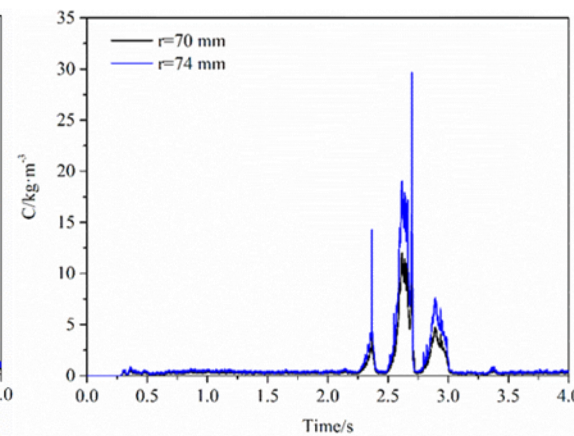
Z=235 mm



Z=394 mm



Z=659 mm

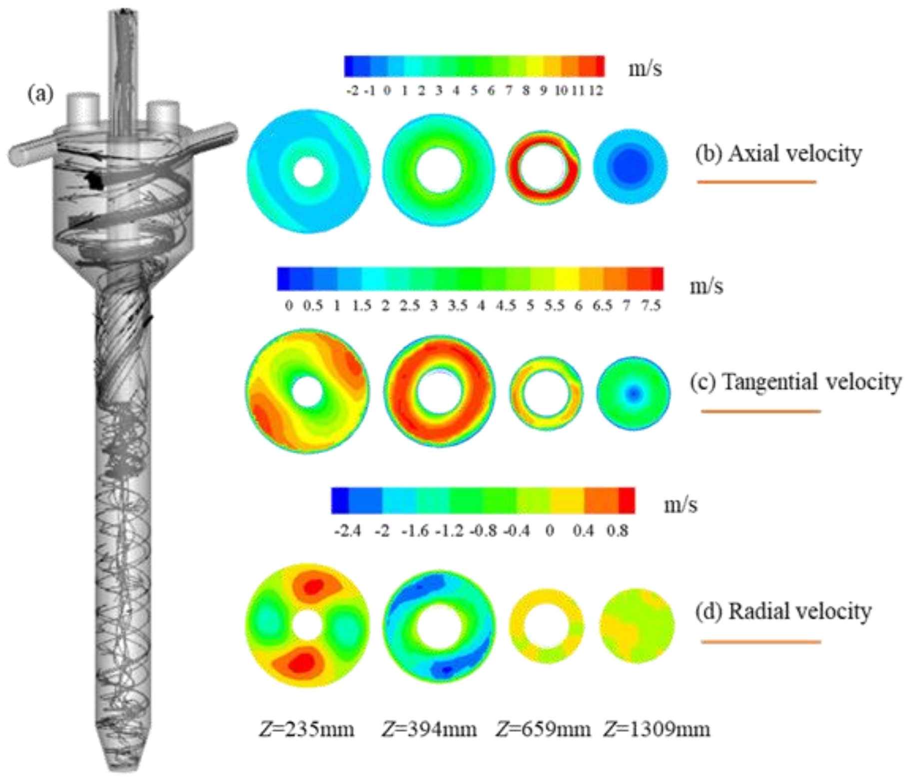


Z=1309 mm

- Particle concentration fluctuates around an appropriate value.
- The fluctuation is severe in the mixing chamber and annulus chamber.
- Clusters formation and fragmentation can be observed in the separation chamber.

RESULTS AND DISCUSSION

➢ Dynamic flow of gas

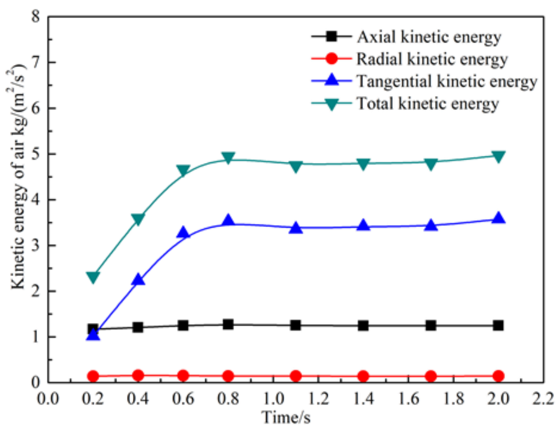


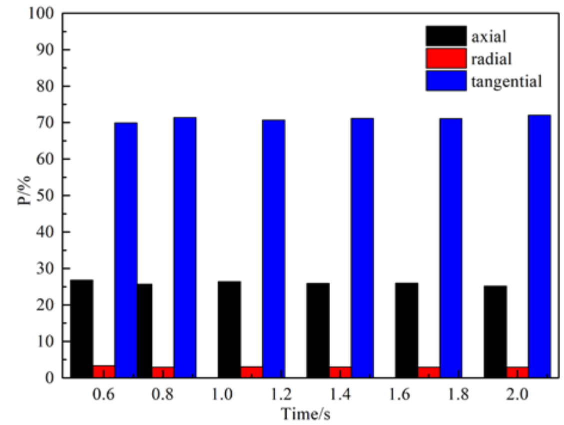
- The characteristic of circling is well calculated by current model.
- Axial velocity is negative in the central region of the separation chamber.
- Tangential velocity is higher in the mixing chamber and annulus chamber.
- The radial velocity is smaller than other velocity components.

RESULTS AND DISCUSSION

- Kinetic energy of gas

$$K_i = \sum_{cell=1}^{cell=n} (1/2) m_{gas} \left| v_{cell} \right|^2$$





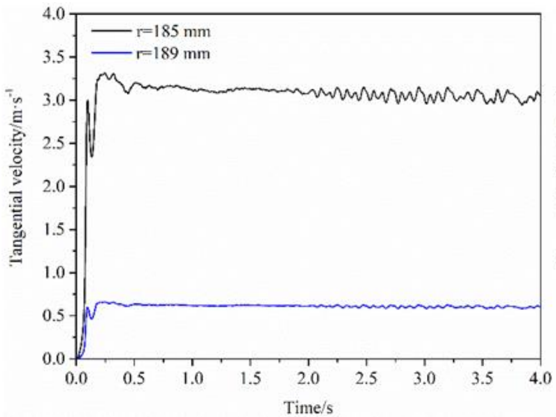
Tangential and axial kinetic energy accounts for 96.69%-97.11% of total kinetic.

⇒

Gas flow is dominated by tangential and axial velocities.

RESULTS AND DISCUSSION

➢ Dynamic flow of gas



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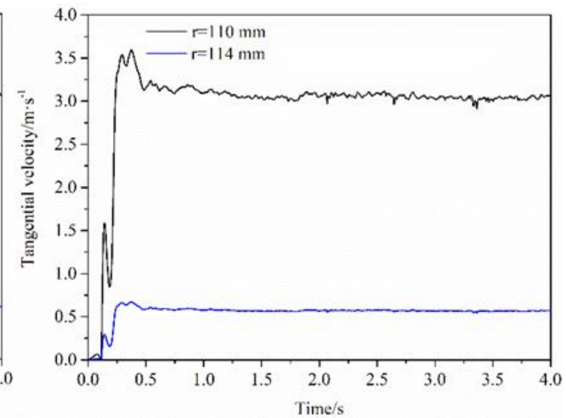

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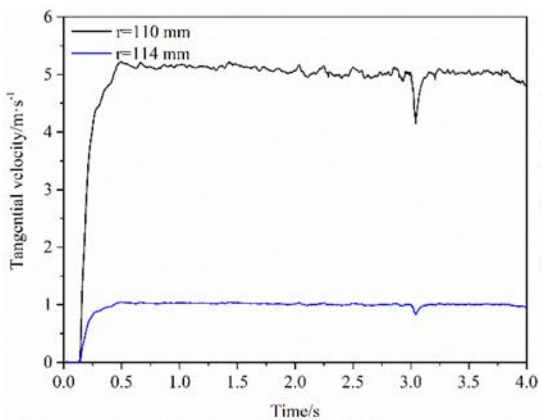

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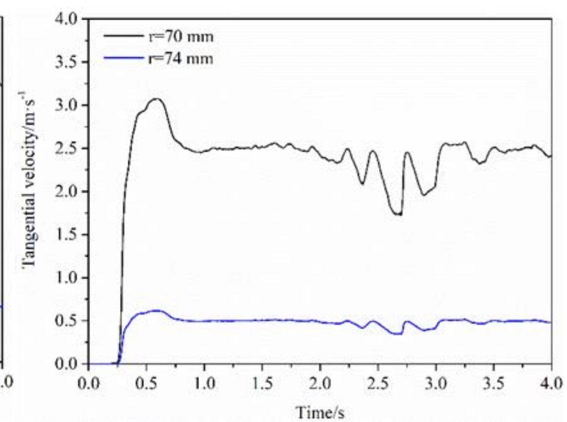

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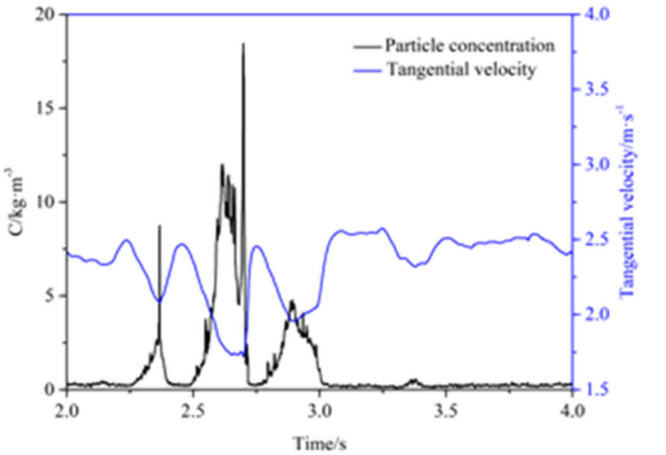

- Gas velocity decreases when particle clusters appear, and gas velocity increases when clusters break up.

Contents

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CONCLUSION

- The results calculated by DDPM are more accurate than DPM.
- Particles descend in strands in the conical segment and separation chamber.
- Tangential and axial kinetic energy are accounting for 96.69%–97.11% of total kinetic energy and thus dominant.
- The distribution of instantaneous particle concentration and the distribution of instantaneous gas velocity are interrelated. Gas velocity decreases when particle clusters appear, and gas velocity increases when clusters break up.

Thank You !

Fluidization XVI