能源清洁利用
国家重点实验室

Effects on ash formation of coal particle properties during fluidized bed combustion

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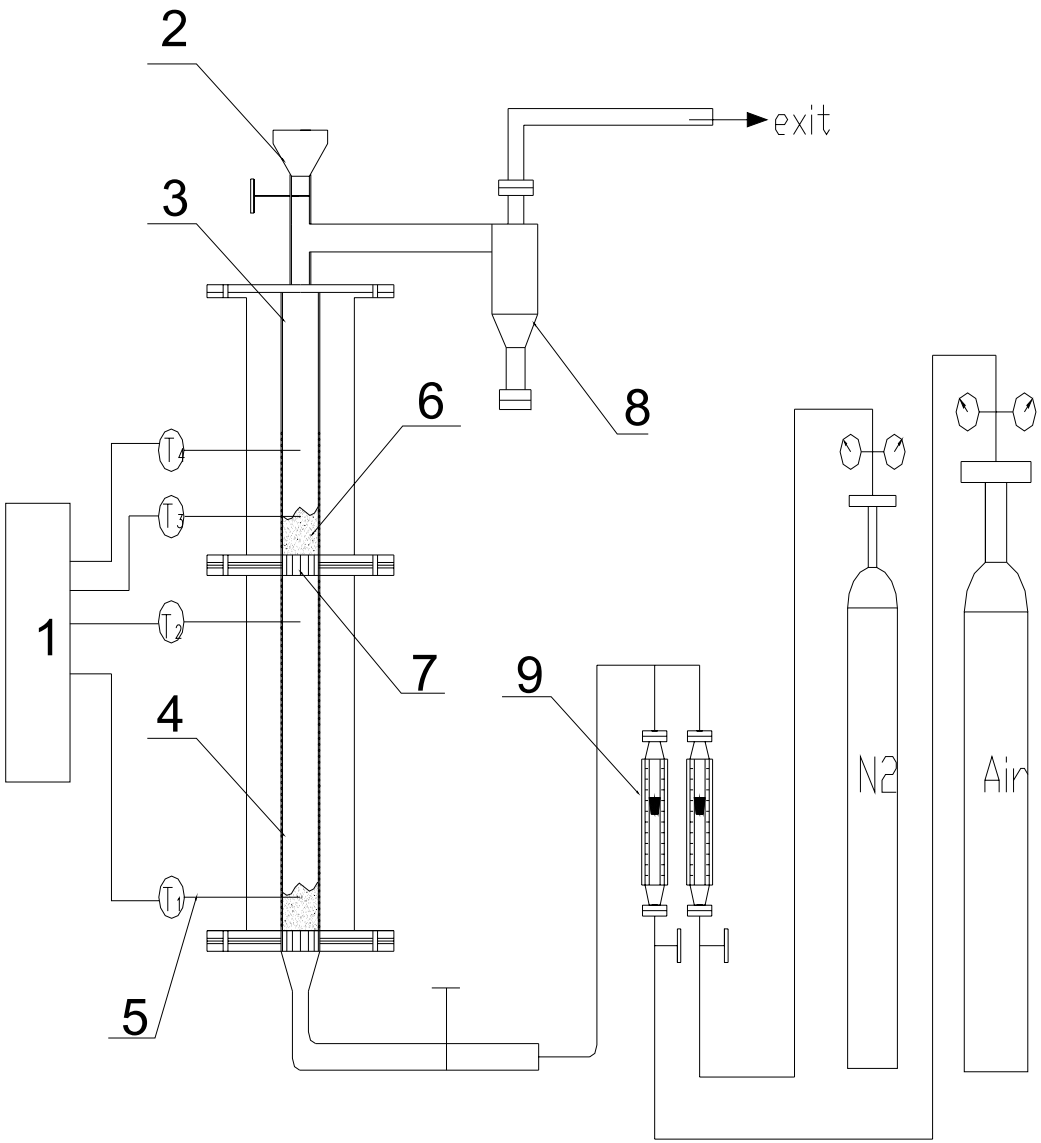
INTRODUCTION

- Ash formation is a very important process for the design and operation of coal fired CFB boilers;
- Coal particle properties is one of the main influence factors on the ash formation
- For a given coal type, the properties of coal particles aren't identical and vary from time to time. The analysis data are only the mean values of a distributed function for all particles present in the sample
- Particle with different properties has different contribution to the ash formation during FBC
- Investigating the effect of particle properties on the ash formation on a bench scale fluidized bed combustor.

EXPERIMENTAL-FBC



- *1 - controller*
- *2 - feed hopper*
- *3 - Fluidized bed reactor (*ID=50 mm, H=600 mm
- *4 - preheating furnace*
- *5 - thermocouple*
- *6 - quartz sand*
- *7 - air distributor*
- *8 - cyclone*
- *9 - flowmeter*

Sample preparation

- Yima bituminous coal
- Divided into 6 ranks with different density by the $ZnCl_2$ solution floatation

density (g/cm³)	Proximate analysis (%)				Calorific value (J/g)	Ultimate analysis (%)				
	A_{ad}	V_{ad}	M_{ad}	FC_{ad}		C_{ad}	H_{ad}	N_{ad}	S_{ad}	O_{ad}
1.2-1.3	5.65	33.50	6.20	54.65	26859	66.58	4.47	1.22	0.53	15.35
1.3-1.4	9.01	30.19	6.38	54.42	25871	64.54	4.15	1.07	0.56	14.29
1.4-1.6	15.82	28.13	5.78	50.27	22547	57.18	3.54	0.85	0.53	16.30
1.6-1.8	23.97	26.18	5.62	44.23	19423	50.14	3.31	0.71	0.68	15.57
1.8-2.0	44.82	18.12	6.41	28.64	13965	37.14	2.20	0.44	0.54	8.45
2.0-2.4	68.75	6.31	6.52	18.42	9568	15.21	1.84	0.37	0.41	6.90

Bed material preparation

- Washed quartz sand with a size range from 0.50 to 0.56mm
- Roasted for 1 hour with a temperature of 900℃ in the bench-scale fluidized bed combustor before they were sieved.

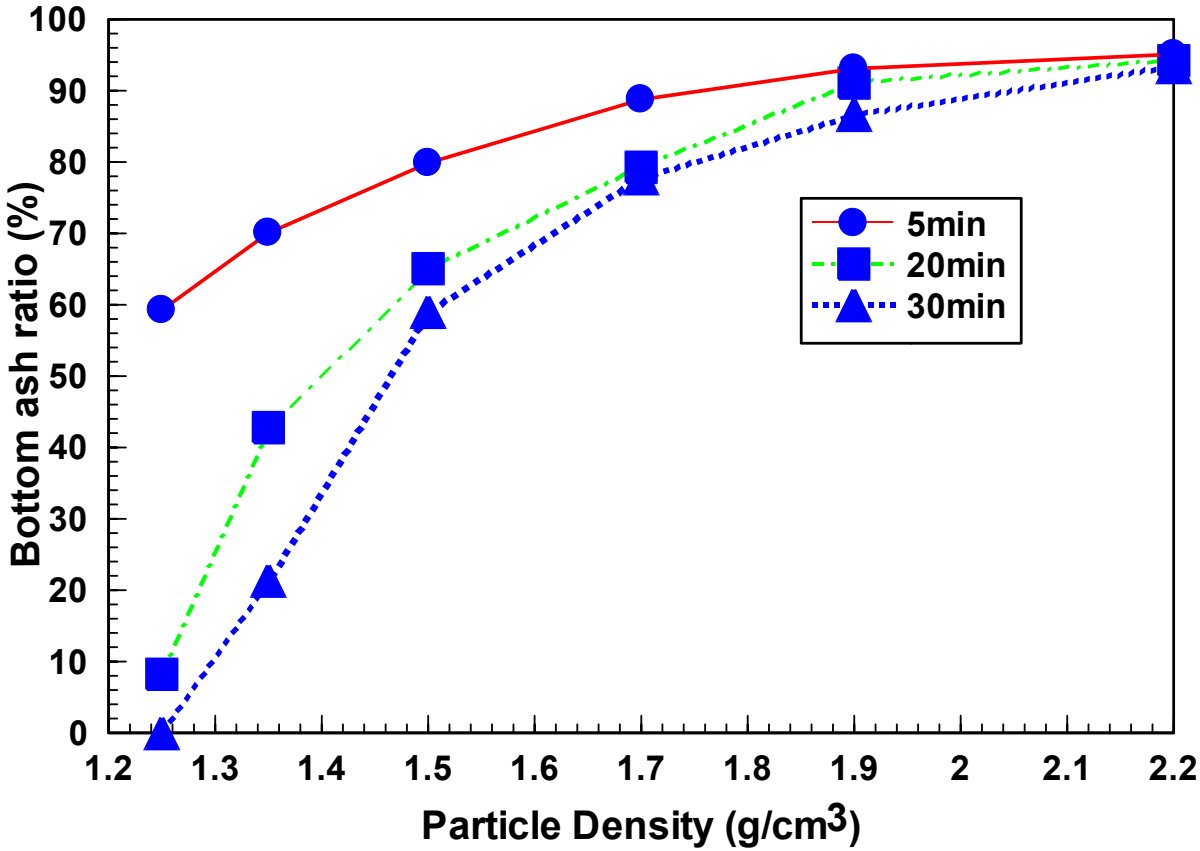
experiments Procedures

- Fed the quartz sand as the bed material;
- Heat around 850℃ with a velocity of v= 0.8 m/s;
- Fed 10g experiment coal particle sample and began to clock;
- Stopped for the selected burn time, the air would be stopped and nitrogen would be introduced into the reactor to cool the particles;
- Separated the bottom residue particle and the ash particle from the bed material by sieve.
- The fly ash was collected by the cyclone and the filter behind the exit;
- Sieved the bottom residue particle and the fly ash into different ranks and got the size distribution, then measured the carbon content of different ranks.

RESULTS AND DISCUSSION

- **Effect of the particle density on ash formation**
- **Effect of the fed coal particle size on the particle size distribution of the bottom residue**

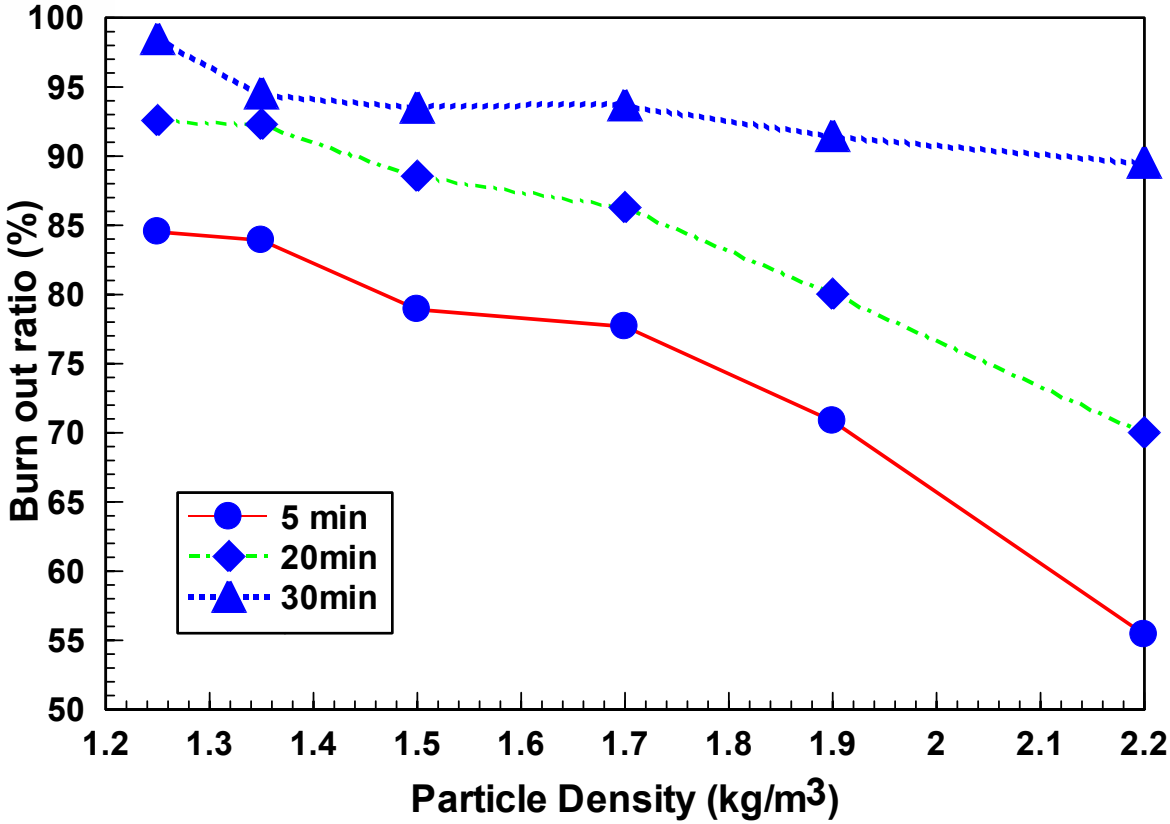
Effect of particle density on bottom residue mass ratio

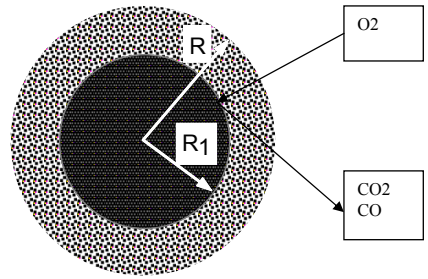


Effect of particle density on bottom residue mass ratio (d=2.0-3.2mm, T=1123K, V=0.8m/s)

- **For the lower density particles, the bottom residue mass ratio is low and decreases rapidly with increasing the burning time**
- **For the higher density particle, the bottom residue mass ratio is high and there is no obvious difference on the bottom residue mass ratio in different combustion residence time**

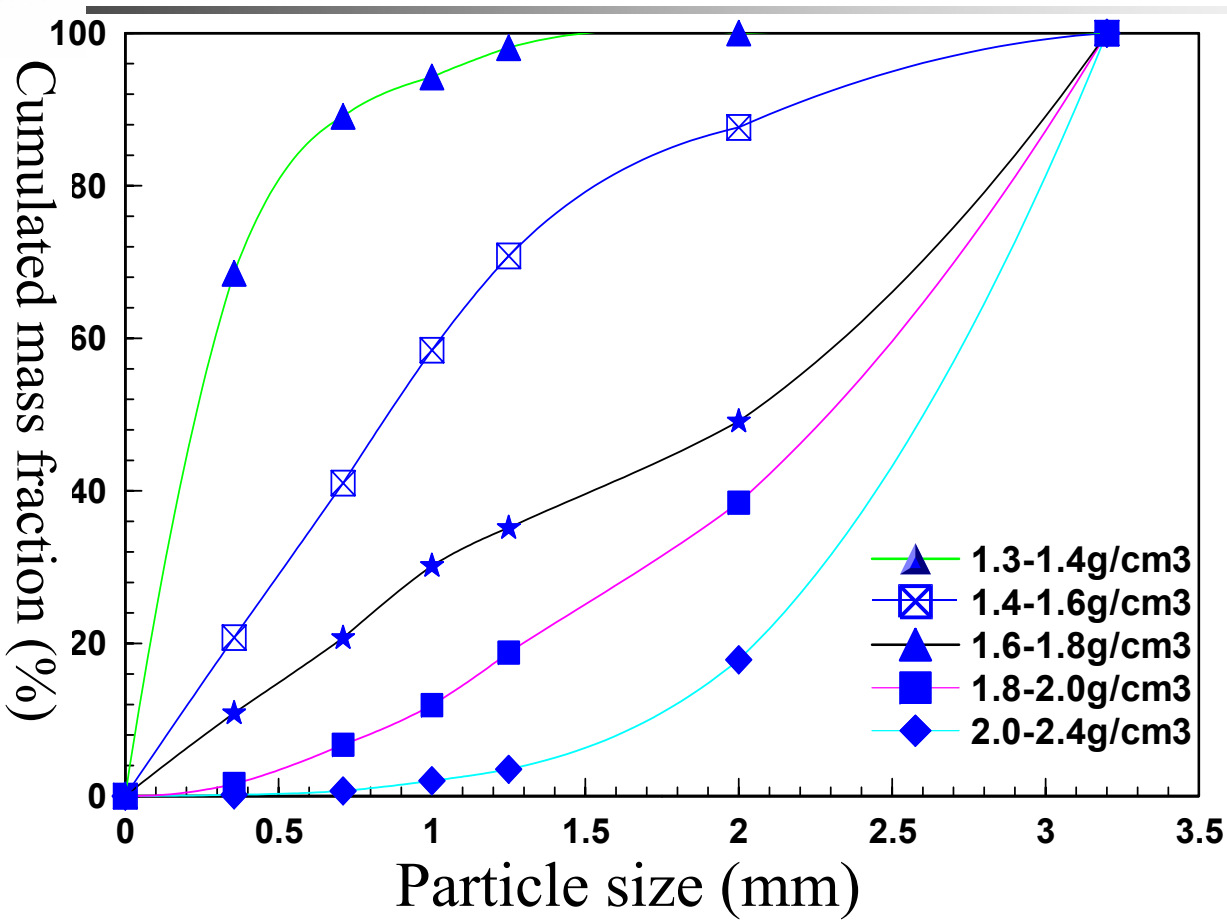
Effect of particle density on particles burnout rate





- **Decreases with an increment in particle density in different burning time**
- **Ash layer is the resistance of oxygen diffusion and decreases the combustion rate during the combustion**
- **There exists an obvious unburned carbon core in many bottom residue particles from the coal particles with high density**

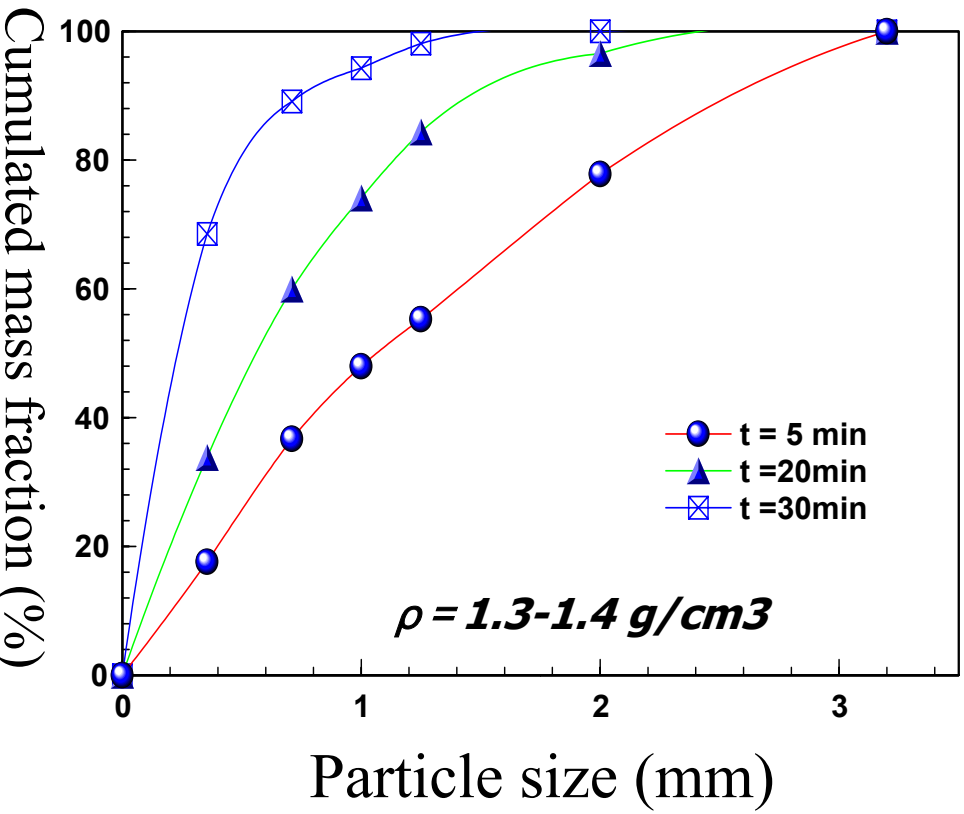
Effect of particle density on the bottom residue size distribution

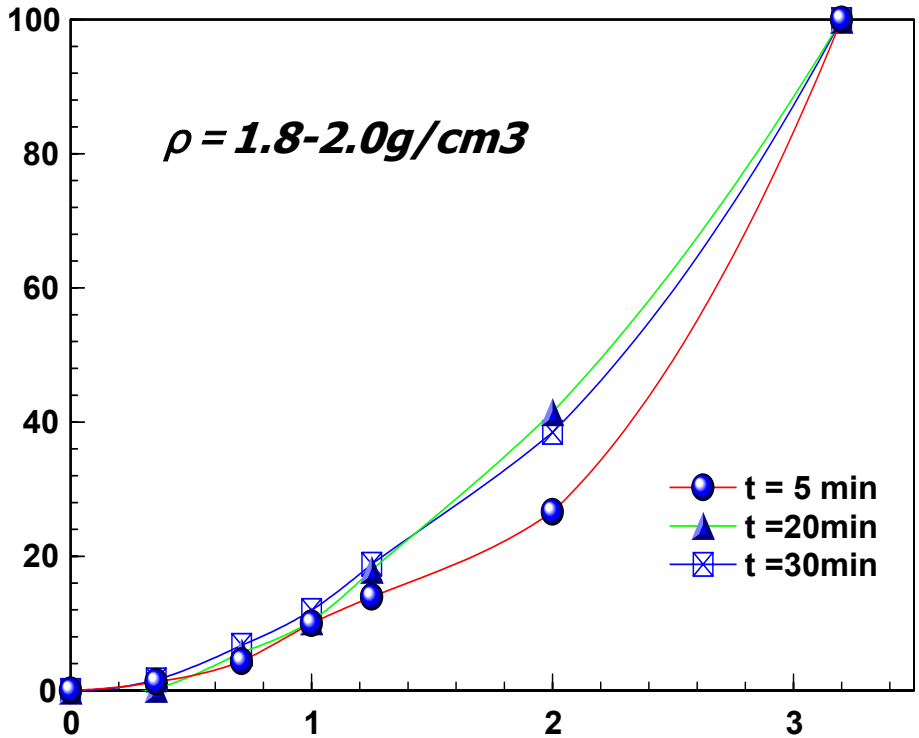


(d=2.0~3.2mm t=30min v=0.8m/s T=1123 K)

- Effect of the primary fragment, secondary fragment and attrition on the size distribution of the formed ash particle is small for the coal particle with high density

Effect of particle density on the bottom residue size distribution





(d=2.0~3.2mm v=0.8m/s T=1123 K)

- Fine ash particles increases rapidly with an increment on the combustion residence time for the low density particles

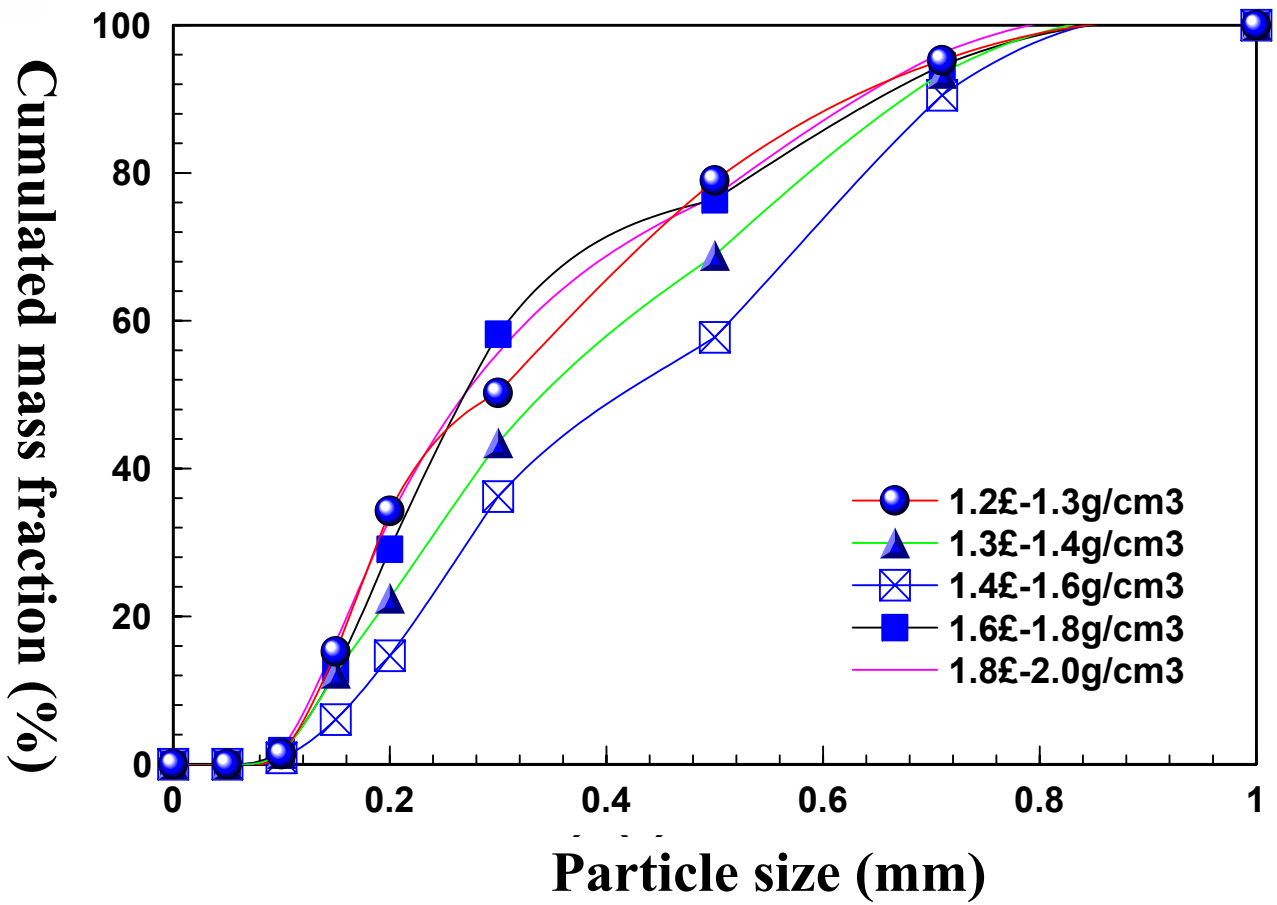
Mean size of the bottom residue under different burning time

(d=2.0~3.2mm v=0.8m/s T=1123 K)

Particle density (g/cm3)	1.2-1.3	1.3-1.4	1.4-1.6	1.6-1.8	1.8-2.0	2.0-2.4
	mm	mm	mm	mm	mm	mm
5 min	0.65	1.26	1.68	1.97	2.23	2.42
20 min	0.37	0.72	1.15	1.78	2.12	2.40
30 min	-	0.35	1.03	1.76	2.07	2.36

Most of the bottom residue particles is from the fed coal particles with higher density during fluidized bed combustion

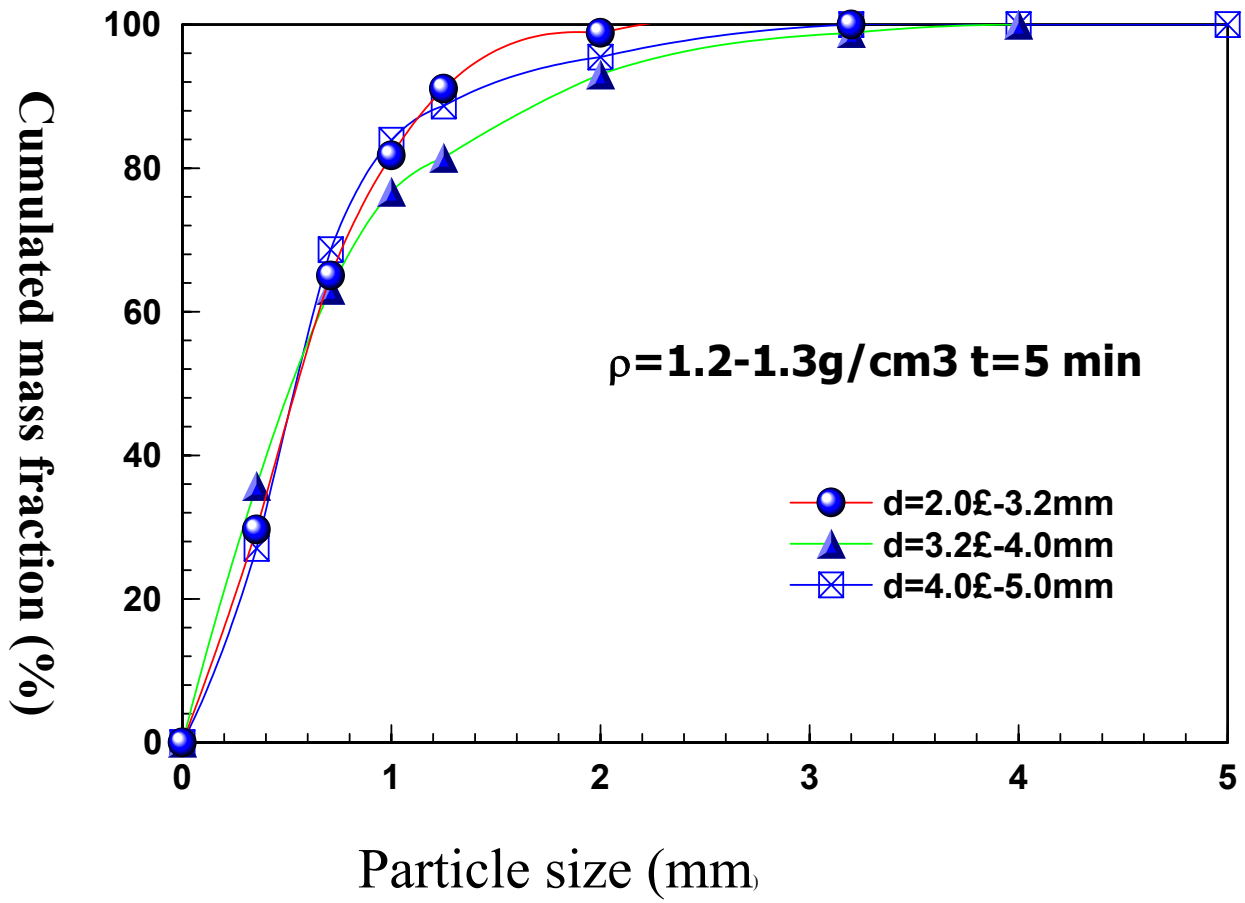
Effect of particle density on the fly ash size distribution



(d=2.0~3.2mm t=30min v=0.8m/s T=1123 K)

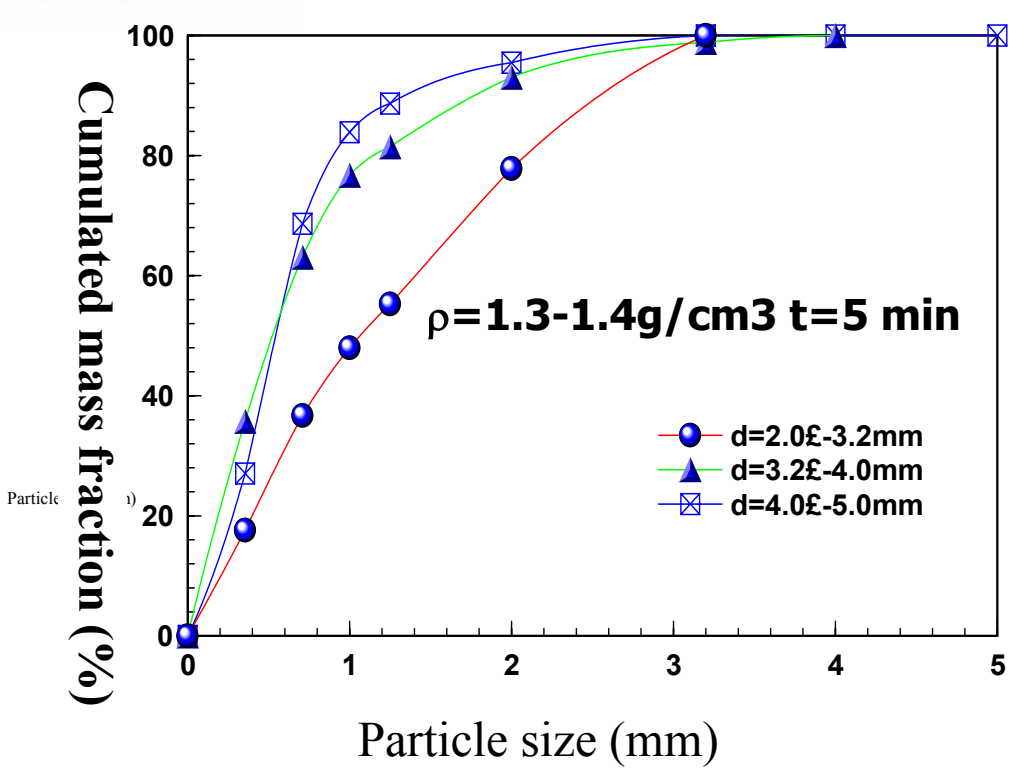
- No great difference on the size distribution of the fly ash and the circulation ash particle.

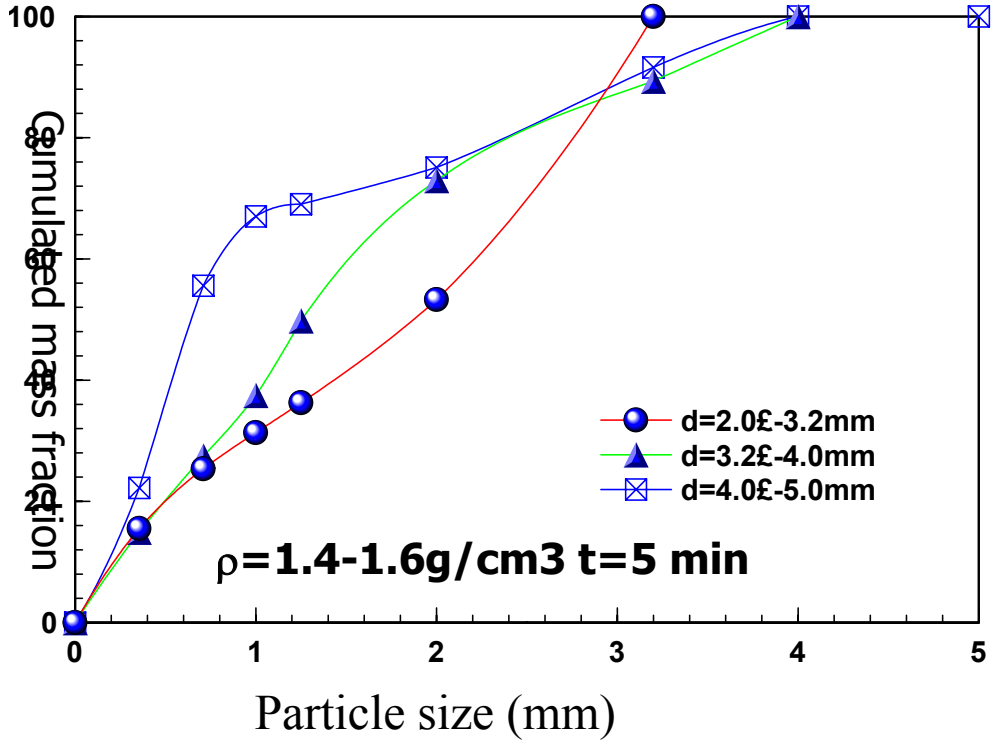
Effect of the fed coal particle size on the particle size distribution of the bottom residue (1)



- For a density range from 1.2g/cm3 to 1.3g/cm3 , the formed bottom residue particles have similar size distribution
- All ash particles are less than the initial fed particle

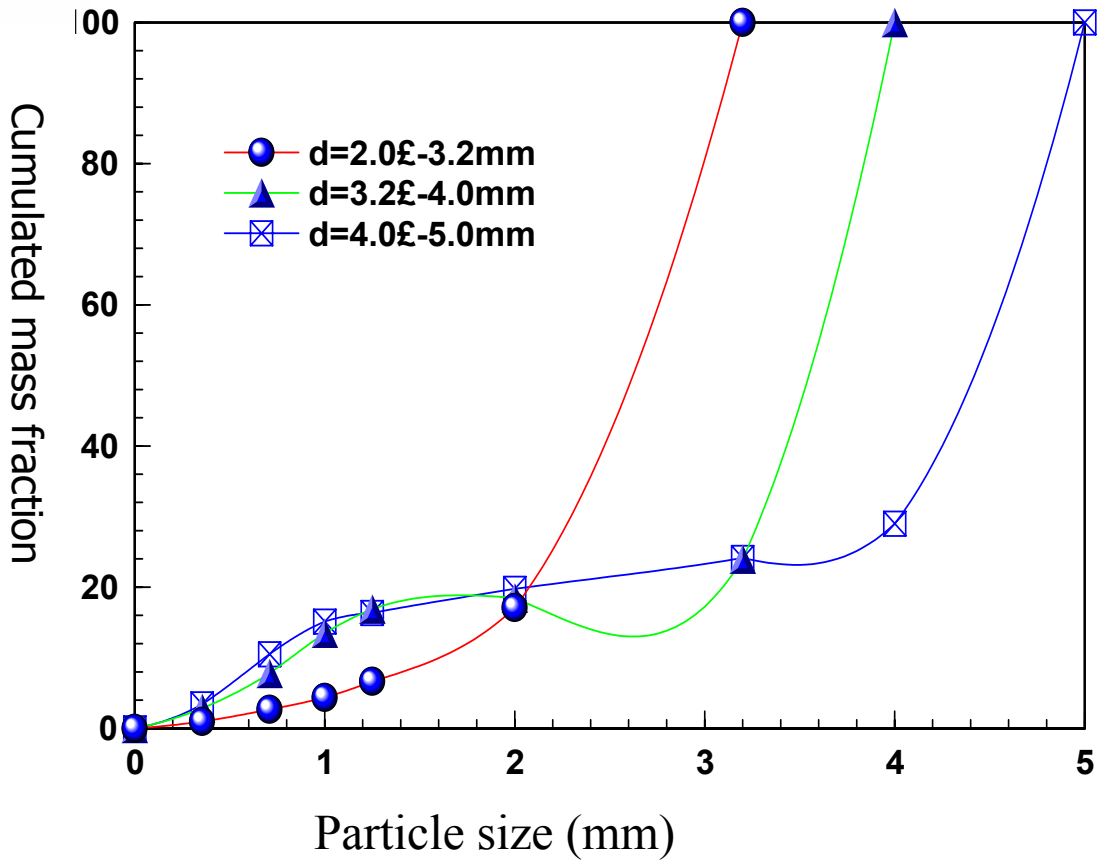
Effect of the fed coal particle size on the particle size distribution of the bottom residue (2)





- **For the density range from 1.3g/cm3 to 1.6g/cm3, the small particles (less than 2mm) increases with increasing in initial size of the fed coal particles.**
- **The fragment is more violent for the large size particles**

Effect of the fed coal particle size on the particle size distribution of the bottom residue (3)



ρ=2.0-2.4g/cm3 t=5 min

- **For the high density particles, the size of most of the formed ash particles are similar with the initial fed coal particles.**
- **The fragment is faint for the high density particles due to the low volatile content and the compact structure**

CONCLUSIONS (1)

- The coal particles from the same coal type may be divided into several ranks with different properties. With increasing the coal particles density, the content of volatile matter, C, H, N and O and the calorific value are lower while the ash content is higher.
- The low density particles with low ash content burn in the shrinking-core model with no surrounding ash layer and little bottom residue is left with a longer burning time
- The high density coal particles with high ash content burn in the dual shrinking-core model and most of the ash content is formed as the bottom residue.

CONCLUSIONS (2)

- With increasing in the particle density, the mass fraction of the bottom residue increases while the burn-out rate and the mass fraction of the fly ash decrease.
- For the higher density particles, the formed bottom residue particles with similar size as the fed particles is more while less small ash particles are formed.
- With an increment in the coal particle density, the influences of the fed particle size distribution on the particle size distribution of bottom residue increase gradually.

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Thanks for your attention!