Co-gasification of Biomass and Coal in a Fluidized bed

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Biomass utilization in China

- Much more attention has been paid now and future
- Many technologies are being developed such as marsh gas, feedstuff, return to field as a fertilizer, briquette, gasification, etc
- Biomass gasification for power generation or synthesis (main direction)
- Existing some problems

Co-gasification of Biomass and Coal in Fluidized Bed

Disadvantage of sole biomass gasification	Advantage of co-gasification
Season limitation small scale	No season limitation big scale (economically)
Tar production low gasification temperature	No tar production tar converted to gas at high T bio-ash as catalyst to coal gasi. higher gas yield
Low heat value high CO_2 content	High heat value CO_2 converted to CO at high T
Fluidization quality anomalistic shape, inert bed particle (sand), abrasion	Fluidization quality coke as bed particles , abrasion reduced and power saved

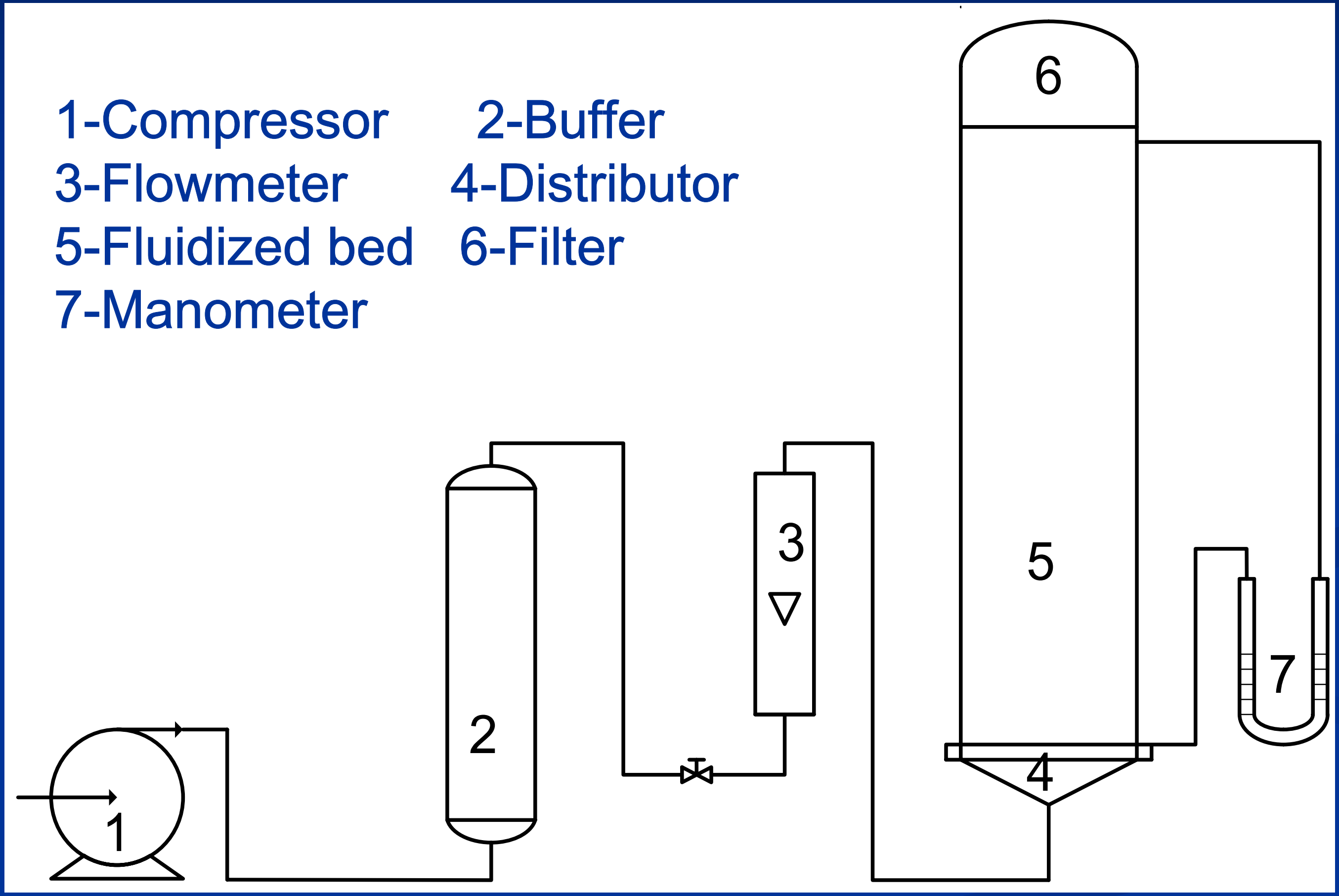
Synergistic effects

Co-gasification of Biomass and Coal in Fluidized Bed

Present work

- Fluidization characteristics of multi-particles with various ratios of biomass, coal and coke particles in a cold fluidized bed
- Basic co-gasification reaction characteristics of biomass and coal by TG
- Co-gasification in a laboratory scale fluidized bed

Cold apparatus of fluidized bed



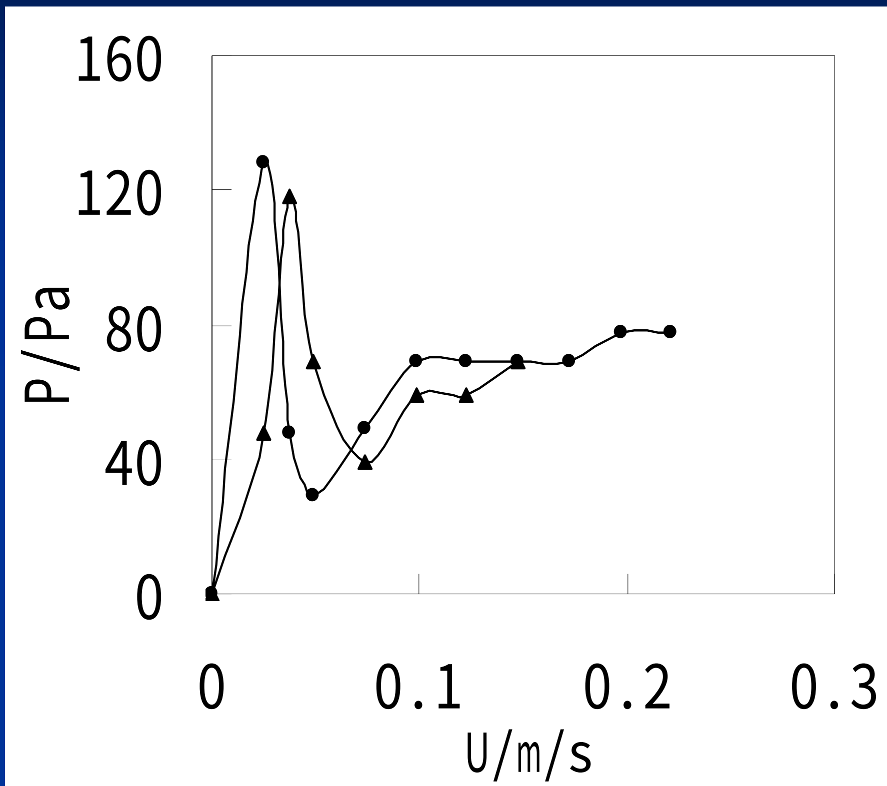
ID 110mm H 1200mm

Properties of particles

Particle	d_p /mm	ρ_b /kg/m^3	ρ_p kg/m^3
Coal 1	0.75	600	1230
Coal 2	1.50	600	1230
Cornstalk	0.37	163	500
Rice haulm	0.38	158	490

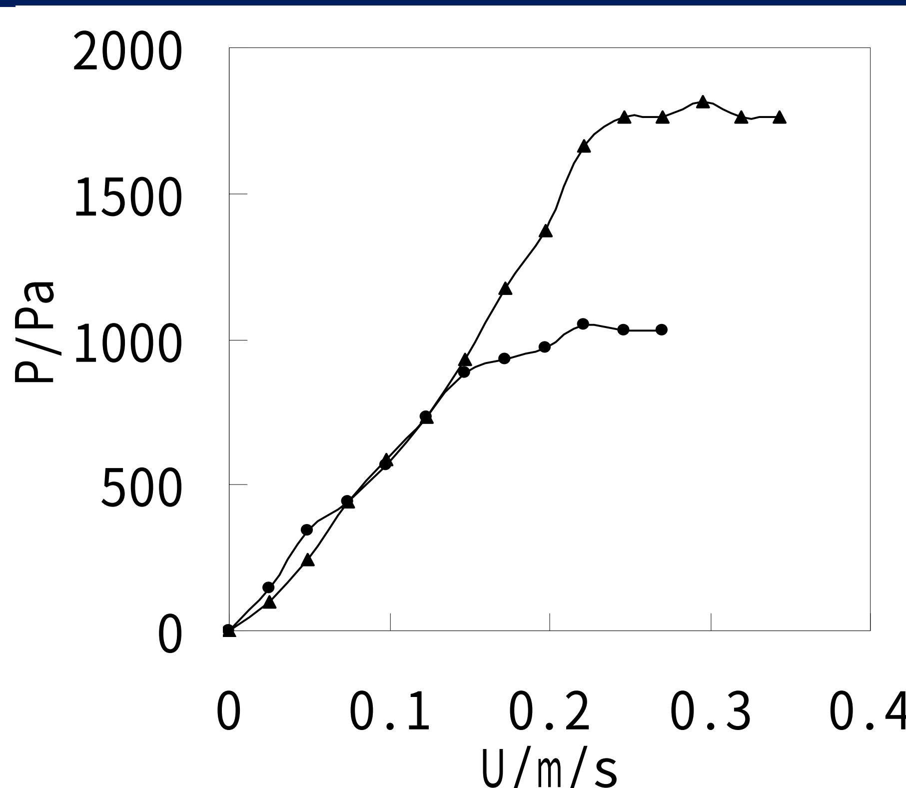
Geldart B particle

Fluidization characteristics of sole biomass, coal particles



Biomass particles

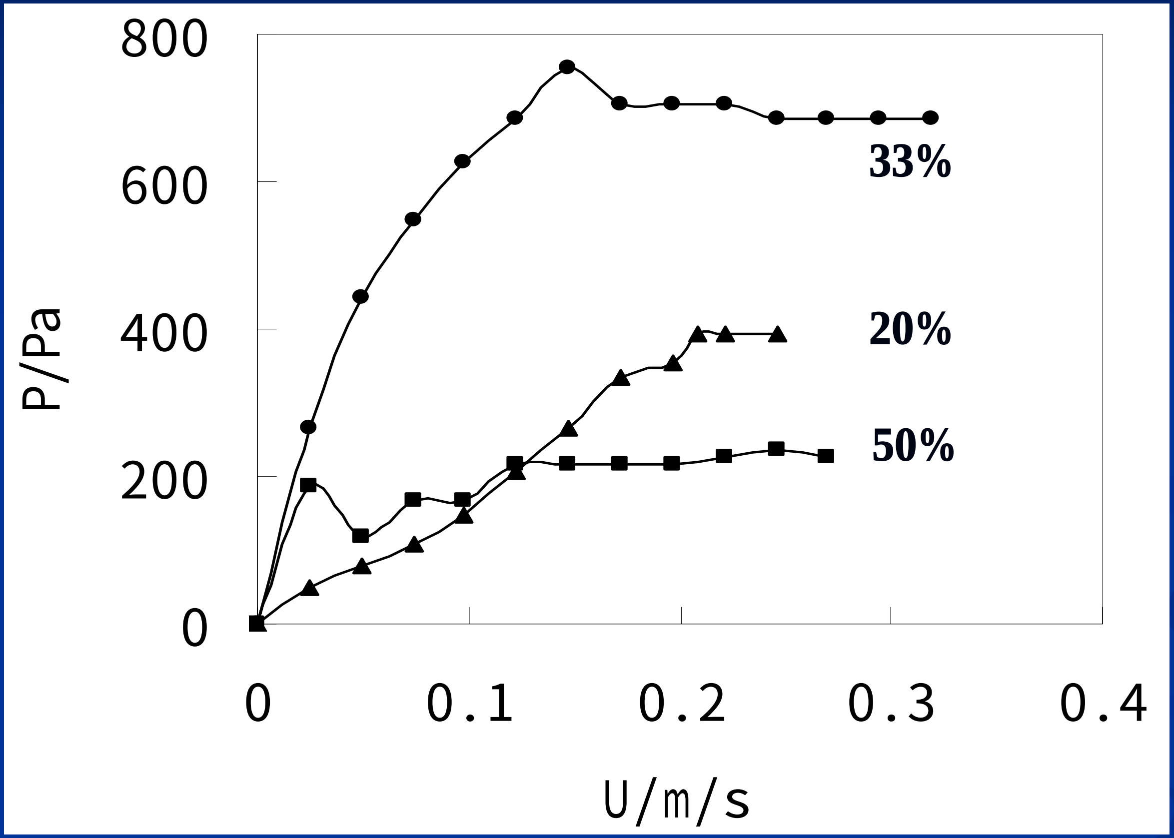
—●—cornstalk —▲—rice haulm



Coal particles

—●—coal 1 —▲—coal 2

Fluidization characteristics of biomass and coal particles



Effect of biomass fraction on fluidization

Experiment and calculation of U_{mf}

Mixtures	x_2 /%	U_{mf} m/s		Relative error %
		Experi.	Predicted	
Cornstalk +coal 1	20	0.209	0.202	3.3
	25	0.196	0.191	2.5
	33	0.174	0.175	0.6
	50	0.123	0.147	19.0
Rice haulm + coal 1	20	0.197	0.206	4.6
	33	0.172	0.183	6.4
	50	0.135	0.161	19.3

Ergun equation

$$u_{mf} = \frac{d_p^2(\rho_p - \rho_f)g}{1650\mu}$$

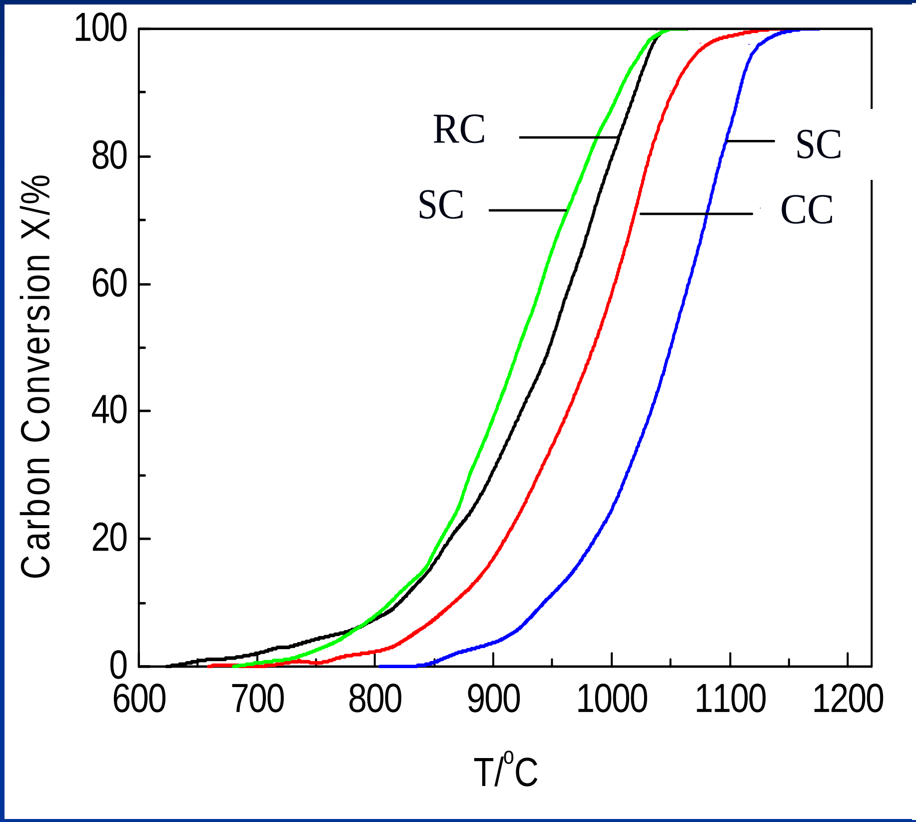
(Re<20)

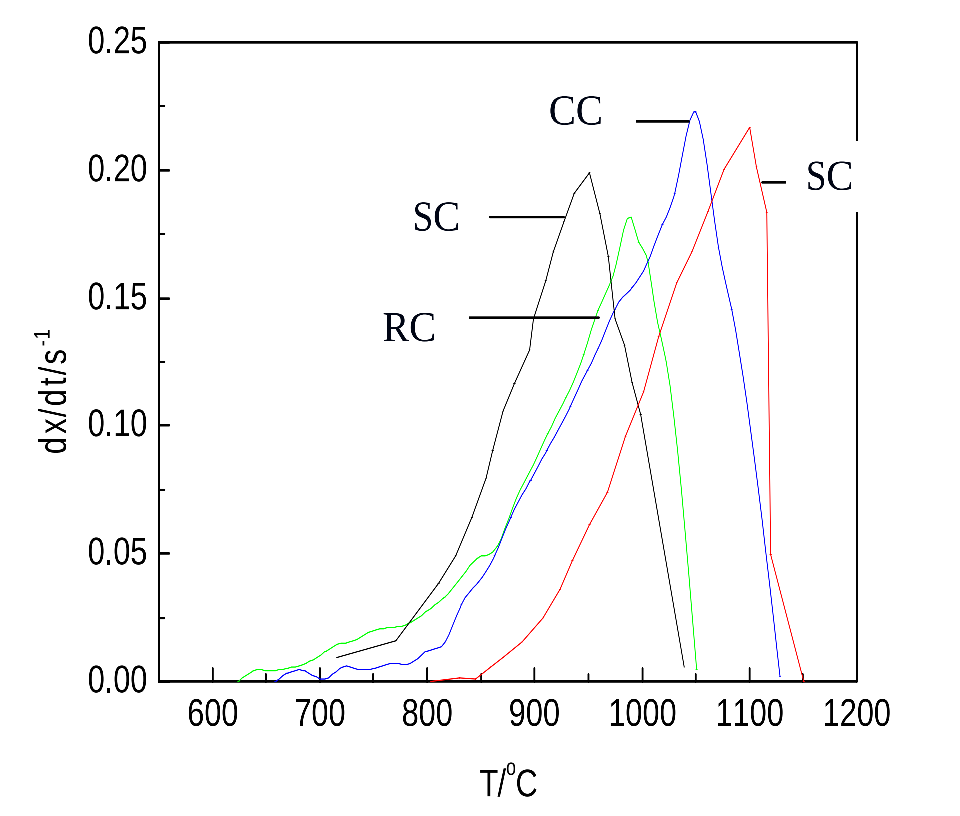
Analysis of biomass, coal, coke and ash

Sample	Proximate analysis/w%, ad				Elemental analysis/w%, ad				
	M	A	V	FC	C	H	O	N	S
sorghum haulm	**6.1**	**8.9**	**661**	**18.9**	**38.6**	**4.7**	**39.9**	**1.2**	**0.6**
corn haulm	**6.7**	**6.1**	**69.6**	**17.6**	**42.3**	**4.7**	**38.5**	**1.1**	**0.6**
rice haulm	**5.6**	**12.1**	**65.2**	**17.1**	**38.6**	**4.3**	**37.7**	**1.1**	**0.7**
Shenmu coal	**8.8**	**5.6**	**32.4**	**53.3**	**73.1**	**4.5**	**4.6**	**1.0**	**0.3**
sorghum haulm coke	**1.1**	**31.9**	**4.3**	**62.7**	**53.9**	**0.4**	**10.8**	**1.1**	**0.8**
corn haulm coke	**1.0**	**25.8**	**2.6**	**70.6**	**66.2**	**0.4**	**4.5**	**1.2**	**0.9**
rice haulm coke	**0.9**	**41.3**	**2.2**	**55.6**	**51.2**	**0.5**	**3.9**	**1.1**	**1.1**
Shenmu coal coke	**0.9**	**9.1**	**1.5**	**88.5**	**87.1**	**0.4**	**0.3**	**1.4**	**0.9**

Ash	**K wt%**	**Na wt%**
rice haulm	**4.84**	**1.78**
corn haulm	**4.56**	**1.36**
sorghum haulm	**12.32**	**1.21**

Steam gasification of biomass coke and coal coke

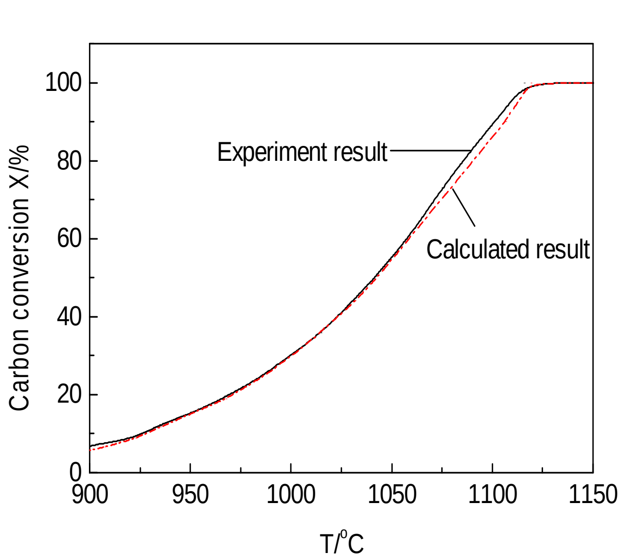




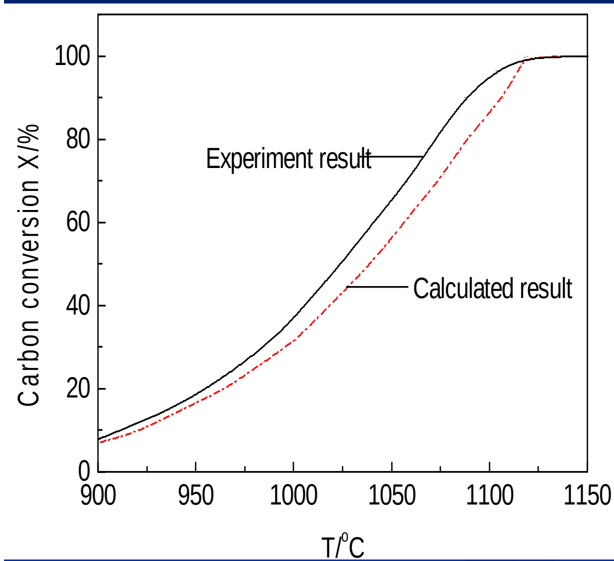
Gasification activity：

sorghum haulm coke > rice haulm coke > corn haulm coke > Shenmu coal coke

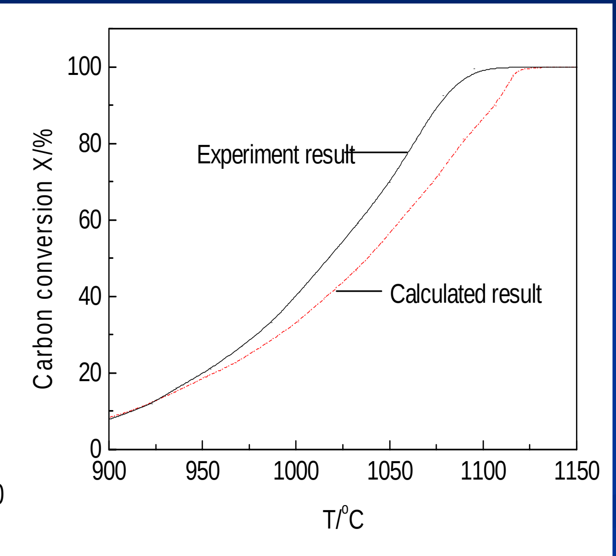
Gasification reaction characteristics of biomass and coal



corn haulm coke+ coal coke



rice haulm coke+ coal coke



sorghum haulm coke + coal coke

$$X_m = \frac{X_b \cdot y_b \cdot FC_b + X_c \cdot y_c \cdot FC_c}{y_b \cdot FC_b + y_c \cdot FC_c}$$

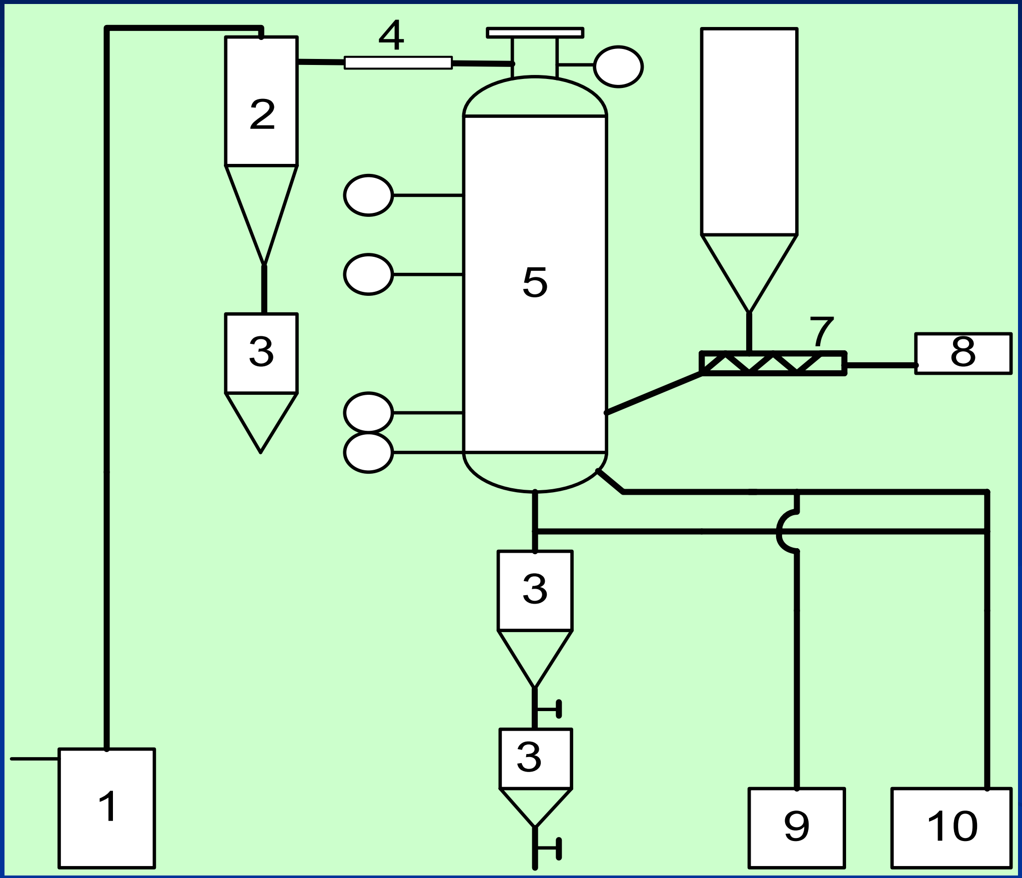
Kinetics analysis of steam gasification of various coke

Sample	*E*/KJ/mol	k_0/min^{-1}/1*10^6	R^2
SMJ(860-1110 ^{o}C)	239.85	753.82	0.992
YJ(800-1100 ^{o}C)	191.50	20.43	0.996
GJ(800-1030 ^{o}C)	171.68	6.35	0.996
DJ(800-1030 ^{o}C)	154.22	0.75	0.995
YJ+SMJ(1:4)(860-1100 ^{o}C)	215.44	84.49	0.988
GJ+SMJ(1:4)(860-1100 ^{o}C)	204.15	36.79	0.981
DJ+SMJ(1:4)(860-1100 ^{o}C)	210.99	71.34	0.995

$$\frac{dx}{dT} = \frac{k_0}{\varphi} e^{-\frac{E}{RT}} (1 - x)$$

Co-gasification can be described by one order kinetics equation

Schematic diagram of the fluidized bed gasifier



1-Water tank 2-Cyclone 3-Ash pot 4-Water cooler 5-Gasifier
6-Hopper 7-Screwfeeder 8-Motor 9-Steam generator 10-Compressor

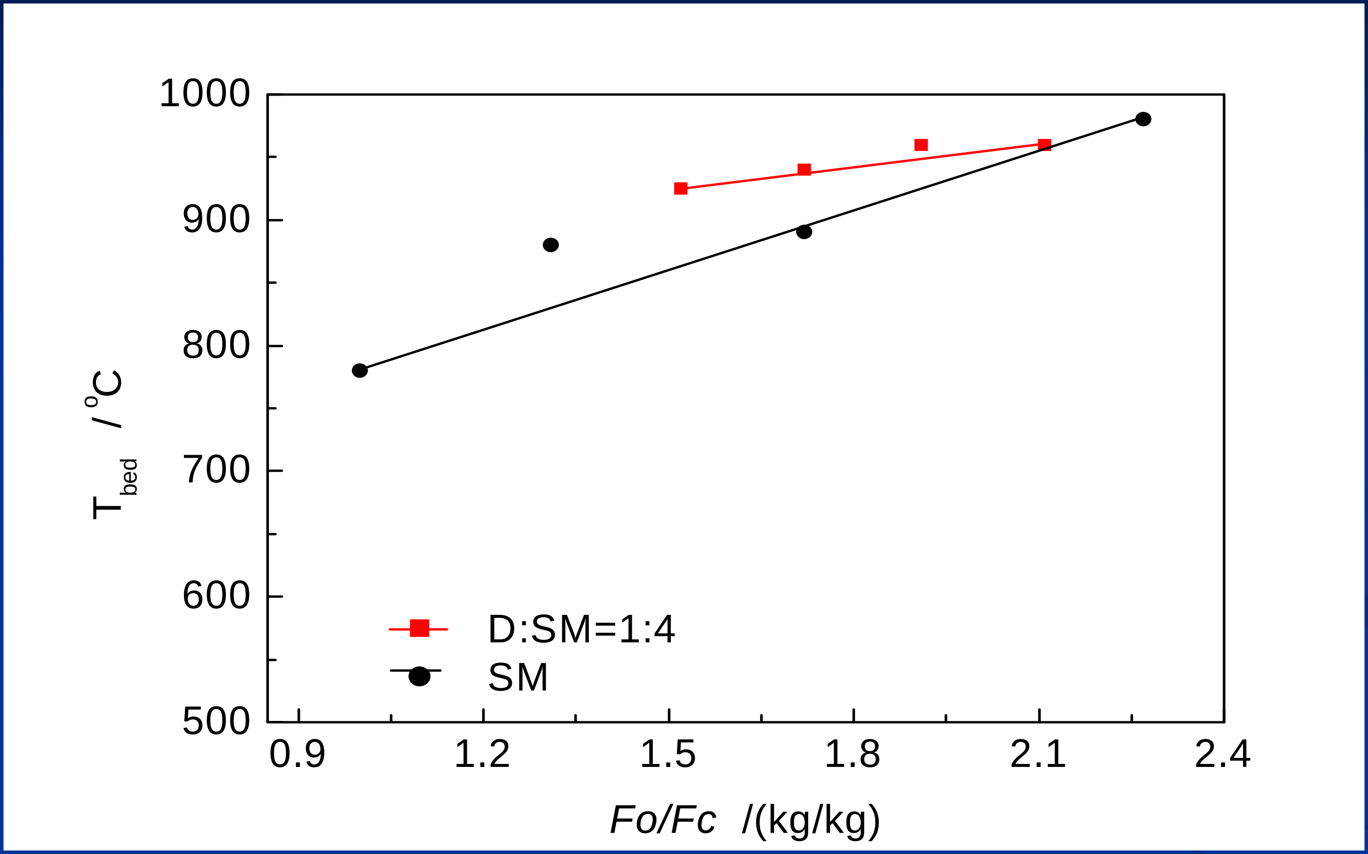
Fluidized bed gasifier

D120mm×800mm P 20MPa Capacity 20kg/h

Experiment conditions

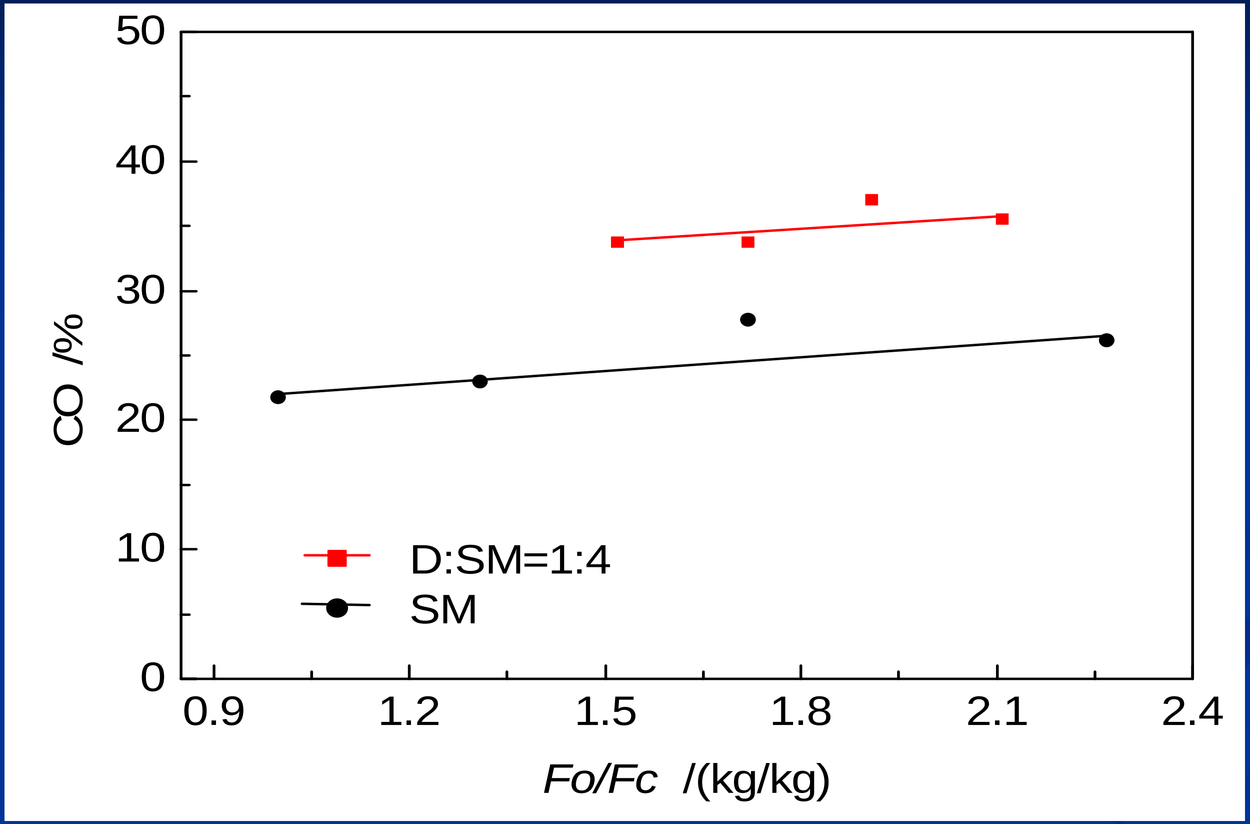
Feeding materials	Shenmu coal, rice haulm
Gasifying agent	Air, steam
Steam/carbon (wt/wt)	0.53
Rice haulm/coal	1:4
Particle diameter	rice haulm（0.1-3mm)
	coal (0.5-2mm)
Mass balance	<10%

Experimental results



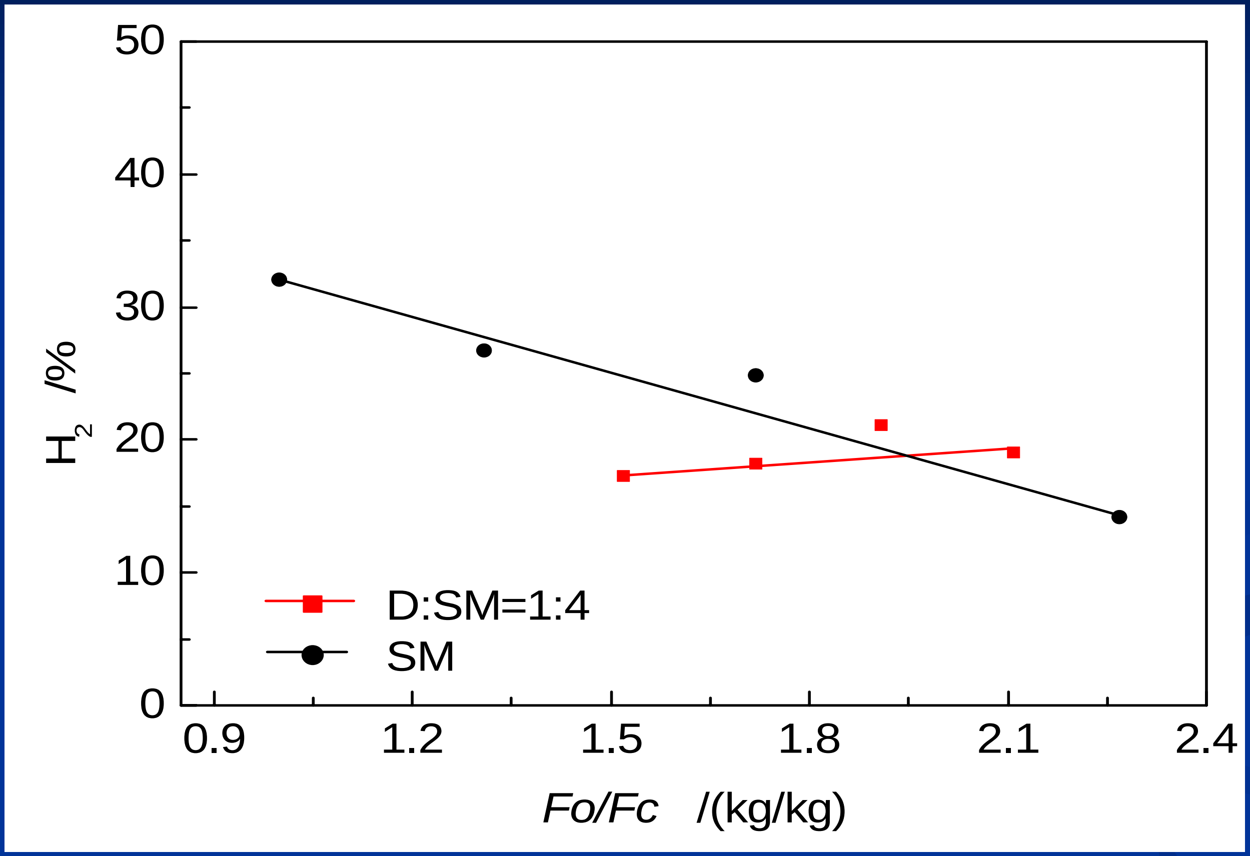
Temperature in gasifier varying with O2/carbon

Experimental results



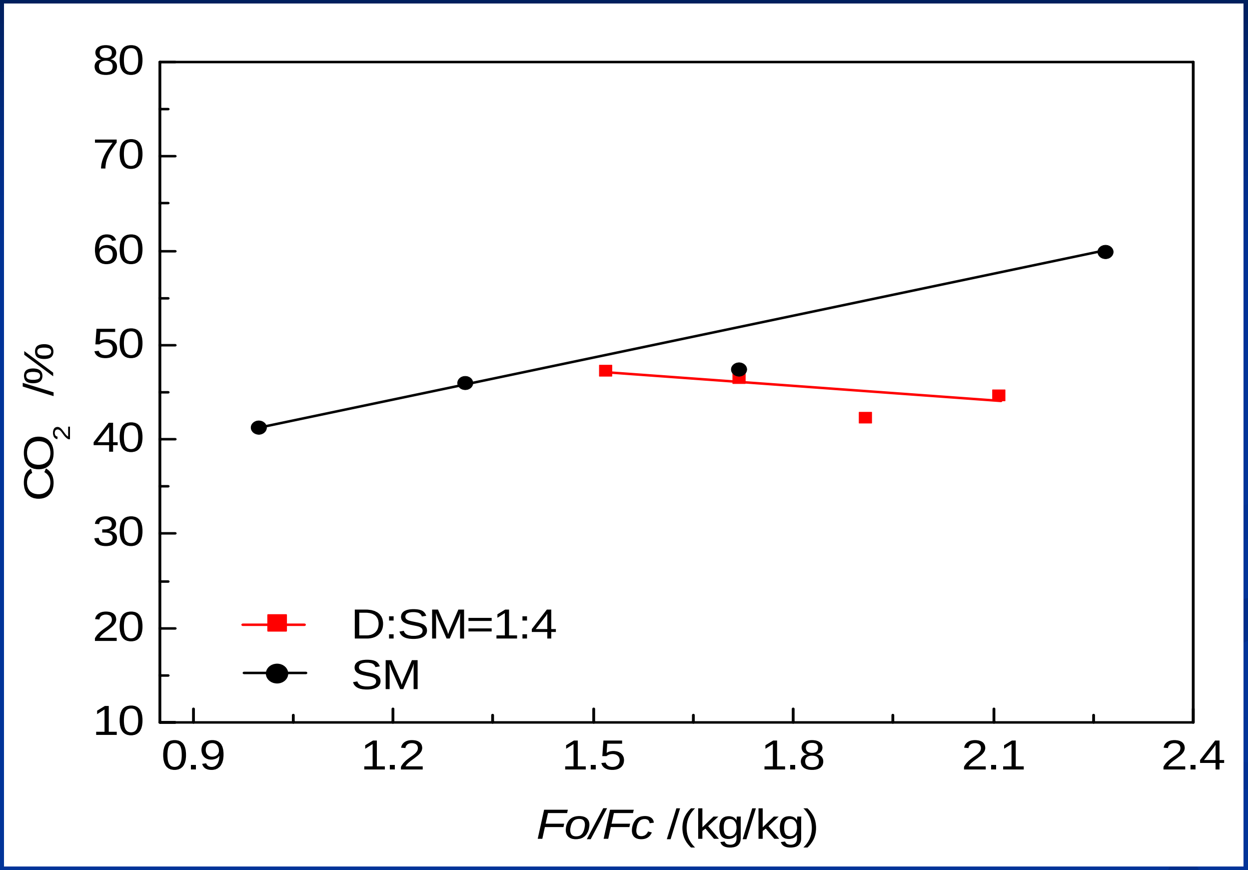
CO content varying with O2/carbon

Experimental results



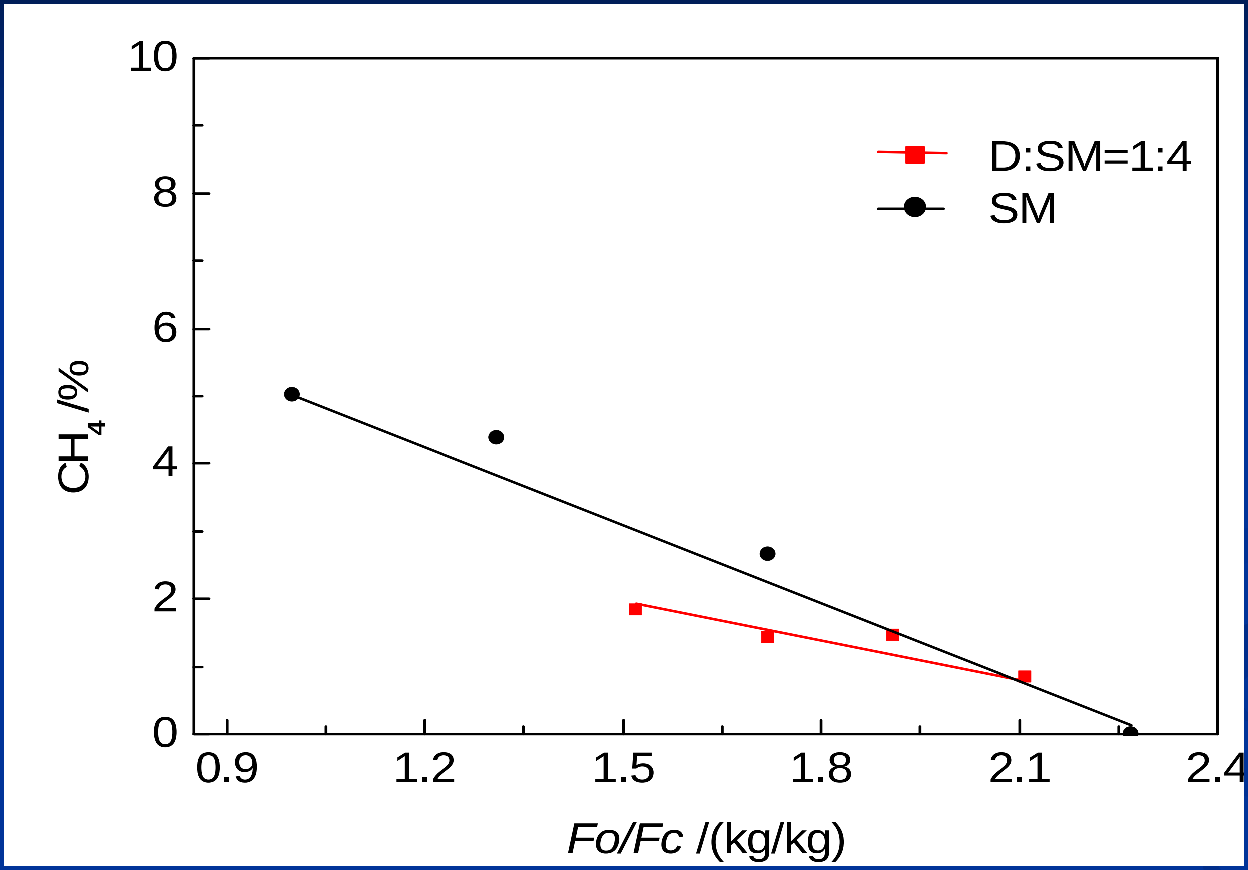
H2 content varying with O2/carbon

Experimental results



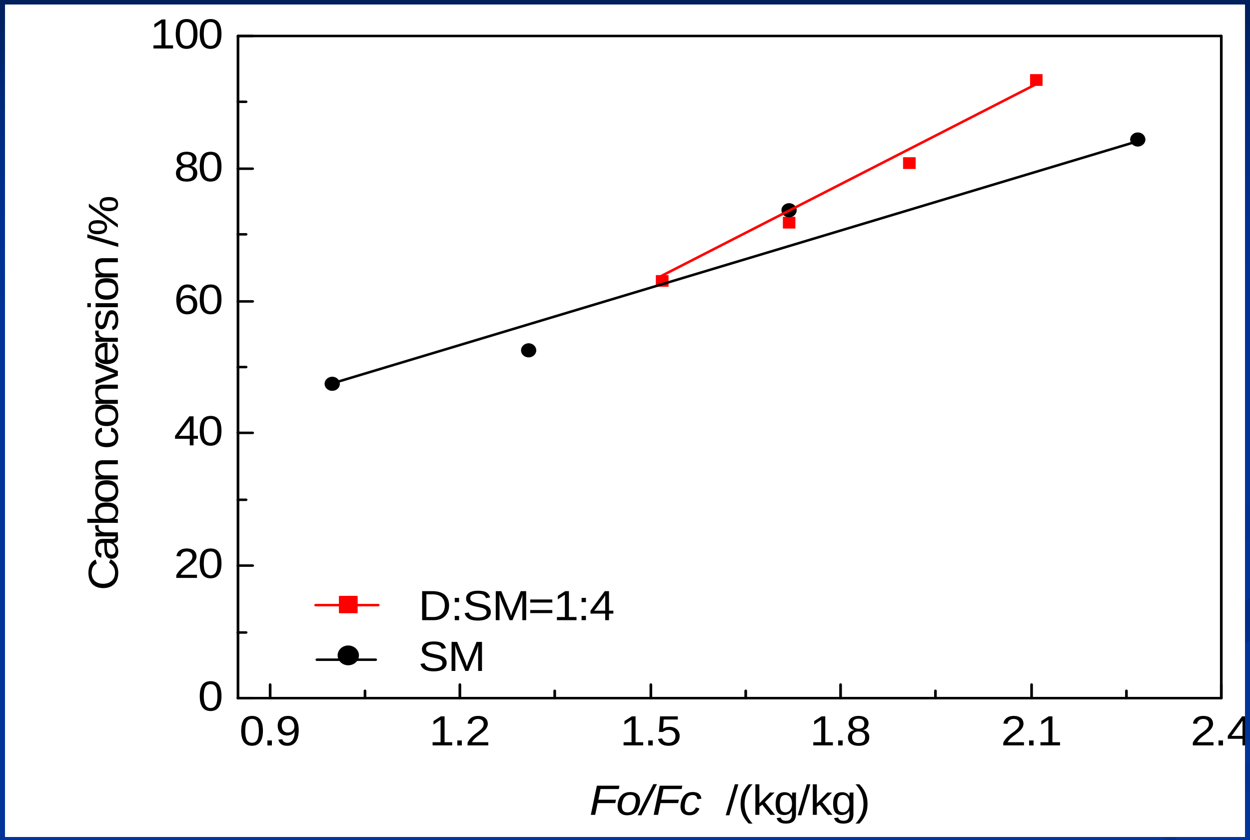
CO_2 content varying with O_2/carbon

Experimental results



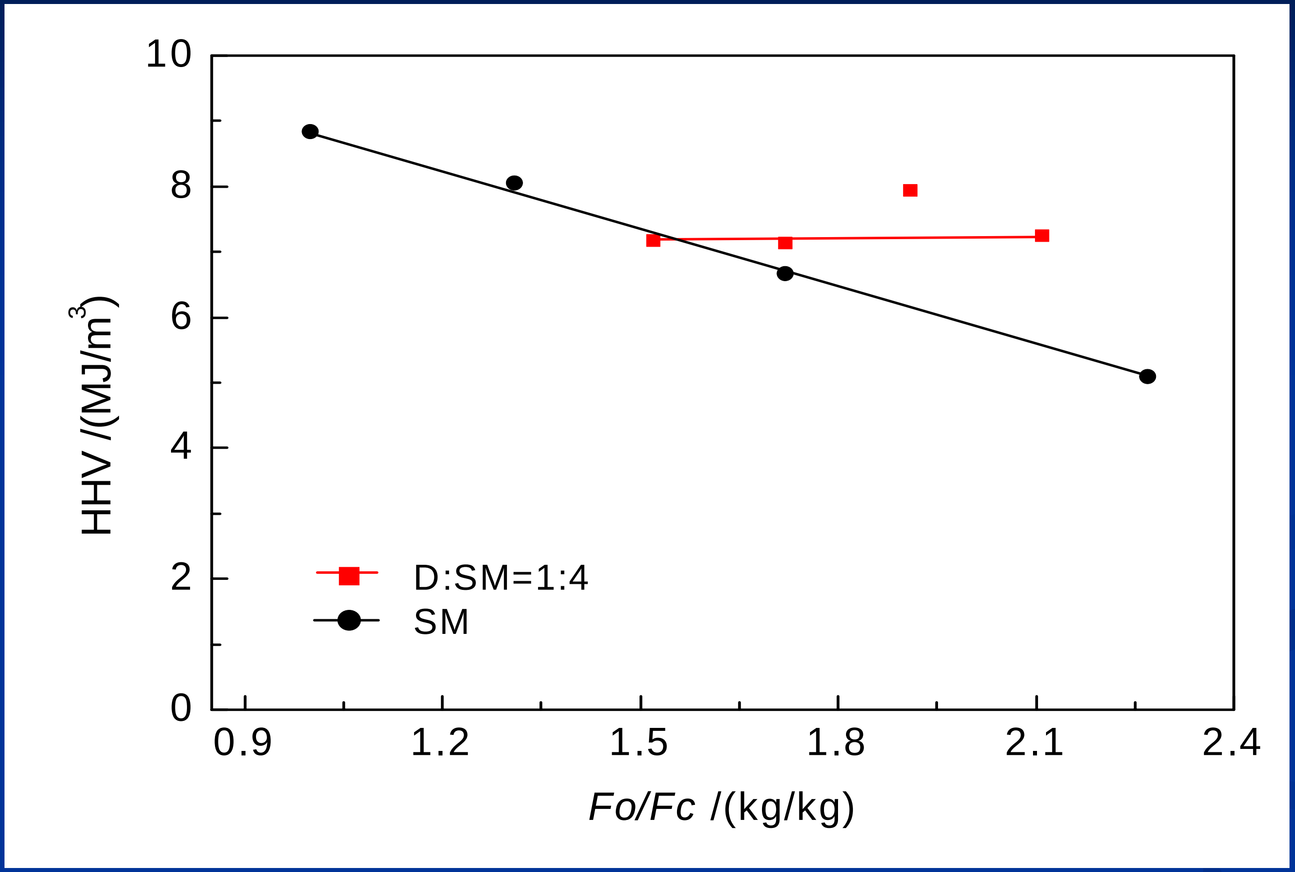
CH4 content varying with O2/carbon

Experimental results



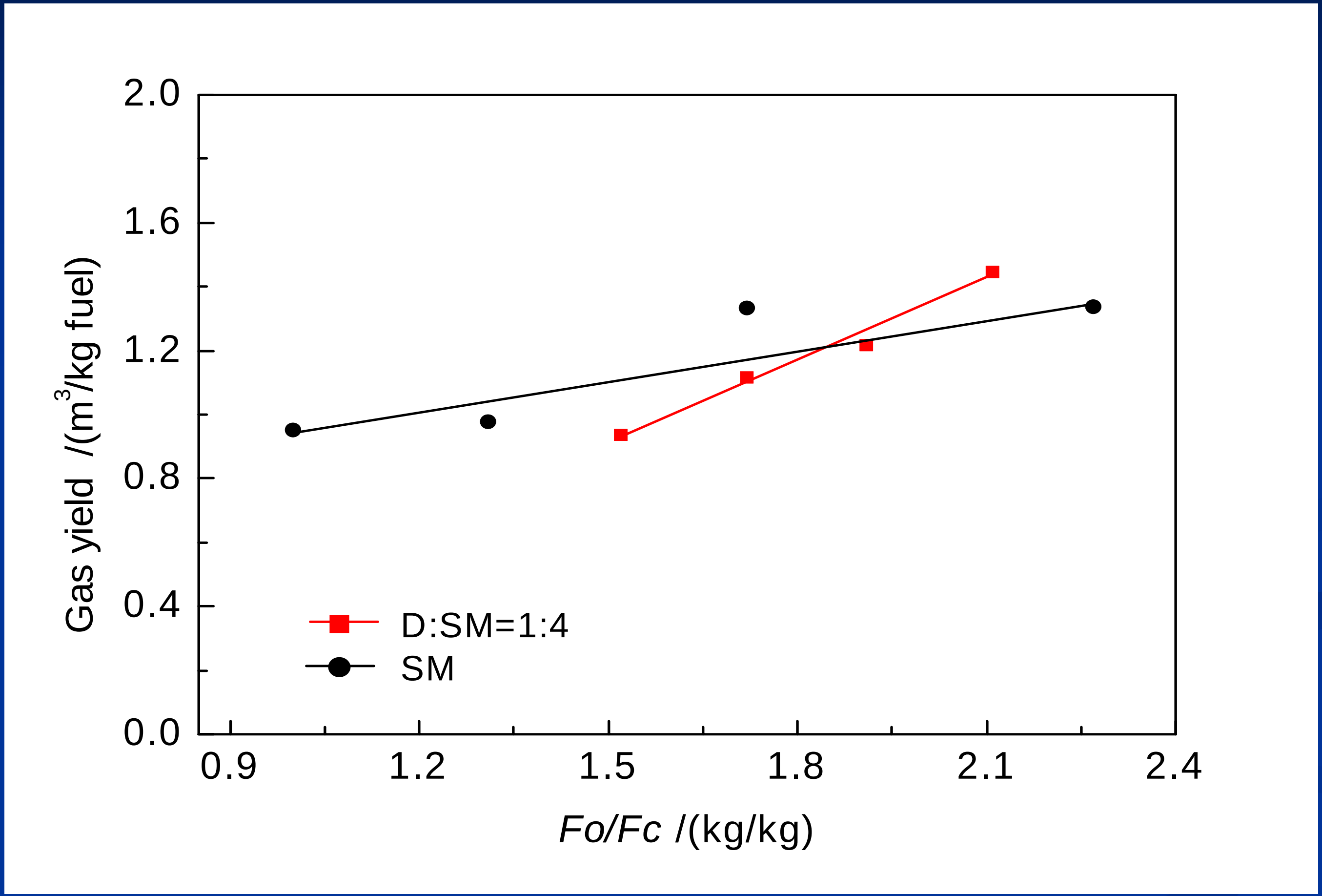
Carbon conversion varying with O2/carbon

Experimental results



Gas heat value varying with O2/carbon

Experimental results



Gas yield varying with O2/carbon

Conclusion

1. Mixing particles of biomass and coal can be well

   fluidized only when biomass fraction is less than 50%.

   Umf of mixing particles can be calculated by Ergun equation.

2. Various biomass has higher gasification rate than coal. Co-gasification rate can be described by one order kinetics equation.

3. Co-gasification has higher efficiency than sole coal gasification.