中国科学院
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The 3rd International Workshop on Oxyfuel-FBC Technology

Study of oxy-fuel CFB combustion at high oxygen concentrations at IET-CAS

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Background

- Oxy-fuel CFB is a promising CCS technology in China.
- The total power capacity of CFB boiler is more than 10% of total Chinese coal fire power installation.
- IET-CAS has researched CFB combustion for nearly 30 years.

Main advantages of oxy-fuel CFB combustion

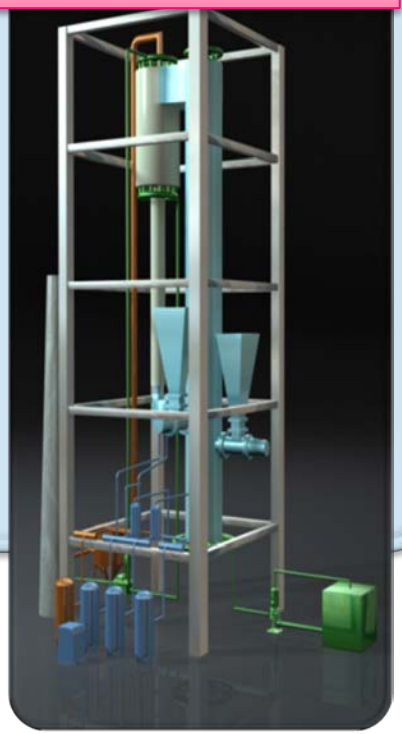
- Efficient heat transfer and uniform heat flux.
- The established CFB advantages also exist in oxy-fuel CFB combustion: low furnace temperatures, hot circulating solids, long solid residence time, etc.
- Reduce boiler size (~50%) using high O_2 concentration.
- Multi-fuel capability (coal, petroleum coke, biomass).
- NOx and SOx reduction without back-end cleaning.
- Good fuel burnout and sorbent utilization.
- The same boiler can be operated in air combustion or oxygen combustion mode with CCS .

Oxy-fuel CFB activities at IET-CAS

- **Work on oxy-fuel CFB combustion at high oxygen concentrations within the frame of the CAS "Strategic Priority Research Program" Demonstration of Key Technologies for Clean and Efficient Utilization of Low-rank Coal (funded by Ministry of Science and Technology of the People's Republic of China, 2013-2016)**
  - Oxy-fuel circulating fluidized bed combustion technology
- **Main research of IET-CAS**
  - Build the test facilities for different scale: from bench scale to pilot plant
  - Study of combustion characteristics, operational strategies, heat transfer, hydrodynamics of solid circulation, pollutant formation and control, ash characteristics at high oxygen concentration (up to 55%)

Oxy-fuel CFB test facilities at IET-CAS

2014, Commissioning



Bench-scale
BFBC 100mm

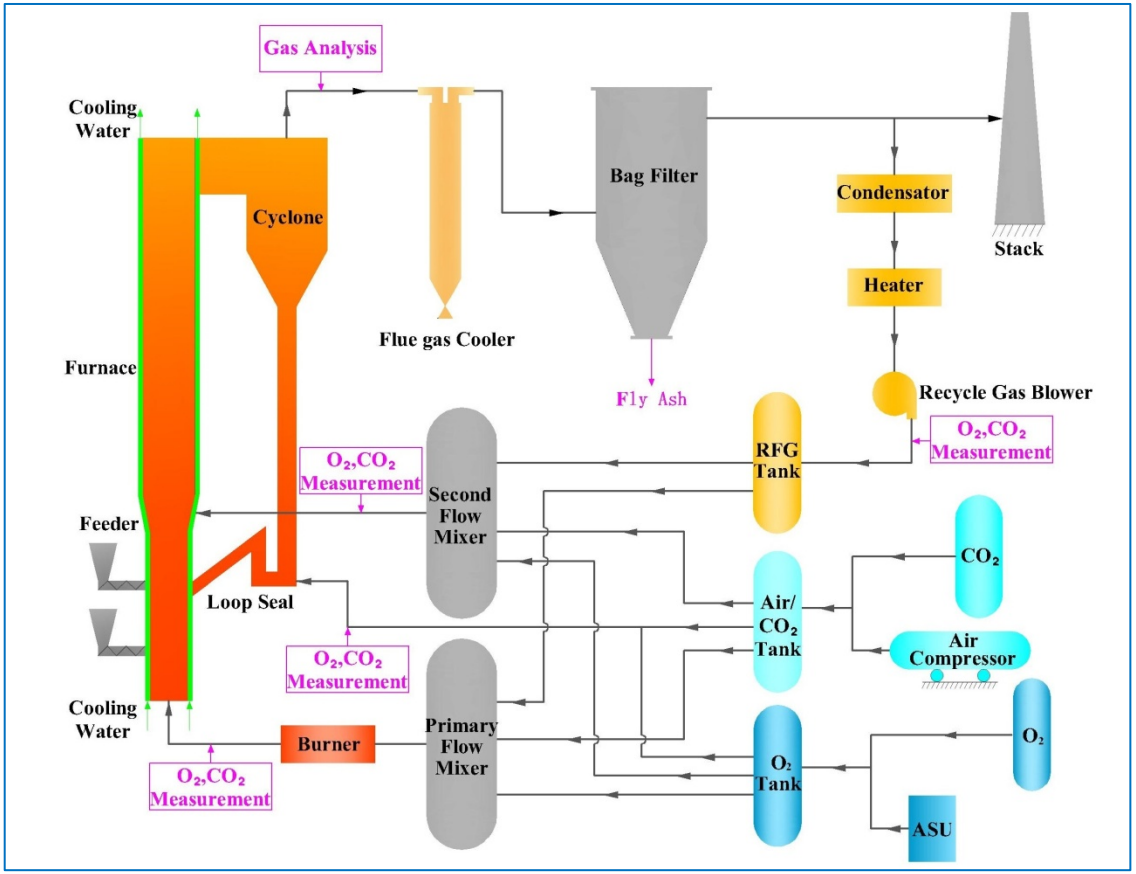
Bench-scale
CFBC 100mm 30-50kW
O_2: 21-50%

Bench-scale
CFBC 140mm 0.1MW
O_2: 35-55%

Pilot Plant
CFBC 420mm 1MW
O_2: 21-50%

Scale-up

0.1 MWth Oxy-CFBC test facility

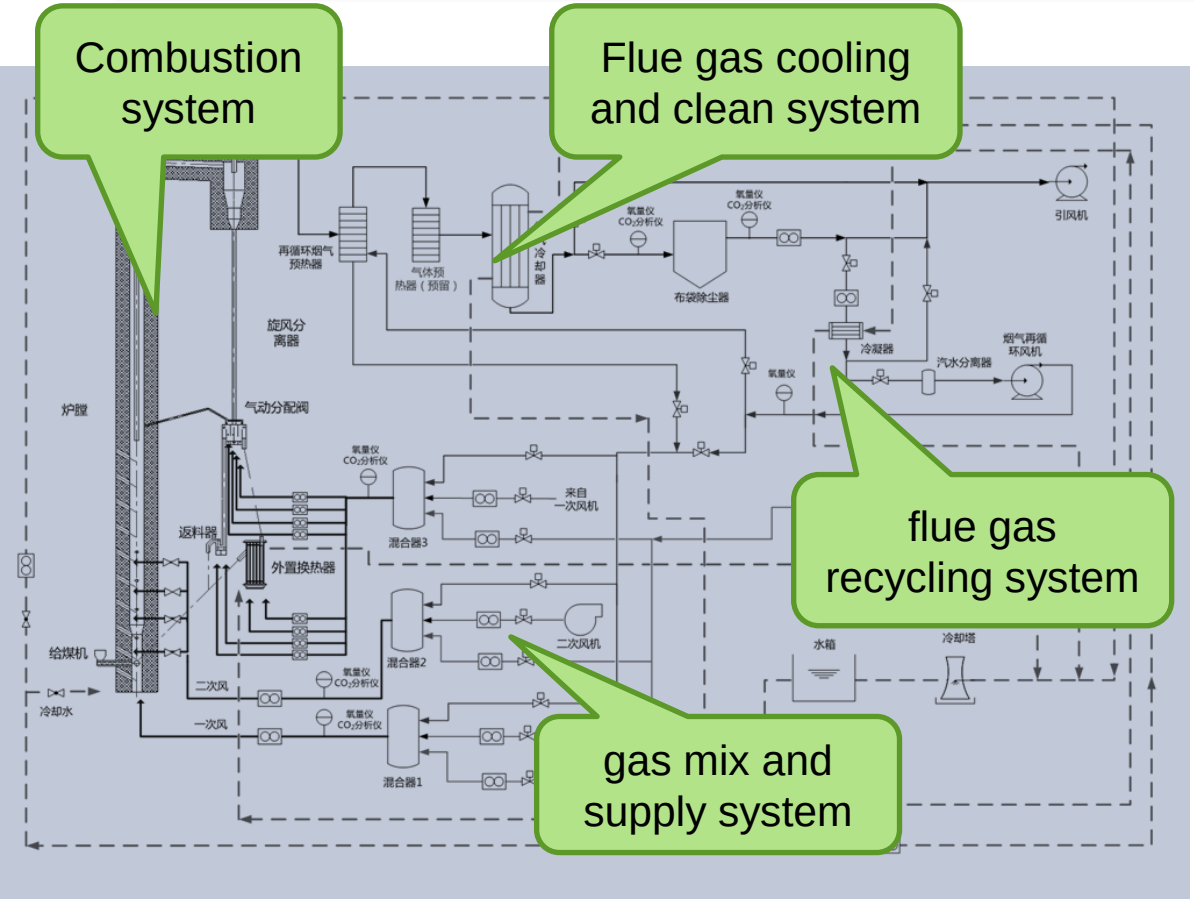


Schematic diagram of 0.1 MWth Oxy-CFBC test facility

- It was built in 2010 and retrofitted to use recycled flue gas (RFG) in 2012
- Height: 6 m
- Diameter: 100 mm,140 mm
- Water cooling tubes embed in the Refractory material to cool the furnace
- Input thermal power: 0.1-0.15MW
- Total O_2 concentration: 35-55%
- O_2 source：Air separate unit and liquid O_2 tank

1 MWth pilot scale oxy-CFBC facility

- Current status: Under construction
- Commissioning: June, 2014



Schematic diagram of 1 MWth pilot plant Oxy-CFBC test facility

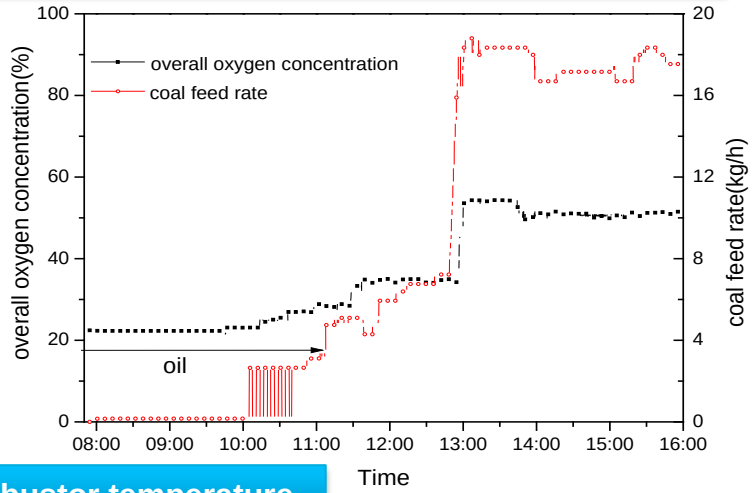
Technical data:

- Height: 15 m
- Temperature: up to 950°C
- Total O_2 concentration: 21%-50%
- External Heat Exchanger (EHE) and bayonet exchanger
- Oxygen/flue gas staging: primary, secondary, tertiary injection

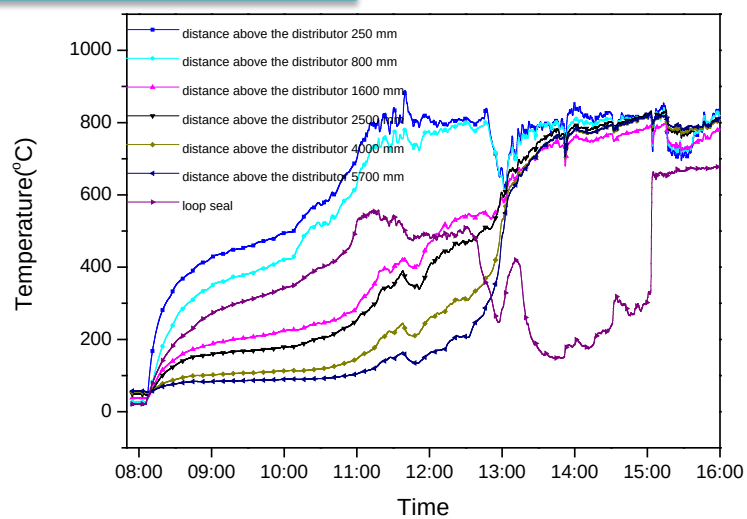
Study of oxy-fuel coal combustion in a 0.1 MWth Oxy-CFBC at high oxygen concentrations

Start-up stage

Overall O_2 concentration of inlet gas and coal feed

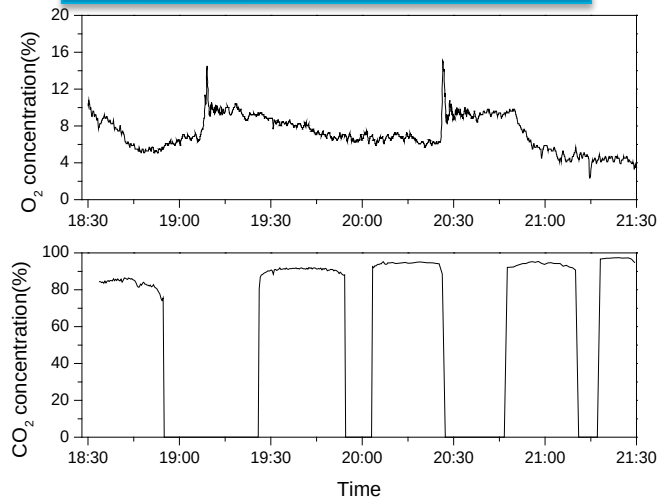


Combustor temperature

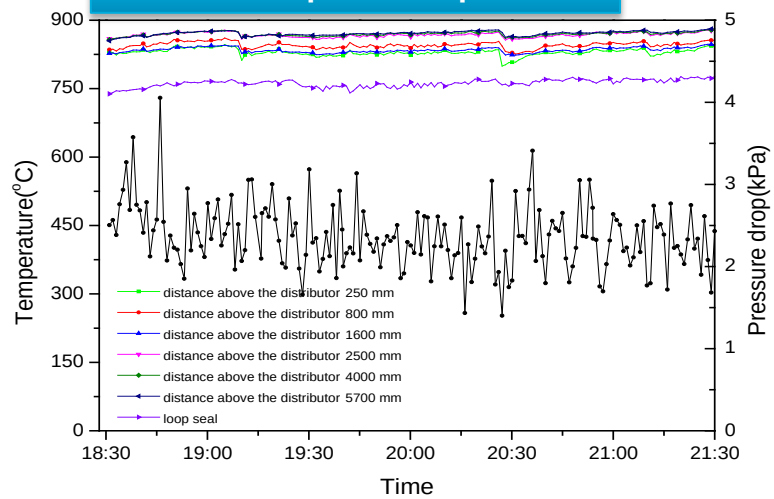


O_2/RFG-mode operation

CO_2 and O_2 concentrations



Pressure drop and temperature



Study of oxy-fuel coal combustion in a 0.1 MWth Oxy-CFBC at high oxygen concentrations

Experimental conditions

Condition	1	2	3	4	5	6	7	8
Combustion mode	O_2/ RFG				O_2/CO_2		O_2/N_2	
Average combustor temperature (°C)	850	852	851	856	850	863	850	852
O_2 source	ASU	LOT	LOT	LOT	ASU	LOT	ASU	ASU
O_2 purity (%)	79.1	99.9	99.9	99.9	79.0	99.9	94.9	90.1
Primary O_2 concentration (%)	49.5	56.7	55.2	55.3	46.6	50.0	52.2	50.1
Secondary O_2 concentration (%)	45.3	51.5	51.7	51.1	46.2	50.1	51.7	49.9
Overall O_2 concentration (%)	48.0	54.6	53.8	53.6	46.4	50.0	52.0	50.1
Ca/S	0	2.2	2.6	3	0	2.2	0	2.2
Flue-gas recycle ratio (%)	37.5	47.3	48.0	49.2	—	-—	—	—
Flue-gas O_2 concentration (%)	1.1	7.51	7.2	5.9	4.3	7.45	5.3	6.57
RFG O_2 concentration (%)	2.1	7.28	6.7	5.9	—	—	—	—
CO_2 in flue gas (dry vol%)	67.1	84.1	92.2	93.9	84.1	91.0	44.4	43.3
Fuel (kg/h)	17.8	17.9	17.9	18.2	17.2	16.5	16.8	17.3
Fluidization velocity at upper part (m/s)	3.5	3.2	3.3	3.3	3.6	3.32	3.6	3.4
Fluidization velocity at lower part (m/s)	4.5	3.9	3.9	3.9	4.3	3.93	4.4	4.0
CO (mg/MJ)	803.4	92.2	71.2	99.6	166.6	43.7	104.7	164.5
NO (mg/MJ)	19.0	21.3	19.4	15.9	36.0	38.0	42.0	41.5
SO_2 (mg/MJ)	197.0	227.6	159.0	118.8	87.0	52.2	231.0	51.1
Sulfur capture efficiency (%)	70.7	70.2	79.7	83.9	80.1	92.6	71.6	93.7

Effect of operation parameters on pollutant emission at O_2/CO_2 fire mode

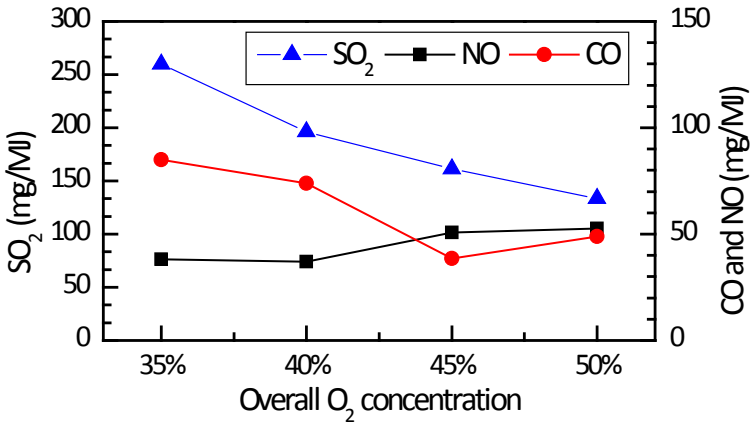
- The experiments were conducted in 0.1MWth Oxy-CFBC facility.
- The objective is to obtain the data at different operation parameters and evaluate the effect on combustion and emission.

Operation parameters:

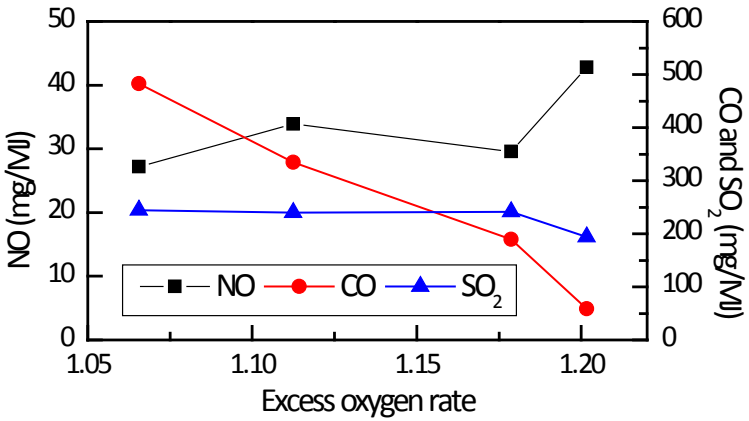
- Combustion temperature: 800℃, 850 ℃, 900 ℃
- Overall O_2 concentration: 35%, 40%, 45%, 50%
- O_2 concentration in primary gas: 30%~55%
- excess oxygen/ O_2 concentration in flue gas: 3-8.5%
- Gas staging

Effect of operation parameters on pollutant emission at O_2/CO_2 fire mode

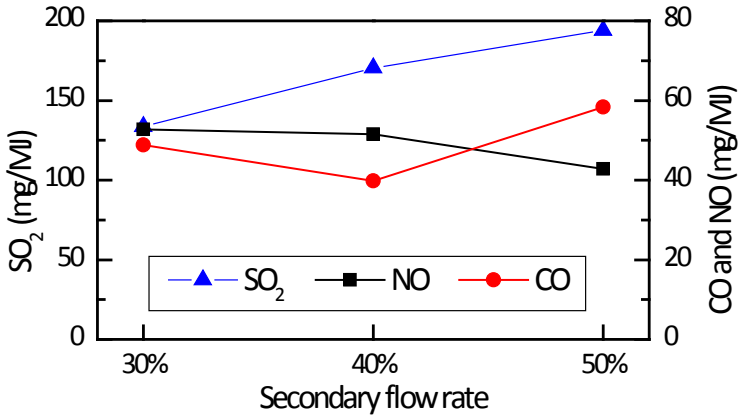
Effect of overall O_2 concentration



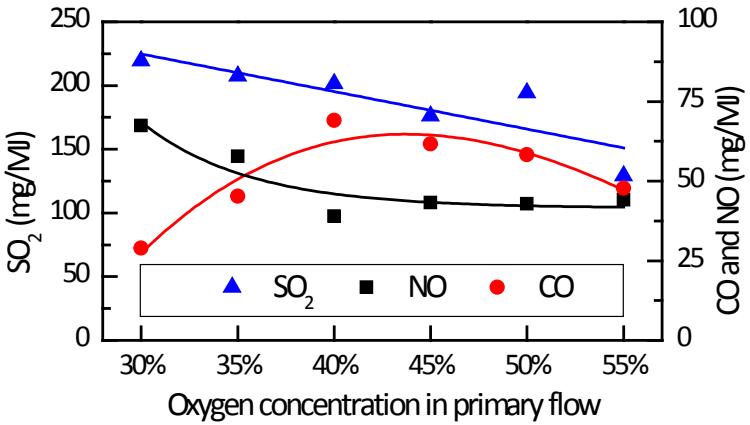
Effect of excess oxygen rate



Effect of gas staging



Effect of oxygen staging



TGA study of oxy-fuel combustion of coal/biomass blends

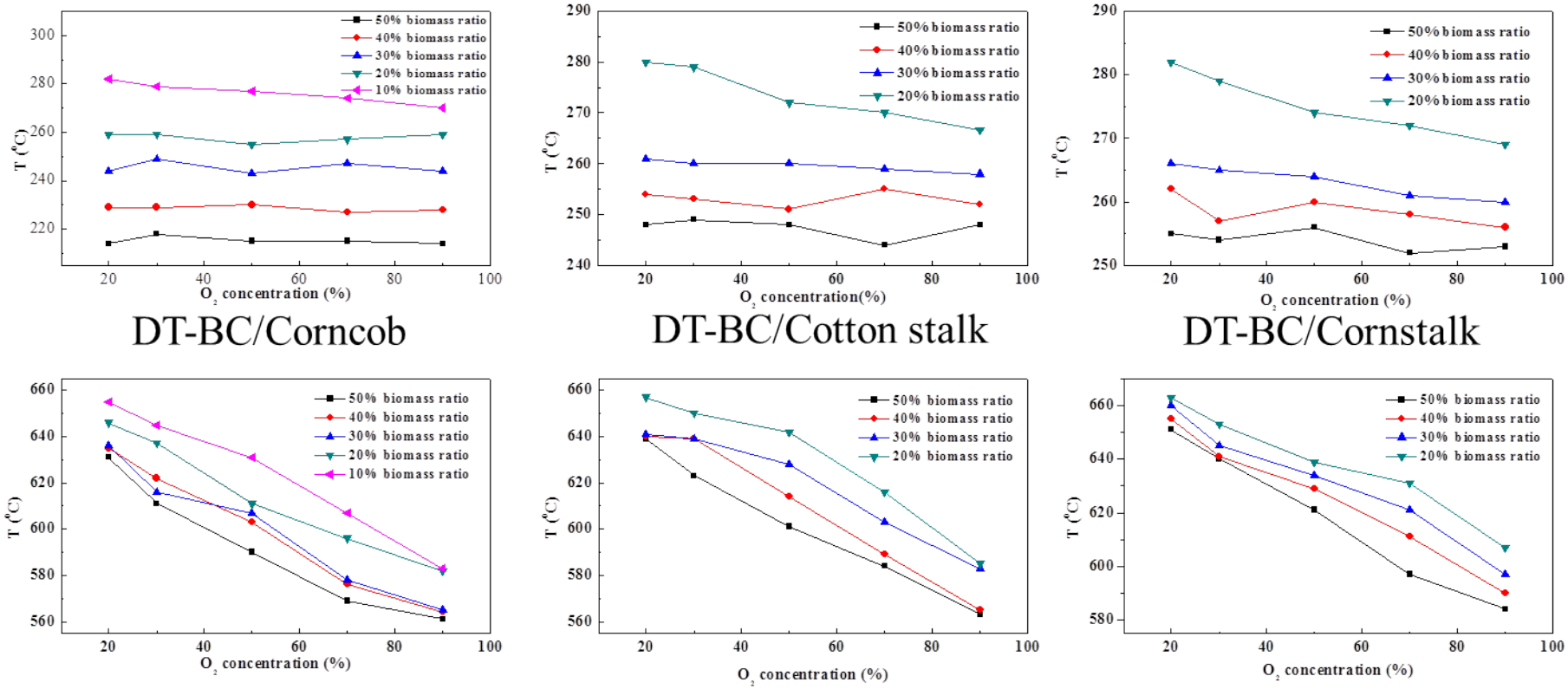
- TGA well established tool for predicting apparent activation energy of combustion of coal/biomass blends.
- Experiment designed to obtain data that can be analyzed in wide variety of ways.

Experiment conditions

Coal	Biomass	Biomass ratio	Atmosphere
An semi-coke(SE) Two anthracites(AN) Two bituminous coals(BC) Two lignites(LI)	cornstalk corncob cotton stalk wheat-straw rice straw rice husk furfural-residue	10% 20% 30% 40% 50%	$20\%O_2/80\%N_2$ $20\%O_2/80\%CO_2$ $30\%O_2/70\%CO_2$ $50\%O_2/50\%CO_2$ $70\%O_2/30\%CO_2$ $90\%O_2/10\%CO_2$ $100\%O_2$

TGA study of oxy-fuel combustion of coal/biomass blends

Experiment results – Ignition & burnout



- While biomass ratio below a certain proportion, the ignition temperature of blend decreases obviously with the increase of oxygen concentration.
- It is related with the level of volatiles content and ash content in biomass.

Conclusion/Future work

- Oxy-fuel combustion experiments employing high oxygen concentrations under various gaseous atmospheres were successfully carried out at the IET-CAS facility using the 0.1 MWth oxy-fuel CFBC unit.
- The total experimental oxygen concentration used was in the range of 46.4–54.6%, while oxygen concentration of the primary gas was in the range of 46.6–56.7%. It has been shown that this facility operates reliably in a high-concentration oxy-fuel mode and is able to produce flue gas highly concentrated in CO_2 (93.9%).
- The project is supported by Chinese Academy of Sciences from 2013 to 2016.The important study of this project is the building of MWth pilot plant oxy-CFBC facility which can test at high oxygen concentration (up to 50%).
- The current status of 1 MWth pilot scale oxy-CFBC facility is under construction. The commissioning will start on June, 2014.

THANK YOU FOR YOUR ATTENTION !

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