DESIGN AND OPERATION OF 127MW CFB BIOMASS BOILER IN THAILAND

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Abstract – Biomass fuel is one kind of typical sustainable fuel which is supposed to replace fossil fuel in the future. CFB boiler is an ideal tool to make use of biomass due to fuel flexibility and high combustion efficiency. A major challenge when firing biomass fuel is the inhomogeneous quality of the fuel, which makes it difficult to maintain constant combustion conditions and low emissions. Meanwhile the low ash softening/melting points may cause sintering of bed material, and chlorine content will bring about high temperature corrosion. This paper introduces the design and operation of the 127MWe CFB biomass boiler in Thailand. The 384t/h boiler is of once reheat, natural circulation, single drum, with full membrane water wall structure. The design fuel of the biomass CFB boiler is the mixture of 8.04% rice husk, 8.04% wood bark, 82.60% wood chip and 1.31% sand. The LHV of design fuel is 9731 KJ/kg. Biomass fuel particles should be smaller than 50mm. The design value of fuel consumption is 133.9t/h. The design main steam pressure is 13.83Mpa, and the design main steam temperature is 540℃. The operation parameters nearly meets the design value. The problems and solutions during trial test are also introduced.

Keywords – CFB boiler, biomass, design, operation

INTRODUCTION

Circulating fluidized bed combustion technology is well known for its fuel flexibility, low emission and high combustion efficiency. One trend of the CFB boiler development according to Yue (2009) is to increase the main steam parameters to improve the power supply efficiency. And another one according to Zabetta (2013) is to improve the boiler ability of firing non-conventional fuels, such as biomass. With the increase of coal price, firing biomass fuel for power supply looks reasonable; at the same time, substitution of fossil C by biomass C can reduce CO_2 emission. According to Yifu (2009), the total global biomass power installed capacity reached 39 GW in 2004, and the annual energy generation achieved was approximately 200 billion kWh. Biomass can be classified into four major categories, according to its source, i.e., woody, agricultural, waste, and excrement. Among these, woody biomass is the largest biomass energy source; it covers forest residues (e.g., dead trees, branches and tree stumps, leaves), landscaping residues (yard clippings), industrial wood residue (wood chips, sawdust, etc.), waste wood residues, and so on.

There are some possible problems when firing biomass fuel. A major challenge according to Montgomery (2002) is the inhomogeneous quality of the fuel, including large variations in calorific value, moisture content, particle size, etc. This makes it difficult to maintain constant combustion conditions and low emissions. Another challenge of biomass combustion according to Miettinen (2003) is the high levels of alkali metals and chlorine, which are known to limit the steam data in order to avoid corrosion problems. High moisture content can contribute to the corrosion process as well, as pointed out by Regina (2004). Because of the risk for corrosion problems, the steam data in biomass-fired boilers are kept comparatively low, resulting in lower power efficiency (approximately 10% lower than that for coal-fired boilers). Considering its fuel flexibility and high combustion efficiency, CFB boiler is an ideal tool to make use of biomass, either alone or co-fired with coal. This paper only focused on pure biomass combustion. So far there are some successful operating biomass CFB boilers in several countries. In Sweden, there is a 35MWe CFB boiler burning wood biomass reported by Davidsson (2007), with the main steam flow rate at 154t/h and main steam temperature at 540℃. The largest biomass CFB boiler all over the world is Polaniec 205MWe CFB boiler reported by Natunen (2013). The boiler burns wood chips and agro biomass, with the main steam flow rate at 569t/h and main steam temperature at 535℃.

This paper introduces the design and operation of 127MWe CFB biomass boiler in Thailand, which is designed by Research Center of Clean Coal Tech, Tsinghua University and manufactured by Harbin Boiler Co. Ltd., China. The basic structure and main parts of the boiler are introduced. The biomass fuel characteristics are described and the operation experience is discussed.

BOILER STRUCTURE

The schematic structure of the 127MWe CFB biomass boiler in Thailand is shown in Fig.1. The 384t/h reheat CFB boiler comprises furnace, cyclone, loopseal and backpass. The boiler is of once reheat, natural circulation, single drum, with full membrane water wall structure. Combustion and desulfurization are finished in furnace. The flue gas carrying solid materials enters two cyclone separators. The cyclone inlet declinates a little, so that the flue gas carrying solid materials moves downward, which leads to a high separation efficiency. The clean flue gas after cyclone enters the backpass, superheater, reheater, economizer and air preheater in turn. The ash captured by cyclone goes back to furnace through loopseal to burn and desulfurize again. The specially designed loopseal has a higher flow rate, so less high pressure air is needed. There is an auto balance inside the loopseal without ash flowing back.

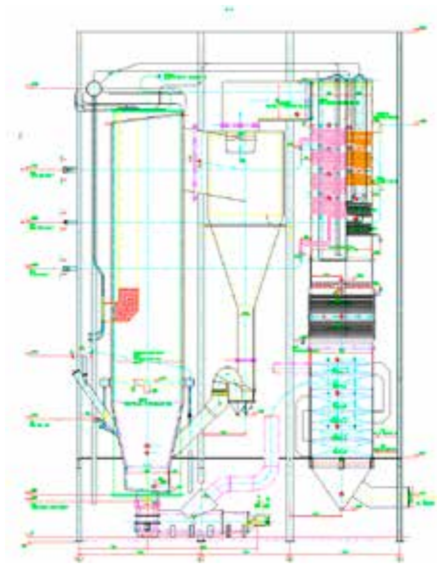


Fig. 1. Layout of the 127MWe biomass CFB boiler

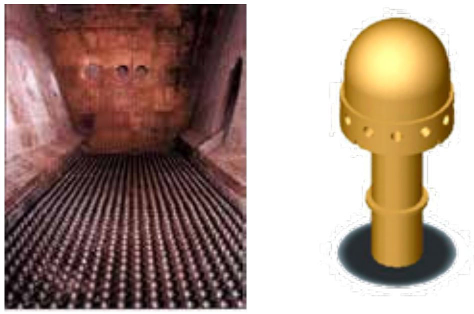
The furnace roof uses the anti-erosion structure. The coal inject tube and secondary air injection has direct seal structure and manufactured in factory. The systemic anti erosion measures and kick out tube are adopted to avoid erosion. The tube of water wall is of 60mm diameter, with a 90mm pitch. A separation water wall is located in the furnace center as evaporator. The primary and secondary superheater are equipped in the upper part of the furnace. Two thermal insulation cyclones with 8,100mm inner diameter are located between the furnace and the backpass. In the backpass there are final superheater and reheater, surrounded with a steam-cooled membrane cage. Below the cage is the economizer.

There are six fuel feed points in the front wall of the furnace with fuel spread air. Six fuel feeders are located outside the furnace, connected with storage bunker and fuel chute. In fact four feeders are enough for the fuel supply. Considering the possibility of feeder repairing and fuel change, two of the six are against emergencies. Since the density of biomass particle is small, the gauge pressure at feeding position should be negative. Therefore it is necessary to choose exhaust fan carefully.

The primary air is injected through nozzles below the dense bed. Four light-oil fired start-up burners are located in the primary air duct. The secondary air is injected above the dense bed to ensure good mixing, low NOx emission and burnout. The total combustion air flow is 140.56kg/s (506t/h). And the excess air ratio is about 1.20. The location of secondary air inlets shows a centralized arrangement. Less nozzles were used to get a higher momentum of secondary air, in order to improve the combustion efficiency.

There is a risk for ash problem in secondary pass. Thus the gas velocity in the secondary pass is specially designed to decrease the ash fixed on the heating surface. What is more, some soot blower were adopted to ensure the heating surface performance.

The distributor and the primary wind box are also equipped with water wall. The water cooling distributor consists of membrane tube platen and wind nozzle. The air nozzle has similar structure as bell jar nozzle, while, in order to avoid drawback such as the heavy erosion, high resistance and difficult replacement, it has some special features, such as reasonable diameter of nozzle cap, diameter of hole and easy replacement jacket tube. Because the velocity in holes is reasonable, the erosion is reducing. After certain period, the jacket tube and nozzle cap can easily be replaced. This can greatly reduce the cost of maintenance. The distributor and the nozzle are shown in Fig.2.



(a) (b)

Fig. 2 appearance of the distributor and the nozzle.

The water and steam system includes economizer, drum, water wall, superheater and reheater, which are shown in Fig.3. The water and steam system is consist of water supply system, main circulating system, SH steam system and RH steam system. In the water supply system, the feed water is heated from 238 ℃ to 287 ℃ in primary and secondary economizer, and then sent into drum. At start-up, the two valves on the pipes are switched on so that there is a natural circulation between economizer and drum; the valves are switched off when the boiler has enough water for work. In the SH steam system, SH steam passes in turn the partition wall superheater, primary platen superheater, primary desuperheater, secondary platen superheater, secondary desuperheater, final superheater and main steam outlet, and finally comes to 540 ℃.

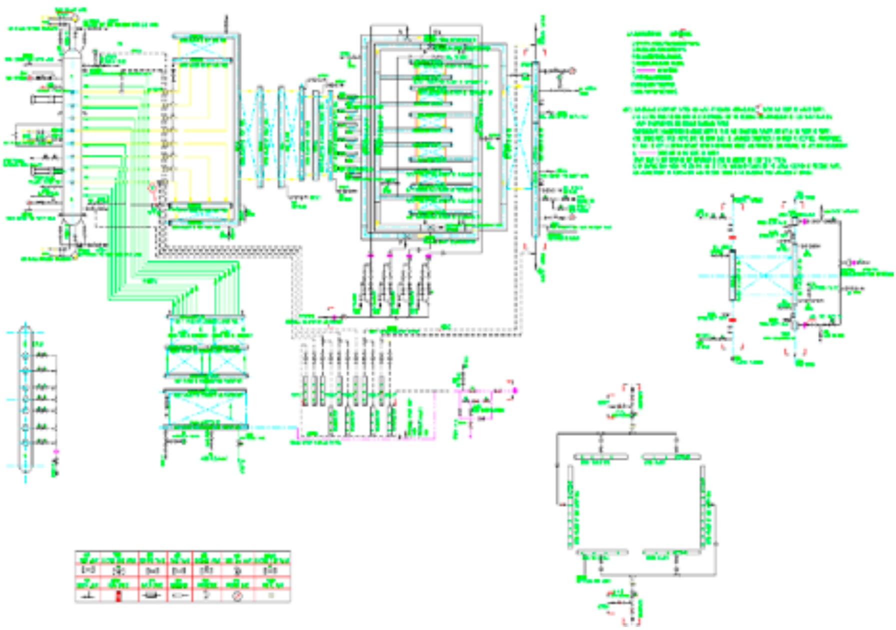


Fig. 3 Water and steam system.

DESIGN FUEL

The design fuel of the biomass CFB boiler is the mixture of 8.04% rice husk, 8.04% wood bark, 82.60% wood chip and 1.32% sand. The fuel analysis results are shown in Table 1. The design biomass fuel is characterized by a relatively high volatile matter content (36.80%) and a low ash content (2.92%). Meanwhile, the fuel has a high content of Oxygen and Moisture. The former means larger potential for alkali oxides formation, while the latter means more chance for corrosion. The LHV is 9731 KJ/kg. Biomass fuel particles should be smaller than 50mm before fed into the furnace. The design value of fuel consumption is 133.9t/h, while the makeup sand consumption is 1.76t/h.

Table.1: Fuel analysis.

Content			Rice Husk	Wood Bark	Wood Chip	sand	Design fuel (mixing)
Percentage			8.04%	8.04%	82.60%	1.32%	100.00%
Analysis		Unit					
Carbon	Car	%	37.51	22.35	29.01	0.00	28.78
Hydrogen	Har	%	3.83	1.80	2.70	0.00	2.68
Oxygen	Oar	%	34.08	21.01	26.01	0.00	25.91
Nitrogen	Nar	%	0.29	0.15	0.07	0.00	0.09
Sulfur	Sar	%	0.03	0.01	0.01	0.00	0.01
Ash	Aar	%	13.52	2.53	0.38	100.00	2.92
Moisture	Mar	%	10.74	52.14	41.82	0.00	39.60
Volatile	Vdaf	%	60.89	37.61	34.96	0.00	36.80
LHV	Qnet.v.ar	KJ/kg	13917	6845	9759	0	9731.24

LIMESTONE CONTENT

Limestone is used for desulfurization and de-HCI in the furnace. Limestone is injected into furnace by secondary air nozzles. The content of limestone is shown in Table 2.

Table.2 Content of limestone.

content	unit	value
CaCO3	%	92.0
MgCO3	%	0.43
H2O	%	0.15
Else	%	7.42

Limestone particle diameter is supposed to be smaller than 1mm. The design value of limestone consumption is 0.1t/h. According to the fuel consumption, it can be inferred that the Ca/S ratio is about 2.9. In CFB boiler, the desulfurization reaction is diffusion-dominated, so too big particle diameter is not good for limestone utilization. On the other hand, if particle diameter is too small, the residence time in the furnace is short, so the desulfurization performance will be bad. Therefore, the limestone particle diameter should be in a special recommended range between two curves, which is shown in Fig.3.

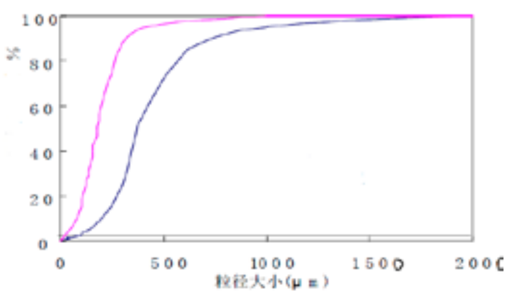


Fig. 3 Limestone diameter range.

DESIGN PARAMETERS

The main design parameters of the boiler are shown in Table 3.

Table.3 Design parameters of the 127MWe biomass CFB boiler.

	unit	B-MCR
Main steam flow	**t/h**	**384**
SH steam pressure outlet	**MPa**	**13.83**
SH steam temperature	**℃**	**540**
RH steam flow	**t/h**	**354.64**
RH steam pressure inlet/outlet	**MPa**	**2.419/2.219**
RH steam temperature inlet/outlet	**℃**	**311.90/540**
Feed water temperature	**℃**	**238.10**

OPERATION STATUS

The operation parameters of the boiler during trial test are shown in Table 4.

Table.4 Operation parameters of the 127MWe biomass CFB boiler in trial test.

	unit	Test 1	Test 2	Test 3
Load	**MWe**	**106.40**	**115.37**	**126.82**
Main steam flow	**t/h**	**364.3**	**361.7**	**378.6**
Main steam pressure outlet	**MPa**	**8.78**	**12.03**	**12.03**
Main steam temperature	**℃**	**537.8**	**535.3**	**536.0**
RH steam pressure outlet	**MPa**	**1.8**	**1.9**	**2.1**
RH steam temperature outlet	**℃**	**559.4**	**524.7**	**528.9**
Feed water flow	**t/h**	**350.4**	**357.3**	**360.6**

Basically, the boiler performance is steady, and the main parameters are supposed to meet the design requirements. But there are still some problems as following.

The RH steam temperature at outlet (559℃) in test 1 is higher than design value (540℃). That is because the RH steam temperature at inlet (338℃) is higher than design value (308℃). The first solution is to adopt valve to increase the pressure drop between water feeding pump and reheater as well as superheater. The second step is to modify the water cooling system.

The exhaust gas temperature comes to a high value as 175℃. That is because the shock wave sootblower does not work well, so the accumulated ash influences the performance of heating plane. The solution is to modify the sootblower, and add water cooling pipe for air preheater if necessary.

The main steam temperature should be a little smaller than design value, considering the low ash melting point.

CONCLUSIONS

The 127MWe CFB biomass boiler in Thailand is introduced in this paper. Details about boiler structure, key equipment, fuel characteristics, and limestone content are given. Design parameters and operation parameters are listed and compared. Basically, the boiler is supposed to meet the design requirements. Some problems and the solution in operation are discussed. The RH steam temperature is higher than design, so it is necessary to modify the water cooling system for superheater. The exhaust gas temperature is too high, therefore sootblower should be checked to guarantee the performance of heating plane.

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