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# Effect of large Scale of Coal-fired Units Directly Coupled to Biomass Power Generation on some Boiler Parameters

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## ABSTRACT

In order to reduce carbon dioxide emissions in the environment while improving the efficiency of biomass utilization, the use of coal-fired units coupled with biomass power generation is one of the important ways to achieve carbon reduction in coal-fired units in the future. In this paper, thermal calculations and analysis of a 300 MW power plant are studied based on the law of conservation of energy. The effects of coal-fired units on boiler parameters when blended with different types and proportions of biomass are investigated at BMCR, 75% THA, 50% THA and 30% THA loads, and corresponding improvement suggestions are given.

**Keywords:** coal-fired boiler; biomass; direct coupled power generation

## 1. INTRODUCTION

Biomass, as a renewable zero carbon emission fuel, has a unique advantage in carbon emission reduction. However, due to the low calorific value, scattered distribution, difficult collection and seasonality of biomass, the utilization of biomass in China is still based on direct return of straw, composting and direct combustion of small units, and the technology level is relatively low. How to take advantage of the high efficiency and environmental protection of existing large coal-fired units through coupled biomass power generation to significantly reduce their carbon emissions is a hot concern for power workers at present.

Sun et al. [1-8] simulated the combustion and environmental characteristics of different biomass gases coupled with various coal-fired power plant boilers. Wang et al. [9-10] analyzed the effect of biomass gas characteristics on the exhaust temperature, desuperheated water volume, and thermal efficiency of coupled generating units.

Although many previous studies have been conducted on biomass coupled power generation, most of the existing studies have focused on mixed combustion characteristics [11-13], post-gasification coupled power generation and small-scale direct coupled power generation, and fewer studies have been conducted on large-scale direct coupled biomass power generation for coal-fired units. This paper presents a systematic analysis of large scale direct-coupled biomass power generation in coal-fired power stations and analyzes the impact of large scale direct-coupled biomass power generation on some boiler parameters to provide a basis for promoting the design of coupled biomass generating units.

## 2. CALCULATION OF BASIC PARAMETERS

### *2.1 Unit overview*

Starting from the characteristics of low calorific value of biomass, high dispersion, and limited collection and storage radius, 300 MW coal-fired unit is a more realistic choice for coupled biomass power generation. Therefore, a typical 300 MW unit is selected for calculation and analysis in this paper, with a conventional Π-type arrangement of the boiler, a positive pressure direct blowing pulverizing system and a four-corner tangent circle combustion method, which allows the burner to swing up and down by 30° considering the more combustible characteristics of biomass, and the unit is equipped with a subcritical, primary intermediate reheat, single-shaft, two-cylinder, double-exhaust, reaction, condensing turbine, and the rest of the design parameters are shown in Ref [14].

### *2.2 Design coal and biomass parameters*

Calculation of coal quality selected from the actual combustion coal, biomass selected from four typical biomass, the specific parameters are shown in Table 1 and Table 2.

Tables 1 and 2 show the coal properties and several operating parameters according to actual operation.

Table 1 Coal properties

| Ingredients | Count | Ingredients | Count |
|---|---|---|---|
| $w_{ar}(C)$/% | 50.25 | $w_{ar}(Cl)$/% | 0.005 |
| $w_{ar}(H)$/% | 3.08 | $w_{ar}(A)$/% | 34.56 |
| $w_{ar}(O)$/% | 4.25 | $w_{ar}(M)$/% | 6.0 |
| $w_{ar}(N)$/% | 0.93 | $w_{daf}(V)$/% | 27.87 |
| $w_{t,ar}(S)$/% | 0.93 | $Q_{net,ar}/(kJ \cdot kg^{-1})$ | 19 230 |

Table 2 Coal properties

| Ingredients | corn straw （YM） | wheat straw （XM） | peanut shells （HSK） | larch （SM） |
|---|---|---|---|---|
| $w_{ar}(C)$/% | 34.28 | 40.43 | 43.53 | 48.89 |
| $w_{ar}(H)$/% | 3.36 | 5.06 | 6.54 | 6.19 |
| $w_{ar}(O)$/% | 35.31 | 36.80 | 34.04 | 36.07 |
| $w_{ar}(N)$/% | 0.343 | 0.81 | 2.24 | 0.12 |
| $w_{t,ar}(S)$/% | 0.093 | 0.22 | 0.12 | 0.09 |
| $w_{ar}(Cl)$/% | 0.001 | 0.08 | 0.003 | 0.002 |
| $w_{ar}(A)$/% | 19.414 | 9.6 | 8.84 | 7.63 |
| $w_{ar}(M)$/% | 7.20 | 7.0 | 4.69 | 1.01 |
| $w_{daf}(V)$/% | 82.15 | 81.27 | 78.0 | 75.0 |
| $Q_{net,ar}/(kJ \cdot kg^{-1})$ | 13 680 | 14 730 | 16 280 | 16 829 |

### *2.3 Calculation method*

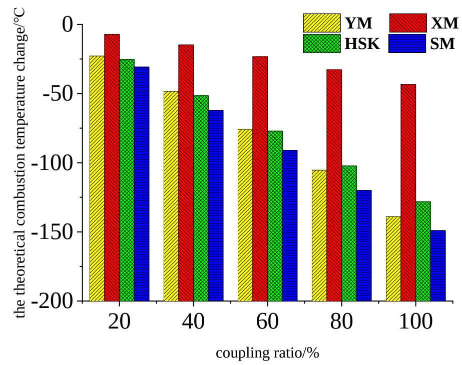
In this calculation, the boiler thermal calculation calibration software developed by the group of Professor Che Defu of Xi'an Jiaotong University was used, and the accuracy of this software was verified by several engineering examples (boiler capacity of 75 to 2,955 t/h) in major boiler plants. The calculation requires the conversion of raw coal and biomass into new fuel according to the blending mass ratio, and the specific calculation process is described in the literature [15].

## 3. RESULTS AND DISCUSSION

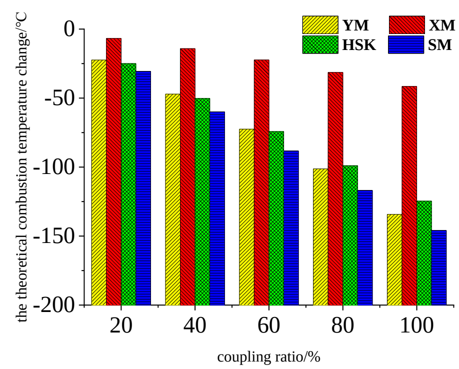
Boiler thermal calibration calculations were performed for units blended with various mass ratios of biomass at BMCR, 75% THA and 50% THA operating conditions. The thermal calibration calculations were carried out assuming that the excess air coefficient, solid incomplete combustion heat loss and chemical incomplete combustion heat loss before and after biomass blending were kept constant.

### *3.1 Effect on theoretical combustion temperature*

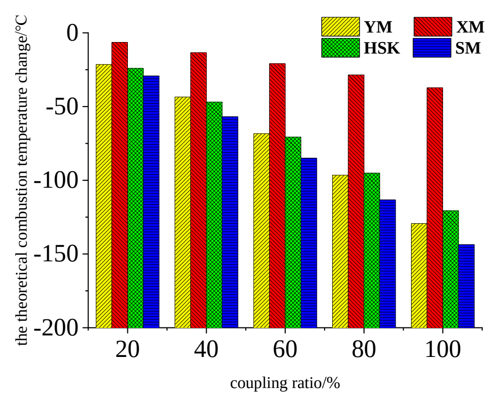
The effect of blending different biomass on the theoretical combustion temperature of the boiler is shown in Fig 1.




(a) BMCR




(b) 75%THA




(c) 50%THA

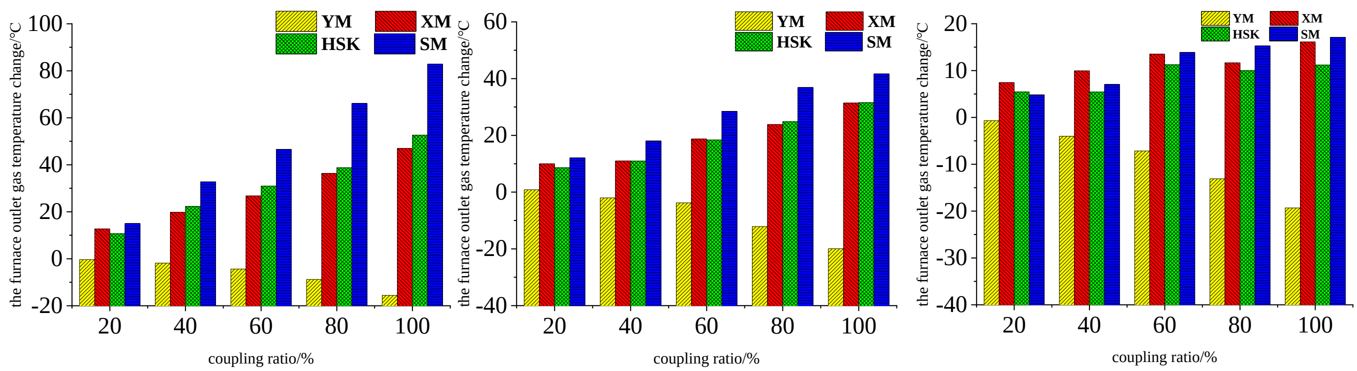
Fig. 1. The effect to the theoretical combustion temperature of biomass blending

As can be seen from Fig 1, the theoretical combustion temperatures varied from -138.9 to -16.8 °C (corn straw), -43.3 to -4.2 °C (wheat straw), -128.1 to -20.0 °C (peanut shells) and -149.0 to -25.2 °C (larch) for different coupling ratios at full load. The theoretical combustion temperature of flue gas is related to factors such as the calorific value of the fuel, the characteristics of combustion products (quantity, specific heat capacity) and the excess air coefficient. In general, the theoretical combustion temperature decreases with the decrease of the calorific value of the fuel, so it basically shows a linear decrease with the increase of the biomass coupling ratio.

### *3.2 Effect on the flue gas temperature at the furnace exit*

The effect of blending different biomass on the flue gas temperature at the furnace exit is shown in Fig 2.

The furnace exit flue gas temperature is influenced by the flame center (burner swing angle) in addition to the incoming heat, the arrangement of the heating surface in the furnace chamber, and the combustion product characteristics. As can be seen from the Fig 2, the furnace outlet flue gas temperature of three types of biomass blended with wheat straw, peanut shells and larch at BMCR~50% THA load have different increases. This is mainly due to the increase in flame center caused by the need to swing the burner upward to ensure the reheat steam temperature. In the case of corn stover blending, there is no need to adjust the reheat steam temperature by burner swing because of the larger amount of flue gas produced by combustion. The ash melting point of biomass fuel is lower than that of raw coal, so it is extremely unfavorable to the ash slagging on the heated surface after the furnace exit.




(a) BMCR (b) 75%THA (c) 50%THA

Fig. 2. The effect to the furnace outlet flue gas temperature of biomass blending

## 4. CONCLUSION

(1) After the large proportion of direct-coupled biomass power generation, the exhaust temperature of the unit rises and the thermal efficiency of the boiler decreases, and the original heating surface arrangement can basically meet the heat exchange needs.

(2) Because of the high oxygen content of biomass, the theoretical air volume of the fuel after mixed combustion decreases. The original air supply system can meet the requirements of large proportional blending of biomass; however, because the amount of fuel required for the same heat input increases, the induced draft fan needs to be expanded and modified to meet the requirements of large proportional blending of biomass.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