# Effects of wet sludge amount on sludge-coal blending combustion for power generation

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#### ABSTRACT

To study the effects of wet sludge amount on the coal-fired boiler parameters by blending flue gas dried sludge, a thermal calculation and analysis of 300 MW power plant are studied in this paper based on the energy conservation equation. Under the load of BMCR, 75%THA, 50%THA, and 30%THA, the influences on flue gas extraction ratio (extracted from low-temperature superheater outlet), thermal efficiency, and coal consumption are calculated and analyzed. The results show that blending sludge will cause the deterioration of the boiler's main parameters. The variation increases as the boiler load and the amount of wet sludge decreases. For comprehensive consideration of engineering cost, boiler parameters and the influences on environmental facilities, the percentage of wet sludge and fuel should be controlled below 10% under different load conditions. The influence on the sludge-coal blending combustion with extracted flue gas under full load condition is revealed and a mathematical conclusion is obtained.

**Keywords:** wet sludge, blending amount, flue gas desiccation, blending combustion, coal-fired boiler

#### 1. INTRODUCTION

With the development of our society, it has become a severe challenge for us to solve the sludge generated by human activities. Statistics show that the amount of sludge produced in China has reached 63.25 million tons in 2019 and will increase to 97.72 million tons in 2023[1]. Sludge not only contains a large amount of organic matter, which produces a strong stench when decay, but also contains a large number of pathogens, heavy metals, organic polymers and many other toxic and harmful substances[2], if there is no strict harmless disposal and management, it will lead to serious secondary environmental pollution.

At present, the disposal methods of sludge mainly include landfill, building materials use, land use, incineration and other[3]. Among them, incineration is the main method of large-scale, low-cost and harmless treatment of sludge. However, it is faced with the problems of large investment and high operating cost, which seriously restricts the harmless treatment of sludge. China has the largest ultra-low emission coalfired unit group in the world. Sludge drying coupling power generation with the help of existing in-service coal-fired units can not only increase the proportion of non-fossil energy consumption and fossil energy substitution, but also give full play to the advantages of a platform for clean and efficient centralized treatment of coal and electricity pollutants. promoting the coordinated prevention and control of air, soil and water pollution is the best way to achieve sludge reduction, harmless, resource utilization and large-scale disposal[4]. Therefore, it has been widely concerned by power plant operators in recent years.

Cao et al[5] conducted an experimental study on the mixed burning of sludge in a 420t/h industrial boiler, and found that with the increase of the proportion of sludge mixed burning, the furnace temperature decreased, the carbon content of fly ash increased, and the boiler thermal efficiency decreased obviously when the mixed burning ratio was 10%. Bi, Tong and Zhang et al[6-8]. used thermogravimetric analyzer and tube furnace to study the SO<sub>2</sub> and NO emission characteristics of mixed

Selection and peer-review under responsibility of the scientific committee of the 13<sub>th</sub> Int. Conf. on Applied Energy (ICAE2021). Copyright © 2021 ICAE

combustion of sludge and raw coal under different combustion conditions. Ma et al[9] calculated the influence of different sludge mixing ratio on boiler exhaust gas temperature, exhaust gas heat loss and boiler thermal efficiency, and analyzed the influence of mixed burning ratio on boiler. Li Feng and others[10] conducted an experimental study on the mixed combustion of 60% moisture content sludge in a 1000MW coal-fired power station boiler. the test results showed that the boiler thermal efficiency decreased by 0.34% and 0.58% after burning 7.3% and 6.5% wet sludge at medium and low load. Most of the existing studies focus on the mixed combustion of dried sludge, but lack of attention to the changes of the main parameters of the boiler after the extraction of flue gas dried sludge.

In this paper, on the basis of the author's previous research[11], aiming at the boiler of 300MW coal-fired unit in a power plant, based on the law of conservation of energy, through thermal calculation[12], the full load calculation of flue gas drying wet sludge coupling power generation from low temperature superheater outlet is carried out, and the effects of wet sludge mixing amount on flue gas extraction ratio, boiler thermal efficiency and coal consumption are analyzed. The research results reveal the influence of the amount of wet sludge on the boiler under full load, and put forward the best mixing ratio of dry wet sludge with flue gas.

#### 2. MATERIAL AND METHODS

#### 2.1 General situation of boiler



Fig 1 Sketch of the boiler

The type of boiler in a power plant is SG-1025/17.50-M749, with subcritical parameters, primary intermediate reheat and natural circulation drum furnace. The maximum continuous load (B-MCR) conditions are design parameters, maximum continuous evaporation 1025t/h, superheater steam outlet temperature 540 °C, reheater steam outlet temperature 540 °C. The boiler adopts balanced ventilation and tangential combustion. The superheater temperature regulation mode is water spray + burner swing, and the reheater temperature regulation mode is burner swing + excess air coefficient regulation.

The schematic diagram of the boiler layout is shown in figure 1. The boiler has a cross-section 14020mm×12350mm, and the burner is tangentially fired at the four corners, which can swing up and down 20° to adjust the steam temperature.

#### 2.2 Design of coal quality and sludge parameters

#### 2.2.1 Coal quality parameters

The design coal quality is selected for the calculation of coal quality, and the specific parameters are shown in Table 1.

Table 1 The coal parameters						
Number	Parameters	Symbol	Unit	Value		
1	As-received C	$C_{ar}$	%	50.25		
2	As-received H	H <sub>ar</sub>	%	3.08		
3	As-received O	$0_{ar}$	%	4.25		
4	As-received N	Nar	%	0.93		
5	As-received S	S <sub>t,ar</sub>	%	0.93		
6	As-received ash	A <sub>ar</sub>	%	34.56		
7	total moisture	M <sub>ar</sub>	%	6.00		
8	dry ash free basis volatile matter	$V_{daf}$	%	27.87		
9	Low calorific value	Q <sub>net,ar</sub>	kJ/kg	19230		

#### 2.2.2 Sludge parameters

Wet sludge is a wet sludge with a moisture content of about 80% produced by centrifugal dewatering in a sewage treatment plant, and the specific parameters are shown in Table 2. According to the current situation of sludge coupling power generation treatment in China, the moisture content of dried sludge is 35%.

#### 2.3 Mathematic model

The thermal check calculation was carried out on the 300MW primary reheat boiler of a power plant after drying sludge with flue gas. The mathematical model

mainly includes thermodynamic calculation model and sludge drying co-firing model.

Number	Parameters	Symbol	Unit	Value
1	As-received C	$C_{ar}$	%	5.75
2	As-received H	H <sub>ar</sub>	%	0.73
3	As-received O	$0_{ar}$	%	2.87
4	As-received N	Nar	%	0.96
5	As-received S	S <sub>t,ar</sub>	%	0.13
6	As-received ash	$A_{ar}$	%	7.56
7	total moisture	M <sub>ar</sub>	%	82.00
8	dry ash free basis volatile matter	$V_{daf}$	%	86.81
9	Low calorific value	$Q_{net,ar}$	kJ/kg	465.1

Table 2 The sludge parameters

#### 3. RESULTS AND DISCUSSION.

#### 3.1 Influence on the proportion of flue gas extraction

The proportion of flue gas needed to extract flue gas to dry wet sludge under different mixing amount is shown in figure 2. It can be seen from the figure that when the mixing amount of wet sludge increases from 100t/d to 300t/d, the amount of flue gas that needs to be extracted increases from 1.75% 4.93% to 4.84% 12.52% before the moisture content of wet sludge can be dried to 35%. From the calculation results, it can be seen that with the increase of the mixed burning amount of wet sludge, the amount of flue gas required is also increasing, and with the decrease of the load of the unit, the proportion of flue gas needed for drying sludge is also increasing.



### 3.2 Influence on Thermal efficiency of Boiler

The thermal efficiency of the boiler after the mixed combustion of flue gas drying sludge with different mixing amount is shown in figure 3. From the calculation results, it can be seen that the thermal efficiency of the

boiler decreases with the increase of the burning amount of wet sludge and the decrease of the load. This is because when the flue gas drying sludge is extracted and recycled into the furnace, the temperature of the recycled flue gas is much lower than that of the original furnace, resulting in a decrease in the heat absorption of the radiation heating surface and an increase in the heat absorption of the convective heating surface. because the heat transfer area of the convective heating surface is a fixed value, the excess heat can not be absorbed completely, which eventually leads to the increase of flue gas heat loss and the decrease of boiler thermal efficiency, which is more significant at low load. In addition, due to the high moisture content of sludge and extremely low calorific value, the amount of flue gas increases after mixed combustion, which will also lead to an increase in heat loss of exhaust gas, so the thermal efficiency of the boiler decreases after mixed burning of sludge, and the decrease of boiler efficiency is more obvious with the increase of mixed burning amount.



Fig 3 The effect to the thermal efficiency of sludge blending ratio

#### 3.3 Influence on coal consumption

The change proportion of coal burning quantity of flue gas drying sludge mixed with different burning amount is shown in figure 4. As the amount of sludge mixed with combustion of the unit under different loads is a fixed value, this section only discusses the impact on coal consumption. After drying the wet sludge to 35% moisture content, the calorific value is only 7685.1kJ/kg[4], which is only 40% of the calorific value of coal combustion. The calorific value of the sludge after combustion is not enough to replace the raw coal of the same quality, so it is necessary to consume more raw coal to meet the heat input needs of the boiler. From the calculation results, it can be seen that with the increase of the amount of sludge mixed with burning, the consumption of coal is also more and more, and the

## increase of coal caused by burning different proportion of wet sludge is between $0.17t/h \sim 1.14t/h$ .



Fig 4 The effect to the coal consumption of sludge blending ratio blending ratio

3.4 Selection of the amount of wet sludge blended combustion

From the calculation results, when the amount of wet sludge mixed with 150t/d, the thermal efficiency of the boiler decreased by 0.25%-0.54% under full load conditions, and the overall impact on the main operating parameters of the boiler under BMCR conditions is small. Considering the retrofit cost, the influence on boiler operation parameters and environmental protection equipment and other factors, it is suggested that the mixed burning ratio of wet sludge under full load should be controlled within 10%.

#### 4. CONCLUSION

(1) The amount of flue gas needed for drying sludge increases with the increase of wet sludge and the decrease of unit load.

(2) The mixing of dried sludge will lead to the decrease of boiler thermal efficiency and the increase of coal consumption, and the range of change increases with the increase of wet sludge and the decrease of load.

(3) When the wet sludge is mixed with 100~300t/d, the flue gas is extracted from the outlet of the low temperature superheater to dry the sludge and then mixed with it. Under full load, the thermal efficiency of the boiler decreases by 0.16%-1.07%, and the coal consumption increases by 0.17%-1.45%.

(4) The greater the proportion of wet sludge cofiring, the greater the impact on various parameters of the boiler, comprehensively considering the transformation cost, the impact on boiler operation parameters and environmental protection equipment and other factors, it is suggested that the proportion of wet sludge Co-firing under full load should be controlled within 10%.

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