Research on Ash Clogging of Rotary Air Preheater in Coal-fired Power Plant

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Abstract. The air preheater of coal-fired units has the problem of ash blocking. Combining the working principle and ash blocking mechanism, FLUENT uses the porous media model to simulate the air preheater, and the corresponding mass flow rate at different speeds or air side inlets is obtained. The temperature results are compared and analyzed, and a reasonable air preheater is used to reduce ash clogging.

1 Introduction

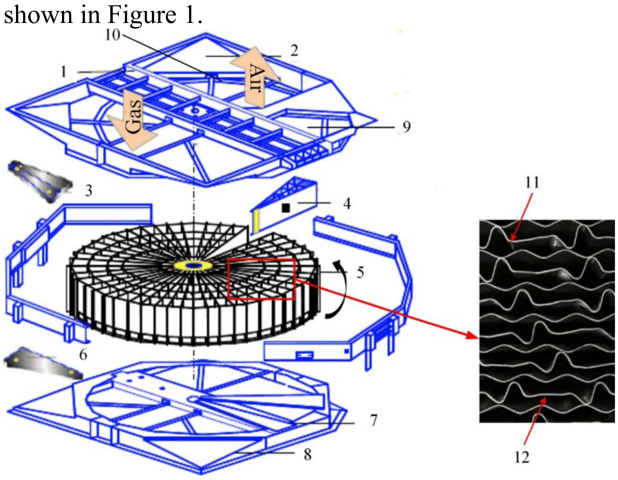
The rapid development of social economy has led to an increase in energy demand year by year. At present, my country's energy structure is still dominated by coal. According to incomplete statistics, my country's coal-fired power plants ranked first in the world in total power generation in 2019, accounting for 50.2% of the world's total power generation by coal-fired power plants. Many power plants consider various aspects to improve power generation efficiency and reduce environmental pollution caused by coal burning. Among them, the rotary air preheater has a good effect (hereinafter referred to as the air preheater).

The air preheater has the problem of ash blocking. The serious ash blocking phenomenon increases the flow resistance, reduces the heat exchange efficiency of the air preheater, and also causes an increase in air leakage, which seriously threatens the economy and safety of the unit's operation. In the actual production process, it often happens that the air preheater has to be shut down for cleaning due to serious dust accumulation. This shows that the in-depth analysis and research on the air preheater is imminent.

2 Analysis of ash blocking mechanism

2.1. Structure and working principle

The air preheater uses a heat transfer plate to recover the heat in the high-temperature flue gas. Through the rotation of the central rotor, the heat is brought to the low-temperature air area and transferred to the air to achieve the purpose of recovering the flue gas heat and increasing the temperature of the incoming air. This greatly reduces environmental pollution and improves boiler efficiency. The flue gas and air of the air preheater are usually arranged in a countercurrent manner, that is, the direction of the flue gas flow through the air preheater is opposite to the direction of the air flowing through the air preheater, and the rotor speed is generally relatively low, which facilitates the sufficient heat exchange process. get on. The air pre-device structure is shown in Figure 1.



(1. Upper beam; 2. Upper gas channel; 3. Hot end sector seal; 4. Segmented steel plate; 5. Corrugated plate; 6. Cold end sector seal; 7. Lower beam 8. Bottom flue gas channel; 9. One time Air outlet; 10. Secondary air outlet; 11. Corrugated board; 12. Positioning board)

Fig. 1. The working principle and structure of air preheater

2.2 Ash blocking mechanism

First of all, the air preheater on the structure is easy to accumulate and block up. Its rotor is composed of a large number of heat transfer elements closely arranged. The heat transfer elements are often very thin metal plates, and the gap between the plates is very small. At the same time, in terms of sediment, due to the relatively low temperature at the cold end of the air preheater, sulfuric acid and ammonium bisulfate vapors are prone to condense here, resulting in fouling and clogging.

Ammonium bisulfate blockage: Ammonium bisulfate is a highly viscous liquid substance in the temperature range of 150-220 ℃, which is easy to stick. In coal-fired

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power plant units with SCR denitration systems, the escaped ammonia can easily react with sulfur oxides in the flue gas to form ammonium bisulfate, which will block the air preheater.

Cold end low-temperature acid corrosion: The cold end temperature of the air preheater is low, and the sulfuric acid vapor in the flue gas is attached to the heat transfer element, causing acid corrosion at the cold end of the air preheater, which intensifies the dust accumulation and blockage of the air preheater.

3 Air preheater model establishment

Taking the three-division silo rotary air preheater of a 310MW coal-fired power plant as the research object, the geometric model of the air preheater is established based on the actual situation, and the FLUENT software is imported for analysis and solution. The actual air preheater model is more complicated, including components such as beam structures that have less effect on heat transfer. These components are omitted in the modeling to simplify the calculation. The simplified model is roughly composed of a central cylindrical rotor and three corresponding upper and lower fan-shaped flow channels. The geometric parameters are set according to the actual geometric parameters of the air preheater. Based on the fact that the air preheater rotor is composed of densely arranged heat storage plates, there is only a small gap between which there is fluid passing.

At the same time, in order to ensure the heat transfer efficiency, the heat storage plate has ripples, so it is extremely complicated to calculate the heat transfer problem of the air preheater. Big. Through the analysis of the structure of the air preheater, the metal plate divides the rotor into a large number of narrow semi-enclosed spaces, and the fluid passes through these pore-like structures to complete heat exchange, which is just in line with the characteristics of the porous medium model. According to formula, it can be calculated that the flow Reynolds number of porous media is about 2500-6000.

When the cold-end and hot-end fluids continuously pass through the workpiece in opposite directions, the local thermal equilibrium assumption of the porous media model cannot be satisfied. Therefore, the two-element non-equilibrium thermal model should be used, which can obtain more accurate results than the application of the local thermal equilibrium model. The specific method is to apply different energy equations to describe the heat transfer problems in the solid term and the fluid term respectively.

The actual parameter setting of the analog parameter data of the air preheater. Under normal working conditions, the inlet temperature of the primary and secondary air at the cold end is similar to the atmospheric temperature, and the inlet temperature at the flue gas side at the hot end is about 390℃. The specific physical and material parameters of the air preheater are shown in Table 1 and Table 2.

Table 1. Operating parameter table of rotary air preheater for three-division warehouse

Operating parameters	Numerical value
Air preheater speed	1 .14 r/min
Flue gas inlet temperature	668 K
High temperature primary air inlet temperature	293 K
High temperature secondary air inlet temperature	293 K
Flue gas mass flow	1384090 kg/h
High temperature primary air mass flow	247625 kg/h

Table 2. Physical parameters of heat transfer element

Hot end	DU	Cold end	NF
material	SPCC	material	Corrosion resistant steel
Void ratio	0 .926	Void ratio	0 .862
Heat transfer original thickness	0 .5 mm	Heat transfer original thickness	0 .75 mm
Interface area density	373 .0 m2 /m3	Interface area density	330.8 m2 /m3

When the number of grids is 312,984, the grid independence can be proved. The specific meshing situation is shown in Figure 2.

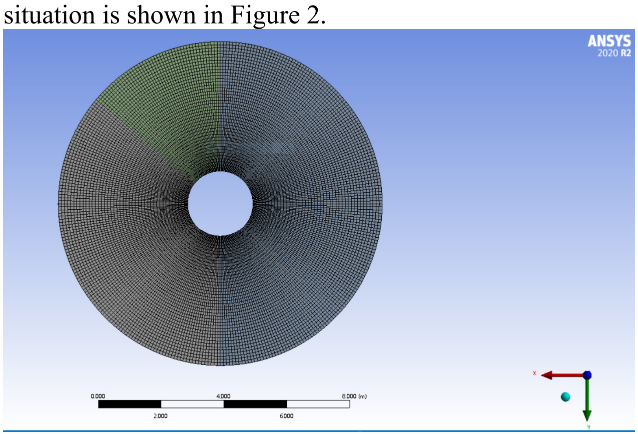

Fig. 2. Schematic diagram of grid division of air pre-heater

4 Results and analysis

4.1. Simulation of basic conditions analysis

The average temperature of the cold end is around 410K, and the flue gas outlet temperature gradually increases along the direction of rotation. It can be seen from the figure that the temperature of the primary air inlet at the cold end is slightly greater than that of the secondary air inlet. However, since the gap between them is very small, they can be approximately regarded as equal. At the same time, it can also be found that the temperature distribution trend of the cold end is also similar to the temperature distribution trend of the cold end. The average temperature of the hot end is around 620K. It can also be seen that the temperature distribution of the hot end is similar to that of the cold end through the hot end temperature distribution graph.

In engineering, combined with the actual working conditions of the SCR denitrification system, it is usually specified that the formation temperature of ABS in the rotary air preheater is 190°C. The condensation temperature of ABS is about 145°C, so it can be determined that the deposition temperature range of ABS is between 140°C and 190°C. Therefore, according to the temperature distribution map, the area where the serious fouling and clogging phenomenon occurs and the reason can be analyzed. The most serious area of ABS deposition is at the junction of the hot end and the cold end.

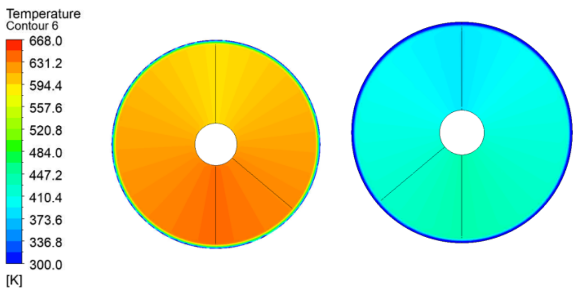

Fig. 3. Temperature distribution diagram of the hot end and the hot end of the air preheater

4.2. The influence of air inlet mass flow

Due to frequent changes in operating conditions during boiler operation, the influence of mass flow on RAPH cannot be ignored. As the mass flow decreases, the efficiency of the preheater increases. As shown in Figure 4, it can be seen that as the mass flow increases, the pressure drop increases significantly.

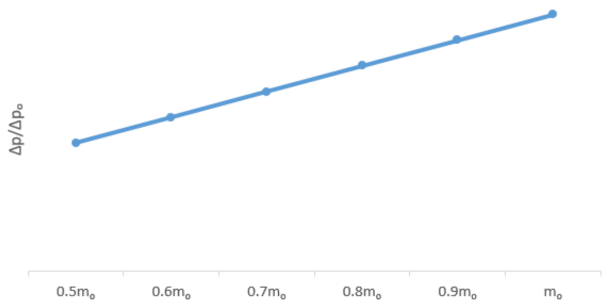

Fig. 4. The influence of mass flow on pressure drop of preheater

Calculate the loss according to W=V·N·q (V is the volume, n is the speed, and q is the flow rate). As the mass flow rate decreases, the delay temperature decreases. Because of the nature of the fluid, the flue gas will become denser. Therefore, when the air preheater is in operation, the residual flue gas is serious. Especially under the condition of high speed, the loss will increase sharply.

Cold-end corrosion and ABS deposition are basically not affected by the mass flow rate. Although it can be seen that the two areas have decreased, the heat transfer between the phases increases, and the heat transfer element can absorb more heat from the flue gas. Finally, the area of the substrate decreases at low temperatures.

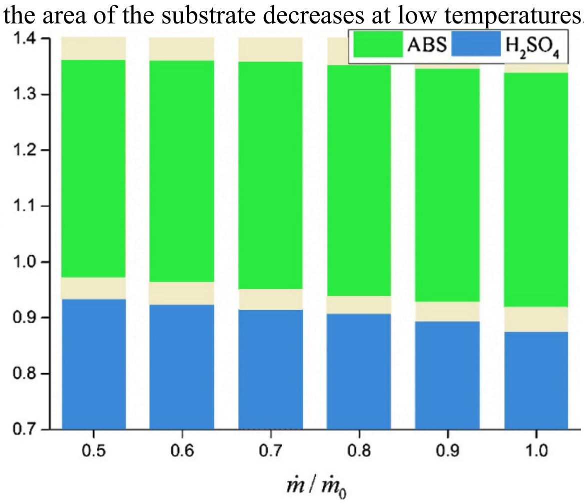

Fig. 5. The influence of mass flow rate on cold end corrosion and ABS deposition distribution

4.3. Influence of rotor speed

The influence of the rotation speed on the air preheater is obvious. According to the continuous increase of the rotation speed as shown in Figure 6, the efficiency increases. The heat that can be absorbed by the heat transfer plate increases, the pressure loss decreases, and when the speed reaches the interval near the predicted value, the air preheater operates stably.

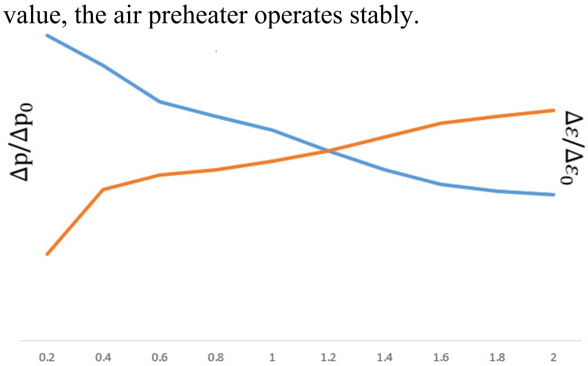

Fig.6. The effect of speed on the efficiency and pressure drop of the preheater

As the speed increases, the efficiency increases significantly. Regarding pressure loss, as the rotational speed increases, more heat can be absorbed from the flue gas by the heat transfer element. The pressure loss is slightly reduced, which may be due to the decrease in fluid viscosity and increase in density as the flue gas temperature decreases. Figure 7 shows the influence of rotor speed on cold end corrosion and ABS deposition distribution. The speed of rotation continues to increase, the heat transfer efficiency of the air preheater continues to increase, and the cold end corrosion and ABS deposition position increase. On the contrary, the speed is reduced, the flue gas does not have enough temperature drop, the temperature of the heat transfer elements in the whole mechanism rises, the cold end corrosion and the ABS deposition are weakened, and the power plant occasionally reduces the speed and supplements the soot blower to achieve the purpose of cleaning the air preheater. The outlet temperature at different speeds is shown in Table 3.

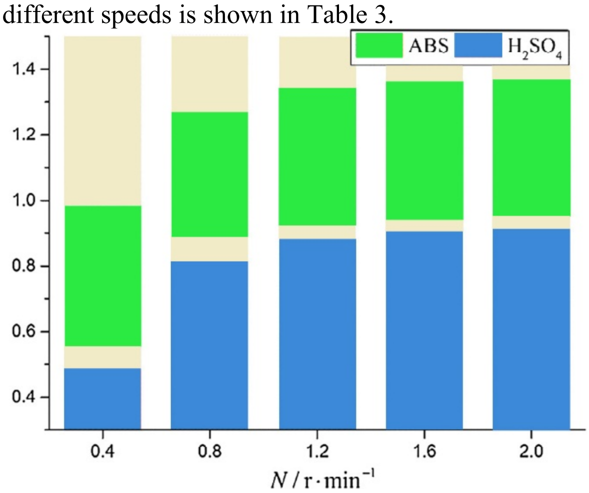

Fig. 7. Effect of Rotor Speed on Cold End Corrosion and ABS Deposit Distribution

Table 3. Outlet temperature/K under different speed conditions

Rotating speed	0.34	0.74	1.14	1.54	1.94
Primary air outlet temperature	554.27	525.02	525	521	518
Secondary air outlet temperature	454.49	471.69	471	473	473
Outlet temperature of flue gas channel	496.41	488.99	488	488	488

5 Conclusion

By using the porous medium model in FLUENT, the air preheater model is processed, and the operating conditions of flue gas and air in the machine are simulated. The temperature distribution, sulfuric acid corrosion and ABS deposition are described. For the transformation, we can design by reducing the inlet temperature, increasing the speed and reducing the mass flow of the inlet air.

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