Analysis on “against the wind” of primary air fan in 300MW CFB boiler

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Abstract. When the primary air fan of a 300MW circulating fluidized bed boiler is operated at a variable frequency, there is a problem of “against the wind” under the condition that the fan is under low load and the air pressure is low. This paper aims at fixing the aforementioned problem and finding out the cause of the “against the wind” of the primary air fan, and proposing the solutions of adjusting the frequency conversion and the inlet diversion at the same time by analyzing the cold fluidization test, the combination test of the fan adjustment mode, the frequency and speed test of the frequency converter, etc. This method successfully avoids the “Against the wind” situation during low load operation, which is important for the adjustment of low-load down-conversion operation of primary air fan of circulating fluidized bed boiler.

1. Introduction

The circulating fluidized bed boiler is one of the most recognized commercial clean coal technologies in the world. It has the advantages of strong fuel adaptability, wide adjustment load ratio and desulfurization in the furnace [1]. It requires more fans than a pulverized coal boiler. If only the inlet deflector is adopted, the interception phenomenon is serious, which affects the economic operation of the fan. Therefore, the fan generally adopts the frequency conversion technology.

By adjusting the frequency conversion to change the air fan volume can improve the operating efficiency of the power plant boiler fan to a certain extent, but for the primary air fan, especially the CFB boiler primary air fan, will confront a problem of “against the wind” for the change of operating characteristics when it is in actual operation, affecting the safe production of power plants [2]-[4]. This paper aims at fixing the aforementioned problem and proposes a feasible solution for low-load operation.

2. Equipment overview

The circulating fluidized bed unit of the power plant is a 1065t/h subcritical and natural circulating fluidized bed boiler. It was designed and manufactured by Dongfang Boiler (Group) Co., Ltd. with intermediate reheating and steam-cooled cyclone separator, single furnace, balanced ventilation, and solid waste slag. The boiler model is DG1065/17.4-II3.

Each boiler is equipped with two double-suction double-support centrifugal and variable frequency speed control primary air fans (GJ35056) produced by Chengdu Electric Power Machinery Factory. It is arranged symmetrically in the left and right sides of the motor. Seeing from one end of the motor, the impeller rotates clockwise to turn the fan and the fan is rotated to the left vice versa. The technical specifications of primary air fans and their ancillary equipment are shown in Table 1.
Table 1. Primary air fan technical data.

| Item              | Unit | Numerical Value |
|-------------------|------|-----------------|
| Model             | /    | GJ35056         |
|                   |      | (Double Suction Double Support Centrifugal Type) |
| Air flow          | Nm³/h| 362150          |
| Full Pressure     | Pa   | 23074           |
| Rotating Speed    | r/min| 1493            |
| Manufacturing Plant| /    | Chengdu Electric Power Machinery Factory |

Figure 1 shows the layout of Primary air system. The air from the primary fan is divided into two ways and sent to the boiler: the first, the air heated by the air preheater enters the water-cooled air chamber at the bottom of the boiler, and fluidizes the bed materials through the air caps arranged on the air distribution plate; the second, it is used for transporting coal to the front of the boiler.

In order to improve the efficiency of the fan and reduce the power consumption rate of the plant, the primary air fan adopts the frequency conversion operation mode[5]. During the operation of frequency running at low load, it was found that, the air wind and current of one side fan decreased instantaneously, while the air wind and current of the other side fan rised rapidly. In severe cases, the primary air flow was lower than the setting critical fluidizing air wind, causing the unit MFT action.

3. Causes analysis

3.1. Analysis of fluidized test data

According to the analysis of the resistance of the air distribution plate and the resistance of the material layer, a certain fluidized wind pressure and air volume should be maintained under different material layer thicknesses to ensure the normal fluidization state. Therefore, these critical fluidization parameters should be noted in the primary frequency converter operation.

3.1.1. Air plate resistance characteristics. After all hood inspections have been completed, the air panel resistance test is performed. The primary air flow is gradually increased from low to high, and the primary air flow (left/right) and air distribution plate resistance under each air flow are recorded, and the furnace negative pressure is basically stabilized throughout the test period. The air volume and
the air plate resistance curve are shown in Figure 2. Through the test, the relationship between the air volume and the resistance of the air distribution plate is:

\[
P = 0.032Q^2 - 0.2431Q
\]

In the formula: 
\(P\) - Air Plate Resistance, Pa  
\(Q\) - Fluidized Air flow, \(\text{km}^3/\text{h}\)

![Figure 2. Wind plate resistance curve.](image)

3.1.2. Resistance characteristics of different bed material. After completing the wind plate resistance test, a certain thickness (700mm, 900mm, and 1000mm) of qualified primer is laid on the air distribution plate. Adjusting the primary air flow from low to high, and recording the primary air flow under each air flow (left/right), primary air temperature, furnace negative pressure, wind chamber wind pressure and material layer pressure. The material layer resistance test is carried out in two conditions of up and down, and the furnace negative pressure is basically stabilized throughout the test period [6]-[7]. Material resistance refers to the loss of pressure when the air pass through the layer on the air distribution plate. Using the wind pressure of the wind chamber minus the resistance of the air distribution plate under the same air flow, to obtain the resistance of the material layer, and then changing the Bed height, and repeating the test, and the relationship between the air volume and the material layer resistance is plotted, as shown in Figures 3, 4 and 5.

![Figure 3. Resistance characteristics curve of 700mm thickness layer.](image)
According to the resistance curve of the air distribution plate and the resistance curve of the material layer, the critical fluidized air flow and fluidized wind pressure under different material layer thicknesses are shown in Table 2.

| Material Layer Thickness (mm) | Critical Fluidized Air Volume (kNm³/h) | Critical Fluidizing Wind Pressure (kPa) |
|------------------------------|---------------------------------------|---------------------------------------|
| 700                          | 130                                   | 7.3                                   |
| 900                          | 150                                   | 9.7                                   |
| 1000                         | 160                                   | 11.2                                  |

From the cold test data analysis, in order to ensure the normal fluidization state, the parameters of Table 2 must be met to achieve the effect of critical fluidization. If the speed of the flow is below this range, the fluidized air volume and the fluidized wind pressure cannot be guaranteed at the same time, which may result in the phenomenon of “against the wind” due to the fluidization state of the fluidized bed.
3.2. Fan adjustment mode combination test

Through the upward fluidization test with a material layer thickness of 1000mm, it is found that when the frequency of the inverter rises above 40Hz, the fan’s unstable working condition can be transferred to the stable working condition, and the parameter of the fluidized wind is higher than the critical fluidization parameter. We observe the unstable region of the fan by carrying out the downstream test through means of the inlet deflector and the frequency conversion adjustment mode. When the inlet deflector’s opening degree is 85%, the inverter frequency is down to 38Hz, and the current of the two fans is stable. At this time, the fluidizing air volume is 240kNm\(^3\)/h, and the wind chamber wind pressure is 14kPa; when the inlet deflector’s opening degree is adjusted to 60%, the frequency of the inverter goes down to 37Hz, and the current of the two fans is stable. At this time, the fluidizing air volume is 210kNm\(^3\)/h, and the wind chamber wind pressure is 13.8kPa. After adjusting the frequency of the primary air fan B to 36.5Hz (the frequency of the primary air fan A is not adjusted), the current of the fan is reduced from 120A to 59A under the condition of 36.5Hz, which results in fan’s unstable operation. The fluidization state failed and the air volume dropped to 97kNm\(^3\)/h.

3.3. Frequency converter and speed relationship verification test

Regardless of whether the bed material is in the fluidized state, adjusting the frequency of the fan inverter, to measure the fan speed in the field, and verify the change of the speed of the two primary air fans with the frequency of the inverter, and the change of the speed of the fan at the same frequency in the state of “against the wind” (the fan current changes greatly).

Through the single-stage operation of the primary air fan, the frequency of the inverter is increased from 20Hz to 48Hz, the frequency interval is 2Hz, the fan speed is gradually increased from 594.4r/min to 1405r/min, as the frequency changes, the speed is approximately linear, and the average speed corresponding to 2Hz is 60r/min.

When two primary air fans are running at the same time, the frequency of the inverter is increased by 20Hz at the same time. Under the same frequency of the inverter, regardless of whether the fan is in stable condition or not, the linear state of the inverter’s frequency is better. The difference between the speeds of two fans is very small. At the same frequency, the speed of a single fan and the combined operation of two air volumes is approximately equal. It has a good linear relationship between the rotational speeds of the frequencies, which matches each other. The frequency and speed relationship data of the inverter is shown in Figure 6.

![Figure 6](image.png)

**Figure 6.** In this case simply justify the caption so that it is as the same width as the graphic.
3.4. Analysis of air duct A and B

According to Figure 1, the outlets of the primary air ducts of A and B are equipped with communication pipes. One of the primary air fans provides with fluidized air, and the primary air fan B offers fluidized wind and coal-transporting wind (a total of 8 coal-transporting wind). Therefore, the air duct curves of the two fans are different.

4. Conclusions and suggestions

The problem of “against the wind” under variable frequency and low load conditions is caused by the mismatch between the fluidized characteristics of the circulating fluidized bed and the fan adjustment mode. In order to maintain normal fluidization, the circulating fluidized bed needs to maintain the lowest fluidizing air volume and the lowest fluidizing wind pressure under low load conditions, otherwise it will cause fluidization state failure. According to the results of fluidization test: when the thickness of the layer is 700mm, the critical fluidized air volume is 130kNm3/h and the wind pressure is 7.3kPa; when it is 900mm, the critical fluidized air volume is 150kNm3/h, the wind pressure is 9.7kPa; when it is 1000mm, the critical fluidized air volume is 160 kNm3/h and the wind pressure is 11.2 kPa.

The characteristics of the fan's variable frequency operation determine that the total pressure provided by the fan is also low at low air volume. Therefore, in the near-fluid state, the fluctuation of the local conditions of the two primary air fans will cause violently fluctuation of the two turbines. The wind turbine with a lower wind pressure will be compressed by the wind turbine with a higher wind pressure, which will result in a surge phenomenon of the two parallel fans, with the performance of the fan current is rapidly increased and decreased.

Verifying the test result from the relationship between frequency and speed of the inverter, the frequency and speed of the inverter show a good linear relationship, and the characteristics of the two inverters are very consistent.

The asymmetry of the air duct setting of A and B increases the occurrence of this phenomenon.

Through the above tests and analysis, the power plant operation should adopt the method of frequency conversion adjustment and inlet diversion regulation at the same time: that is, when it is at the low air volume state, the opening degree of the small fan inlet damper is relatively small. Firstly adjusting the frequency converter to a certain frequency to ensure the fan’s speed, and then adjusting it with the damper; when the damper is adjusted to a certain degree of opening, then adjusting it with the frequency conversion; at the same time, the corresponding relationship curve of fluidized air volume, primary air pressure and frequency conversion is established, specifying the minimum fluidized air volume and the minimum rotational speed. Since the implementation of the new scheme, the phenomenon of “against the wind” has been alleviated to a certain extent, which has fundamentally avoided the situation of “against the wind” and ensured the safe and stable operation of the unit.

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