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Study on air distribution system of 350MW supercritical boiler

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Abstract. In order to explore the best air distribution scheme, and set up a air distribution test bench, which is according to the similarity principle, in this paper, a 350MW supercritical boiler of a power plant is taken as the research object. This test the selection of fan power and the design of bellows and air duct size is according to the similarity principle. According to the test procedure, the resistance coefficient and flow rate of the damper are measured when the single and each damper is changed. It is found that the drag coefficient and flow rate are greatly affected by the opening of the damper. When the opening of the damper changes from 15 to 30 degree, they both change dramatically. When the opening of the damper is greater than 30 degree, the change of them tends to be stable. At the same time, different locations of damper will interact with each other. The resistance coefficient curve is not only plays a guiding role in the manual control of the old equipment, but also plays a vital role in the programming of the modern automatic control of the damper. At the same time, the flow distribution law plays a guiding role in the design of the air distribution control system. The resistance coefficient curve and the flow distribution curve obtained in this paper can play a guiding role in the test design and boiler operation regulation of power plant.

1. Introduction

Thermal power plants are increasingly concerned about the unit efficiency and air pollution problems, accurately measure and control the primary and secondary air flow is one of the most effective and cost-effective ways to improve boiler thermal efficiency and reduce air pollution[1].So reasonable air distribution is indispensable in the process of boiler combustion. Each boiler's secondary air distribution nozzle is varied from tens to twenty. Different air distribution will affect the boiler thermal efficiency, and then affect the consumption of coal. The unreasonable air distribution will directly lead to the increase of coal consumption, and the increase of coal consumption will lead to the increase of power generation cost up to 0.15 yuan/kW • h[2]. Therefore, it is significance to study the air distribution and it’s adjustment in boiler air distribution system.

The air distribution system of utility boiler includes primary air and secondary air. The primary air carries pulverized coal directly into the furnace and plays the role of carrying fuel. Secondary air first passes through the air preheater and blows into the furnace through several layers of secondary air nozzles and play the role of combustion-supporting. The distribution of secondary air and the adjustment of secondary air in each layer with the change of boiler load are important parameters in boiler operation. Therefore, obtaining accurate secondary air parameters have great realistic significance [3].

2. Test bench build

2.1. Similarity principle

In this paper, the principle of similarity is used to simplify the object and reduce the size of the test-bed as much as possible to meet the accuracy of the test results. However, if we want to use the principle of similarity to establish the test bench, we must satisfy the additional conditions of the principle of similarity. First, we must satisfy the geometric similarity between the test bench and the object, secondly, we must satisfy the motion similarity. We also need to construct a force field, which is identical to the real object, to ensure that the gravity, pressure, viscous force, elastic force, surface force act on the fluid molecules are in the same direction with the real object, which is called dynamic similarity [4].

2.2. Construction of 3D simulation test stand

The shape and size of bellows and ducts are designed by similarity principle, and the 3D geometric model is built by 3D modeling software, as shown in Figure 1.

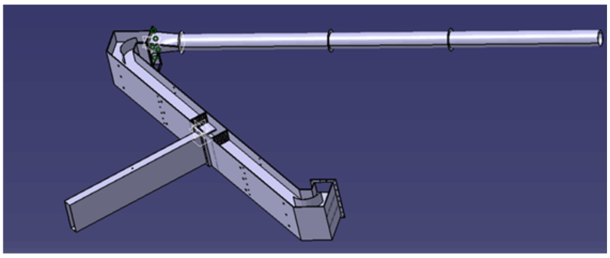

Figure 1. Overall 3D simulation of test bed.

In this test, Symmetrical design is adopted in the structure, and the opening of both sides of the damper is also symmetrical during the test. In this paper, the opening of the first, second and third layers are set at X1, X2 and X3 respectively, as shown in Figure 2.

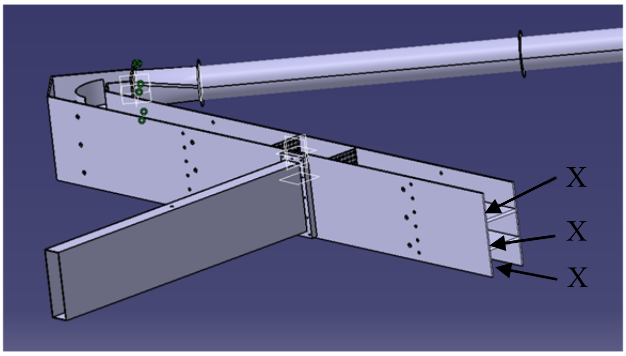

Figure 2. Diagram of ducts location.

The experimental platform mainly includes: bellows, ducts, air doors, diversion plates, comb orifice plate, celestial earth tube, observation orifice plate, straight pipe section, Venturi tube and differential pressure transmitter. According to the experimental requirements, build the experimental bench, as shown in Figure 3.

Figure 3. Test bench.

3. Analysis of experimental results

3.1. Accuracy analysis

The resistance coefficient has corresponding relationship with the pressure difference between ends of damper and the air velocity at the outlet of the damper. It can be expressed as ζ=2ΔP/ρV2, in which ρ=1.225 kg/m3.then the resistance coefficient corresponding to different open degree of damper can be obtained by calculation [5].

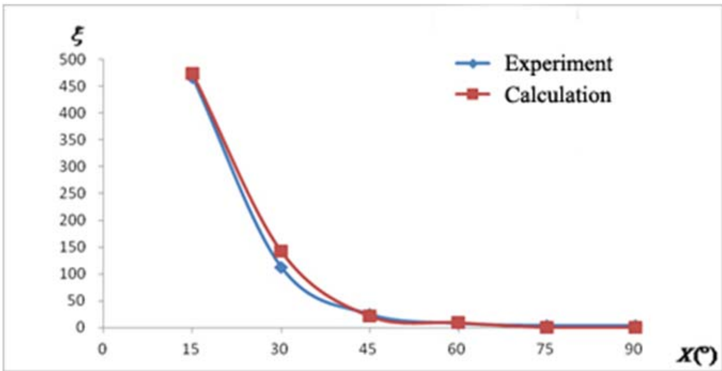

Figure 4. Comparison of resistance coefficient curves between and calculation.

As shown in Figure 4, the experimental curves and the calculated curves have the same trend, and the error between them is less than 5%. So, we can think that the experimental results are reliable.

In order to verify the accuracy of the air flow data at the outlet of the air duct of the test bench, this test compared the operation data and the measured data of the test bench, as shown in Figure 5.

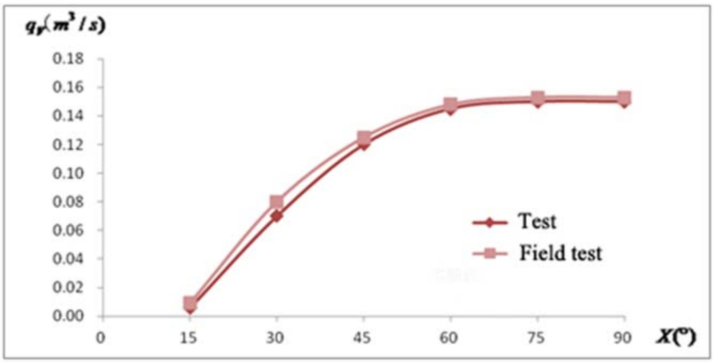

Figure 5. Comparison of flow-rate between test and field test.

As shown in Figure 5, the trend of the two flow curves is the same and the error between them is less than 5%. So, we can think that the experimental results are reliable.

3.2. Analysis of resistance coefficient
Firstly, the most commonly used operating conditions in power plants are selected, in this condition the middle and lower levels of the valve were kept open. By adjusting the open degree of upper level damper, the variation of the resistance coefficient of the damper with the open degree is studied.

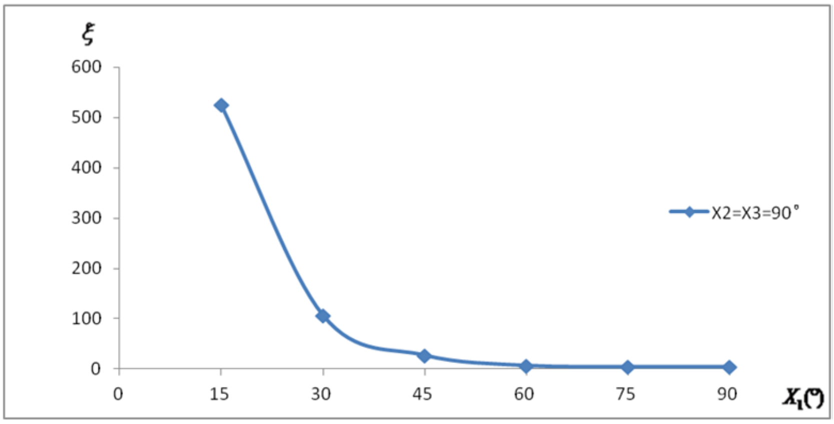

Figure 6. Curve of resistance coefficient of single door with wind door opening.

As shown in Figure 6, the opening of X1 changes from 15 degrees to 90 degrees. When the opening of X1 is 15 degrees, the damper is closed completely. At this time, the pressure loss of local resistance parts is the greatest, and the resistance coefficient should be the greatest, reaching 524.41. When the valve opening is 90 degrees, the valve is fully open, and the resistance coefficient of the damper is the smallest, only 4.11. When the valve opening is greater than 45 degrees, the change rate of resistance coefficient decreases, as the damper opening increases gradually, the change rat e of flow-path area decreases gradually, which leads to a stable change of resistance coefficient.

By changing the opening of the middle and lower damper, the resistance coefficient of the upper damper is studied, as shown in Figure 7.

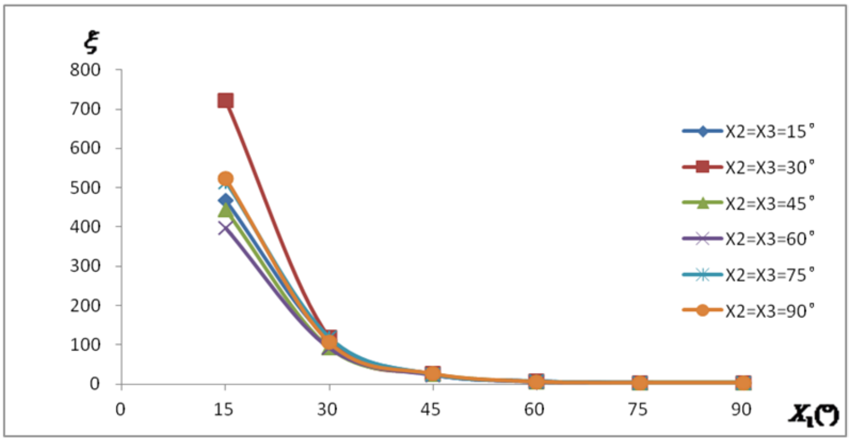

Figure 7. Upper layer resistance coefficient curve under different opening of middle and lower damper.

As shown in Figure 7, the resistance coefficient curve of the upper damper tends to be the same in the process of the change of the opening of the lower and middle ducts X2 and X3. The peak value of resistance coefficient is affected greatly. When X2 = X3 = 15 degrees, the damper closes completely and the drag coefficient is the largest. When X2 = X3 = 60 degrees, the peak value of resistance coefficient of upper air damper is the smallest. This is because the opening of the middle and lower air duct increases further, and the differential pressure between the ends of upper damper decreases sharply.

3.3. Analysis of flow-rate

Fixed the middle and lower damper at 30 degrees, the air flow rate with the open degree was studied by adjusting the upper damper opening, as shown in Figure.8.

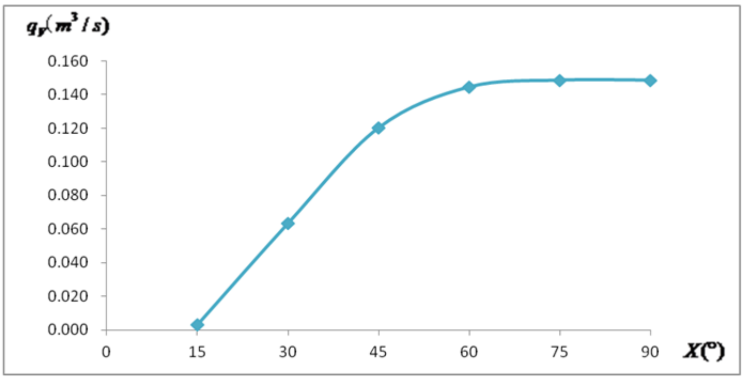

Figure 8. Curve of flow-rate of single door with wind door opening.

As shown in Figure 8, the air flow-rate increases sharply in the process of the opening changing from 15 to 45 degree, because the opening has a greater impact on the cross-section area of the damper. When the opening changes from 45 to 60 degree, the increase of the air flow rate in the damper decreases, which is due to the decrease of the increase rate of the effective cross-section area of the damper and the secondary air, the velocity at the throttle decreases at the same time. The flow rate of secondary air tends to be stable at about 0.15m3/s when the opening is between 60 and 90 degrees. This is due to the further decrease of the sectional area increase rate at the secondary air damper and the further decrease of the velocity of secondary air.

Change the opening of the middle and lower damper to study the air flow rate of the upper damper, as shown in Figure 9.

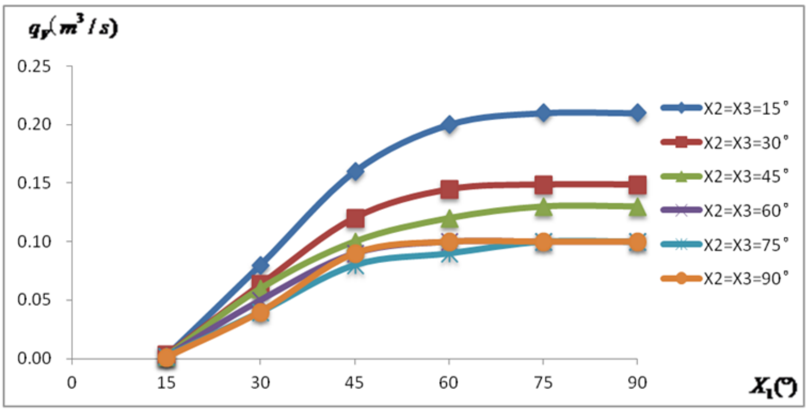

Figure 9. Upper layer flow-rate curve under different opening of middle and lower damper.

As shown in Figure 9, the flow rate of change and the peak flow rate decreases as the opening of the lower and middle air valves increases. This is because with the opening of the lower and middle air doors increasing, the secondary air from the fan into the test bench will be distributed to the lower and middle layers, resulting in a decrease in air flow through the upper damper.

4. Conclusions

In this paper, the influence of damper opening on secondary air resistance coefficient and flow rate in air distribution system of 350MW supercritical boiler is studied. Through the study of the single-layer valve opening, we find that the valve opening has an important impact on the resistance coefficient and flow rate. When the valve opening varies from 15 to 30 degree, the two parameters are greatly affected. When the angle increases further, the influence on these two parameters gradually decreases, and both of them tend to be stable. Therefore, these two parameters are highly sensitive to the opening of 15-30 degree, which should be paid more attention in engineering practice. At the same time, the influence of the opening of the middle and lower air doors on the resistance coefficient and flow rate is studied. It is found that the opening of the middle and lower air doors has an important influence on the peak value of the resistance coefficient and flow rate. Therefore, in the process of regulating secondary air in utility boilers, we should consider the influence of the change of the opening of one of the air doors on the air volume of other layers, and also consider the mutual influence between the air damper of each layer. Reasonable boiler air distribution can not only improve the efficiency of the boiler, reduce the emission of pollutants, but also reduce the cost of fuel, bringing great economic benefits to the power plant.

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