Research on Noise Control Optimization of Mechanical Cooling Tower in Gas Turbine Power Plant Based on Sound Source Monitoring and Noise Simulation

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Abstract: Because of the limitation of location and area, the noise problem of gas turbine power plant is gradually getting attention. The mechanical cooling tower has large volume, high noise value, so the cost of treatment is high. Based on the measured noise spectrum, this paper gives the main points of noise control measures for mechanical cooling tower. Based on the actual project, this paper compares the scheme and cost for configuration of mechanical cooling tower and the main noise control measures in the case of single-side and double-side air intakes. The results show that the scheme of single-side air intake is better. At the same time, refined noise simulation is conducted on the boundary before and after taking measures on the mechanical cooling tower, and the data is compared with the actual monitoring value. The data is basically consistent, and the noise of boundary meets the standard requirements after optimization and treatment.

1 Introduction

In recent years, with the proposal of the ' double carbon ' target, the proportion of clean energy power generation in the power industry has increased year by year, and the proportion of gas power plant is also increasing. Due to the limitation of gas access points and heating users, gas power plants will not be located in relatively remote areas. In most cases, there are environmental sensitive points around the plant site. At the same time, the area of the plant is small and the layout is compact. Therefore, the noise problem of gas power plant has been paid more and more attention. If it is not managed as a whole, the noise at the plant boundary can not meet the standard requirements.

In the gas turbine power plant, the noise sources are mainly distributed in the main plant area, the voltage regulating station area, the transformer area, the cooling tower area and the auxiliary plant area. The sound sources of the main building are mainly gas turbines, steam turbines and waste heat boilers. Gas turbine, steam turbine, generator are set sound insulation cover; The exterior walls of gas turbine and steam turbine workshops are equipped with composite sound insulation panels with glass wool or directly using block brick walls, and the sound insulation can reach more than 30 dB (A). The air inlet of the gas turbine is located on the roof platform of the main building. The position is high and the sound source area is large. Sound insulation barrier is set at the air inlet[1].

The waste heat boiler in the north may be tightly closed, and most of the waste heat boilers in the south are arranged in the open air. For the waste heat boiler arranged in the open air, sound insulation barriers are set on both sides of the plant boundary according to the need of noise reduction. The chimney is equipped with a muffler, and the noise is controlled within 65 dB (A).

The pressure regulating station and transformer area are generally arranged near the factory boundary. The main equipment of the pressure regulating station is the pressure regulating valve group. The noise in this area is superimposed by aerodynamic noise and pipeline vibration noise, which has the characteristics of wide frequency band and strong low frequency noise. The low frequency noise of transformer is prominent. Generally, sound barriers are set around the voltage regulating station and transformer.

Comprehensive water pump room, water treatment workshop, air compressor room and other auxiliary workshops, the plant adopts the form of block brick wall with high sound insulation.

In the gas power plant, the mechanical ventilation cooling tower (hereinafter referred to as the mechanical tower) is mostly arranged near the boundary, it's volume is large and the noise value is high. Therefore, the noise control cost of the mechanical tower accounts for a high proportion of the noise control cost of the whole plant, which is generally more than 30 % under normal conditions.

In this paper, the noise source characteristics of the mechanical tower are analyzed based on monitoring. Combined with the engineering practice and experience summary, the relevant optimization measures and cost comparison are put forward. At the same time, the noise simulation and prediction of the mechanical tower before and after the measures are taken are compared with the actual monitoring values.

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2 Noise source analysis of mechanical tower

The noise generated by the operation of mechanical tower mainly includes the aerodynamic noise generated by the top axial flow fan, the water spray noise generated by the circulating water hitting the filler and the sump, the mechanical noise generated by the motor and the transmission components, and the noise excited by the vibration of the tower wall and the top platform caused by the fan and the motor[2].

According to the actual monitoring results, the noise value at 1m of the motor is about 89dB (A), the noise value at 1m in the 45 ° direction outside the fan duct is 83-85dB(A), and the noise value at 1m outside the air inlet is 85-88dB (A). The noise spectrum is shown in Fig. 1—Fig. 3.

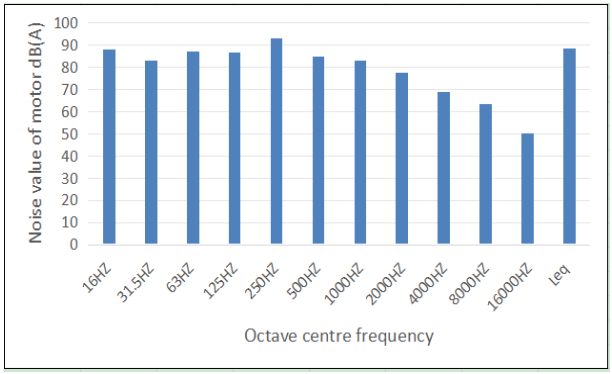

Fig. 1. The motor noise spectrum diagram of mechanical cooling tower.

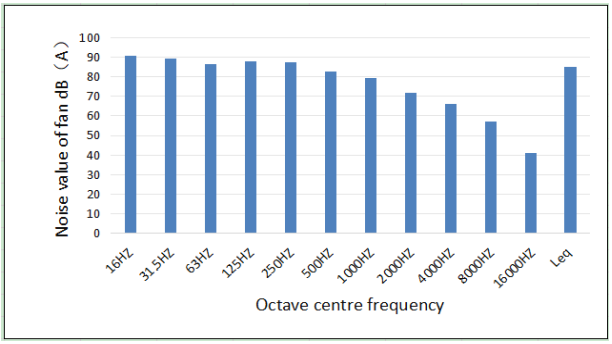

Fig. 2. The fan noise spectrum diagram of mechanical cooling tower.

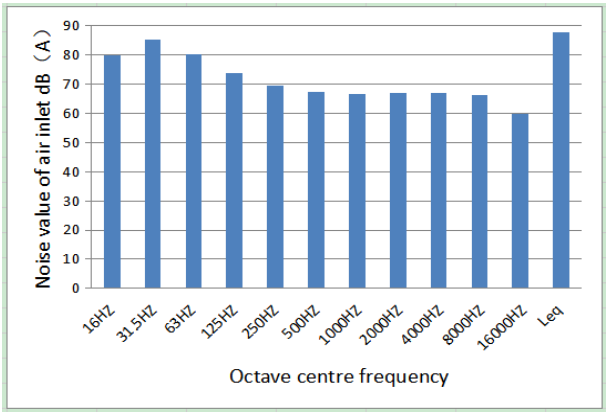

Fig. 3. The water spraying noise spectrum diagram of mechanical cooling tower (fan on).

From the above spectrum diagram, it can be seen that the middle and low frequency of the motor noise and fan noise of the power tower are prominent, and the middle and high frequency of the water spray noise are prominent. According to the water spraying noise spectrum diagram of mechanical tower, it can be seen that when the fan is open, part of the fan noise propagates downward through the inlet to the outside, so the middle and low frequency noise of the inlet is also very prominent in the actual operation, and the attenuation is slow with the distance.

3 The influence of meteorological conditions on the noise of mechanical tower

For the mechanical tower, the higher the ambient temperature, the more the cooling water to achieve the same cooling effect, the greater the water spray noise and fan noise ; When the wet bulb temperature is much lower than the outlet water temperature, the cooling air volume does not change much as the temperature increases; When the wet bulb temperature approaches the outlet water temperature, as the temperature rises, the cooling air volume increases sharply and the noise increases [3].

when the humidity in the ambient air is higher, the higher the wet bulb temperature under the same dry bulb temperature, the more the cooling tower water volume under the same cooling effect, the greater the water spray noise and fan noise.

Therefore, the same tower will generally operate in different zones in winter, and the noise is small. Similarly, the amount of cooling water in the arid area under the design conditions will be small, and the noise value will be small.

Research has shown that the impact of ambient temperature on cooling water temperature drop is not as significant as the impact of air humidity [4], which means that under the same conditions, the impact of air humidity on noise is greater than that of ambient temperature.

4 Analysis of main noise reduction measures of mechanical tower

For equipment noise reduction, the first step is to control the sound source. Therefore, low-noise equipment is required in the ordering of fans, motors and other equipment, and the material for energy dissipation of water-falling is laid in the pool to reduce the water-spraying noise; according to the above noise characteristics of different noise sources in the operation of the mechanical tower, mufflers need to be set up at the inlet and outlet to control the noise effectively. Vibration reduction treatment of fans, motors and other equipment is carried out to reduce the impact of vibration on the structure effectively, thereby reducing noise propagation[5].

In the above measures, the vibration reduction treatment of fans, motors and other equipment is recommended by the equipment manufacturer. Under normal condition, the noise of low noise fan can be

reduced by 8-12dB (A)[6]. The most important noise reduction measure of the mechanical tower is to set up array ventilation mufflers at the inlet and outlet. The noise reduction of the muffler is determined according to the distance from the plant boundary, whether there is building occlusion in the middle, the noise standard requirements of the plant boundary and other factors. Setting muffler at the air inlet needs to consider reserving about 1.5-2m maintenance channel before the muffler and the tower wall.

The cooling water volume of the gas power plant is relatively large. The mechanical tower adopts a concrete structure, and the wall has a certain amount of sound insulation, simultaneously possessing sound absorption function[7].In order to prevent noise leakage, a sound absorption and insulation board needs to be set between the muffler and the tower body to form a sound insulation room[8]which is shown as Fig. 4.

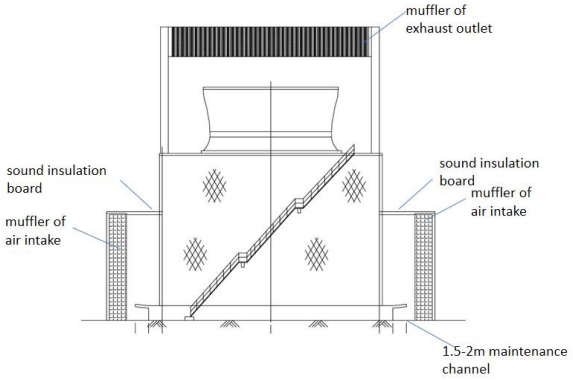

Fig. 4. The schematic diagram of main noise control measures for mechanical cooling tower.

Table 1. The comparison of the scheme and cost for configuration of mechanical cooling tower and the main noise control measures in the case of single-side and double-side air intakes.

		Air intake on both sides	Air intake on one side
The configuration of mechanical tower		The mechanical tower of the whole plant is equipped with one tower, including three cells, each cell size is 17.6 m × 17.6 m, the total height of the tower is 16.7 m, the height of the inlet is 5.5 m, and the height of the inlet pipe is 9.4 m.	The mechanical tower of the whole plant is equipped with 1 tower, including 4 cells, each cell size is 16.4 m × 16.4 m, the total height of the tower is 18.2 m, and the height of the inlet pipe is 9.5 m
Distance requirements with the plant boundary		According to the relevant specifications, the distance between the air inlet side of the mechanical tower and other buildings or structures should not be less than 2 times the height of the air inlet, so the distance between the air inlet of the mechanical tower and the plant boundary should not be less than 11 m	No requirements
Muffler consumption		The amount of noise reduction is considered as 30dB (A). The calculated amount of muffler at the air inlet is about 3168m^3, and the amount of muffler at the air outlet is about 2788m^3 (total 5956m^3)	If the tower is placed in the same area near the plant boundary, considering the orientation of the air inlet, the noise reduction requirement will be reduced to about 25dB (A) when the plant boundary meets the standard. The amount of muffler at the air inlet is about 1640m^3, and the amount of muffler at the air outlet is about 3228m^3 (total 4868m^3)
Investment	Mechanical tower (equipment + civil)	6.75 million	8.4 million (due to the one-sided air intake, the mechanical tower of this project considers spare margin in the selection. If the spare margin is not considered, the total investment will be about 6.85 million)
	Muffler (Equipment + Installation)	16.38million	13.39million
	Total	23.13million	21.79million

Note: The cost of the mechanical tower in the table is the estimated price. According to the engineering experience, the actual order price of the equipment is lower than the estimated price.

5 Optimization and comparison of noise reduction measures for mechanical tower

The main engineering quantity and measure cost of noise reduction for the mechanical tower are mufflers. Huis Int Veld M.H. effectively reduced the noise of the cooling tower by optimizing the intake and exhaust fans[9]. Under normal circumstances, the mechanical tower is air inlet on both sides. Under the condition of meeting the same noise reduction amount, the engineering quantity of the muffler at the air inlet is more than that at the air outlet. If it is changed to one-sided air intake, although the size of the mechanical tower will be appropriately increased, but if it is arranged in the same area near the plant boundary, the air inlet will face the factory, and the other side is the concrete structure. Therefore, the noise reduction requirements will be reduced when the factory boundary meets the standards. Considering the above factors, the muffler of the air inlet will be reduced by nearly half, so

the whole noise reduction project will be reduced effectively.

A 200 MW gas power plant is constructed, including three sets of gas-steam combined cycle units, of which No.1 and No.2 units are straight condensing units, and No.3 unit is back pressure unit. Based on this project, the selection of mechanical tower and noise reduction measures are optimized, and the two schemes and costs are compared. The comparison contents and results are shown in Table 1.

From the above comparison, it can be seen that the total cost of the mechanical tower and noise reduction equipment in the case of unilateral air intake is about 1.34 million RMB less than that of bilateral air intake. At the same time, due to the unilateral air intake, the mechanical tower of this project considers a large reserve margin for cooling water in the selection. If the margin is not considered, the total investment is about 6.85 million, the size of the cooling tower is reduced accordingly, and the amount of noise reduction equipment will also be reduced. On this basis, considering the reduction of the order price of the cooling tower equipment, the cost difference between the two schemes will be greater.

In addition, in order to prevent the influence of the surrounding buildings or structures on the cooling effect of the mechanical tower, according to the requirements of specification, the building or structure of this project needs to be at least 11 m away from the air inlet, while the unilateral air inlet is basically not limited by the distance, saving space and saving land area effectively.

In general, from all aspects of comparison, the scheme and noise reduction measures in the case of unilateral air intake of the mechanical tower are better than those of bilateral air intake. In the actual project, whether the mechanical tower adopts unilateral air intake is considered according to the engineering situation.

6 Other factors to be considered in unilateral air intake

There may be uneven cooling in the unilateral air intake of the mechanical tower. In general, the amount of cooling water in the selection of the mechanical tower will be greater than that of the bilateral air intake, and some spare allowances are considered. In addition, whether it is bilateral or unilateral inlet, the design value of cooling water volume is the value under pure condensation condition in summer, which is the maximum condition. At the same time, for the gas power plant, the hot water or steam generated is used for residential heating or enterprise heating. There is basically no pure condensation condition during the operation, and the uneven cooling will be basically avoided.

7 Noise prediction simulation

The noise prediction of the mechanical tower is based on the No.1 machine of the above 200 MW unit. Through comprehensive comparison, the final scheme adopts the single-side air inlet mode of the mechanical tower, and the air inlet is close to the boundary.

As mentioned above, because it is not necessary to consider the ventilation problem of the air inlet on plant boundary, in order to save land, the mechanical tower is arranged near the boundary, about 5m from the western plant boundary. The plane layout is shown as Fig. 5, and the mechanical tower corresponding to the No.1 machine is the following two grids.

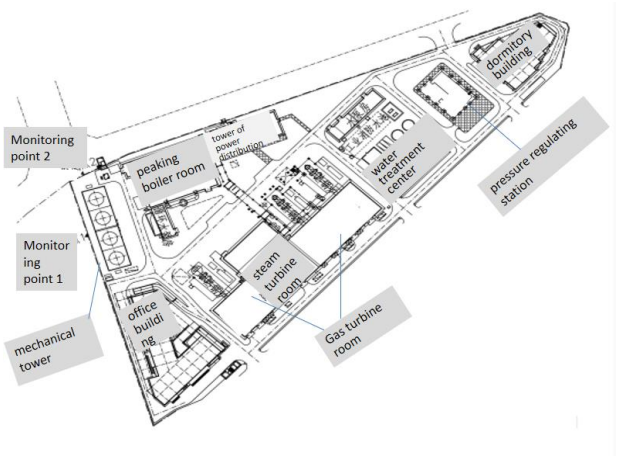

Fig. 5. Layout plan of the power plant.

Except for the southern boundary, other boundaries implement the Class 1 standard limit (55dB (A) at daytime and 45dB (A) at night) of the Emission standard for Industrial enterprises noise at boundary(GB12348-2008), and the southern boundary implements Class 4 standards.

The noise prediction of the tower is simulated and predicted by the acoustic software SoundPLAN. Its main functions include the calculation of environmental sound propagation of point sound source, line sound source, surface sound source and other complex sound sources. Noise assessment and prediction of plant boundaries, residential areas and functional areas; graphic preprocessing can be connected with the CAD software, can input complex terrain, buildings ;the calculation of the software takes into account the effects of ground absorption, air absorption, temperature and wind speed. The industrial calculation module adopts the ISO9613-2 Acoustics-Attenuation of sound during propagation outdoors standard[10], which is basically consistent with the calculation method in China.

This simulation combines engineering experience, takes the layout of the plant and the measured data of the above sound source as the design input, and carries out precise simulation according to the characteristics of the sound source. According to the simulation results, before taking measures, the contribution of the noise generated by the mechanical tower to the environment is predicted as Fig. 6.

It can be seen from the above prediction results that without taking measures, the maximum noise contribution value of the boundary exceeds 70dB (A) and exceeds the standard 25dB (A) when the two mechanical towers corresponding to No.1 gas unit operated separately, which appears in the north boundary.

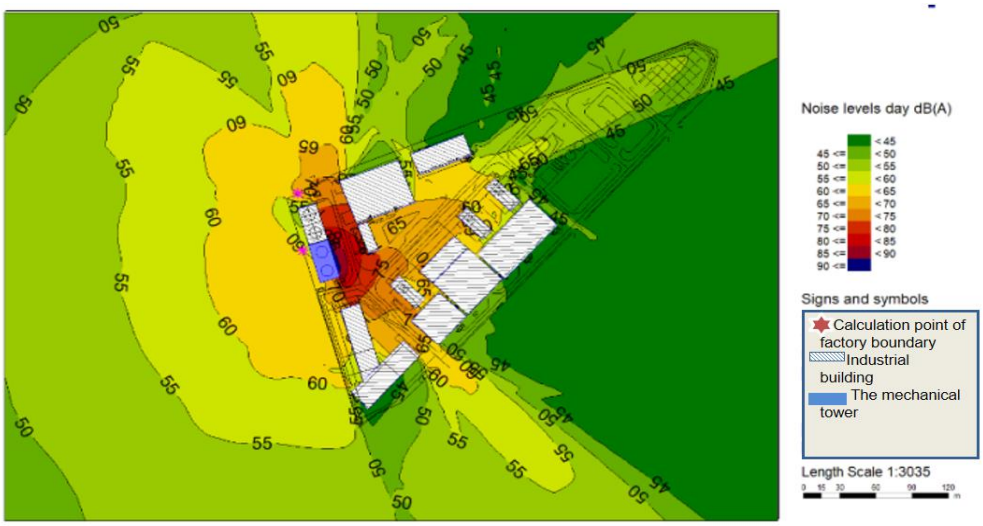

Fig. 6. The prediction map of boundary noise before treatment.

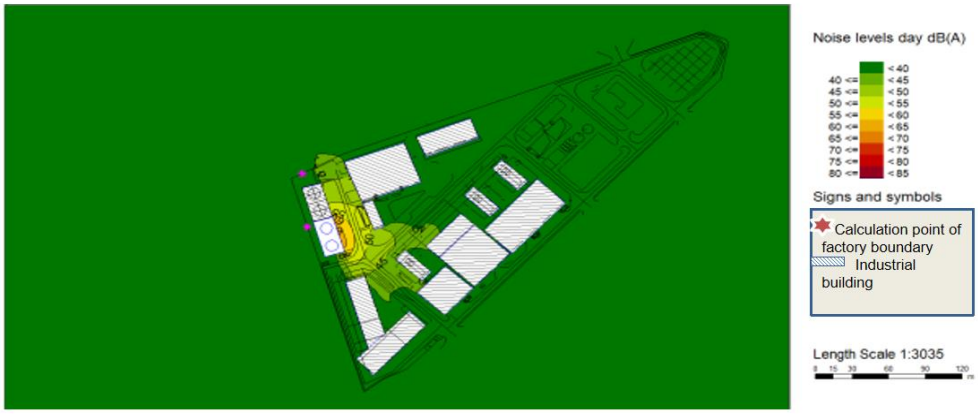

Fig. 7. The prediction map of boundary noise after treatment.

According to the above prediction results, and considering the contribution of the operation of the whole plant to the noise at the boundary, the inlet and exhaust mufflers are set at the inlet and outlet sides, and the noise reduction is about 30dB (A). After taking the above measures, the prediction results of the noise at the plant boundary are shown as Fig. 7.

According to the above prediction results, after taking the above control measures, the noise contribution value of the boundary is less than 45dB (A), which meets the requirements of Class 1 standard of Emission standard for Industrial enterprises noise at boundary (GB12348-2008).

8 Design verification

According to the periodic acceptance report of this project (corresponding to No.1 gas unit), two noise monitoring points are set up at 1m outside the southwest plant boundary and the northwest plant boundary closest to the mechanical tower, as shown in Fig. 5. The noise of the two monitoring points is mainly affected by the mechanical tower, and the comparison between the superposition of predicted contribution value and the current value and the monitoring value of the acceptance report is shown in Table 2.

Table 2. The comparison of simulated and measured values of boundary noise.

Monitoring point	**predicted value** (dB(A))	**measured value** (dB(A))
Monitoring point1	43.3	43.6
Monitoring point2	44.0	44.3
Sensitive point at 100 m	--	43.1

From the above table, it can be seen that when unit 1 is running alone, after taking measures, through simulation prediction by SoundPLAN 7.3, the difference between the predicted value and the measured value of the two boundary monitoring points close to the mechanical tower is small, about 0.3 dB (A), indicating that the predicted value is accurate.

9 Conclusion

In this paper, combined with the noise spectrum of the main sound source of the mechanical tower, the main noise reduction measures are analyzed and put forward. Combined with the actual project, the configuration of the mechanical tower and the main noise reduction measures under the condition of unilateral and bilateral air intake are

compared with the scheme and cost, and the optimization measures are put forward. At the same time, the noise simulation of the plant boundary is carried out before and after the measures are taken, and compared with the actual monitoring value. The difference is small, indicating that the predicted value is accurate and the optimization measures are reasonable.

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