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A novel energy-saving technology for noise reduction of rotary aerators in sewage treatment plants

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Abstract. For oxidation ditch wastewater treatment in the sewage treatment plant, a rotary aerator is often used for aeration. Large noise will be generated during the aeration process, which seriously affects the daily life of nearby residents and workers. This article describes how to reduce noise using the positive and negative pressure difference formed by the rotating brush on both sides and the natural ventilation muffling channel that does not require additional electrical energy in order to replace the traditional closed sound insulation which requires adding a blower to meet the aeration and oxygenation demands. In this way, electrical energy can be saved and noise can be reduced.

1. Introduction

The rotary aerator is a horizontal axis aerator and the key equipment for the oxidation ditch treatment. The brush aerator can not only aerate and oxygenate but mix and plug flow, which prevents the precipitation of activated sludge and is beneficial to the growth of microorganisms [1]. In recent years, the oxidation ditch process of rotating aeration has been widely used in the treatment of industrial wastewater and urban domestic sewage in petrochemical, printing and dyeing, leather, paper, food, pesticide, gas, coal and other industries, and delivered good treatment effect [2,3].

2. Working Principle of Rotary Aerator and Noise Generation

A sewage treatment plant covers an area of 230 mu (1 mu=0.067 acre) with a designed treatment scale of 80,000 t/d. Some use horizontal rotary aerators totaling 20. The aerator is XZPQ type, 9 m long, placed in 10m-wide oxidation ditch; the aerator disk number is 40 pieces, and the oxygenation capacity is 84 kgO₂/h.

2.1. Working principle and use of aeration brush

When the rotary aerator is running, the shaft rotates at a certain speed driven by the transmission device. The rotating blade continuously injects oxygen in the air into the water during the horizontal rotation with the main shaft. In addition, the rotating brush pushes the sewage to circulate in the oxidation ditch at a certain flow rate, which can prevent the precipitation of the activated sludge and fully mix the organics, microorganism and oxygen, thereby effectively meeting the need for mixing and oxygenation during the oxidation ditch process. The rotary aerator is used to oxygenate the sewage, promote the circulation of sewage in the ditch and prevent the precipitation of activated



sludge in the oxidation ditch of the sewage treatment plant so that the sewage and oxygen can be thoroughly mixed to complete the biochemical process [4].

2.2. Noise source of rotary aerator

According to the National Environmental Noise Standard for Urban Areas (GB3096-2008), Class I standards should be implemented, that is, the sensitive point at day is less than 55 dB (A), and at night less than 45 dB (A). The noise should be no more than 45 dB (A) at night for this project (deducting the environmental background sound).

The sound of mechanical friction of the motor in the operation of the rotary aerator, the noise generated by the aeration brush head against the water surface, the noise of eddy current generated by the water drop produce noise of 92 dB (A) one meter from the flow of water generated by the rotary aerator. The noise reduction is required to be 20 dB (A). According to the point source attenuation formula:

$$L(r) = L(r_0) - 20 \log(r/r_0) - \Delta L \quad (1)$$

The noise decrease to residential sensitive points reaches 45 dB (A) at night.

2.3. Sound field superposition of multiple turntable aerators

20 turntable aerators (placed between 120 m and 160 m from the sensitive point) are opened at the same time. The sound field superimposed noise at the sensitive point is calculated according to the multi-source noise formula [5]:

$$L_p = 10 \lg \left(\sum_{i=1}^N 10^{\frac{L_{p_i}}{10}} \right) \quad (2)$$

The traditional scheme or the energy-saving scheme is used to reduce noise by 20 dB (A) to meet the requirement of 45 dB (A) of sensitive points at night.

3. Traditional Noise Reduction Method

The turntable aerator is surrounded by sound insulation board (the upper part is concrete board and the lower part is the sewage surface). The air blower is arranged on the top concrete board to blow the air to the inside. The air volume must reach the requirement for the normal oxygenation capacity of the rotary aerator. For the air volume of the blower, the following factors should be considered: (1) The air volume should meet the requirement for sewage oxygenation; (2) When the blower generates a positive pressure inside as it blows air inside, a small part of the air will be softly connected from the bottom of both sides the air pressed out at the contact of the water surface; (3) As the aeration brush rotates, a small part of the air is introduced into the water and a part of the brush is taken out of the water surface to generate a partial return air which has a low oxygen content.

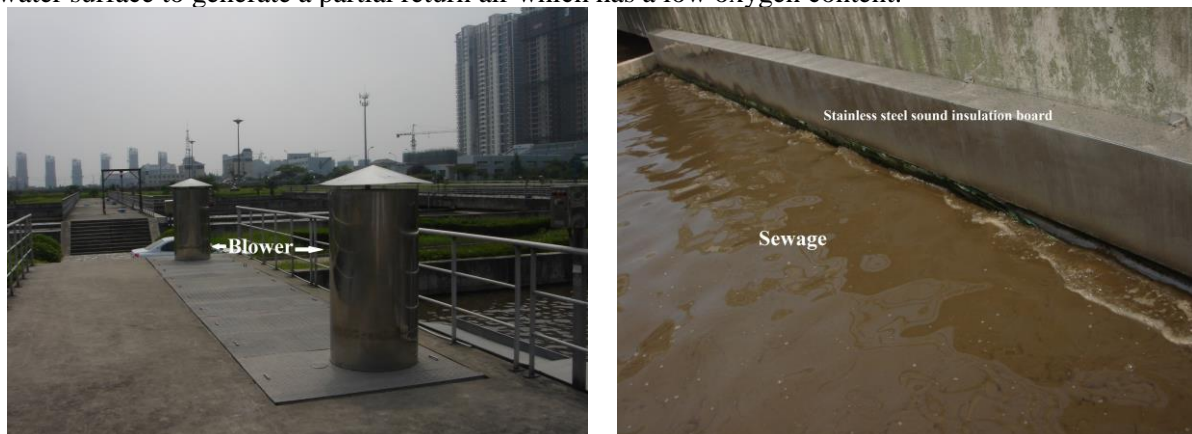


Figure 1. Traditional noise reduction method for a disk aerator

3.1. Annual power consumption of traditional closed sound insulation installed with air blower

The amount of air required for a single aeration tank G_s :

$$G_s = \frac{R_0}{0.28} \times EA \quad (3)$$

The oxygenation rate is 82 kgO₂/h; the oxygen transfer rate is selected as 18%. When the turntable is closed and the blower is blown inward, the air will escape on both sides due to the positive pressure, and fresh air (high oxygen content) and aeration (low oxygen content) will be mixed. To enable normal operation, the amount of oxygenation needs to be increased. Tests show that the dissolved oxygen standard after sewage treatment can be achieved if the amount of air doubles. Therefore, the inward blast volume of a single aerator is 3254 kg/h. Total air volume of the blower:

$$Q = \frac{3254 \text{ kg/h}}{r_1} \times K \quad (4)$$

A single aerator is equipped with two blowers. The performance of the blower is: air volume of 1731 m³/h; wind pressure of 297 Pa; power of 0.55 KW; total annual electricity consumption of 192,720 degrees.

3.2. Amount of insulated sound and reduced noise

The sides of the rotary aerator are made of 1.0 thick stainless steel plate, lined with 80 mm thick centrifugal cotton, 12 wire glass fiber cloth, 0.8 mm thick stainless steel orifice plate with perforation rate of 25%. Its sound insulation is not less than 20 dB (A).

4. Energy saving and noise reduction method

Noises of the rotary aerator are from the mechanical friction of the motor, the aeration brush hits the water surface and water drop against the water. The noise reduction profile of the aeration brush is shown in Figure 2. The perforated composite silencer is made of 304 stainless steel plate with reserved long air passage for air inlet and outlet. The positive and negative air pressure in the local area caused by the rotation of the aeration brush is used to circulate the air. Calculation shows that the air volume is sufficient for the aeration brush to perform normal oxygenation. The bottom of the stainless steel plate is in soft contact with the water contact part with anti-corrosion and wear-resistant materials.

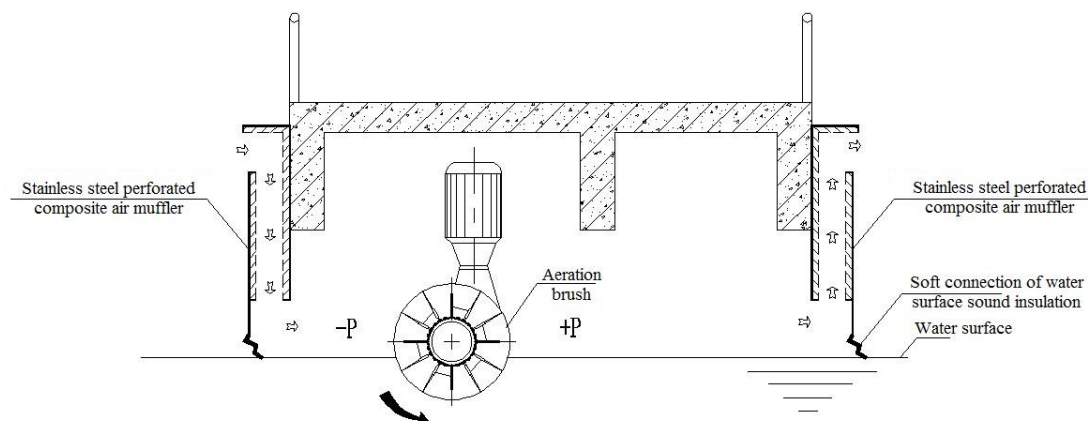


Figure 2. Sectional view of noise reduction of aeration brush

4.1. Test the wind speed of the natural air inlet and outlet muffler on both sides

Both ends of the aeration brush are sealed with sound insulation board (concrete board above and sewage surface below). Natural ventilation muffler is used on both sides. Rapid rotation of the aeration brush is used to generate positive and negative pressure on the left and right sides, causing air to flow from the left to the right. There are nine 1000*400*1400 air inlet mufflers on the air inlet side of each turntable aerator, and nine 1000*400*1400 air outlet mufflers in the wind measurement, as shown in

Figure 3. The effective muffling passage in the muffler has a cross section of 800*200 and is 1.5 m long. After installing the mufflers on both sides of the first rotary aerator, air volume test is first performed. The wind speed table is shown in Table 1. The average wind speed of the inlet muffler is 1.89 m/s.

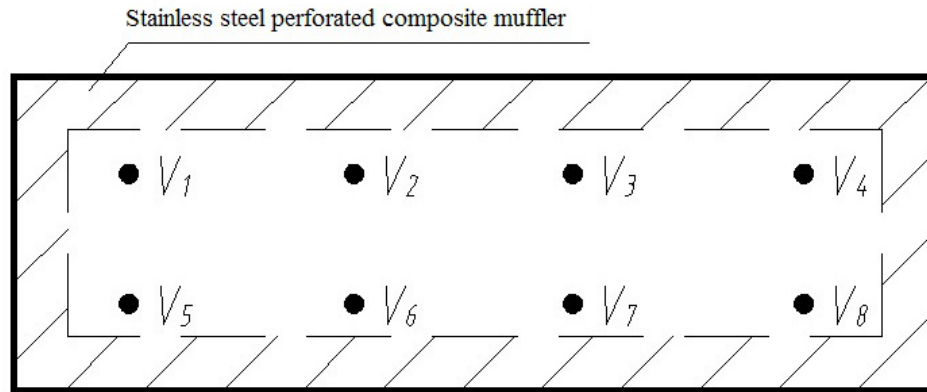


Figure 3. Wind speed measurement point layout

Table 1. Wind speed measurement record

V ₁ m/s	V ₂ m/s	V ₃ m/s	V ₄ m/s	V ₅ m/s	V ₆ m/s	V ₇ m/s	V ₈ m/s
1.93	1.87	1.90	1.83	1.95	1.89	1.91	1.85
$V = (V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7 + V_8) / 8 = 1.89 \text{ m/s}$							

4.2. Total air volume of natural ventilation muffler in inlet and outlet

The total air inlet area of the air inlet muffler is 1.44 m². Apart from the muffler, the rest part is sealed on both sides, so the air volume of the air muffler in the inlet is the same as that of the outlet -- 9979.76 m³/h. This value is greater than the required air volume of a single aeration tank of 3118 m³/h, so the aeration brush can perform normal oxygenation.

4.3. Reduced noise volume of natural ventilation muffler

The reduced noise volume of muffler is [6]:

$$\Delta L = \phi(a_0) \times P \times L / S \quad (5)$$

The muffling coefficient is 1.1; the circumference of the channel section is 2 m; the cross-sectional area of the channel is 0.16 m²; the effective length of the muffler is 1.5 m. Therefore, the reduced noise volume of muffler is 20.63 dB (A).

5. Conclusion

This paper describes a new energy-saving technology for noise reduction of turntable aerators in sewage treatment plants. It adopts the positive and negative pressure difference generated by the rotation of the turntable and natural ventilation method without using electric blast equipment. As it helps to reduce the same amount of noise, it saves energy. The traditional method of turntable aerator denoising or energy-saving method can reduce 20 dB (A), meanwhile, the energy-saving program can save a lot of electric energy every year. This provides a noise reduction method that saves a lot of power for practical applications.

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