Design of Air Floating EGR Water Treatment Device

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Abstract. EGR is an important technical means to reduce NOx emissions from marine diesel engines, but EGR washing waste liquid contains a large amount of pollutants that must be treated before discharging the hull. On January 1, 2016, the IMO Tier III regulations have been implemented and the marine EGR system will be more widely used. Therefore, it is imperative to study the ship EGR plant wastewater treatment system. In this paper the author studied the IMO ship washing wastewater discharge regulations, and introduced the principle, composition, classification, overall layout and causes of wastewater generation of EGR devices. At the same time, the author analyzed the components of wastewater EGR system wastewater pollutants, and compared emission regulations. For the requirements of water quality, various technologies for treating EGR wastewater pollutants were studied. Based on various technologies, the author designed an air-floating wastewater treatment system to treat wastewater. The overall treatment plan, design ideas, structure and size design, and process flow of the device were analyzed and calculated in detail.

1. Introduction
Since 2000, the International Maritime Organization (IMO) has revised the emission regulations several times. The latest ship emission regulations, IMO Tier III, have been implemented on January 1, 2016. Due to the demanding requirements, the latest technology must be adopted to meet NOx emission reduction standards. EGR technology is the cutting-edge technology invented by MAN in Germany. The principle of EGR is to return some of the exhaust gas back to the combustion chamber to reduce the concentration of O2, thereby reducing the temperature of the combustion chamber to achieve the purpose of suppressing NOx formation. This technology can achieve 80% NOx reduction [1]. While as we all know, two-stroke low-speed marine diesel engines use HFO which can cause large number of SOx and PM. That means the recirculated exhaust gas must be treated to remove SOx and PM. The requirements for the low-speed marine diesel EGR system wastewater treatment plant are also increasing. The wastewater generated by the low-speed diesel engine EGR device is also a kind of ship wastewater. However, there are very few studies on the ship low-speed diesel engine EGR device wastewater treatment system [2-4]. The low-speed marine EGR plant wastewater treatment is only recovered by simple cyclone separation or aeration oxidation. The EGR wastewater treated by this process can only reduce the turbidity value and COD value in the EGR plant wastewater, and can’t fully degrade the polycyclic aromatic hydrocarbons (PAHs) and sulfites in the EGR wastewater. Under increasingly stringent environmental requirements, it does not meet the IMO’s latest regulations for the discharge of washing water from ship exhaust systems [5-6]. Therefore, it is necessary to improve the existing equipment and processing technology or to develop a new EGR wastewater treatment unit.
2. Material and Methods

2.1. Aeration Technology
Aeration is a mechanical process in which sodium sulfite is treated by intense contact with air and water in order to dissolve oxygen in the atmosphere while discharging unwanted volatiles and gases from the water out of the water. Aeration promotes the exchange of substances between liquid and gas. The oxygen in the air is transferred to the water by aeration technology, and the oxygen is transferred to the liquid phase.

The aeration method is divided into three types: blast aeration, mechanical aeration and new aeration.

Blast aeration is also called compressed air aeration, and the device includes an aerator and an aeration fan. The air compressor uses a pipe to transfer air to an air diffusing device installed from the bottom of the water tank, which is bubbled out by the diffusing device and finally dissolved in water. The mechanical aeration is rotated by a mechanical impeller installed at the bottom of the tank, and the waste water is vigorously stirred to integrate oxygen in the air. In the past few years, there have been many new types of aeration methods, including deep well aeration, oxygen-enriched or pure oxygen aeration, and aeration technology to assist other biological treatment methods. Pure oxygen aeration is a method similar to blast aeration to inject oxygen-enriched or pure oxygen into the water. The upper part of the aeration tank is provided with a sealing cover, which is beneficial to improve oxygenation efficiency. Biofilm carrier fluidized bed aeration and biological contact oxidation are aeration methods still under development.

2.2. Coagulation Technology
The methods for treating the suspended matter in the wastewater include filtration, coagulation, centrifugal separation, and a gravity sedimentation method. Among them, the filtration method is only suitable for the advanced treatment of wastewater; the gravity sedimentation method is suitable for the treatment of suspended solids with large particle size; therefore, the suspension in the wastewater is treated by centrifugal separation or coagulation air flotation. The essence of the coagulation air flotation method is to rapidly separate the suspended matter which has been precipitated from the wastewater with water by the air flotation method on the basis of the coagulation method.

2.3. Air Floatation Technology
In the low-speed diesel engine EGR wastewater treatment technology, according to the bubble size and the form of action, the air floatation method can be roughly divided into four categories, namely induced air flotation method, dissolved air flotation method, chemical air floatation method and electrolytic air floatation method [19]. The commonly used methods are the jet air floatation method and the impeller air floatation method in the air floatation method, and the pressurized dissolved air floatation method in the dissolved air floatation method, wherein the dissolved air floatation method is most widely used. The dissolved air floatation method includes a dissolved gas vacuum floatation method and a dissolved gas pressurized air floatation method. The working principle of the impeller air floatation method is that the impeller that rotates at high speed attracts a large amount of air, the air that is caught in the impeller is continuously crushed, and becomes a large number of tiny bubbles, and finally a large amount of pollutants adhere to the bubbles; the work of the jet air float method The principle is: the ejector rapidly sprays water and creates a negative pressure inside the nozzle suction chamber. Therefore, a large amount of gas is sucked into the chamber. When the water passes through the mixing section at high speed, the gas carried by the gas is cut into small bubbles, and finally the contaminants are attached thereto. on.

The characteristics of the air floatation method: the scum can be completely removed by the scraper, and the water content is low, and the operation is convenient; in the process of air floatation, a large amount of oxygen is dissolved in the water, and a protection mechanism is easily formed; the equipment and the process flow are simple, and the management Convenient and economical; there is a lot of dissolved air in the water, which can be applied to a variety of water quality.
2.4. Activated Carbon Adsorption Technology

The methods for treating polycyclic aromatic hydrocarbons include microbial degradation, ultrasonic degradation, ultraviolet photolysis, and natural degradation. Among them, the microbial degradation method and the natural degradation method take a long time and a slow speed, and cannot be matched and applied in the entire desulfurization system. The ultrasonic degradation method and the Fenton reagent oxidation method have high cost, complicated operating system, large floor space, and complicated operating system, which are not suitable for the ship environment. Ultraviolet photolysis is easy to produce other toxic substances, and the degradation efficiency is not high. Therefore, the best method for treating polycyclic aromatic hydrocarbons in wastewater is adsorption, and the adsorbent can be used with the lowest cost, most widely used, and recyclable activated carbon.

3. Air Floating Wastewater Treatment Device

According to the water quality research results, the pollutants to be treated in the EGR plant wastewater of the low-speed diesel engine are sulfite, suspended solids and polycyclic aromatic hydrocarbons. Aeration technology is used to treat sulfite in EGR wastewater, flocculation technology is used to treat suspended solids in EGR wastewater, and activated carbon adsorption technology is used to treat polycyclic aromatic hydrocarbons in EGR wastewater. From the above, we can see that the comprehensive scheme of air-floating wastewater treatment is as follows:

- EGR wastewater is first discharged into the waste tank for storage, and the waste tank is opened every six hours to discharge the waste water into the waste gas tank.
- EGR wastewater is oxidized to sulphate in water by aeration in aeration tank.
- EGR wastewater is completely mixed with coagulant and flocculant in the mechanical coagulation tank to form floc.
- EGR wastewater enters the air flotation tank for air flotation treatment and the air bubbles and flocs generated by the air flotation device are combined to form scum, and the scum is discharged through the scraper.
- The water after coagulation and air flotation treatment is discharged into an activated carbon filter device to remove polycyclic aromatic hydrocarbons from wastewater.
- The final treated water enters the detection device. If the concentration of each component meets the IMO standard, it is discharged into the discharge port. If it does not meet the standard, it is discharged into the waste container and treated again.

The air-floating wastewater treatment device is composed of four parts: an aeration device, a coagulation air flotation device, an activated carbon adsorption device, and a detection device.

In this paper, the author selected blower aeration as aeration device, selected advection air flotation cell, and pressurized dissolved air flotation for wastewater treatment. The selected coagulant and flocculant are PAC and PAM.

Table 1 shows the main equipment of air floating water treatment device.
Table 1. Main equipment of air floating water treatment device

| Number | Equipment                          | parameter               | Amount |
|--------|------------------------------------|-------------------------|--------|
| 1      | air compressor                     | Q=0.1 m³/min            | 1      |
| 2      | aeration tank                      | 2200×2200×2200          | 1      |
| 3      | Backflow pump                      | Q=2 m³/h                | 2      |
|        |                                    | H=3m                    |        |
| 4      | air tank                           | Φ250×1000               | 1      |
| 5      | Waste tank                         | 2000×2000×2000          | 1      |
| 6      | water supply pump                  | Q=2 m³/h                | 2      |
|        |                                    | H=3m                    |        |
| 7      | Digital constant flow pump         | 3~6000ml/h              | 3      |
| 8      | dosing tank                        | 420×320×280             | 3      |
| 9      | Activated carbon adsorption unit   | Φ600×600                | 1      |
| 10     | water collecting pipe              | Φ50                     | 1      |
| 11     | clean water tank                   | 500×500×600             | 1      |
| 12     | flotation tank                     | 1600×1600×1600          | 1      |
| 13     | Slag scraper                       | 0.1KW                   | 1      |
| 14     | Stirring motor                     | 0.3KW                   | 1      |
| 15     | Dissolved gas releasing device     | 2 m³/h                  | 1      |
| 16     | Mechanical reaction cell           | 500×500×600             | 1      |
| 17     | flowmeter                          | 10 m³/h                 | 3      |
| 18     | monitoring unit                    | 400×400×400             | 1      |
| 19     | one-way throttle valve             | 10 m³/h                 | 1      |
| 20     | Air blower                         | m³/h                    | 1      |

4. Results
In this paper the author firstly described the comprehensive scheme and design ideas of the air-floating wastewater treatment device, and then comprehensively calculated and analyzed the selection design and size structure of each device and component, and determines the following parameters.: the volume of the waste tank is 8m³, the length of the waste tank is 2000mm, the width is 2000mm, the height is 2000mm; the volume of the aeration tank is 9.92m³, the aeration tank is 2200mm long, the width is 2200mm, the height is 2200mm, the total air volume of the aeration fan is 24m³/h; the diameter of the dissolved gas tank is 250mm, the height is 1000mm, the length of the air floating pool is 1600mm, the width is 1600mm, height is 600mm, mechanical mixing pool and clear water tank are 500mm long, width is 500mm, height is 600mm, air compressor ventilation 0.48m³/h; the volume of the activated carbon adsorption container is 0.32m³, the diameter is 600mm, the height is 600mm; the length of the chemical tank is 420mm, the width is 320mm, the height is 280mm, there are three dosing boxes, respectively, PAC, PAM And NaOH; The detection device has a length of 400 mm, a height of 400 mm and a width of 400 mm.

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