Design and Research of Marine Nuclear Power Platform Engine Room Ventilation System

Meikui He*, Qian Liu, Ting Gui and Zhen Fang.
Wuhan Second Ship Design and Research Institute, Wuhan, Hubei, 430064, China
*Corresponding author’s e-mail: 3923415@qq.com

Abstract. Engine room ventilation system is an important power assist system on marine nuclear power platform. This paper summarizes the development of the engine room ventilation system at home and abroad. The principle of Engine room ventilation system on marine nuclear power platform is researched. This paper takes diesel engine room ventilation system as an example, introduces the design method of engine room ventilation system commonly used on offshore platform and ships at present, and calculates the total ventilation rate of the whole engine room which can maintain the demand for full load work. According to the characteristics of the diesel room of the platform, the suitable ventilation and distribution mode of engine room are determined, including the selection of ventilation mode, the type of air inlet and outlet of the engine room. Based on project example, the core design ideas of ventilation system for engine room are introduced in detail, can provide guidance for the future design of engine room ventilation system on marine nuclear power platform.

1. Introduction

The demonstration project of the marine nuclear power platform (hereinafter referred to as the platform) is a removable offshore power generation platform to meet the requirements of marine energy. And the marine nuclear core is optimized for the power generation on platform. Research and development of marine nuclear power platform can serve the national energy strategy effectively, and provide energy security for ocean resources development and ocean islands.

The ventilation system in the platform is an important part of the power plant and a basic step in the platform manufacturing. Whether the platform power plant can work normally depends on the technical performance of the main equipment (such as reactor, main turbine generator, diesel generator, etc.); whether these main equipment can achieve the technical performance is closely related to the design of the ventilation system of the platform, the selection of ventilation equipment, the determination of energy and quantity, as well as the distribution of air volume and direction. Whether the ventilation system configuration is reasonable or not is directly related to the normal, reliable and safe operation of the platform and its power plant.

The design of the ventilation system in the engine room is to ensure the working environment of the personnel and equipment in the engine room the purpose of the design of the ventilation system in the engine room is:

- it shall take away the heat of a large number of equipment in the cabin to ensure that the temperature in the cabin will not rise too high;
- provide the air quantity necessary for combustion or operation of diesel generators and other equipment;
on the other hand, drain the oil and gas emitted by the cabin equipment and provide a certain amount of fresh air, so as to ensure the normal operation of the equipment in the cabin and normal working conditions for personnel.[1]

The design and calculation of engine room ventilation is an important part of platform design. The calculation of air volume is the basis of fan selection and air volume distribution in each region. The calculation should ensure the total air volume to meet the heat dissipation and combustion requirements of all equipment. The system shall be designed in accordance with the requirements of CCS and international conventions. The pipelines and accessories should adopt a reasonable wind speed to make the resistance of the system pipelines match the fan capacity, resistance calculation should be made as necessary. The system shall be designed to meet the designed air volume and pass the field air volume test. And the air volume in each area can reach the design value by adjusting the device.

2. Analysis of current situation at domestic and international
At present, there are three main design method of domestic cabin system: full fresh air system, circulating cooling and fresh air system and jet. Regardless of the form, the purpose of ventilation is to eliminate hot air in the cabin and make the temperature meet the design requirements; the second is to meet the demand of the machine and staff for fresh air.

2.1. Full fresh air system
The full fresh air system is designed to use the fan to exhaust the dirty air in the cabin to the outside of the cabin and lead the fresh air out of the cabin to the inside. The full fresh air system is composed of fan, air pipe and air filter. The positive pressure design is adopted when the air inlet in the engine room is greater than the air exhaust. The positive pressure design is generally adopted for the engine room with air inlet requirements. When there is no air intake requirement, in order to prevent the high heat and humidity gas from entering other living quarters and other cabins, the negative pressure design is generally adopted for the engine room, that is, the exhaust volume is slightly larger than the air intake volume.

Due to a large number of fresh air entering the cabin, the fresh air system design can ensure the fresh air volume of the cabin while exhausting the heat generated by the equipment in the cabin. However, due to the large air volume, the air inlet and exhaust fan rooms and independent air inlet and exhaust enclosure channels need to be set up separately, which takes up more overall resources. Due to the high air volume, high fan noise and high wind speed in the air duct, the ventilation noise in the whole cabin increases correspondingly. Because there are many heating equipment in the engine room and the space layout is compact, when the air duct is used for air supply and exhaust, it is easy to cause the space layout in the engine room to be particularly tight, and the air duct in some areas can not be delivered, resulting in the local temperature is too high.[2]

2.2. Circulating cooling plus fresh air system
Because the specific heat capacity of sea water is larger than that of air, the way of using sea water to take away the heat in the cabin will inevitably reduce the ventilation volume of the cabin, thus reducing the size of the air duct in the cabin, reducing the wind speed and reducing the noise. Due to the closed cycle cooling, the maximum temperature in the cabin can still be kept within 50 °C when the external fresh air is cut off. This form of design is conducive to the external closure when it is necessary to keep the air tight.[3]

2.3. Jet ventilation
Air jet ventilation system is a system which uses air itself to control the air distribution. By using it together with the main air supply system, the purpose of cabin ventilation is achieved. The engine room ventilation system with air jet ventilation technology will be composed of two parts: the main air supply system and the air jet ventilation system. The air jet ventilation system can replace the large
and complex rectangular air duct in the conventional engine room ventilation system. It makes full use of the characteristics of small space size, simple structure, flexible layout and high ventilation efficiency of the system, and achieves the good ventilation effect of the engine room while giving way to the precious upper space in the engine room for the layout of power and other pipelines and trunk cables.[4]

The design of jet ventilation system mainly lies in the form of air distribution. Its principle is to shoot out high-speed air flow through the characteristics of jet nozzle, guide and drive the air around it to move forward; and organize the air flow in the cabin through the arrangement and direction of nozzle, so as to ensure the uniform temperature distribution and good ventilation effect in the cabin.

The three ventilation modes have their own characteristics. Different ships adopt different modes according to needs. The new air system design of the engine room shall fully consider the intake and exhaust port settings, plan in advance, and fully consider the air flow organization to avoid local high temperature caused by short circuit of air flow. For surface ships with sealing requirements under special circumstances, circulating cooling and fresh air system can be used. The advantage of jet ventilation is that it better disturbs the air flow in the cabin and makes the temperature field more uniform. The design idea of air jet ventilation technology has been widely used in the design of ship ventilation system for decades in the world. European and American companies, such as ABB company, York company and Dutch H & H company, all adopt such ventilation technology in the design of ship engine room ventilation system. Among them, the dirivent system developed by ABB company in Sweden on the principle of air jet ventilation technology has been widely used in the air conditioning ventilation or mechanical ventilation system of ship's cargo hold, mechanical cabin and engine room. [5]

3. Calculation of ventilation volume of engine room

According to relevant standards such as CB/T 3772-1996 "Ventilation design conditions and calculation basis of diesel engine engine room", the determination of ventilation volume of engine room mainly considers two factors: air volume required for equipment combustion and the amount of air required for equipment heat dissipation. The total ventilation volume of the engine room shall be at least the sum of the above two parts. [6] The main equipment of the diesel engine room of the platform includes: two sets of diesel engine generator sets, with the rated power of 2800kw, one for use and one for standby. Under the condition of diesel engine power generation, only one set operates.

3.1. Calculation of air volume required for equipment combustion

Air consumption of diesel engine combustion

\[ Q_{dp} = \frac{P_{dp} \cdot m_{ad}}{\rho} \]  

- \( P_{dp} \) — shaft power at maximum continuous power of main diesel engine, kW;
- \( m_{ad} \) — The air quantity required for unit power combustion of diesel engine, kg l/(kW \cdot s);
- \( \rho \) — air density, 1.13kg/m3 at 35 ℃;
- The stand-by diesel engine of the platform is a two-stroke diesel engine. \( m_{ad} \) is 0.0025 kg l/(kW \cdot s) according to the standard value.

Therefore, the combustion air volume of the equipment is \( Q_{dp} = 22300\text{m}^3/\text{h} \)

3.2. Ventilation required for heat dissipation

The heat dissipation equipment in diesel engine room mainly considers the heat dissipation of diesel engine and generator set, followed by electrical equipment and exhaust pipe system.
The air quantity required for heat dissipation of equipment $Q_h$ is calculated according to the following formula:

$$Q_h = \frac{\Phi_{dp} + \Phi_g + \Phi_{ep}}{\rho \times C \times \Delta T} - 0.4 \times Q_{bp}$$  \hspace{1cm} (2)

- $\Phi_{dp}$ — cooling capacity of diesel engine, kW;
- $\Phi_g$ — cooling capacity of diesel engine of main power generation, kW;
- $\Phi_{ep}$ — cooling capacity of exhaust pipe system, kW;
- $\rho$ — air density, 1.13kg/m$^3$ at 35 ℃;
- $C$ — specific heat capacity of air, 1.01kJ/(kg· K);
- $\Delta T$ — average temperature rise in engine room, 12.5K;
- $Q_{bp}$ — air volume required for diesel engine combustion, m$^3$/s.

Heat dissipation of diesel engine $\Phi_{dp}$

$$\Phi_{dp} = P_{dp} \times L_{dj} \times n_{dp}$$  \hspace{1cm} (3)

- $P_{dp}$ — shaft power at the maximum continuous power of diesel engine, kW;
- $L_{dj}$ — heat loss of diesel engine, %, calculated according to figure 1, taking 0.02.

Heat dissipation of the generator $\Phi_g$

$$\Phi_g = P_g \cdot (1 - \eta)$$  \hspace{1cm} (4)

- $P_g$ — the generating power of an alternator, kW;
- $\eta$ — alternator efficiency, when the value is not specified, it is calculated as 94%.

Heat dissipation of exhaust pipe system $\Phi_{ep}$

The diameter of exhaust pipe of diesel engine is DN700mm, and the insulation thickness is 70mm. According to the atlas, the heat dissipation of exhaust pipe per meter is 0.5kw/m; the length of exhaust pipe of main engine is 10m, so the heat emission of exhaust pipe of each main engine is 5 kW.

Therefore, the total heat dissipation of exhaust pipe system is $\Phi_{ep} = 5$ kW;

The ventilation required for heat dissipation is $Q_h = 32884$ m$^3$/h.

3.3. Calculation of total ventilation required for engine room

$$Q = Q_{dp} + Q_h = 55184$$ m$^3$/h  \hspace{1cm} (5)

4. Design of ventilation system for diesel engine room

4.1. Selection of ventilation mode for diesel engine room

The ventilation of the cabin has the following ways: mechanical air supply, mechanical exhaust; mechanical air supply, natural return air; Natural air supply, mechanical exhaust mode; natural ventilation mode. According to the requirements of CB/T 3772-1996, the ventilation design of the engine room needs to maintain a slight positive pressure of the engine room, usually the positive pressure is not more than 50Pa. Therefore, the diesel engine room of the offshore nuclear power platform is designed by the way of mechanical air supply and mechanical exhaust of the engine room.

One fan is selected for the engine room of diesel engine for air supply (the air volume is about 60000m$^3$/h when the fan is full load). In order to meet the requirements of different working conditions, two speed fan is adopted; one fan is selected for the exhaust of engine room (the air volume is about 40000m$^3$/h when the fan is full load), and the fan is reversible. In order to meet the
characteristics of high efficiency, small volume and convenient forward and reverse rotation, the axial flow fan is selected for the engine room fan.

4.2. Design of ventilation pipeline in engine room
According to the requirements of SOLAS, the diesel engine room belongs to the mechanical space. When the ventilation system pipeline passes through other cabins, the problem of fire protection area shall be considered. The ventilation duct and fire damper shall be set according to the requirements of the standard. Considering that there are many oil pipes, cables, water pipes and other pipelines in the diesel engine room, the main pipes in the diesel engine room mainly adopt the structural air pipes and rectangular air pipes to meet the layout and fire protection requirements.

The structural air ducts of diesel engine room are arranged on both sides of the engine room. The recommended wind speed in the main pipe of the engine room is 12-20 M/s. The wind speed of each branch pipe is controlled at 8-10 M/s. Generally, the air volume is reduced by 10% each time, and the wind speed is reduced 0.5m/s. Each branch pipe is made of 3mm steel plate and painted on the surface to meet the strength requirements and avoid vibration and noise due to insufficient strength of air duct.

4.3. Air supply/return pipe outlet design
The air supply/return air outlet of the diesel engine room of this platform adopts the ventilation grid, which is arranged near the diesel engine and generator. The number of ventilation grids shall control the air speed of the air inlet in the engine room to about 6m/s.

4.4. Design of air inlet and outlet of engine room
The diesel engine room of the platform belongs to class a machine space, and the specification requires that the ventilation of class a machine space shall ensure sufficient ventilation under any sea conditions to maintain the safe operation of the machine and the comfort of the crew, and the ventilation inlet and outlet shall be open. From the perspective of fire protection, according to SOLAS requirements, the main air inlet and outlet of all ventilation systems shall be able to be closed from the outside of the ventilation space. [7] The ventilation inlet and outlet of the diesel engine room are equipped with louvers, and the fans are arranged indoors. The fire-proof closing device can be installed at the fan outlet or the blades of pneumatic / electric adjustable louvers can be used to achieve the purpose of closing.

4.5. Elimination of fan noise and vibration
Due to the large size and high noise of the fan in the engine room, the noise of the engine room and the noise of the upper building may be relatively large. In order to improve this situation, a muffler is added to the front pipe section of the forced draft fan and the exhaust fan to reduce the fan noise sound system for office workers. At the same time, a spring damping base and a hull base are installed under the fan to reduce the vibration of the fan, [8] as shown in the figure 1.

![Fig. 1 Installation of fan muffler](image-url)
5. Summary
This paper introduces the design process of the ventilation system in the engine room of the marine nuclear power platform, expounds the air volume calculation, the design of the air duct and the problems that should be paid attention to in the design process of the ventilation system in the engine room, which has certain reference value for the design of the ventilation system in ships. The ventilation system of the engine room provides a good working environment for the equipment and the staff. The ventilation pipeline is an important part of the ventilation system. How to build a three-dimensional design model of the ventilation system, optimize the design of the pipeline, take the layout of the large equipment (such as diesel engine, generator, etc.) into account as a whole, and at the same time take the comfort of the human body into consideration, improve the overall layout of the grill or the air distributor is the future of the ventilation design of the engine room development direction.

Reference
[1] Yu X.X., Sun P.T., (2002) Design of ventilation system for ship engine room. World shipping, 5: 52-53
[2] Zeng H.Q., Zhou X., (2016) Comparative analysis and Research on design methods of ventilation system in engine room. China ship building, 2: 201-205
[3] Chai Z.J., Wang F.L., (2007) Preliminary study on the technology of improving the air quality in the cabins of fully enclosed surface ships. Ship, 5: 50-51
[4] Shao F., (2007) Application of air jet ventilation technology in engine room ventilation system of ships. Chinese Journal of Ship Research, 4: 47-50
[5] Zhao Y.Z., Liu YaQin, Li Peng, (2014) Design comparison of ventilation systems for three engine rooms of and surface ships. China water transport, 12: 17-18.
[6] China state shipbuilding corporation, (1997) Design conditions and calculation criteria for ventilation in engine room of China National Shipbuilding Corporation and diesel engine: CB/T 3772-1996. Standards Press, Beijing: China.
[7] Wang J.F., (2017) Discussion on some problems in ventilation design of engine room of diesel engine. Ship force device, 6: 63-66.
[8] Lü H.Y., (2017) Design of ventilation system for engine room of 78m platform supply ship/oil recovery ship. Guangdong ship building, 5: 45-48.