Current situation and prospect of air pollutant emission standards for ships

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Abstract. The emission limits and measurement methods of pollutants from ship engines (China's first and second stages) implemented on July 1, 2018 (GB15097-2016) marked the initial establishment of China's ship air pollutant emission standard system. Based on the study of the development of China's ship air pollutant emission standards, this paper analyzes the applicable ships and the types of pollutants controlled by China's ship air pollutant emission standards system, and puts forward some suggestions to improve China's ship air pollutant emission standards system.

1. Introduction
As one of the main ambulatory pollution sources, ships have a great influence on air environment. The development of China's ship air pollutant emission standards is divided into the following stages.

(1) Non-road mobile machinery diesel engine exhaust emission limits and measurement methods (Chinese I, II stage)
"Non-road mobile machinery diesel engine exhaust emissions limits and measurement methods (Chinese I, II stage)" (GB 20891-2007)[1] was jointly issued in April 2007 by the state environmental protection administration and the state administration of quality supervision, inspection and quarantine, and implement on October 1, 2007. The standards stipulate emission limits and measurement methods of exhaust pollutants from non-road mobile machinery diesel engines, and indicate that if the rated net power of non-road mobile machinery diesel engines does not exceed 37kW for ship driving, this standard can be referred to. Therefore, the Marine diesel engine with a net power of no more than 37kW has an emission limit that can be referred to, but this limit is not mandatory.

(2) Notification on the revision of legal inspection technical rules for inland ships in 2008[2]
The revision notice of legal inspection technical rules for vessels and offshore facilities 2008 issued by the maritime administration of the People's Republic of China was implemented on March 1, 2008. The notice clearly requires the NOx emission limit of engines with power greater than 130kW for vessels sailing in the three gorges reservoir area[3].

The standard adopted the prevention of air pollution rules in the first stage (Tier I) requirements for NOx emission limit value from The international convention on the prevention of pollution (MARPOL73/78 convention) supplement VI.

(3) Legal inspection technical rules for inland ships 2011[4]
"Ships and Marine facilities legal inspection rules - legal inspection rules for inland river ships 2011" was implemented on 1 September 2011, including about ship NOx emissions limits standard agree with modify bulletin in 2008, but its scope of application expanded to sail in all inland waters in our country ships used by single power rating of more than 130 kw diesel engine.
(4) Emission limits and measurement methods of exhaust pollutants from diesel engines for non-road mobile machinery (China phase iii and iv)

Emission limits and measurement methods of exhaust pollutants from diesel engines for non-road mobile machinery (China’s third and fourth stages) (GB 20891-2014) [5] was jointly issued by the ministry of environmental protection and the general administration of quality supervision, inspection and quarantine of the People's Republic of China in May 2014 and implemented on October 1, 2014. The standard is the “Road mobile mechanical diesel engine exhaust emission limits and measurement methods (Chinese I, II stage)” (GB 20891-2007) revision, on the one hand tightened the pollutant emission limits (Table 1), on the other hand make clear that the net wattage rating of no more than 37 kw Marine diesel engine should be enforced.

Table 1. Pollutant emission limit of the net wattage rating no more than 37 kw Marine diesel engine

| Stage       | CO (g/kWh) | HC+NOx (g/kWh) | PM (g/kWh) |
|-------------|------------|----------------|------------|
| The third stage | 5.5        | 7.5            | 0.60       |
| The fourth stage | 5.5        | 7.5            | 0.60       |

(5) Notification on the revision of legal inspection technical rules for inland ships in 2015[6]

“The ships and offshore installations legal inspection rules - legal inspection rules for inland river ships 2015 modify bulletin” was implemented on March 1, 2015, this change further reduced the ship NOx emission limits, is in line with the demand for NOx emission limit value in “International convention on the prevention of pollution caused” supplement VI (Tier II). Scope of application is still all ships of inland waters in our country used by single power rating of more than 130 kw diesel engine.

(6) Emission limits and measurement methods of exhaust pollutants from Marine engines (China phase I and ii)

Emission limits and measurement methods of exhaust pollutants from ship engines (China's first and second stages) (GB15097-2016) [7] was jointly issued by the ministry of environmental protection and the general administration of quality supervision, inspection and quarantine of the People's Republic of China in August 2016 and implemented on July 1, 2018. This standard is applicable to class 1 and class 2 ships with net rated power greater than 37kw installed on inland ships, coastal ships, river-sea direct ships, strait [ferry] ships and fishery ships (Table 2,3). The release of this standard marks that China's ship air pollutant emission standard system has been initially established, and the emission limits of all the power range of Marine diesel engines have clear national standards.

Table 2. First-stage emission limits for exhaust pollutants from ships and aircraft

| The ship machine type | Single cylinder displacement (SV) (L/cylinder) | Net rated power (P) (kW) | CO (g/kWh) | HC+NOx (g/kWh) | CH4 (g/kWh) | PM (g/kWh) |
|----------------------|---------------------------------------------|--------------------------|------------|----------------|-------------|------------|
| Class 1              | SV<0.9                                      | P≥37                     | 5.0        | 7.5            | 1.5         | 0.40       |
|                      | 0.9≤SV<1.2                                  |                           | 5.0        | 7.2            | 1.5         | 0.30       |
|                      | 1.2≤SV<5                                    |                           | 5.0        | 7.2            | 1.5         | 0.20       |
|                      | 5≤SV<15                                     |                           | 5.0        | 7.8            | 1.5         | 0.27       |
| Class 2              | 15≤SV<20                                    | P<3300                   | 5.0        | 8.7            | 1.6         | 0.50       |
|                      | 20≤SV<25                                    | P≥3300                   | 5.0        | 9.8            | 1.8         | 0.50       |
|                      | 25≤SV<30                                    |                           | 5.0        | 11.0           | 2.0         | 0.50       |

(1) Only applicable to NG (dual fuel) ships
Table 3. Second-stage emission limits for exhaust pollutants from ships and aircraft

| The ship machine type | Single cylinder displacement (SV) (L/cylinder) | Net rated power (P) (kW) | CO (g/kWh) | HC+NOx (g/kWh) | CH4 (1) (g/kWh) | PM (g/kWh) |
|-----------------------|-----------------------------------------------|--------------------------|------------|----------------|----------------|------------|
| Class 1               |                                               |                          |            |                |                |            |
|                       | SV<0.9                                        | P≥37                     | 5.0        | 5.8            | 1.0            | 0.3        |
|                       | 0.9≤SV<1.2                                    |                           | 5.0        | 5.8            | 1.0            | 0.14       |
|                       | 1.2≤SV<5                                      |                           | 5.0        | 5.8            | 1.0            | 0.12       |
|                       | 5≤SV<15                                       |                           | 5.0        | 6.2            | 1.2            | 0.14       |
|                       | 2000≤P<3700                                   |                           | 5.0        | 7.8            | 1.5            | 0.14       |
|                       | P≥3700                                        |                           | 5.0        | 7.8            | 1.5            | 0.27       |
|                       | P<2000                                        |                           | 5.0        | 7.0            | 1.5            | 0.34       |
| Class 2               |                                               |                          |            |                |                |            |
|                       | 15≤SV<20                                      | 2000≤P<3300              | 5.0        | 8.7            | 1.6            | 0.50       |
|                       |                                               | P≥3300                   | 5.0        | 9.8            | 1.8            | 0.50       |
|                       |                                               | P<2000                   | 5.0        | 9.8            | 1.8            | 0.27       |
|                       | 20≤SV<25                                      | P≥2000                   | 5.0        | 9.8            | 1.8            | 0.50       |
|                       |                                               | P<2000                   | 5.0        | 11.0           | 2.0            | 0.50       |
|                       | 25≤SV<30                                      | P≥2000                   | 5.0        | 11.0           | 2.0            | 0.50       |

(1) Only applicable to NG (dual fuel) ships

2. Analysis of China’s ship air pollutant emission standard system

2.1 Applicable ships

Ships can be divided into international ocean-going ships and domestic ships in the navigation area, which need to meet different standards and management requirements. For international ocean-going ships, China, as a member of category A of the IMO, uniformly implements the provisions of the “International convention for the prevention of pollution caused by ships” (marpol 73/78 convention). Therefore, the control scope of China’s air pollutant emission standard system for ships is ships with Chinese ship registration sailing or operating in China’s waters (including inland river ships, coastal ships, river-sea direct ships, strait [ferry] ships and all kinds of fishing boats, etc.), not including ocean-going ships.

At present, the international ship air pollutant emission control, carries on the control in ship engine as the main body, through the type approval, production consistency check and realize the conformity inspection such as environmental management way of Marine discharge atmospheric pollution control, air pollutant emission standard system of our country shipping also adopted the general management ideas. Therefore, the emission limits stipulated by China’s ship air pollutant emission standard system are only applicable to new ships or ships in use after overhaul, but not to ships in use without overhaul.

In addition, China’s air pollutant emission standard system for ships covers the emission control of diesel engines and gas-fuel engines, but not the gasoline engines installed on yachts.

2.2 Types of pollutants controlled

Most ships use compressed-combustion engines, which are fuelled by diesel or high-sulphur bunker fuel and emit pollutants such as particulates (PM), nitrogen oxides (NOx), hydrocarbons (HC) and carbon monoxide (CO). The emission limits of the above pollutants are stipulated in China’s ship air pollutant emission standard system. Emission limits and measurement methods of Marine engine exhaust pollutants (China’s first and second stages) (GB15097-2016) are implemented in the first and second stages. The first stage is equivalent to the emission control level of the second stage of automobile engine and non-road engine. The second stage is equivalent to the third stage control level of automobile engine and non-road engine.
Sulfur dioxide (SO<sub>2</sub>) control is achieved by controlling the fuel used by ships. According to the research, the level of SO<sub>2</sub> emission is mainly related to the sulfur (S) content of fuel oil. After engine combustion, almost all the sulfur in the fuel is oxidized into SO<sub>2</sub> in the exhaust gas, so the most effective way to reduce SO<sub>2</sub> emission is to use fuel oil with low sulfur content. China's air pollutant emission standard system for ships requires ships to use low-sulfur Marine fuel oil and ordinary diesel oil that meets national standards and regulations (for ships with pollution control devices, whose SO<sub>2</sub> emission does not exceed the use of low-sulfur Marine fuel, they can use other fuels, and the ships should have distinct marks). The bunker requirement applies not only to new ships but also to all ships in service.

3. Suggestions on improving the standard system for the discharge of air pollutants from ships in China

Through the analysis of China's ship air pollutant emission standard system, the following suggestions are put forward to improve China's ship air pollutant emission standard system.

1) Formulate and issue Marine gasoline engine emission standards as soon as possible

China's air pollutant emission standard system for ships has not covered the Marine gasoline engines installed in yachts. Although the number of Marine gasoline engine is relatively small, its application scope is mainly in scenic spots and scenic spots, and its impact on tourists' perception and environment of scenic spots cannot be ignored. Therefore, it is suggested that the emission standard of Marine gasoline engine should be formulated and issued as soon as possible.

2) Carry out research on emission standards for air pollutants from ships in service

The emission limits stipulated by China's air pollutant emission standard system for ships are only applicable to new ships or ships in use after major repair, but not to ships in use without major repair. By 2018, the number of vessels in use in China was 137,000, and due to the backward production technology and design concept at that time, the emission level of air pollutants was generally high. The life cycle of ships is generally 30 years, which means that a large number of existing ships will continuously discharge a large amount of atmospheric pollutants into the environment without supervision in the 30 years before they completely retire from operation, which will adversely affect the improvement of atmospheric environment quality. Therefore, it is suggested to carry out the study on the emission standards of atmospheric pollutants from the in-service ships in time to control the emission of atmospheric pollutants from the source.

3) Increase the types of pollutants to be controlled according to future needs

China's air pollutant emission standard system for ships controls pollutants including particulate matter (PM), nitrogen oxide (NOx), hydrocarbon (HC), carbon monoxide (CO) and sulfur dioxide (SO<sub>2</sub>). It is recommended to increase pollutant categories such as carbon dioxide (CO<sub>2</sub>) and ammonia (NH<sub>3</sub>) at the appropriate time according to future needs.

1) Carbon dioxide

On November 12, 2014, China and the United States issued the China-US joint statement on climate change in Beijing, and China proposed for the first time that "Carbon dioxide emissions will peak around 2030 and will strive to peak at an early date". President Xi Jinping reiterated this position in his speech at the opening ceremony of the Paris conference on climate change in Paris on November 30, 2015. As a responsible country, China will actively reduce carbon dioxide emissions, so it is necessary to increase carbon dioxide in the future revision of standards.

2) Ammonia

On January 1, 2016, North America and the Caribbean emissions control area is first to perform the NOx emission limit value in “International convention on the prevention of pollution caused by ships”(MARPOL73/78 convention) (For foreign ship to the port). Tier III requirements will be implemented in the north sea and the Baltic emissions control area on January 1, 2021, and implemented in China on January 1. To reach Tier III standards, the use of selective catalytic reduction (SCR) system is a priority, and consume large amounts of ammonia in the SCR system operation process, the resulting ammonia escape cannot be ignored, thus adding ammonia standard revision is
suggested in the future.

Acknowledgments
This work was financially supported by national key research and development program (2016YFC0205206) fund.

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