Considerations for the Global Environment in the Latest Large Container Vessels

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With the globalization of the economy, the amount of cargo trades in the world has been increasing with each passing year. About 80% of the physical distribution in the world is supported by marine transport, namely, ships. With mounting global interest in environmental problems and higher cargo-carrying capacities, the environmental loads of ship transport have come to attract considerable attention. Various international rules and regulations on shipping and the environment have been put into effect over the last three decades. Even the ship owners themselves are increasingly concerned about the environment. This paper introduces the treatment of environmental loads in the specifications for the state-of-the-art container vessels built by Mitsubishi Heavy Industries, Ltd. (MHI). Background conditions behind the specifications and examples of actual applications of the specifications are presented.

1. Introduction

Many ships use diesel engines as their main engines and run them with a low-quality fuel called "C-oil." These diesel engines discharge exhaust gas after combustion into the atmosphere, and thus conceivably have impacts on the atmospheric environment. The ships also conceivably impact the marine environment by discarding waste during operation and discharging and loading ballast water at ports to maintain ship stability. Accidents pose another threat of environmental impact on the ocean, as any collision or grounding could lead to an outflow of cargo oil and fuel oil.

Among the various types of ships in service, the cargo-carrying capacities of container vessels (vessels built exclusively to transport containers) are being rapidly expanded to accommodate the rising volume of cargo trade worldwide. The capacities of the vessels sailing the key shipping routes connecting North America, Asia, and Europe are unprecedented. The vessels are being built larger in pursuit of high economic efficiency, and the main engines are being built larger to ensure punctual "weekly service."

Some of the newer large container vessels are being built to the specifications shown below, with consideration for the environment.

2. Measures for the marine environment

(1) Fuel tank arrangement

Ships are controlled by the rules and regulations of the government agencies from the nations that have ratified the international convention MARPOL (International Convention for the Prevention of Pollution from Ships). A new agreement in the annex to the Convention calls for the arrangement of fuel oil tanks in safe positions that will prevent fuel oil from flowing out in the event of accidents at sea such as collisions or groundings.

The new rule requires the correct arrangement of any fuel oil tank with a capacity of 600 m^3 or more, regardless of the type of ship. To be more specific, the rule specifies the distances from the fuel tank to the outer shell at the bottom of the ship and side of the ship. In the case of a large container vessel (with a fuel oil tank capacity of 5,000 m^3 or more), for example, the risk of a fuel oil spill in the worst-case scenario is reduced by arranging the fuel oil tank two meters away from the outer shell of the bottom and one meter away from the outer shell of the side (**Fig.1**). This rule is applied to ships contracted for newbuilding on and after August 1, 2007. Large container ships equipped with large output main engines and long endurance need to have large-capacity fuel oil tanks commensurate with the fuel consumption and navigation distance. Some vessels in the 8,000 TEU class, for example, have fuel oil tanks with capacities as high as 8,000 to 9,000 m^3. If such a vessel was to undergo a worst-case catastrophe, the

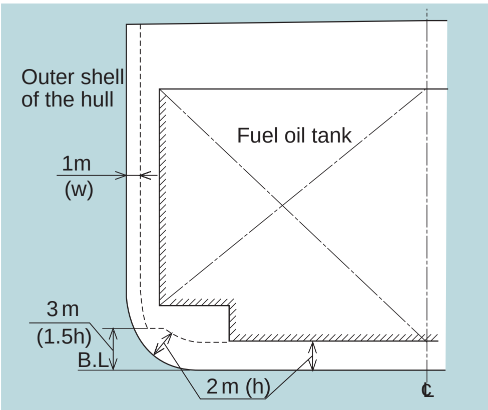

Fig. 1 Required distance from the outer shell of the fuel oil tank (for vessels with a fuel oil tank capacity of 5000m³ or more)

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impact on the environment would be tremendous. MHI has responded by building its newer container vessels based on similar fuel oil tank arrangements, in spite of the new convention now in effect.

(2) Treatment of inboard garbage

A ship produces garbage, residue, sewage, and various other oil-containing liquids as it navigates. Treatment of oil-containing liquids is set down in annex I of MARPOL. Ships are only allowed to discharge water with oil content concentrations of 15 ppm or less after treatment with an oily water separator. The separated oil is burned in an incinerator installed on board the ship or landed. The oily water separator is equipped with a highly sensitive oil content detector. The incinerator, meanwhile, is designed in accordance with the provisions set down by a subordinate organization committee of the International Maritime Organization (IMO). The temperature within the incinerator must be at a constant or higher value at all times, to cope with emulsions and other materials with high oil content.

Annex IV of MARPOL also regulates the sewage (living drainage, etc.) produced during voyage not only for container vessels, but for all types of ships at sea. The regulation requires that a ship be equipped with a sewage treatment unit to break sewage into fragments, disinfect it, and discharge it at sea at a minimum required distance away from land. To ensure this requirement, some of the container vessels built by MHI are equipped with an exclusive tank designed to temporarily collect living drainage at port or during brief navigation in shipping routes close to land.

Container vessels can also carry highly combustible or flammable cargoes packed in containers. If these cargoes are loaded in cargo holds, rainwater or seawater may come into the hold through gaps between the hatch covers and trickle down the loaded containers to the bottom of the hold. The liquids in some types of cargo may contain dangerous components and require careful handling. In general, the rainwater or seawater flowing down to the bottom of the hold collects in a small depression located on the hold bottom called a "well." Some ships have a special tank to hold this water. Incoming rainwater and seawater are fed into the tank by piping and kept in the tank until they can be landed. This exclusive tank is not a requirement in the rule. There are ship's owner, however, who request the installation of this tank as an environmental measure.

(3) Painting

If marine organisms such as acorn shells adhere to the underwater hull, the resulting increase in water resistance will decrease the ship's speed or push up the fuel consumption. To prevent the adhesion of marine organisms, a paint containing a toxic component called "organotin" used to be painted on the outer shells of ships. This practice was called into question in 1986, when a study revealed the bio-accumulation of organotin in marine organisms. The "International Convention on the Control of Harmful Anti-Fouling Systems on Ships" adopted at IMO in 2001 stipulated a complete phase-out of organotin paints from 2003 up to 2008. Shipbuilders nowadays often use an organotin-free paint that prevents adhesion by shedding or melting off the surfaces on which it is painted. Paint makers have also developed a polymeric paint that forms extremely smooth surfaces on which marine organisms find it difficult to adhere.

The ballast tank remains in a corrosive and harsh environment during operation, with alternate exposure to seawater and air through loading and unloading. Ballast tanks used to be coated with a paint containing a tar epoxy with excellent anticorrosion properties. This had drawbacks, however, as certain carcinogenic substances within tar threaten the health of painting workers and can contaminate the marine environment. A modified epoxy paint without tar is now used instead.

There have also been recent measures to protect the human body by reducing the levels of VOCs (volatile organic compounds) in paints. The regulation targets an approximately 30% reduction of the VOCs emission from paints and solvents, relative to the large amounts emitted in 2000. In some cases, the regulation covers the spray painting facilities and drying facilities of shipbuilders. New facilities need to be constructed and existing facilities need to be modified.

(4) Ballast water treatment

Ballast water is seawater loaded in tanks to adjust the trim condition and draft of a ship. The ballast water is also used to ensure stability and relax stresses acting on the hull construction. When cargo is loaded and unloaded at port, the amount of the ballast water needs to be changed according to the change of the weight distribution of the vessel. As many as 10 billion tons of ballast water are believed to be moved annually by vessels of all types. The release and intake of the water at ports and harbors effectively moves seawater from one part of the sea to another. Marine organisms such as seashells and plankton are moved together with the ballast water, as well as pathogenic organisms. Adverse effects on the marine environment are reported. Some organisms, for example, breed in areas where they are moved and change the ecosystems as a result.

This problem came to be handled internationally in the early seventies. In 1997, the IMO adopted a set of guidelines for the control and management of ballast water to minimize the transfer of harmful aquatic organisms and pathogens. The guidelines call for ballast water exchange on the ocean to minimize environmental effects. The "International Convention for the Control and Management of Ballast Water and Sediments" adopted in 2004 permits the exchange on the ocean up to 2015, but thereafter calls for the installation of ballast water treatment units on board ships. The specifications for the treatment units have also been determined. One specification limits the number of living organisms of 50 micrometer or more in size to a maximum of ten per cubic meter of ballast water. Treatment units to meet this specification are hurriedly being developed all around the world.

3. Measures for the atmospheric environment

3.1 Hull forms to reduce the consumption of fuel

A ship requires fuel to sail. In hull forms with good propulsion performance, the same ship speed can be achieved with less horsepower. Hull forms with excellent propulsion performance consume less fuel and are friendlier to the environment.

The Ship & Ocean Laboratory run by MHI in the Nagasaki Research & Development Center has been developing excellent hull forms and efficient propellers since its establishment in 1943. In our earlier work on developing hull forms, we fashioned paraffin models of up to about 7 meters in length and tested them by collecting resistance data, etc. in towing tanks of 100 meters or more in length. More recently, the dramatic improvements in the computation processing of CFD (Computational Fluid Dynamics) have made it possible to simulate a flow around a complicated hull by calculation. With this ability, engineers are now using CFD to refine the hull forms to optimal levels that can be confirmed with model ships. This has shortened the development study time, allowing us to study many more hulls and develop better hull forms.

3.2 Exhaust gas during navigation

The emission quantities of nitrogen oxides (NOx) and sulfur oxides (SOx) in exhaust gas are set down for the diesel engines frequently employed for general merchant ships, including container vessels. This MARPOL annex VI was adopted in September 1997 at IMO and came into effect on May 19, 2005.

The emission quantity of NOx is generally related to the environment during fuel combustion, hence countermeasures against NOx are taken on the engine side. The amount of SOx is related to the amount of sulfur contained in fuel, hence countermeasures against SOx are taken by using a proper type of fuel (**Fig. 2**).

(1) Nitrogen oxides: NOx

The target for NOx emission is 30% reduction compared to the emission quantity in 1990. The regulation value for the general main engines for propulsion is 17 g/kWh. In diesel engines, the emission quantity of NOx and fuel oil consumption rate are in a trade-off relationship. In engines meeting the NOx regulation value, countermeasures are generally taken by adjusting the fuel oil injection timing. As a result, the fuel oil consumption rate is said to deteriorate by about 2%

Fig. 2 Main engine for large container vessel

compared with that for engines not meeting the NOx regulation value. Recently, however, research and development of diesel engine makers has optimized the combustion chamber profiles, ignition timing, fuel spray, and so on. This has led to success in meeting the NOx regulation value while minimizing the deterioration of the fuel oil consumption rate to about 1.2% compared with that for engines not meeting the NOx regulation value. And with the adoption of electronic control engines in recent years, the range of optimization has been expanded to the timing of fuel injection into the cylinder, the amount of injection, injection pressure, etc. Thus, further reductions in fuel consumption are expected.

To certify that the NOx emission quantity of each diesel engine is equal to or less than the regulation value, each parent engine is tested for NOx emission in an engine factory test. The results of the operating parameters and the replaced principal engine spare parts which affect the NOx emission (e.g., the fuel injection timing and nozzle type) are kept on a ship as a record according to the form of a register called a "technical file." Conformance with the convention is checked by confirming that the parameters shown in this technical file agree with the actual units. This is confirmed by two types of surveys, one conducted before a ship is put in service and one conducted periodically after a ship is put in service. The Classification society generally carries out these inspections and issues the certificates on behalf of the Government of the ship's flag.

(2) Sulfur oxides: SOx

The regulation governing SOx emissions from the exhaust gas of diesel engines requires the use of fuel oils with a sulfur content of 4.5% or less. In sea areas where discharges are more strictly controlled (Baltic Sea and the North Sea), the regulation limits the sulfur content to 1.5% or less. Independently from this international convention, some seas around Europe and California are subject to additional controls calling for the use of low-sulfur fuels.

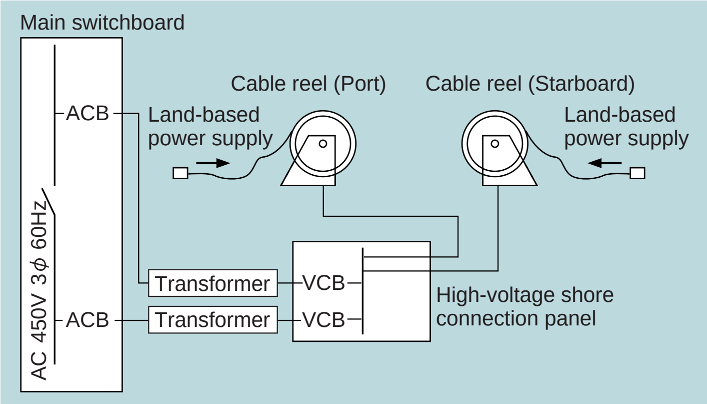

Fig. 3 System configuration (In the case of a 440V low-voltage system)

Fig. 4 Cable reel

Most ships take the countermeasure for the SOx control requirements using the low-sulfur fuel mentioned above. During normal navigation, ships should use fuels with a sulfur content of 4.5% or less. When navigating in special designated sea areas or in sea areas with individual control, the fuel used needs to be switched. The container vessels constructed by MHI meet the requirements by providing a tank exclusive to low-sulfur fuels or a fuel-switching device.

3.3 Reduction of exhaust gas during loading/unloading at port

Electric power is even required for the operation of deck machinery, the feeding of power to reefer containers, and so on during loading and unloading work at port. There are now attempts being made to limit the exhaust gas by feeding necessary power from shore to ships at port, thereby allowing the vessels to shut down their main engines and diesel generator engines. The system is called the "Alternative Marine Power (AMP) System, or in some cases as "Cold Ironing," because all of the inboard sources of heat are stopped.

Container terminals at the Port of Los Angeles (POLA) and the Port of Long Beach (POLB) on the West Coast of the United States are developing the AMP system in advance of others, and the system is spreading to other container terminals. The Port of Los Angeles is spearheading efforts with plans to feed power of 6.6 kV/60Hz, hence this is the power supply voltage likely to be adopted as standard for the AMP system. To meet the requirements of the AMP system, it is generally necessary to have a cable reel housing a power-feeding cable from shore to the ship, a high-voltage shore connection panel, a step-down transformer (only for 440 V low-voltage system ships), a ship/shore power changeover control panel, and so forth (**Figs. 3** and **4**).

The cable reel for supplying the shore power source into the ship needs to be installed not on the shore side, but on the ship, in view of the work time and the state of the wharf where container cranes traverse. The installation of cable reels on all ships that may enter ports equipped with the AMP system will require a large investment in plants and equipment. Given that the AMP system is only in service at a few ports, carriers have recently been studying a plan for storing cable reels and high-voltage shore connection panels in mobile containers. There are various merits to loading this type of container onto ships that call on AMP-equipped ports. The technique enables flexible reactions in response to changes in shipping routes, for example, and the selection between starboard berthing and port berthing at a terminal. In the case of additional installation on a ship in service, the technique can also reduce the work period required for modification.

A 6.6 kV high-voltage system is gradually being introduced on the larger container vessels being built. Yet the power supply systems on most container vessels, including those in service, are 440 V low-voltage systems. To meet the requirements of the AMP system, a container vessel with a low-voltage system must be equipped with a transformer designed to step down the voltage from 6.6 kV fed to 440 V. The transformer capacity has a large impact on the placement and cost. MHI has actually loaded AMP Systems onto container vessels with low-voltage systems after thoroughly studying these matters.

4. Conclusion

Many environmental countermeasures and innovations have been introduced for ships, especially the large container vessels bearing the brunt of physical distribution around the world. The regulatory background and trends are also changing. Concern for the environment on a global scale is heightening. MHI will continue proposing earth-conscious ships by making good use of its technical capabilities while meeting customer needs.


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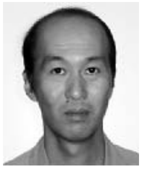
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