Implementation of Ship Energy-Saving Operations with Mitsubishi Air Lubrication System

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Mitsubishi Heavy Industries, Ltd. (MHI) carried out examination of the Mitsubishi Air Lubrication System (MALS), which was developed as an energy-saving system for ships, with the aim of expanding its target ship types. Blowers exclusive to MALS which are capable of providing high pressure and large amount of air flow required for installation of the system on bulk carriers, container ships, ferries and large passenger ships are developed, and outlets and piping systems related to air supply are standardized. This makes it possible to allow MALS to be installed by shipyards other than MHI. The system has also been considered with a view to retrofitting vessels in service. As a result of these efforts, MHI can now supply MALS as a stand-alone system or a comprehensive system including accompanying engineering.

1. Introduction

Revised MARPOL 73/78 Annex VI was adopted in 2011 with the aim of reducing greenhouse gas (GHG) emissions from the international shipping industry, and the regulations define schemes for reducing CO_2 emissions from ships.

In this scheme, Energy Efficiency Design Index (EEDI), which represents the weight (grams) of CO_2 emitted when transporting one deadweight tonnage of cargo one nautical mile, is defined as an engineering method for indicating the energy efficiency.

The revised MARPOL Annex VI requires that all new ships comply with the regulation to have an attained EEDI value (an actual calculated and verified EEDI value) below the EEDI value required in the convention if the shipbuilding contract is placed on or after 1 January 2013.

In the EEDI framework, MALS can be treated as one of innovative energy efficiency technologies. Responding to the continuing high price of fuel, which results in fuel expenses accounting for a high proportion of operating costs, there is growing demand of energy-saving systems.

MHI combines various energy-saving technologies such as ships with low propulsive resistance, high-efficiency propeller systems, heat recovery from main engine exhaust gas, etc., to offer environmental friendly ships that respond to customer needs. Among such technologies, the Mitsubishi Air Lubrication System (MALS), which feeds air to the ship bottom and covers the hull with air bubbles to reduce the propulsive resistance of the vessel, was developed as a new energy-saving device. MALS was installed as the world's first permanent equipment on a module carrier and succeeded at practical application in 2010.[(1)] A module carrier has a wide deck area for mounting large structures, its draft is shallow and the flat part on the bottom is large. The bottom of such types of ships is easily covered with air bubbles, and therefore it was expected that air lubrication would result in a significant energy-saving effect.

There are wide variations of ships in terms of size, type, operating speed, and other factors,

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depending on their application. Now the good prospects for the practical application of MALS have been determined, and one task for the wide adoption of MALS as an energy-saving device is expanding its target ship types.

This paper describes, with some examples, MHI's efforts to consider the installation of MALS on cargo ships such as tankers, bulk carriers, and container ships, which account for the majority of vessels, and ferries, as well as large passenger ships, to which MHI is making a strong efforts as a core business.

2. Efforts to expand target ship types of MALS

2.1 Development of blower for air lubrication system

(1) Required range

In regard to bulk carriers, container ships and large passenger vessels, estimation is performed under given conditions in order to clarify the required pressure and air flow capacities of the blower. Although there are naturally various operating conditions such as ship size and required speed, even for a single type of ship, this estimation considers large ships on which MALS works effectively. **Table 1** compares the estimation results with that of a module carrier. Most of the required blower pressure is static pressure that depends on the draft. The required pressure for the shallow-draft module carrier is no more than 65 kPa, even in the consideration of margins such as pressure loss. On the other hand, the ship compared in this estimation has deep draft and then higher pressure exceeding 100 kPa is required. In addition, the required pressure for VLCCs under a full load condition is, even for only the static pressure, 200 kPa or more, although it is not shown in the table.

Table 1 MALS design conditions and blower specifications

Item	Unit	Module carrier	Bulk carrier	Container ship	Passenger ship
Length, L	m	153	230	350	240
Speed, Vs	kt	13.0	14.0	24.0	17.0
Flow rate, Qs	m^3/min	80～120	150～250	200～550	100～200
Pressure, P	kPa	65	155	170	100
Blower motor rated power, Pm	kW	130～200	500～840	680～1900	230～460

The air flow required for air lubrication increases or decreases in proportion to the air thickness covering the ship bottom (considered as uniform) and ship speed. Along with an increase of the air thickness, the amount of reduced friction resistance increases, but electric power consumption for the blower also increases. Therefore it is necessary to determine the air flow in consideration of the trade-off between the amount of reduced friction resistance and the electric power consumption of the blower in order to obtain the most efficient energy-saving effect. As shown in Table 1, large container ships require larger amount of air flow because of their deep draft and high speed. Supposing that multiple blowers are used in such cases, the required air flow per blower for ships studied can be considered to be approximately 200 to 300 m^3/min.

Blowers required for ships studied are not covered by commercially available general purpose products in many cases. Because it is necessary to order custom made items or furnish multiple blowers, development of blowers suitable for MALS is required.

(2) Mitsubishi turbo blower

Blowers are classified into axial flow blowers, centrifugal (radial or turbo) blowers, and rotary blowers. The module carrier uses one of the rotary blowers, a Roots blower. As described above, commercially available Roots blowers are relatively small in capacity with low pressure and cannot cover all range if they are considered to be used for MALS. Therefore MHI has developed turbo blowers in order to satisfy the characteristics and specifications required for blowers used for MALS, taking advantage of design technologies of MHI's turbochargers for ships and automobiles. **Figure 1** shows a structural drawing of the developed Mitsubishi Turbo-blower for Air lubrication (MTA), and **Figure 2** indicates the MTA operating range. Based on the required ranges that were considered, the size of impeller has been standardized and two MTA models with higher and lower capacity have been developed.

Figure 2 includes the required ranges of the ships studied for comparison purposes. Most ranges required for air lubrication can be dealt with by using properly MTA and commercially available blowers depending on the required range. In this document, as a matter of convenience, "blowers" include devices that are called "compressors" in a classification based on compression ratios.

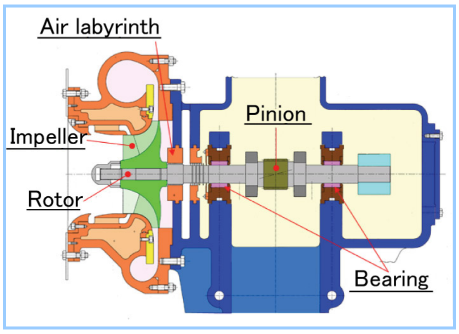

Figure 1 Structural drawing of MTA

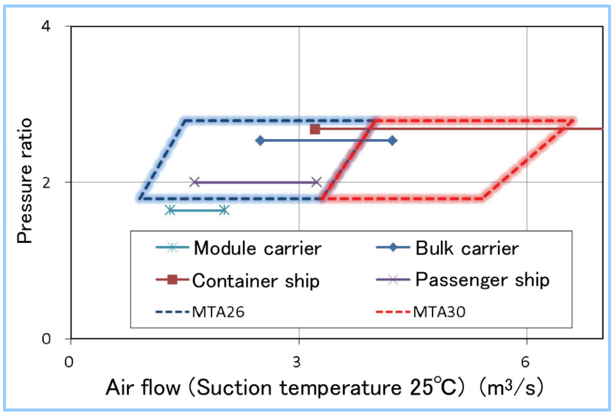

Figure 2 Operation range of MTA

2.2 Study for applying MALS

In regard to expanding the target ship types of MALS, points to consider for design that allows MALS to be installed by shipyards other than MHI are organized. Also recommended standard specifications and design standard are defined in order to quickly respond customer needs.

(1) Air outlets

The locations of outlets are defined so that the surface of the hull is covered by air as widely as possible. Typically, low-speed blunt ships such as bulk carriers have a flat bottom, and high-speed ships such as ferries have a slender hull with a narrow flat bottom. Ships are roughly classified into blunt ships and slender ships. Therefore the locations of outlets are considered for each. **Figure 3** illustrates the water lines and bottom flat areas viewed from the bottom. The upper illustration is a blunt ship, and the lower illustration is a slender ship. For the blunt ship, which has a wide flat area, one outlet is placed near the bow. For the slender ship, the flat area of which is narrow on the bow and aft, three outlets are placed separately.

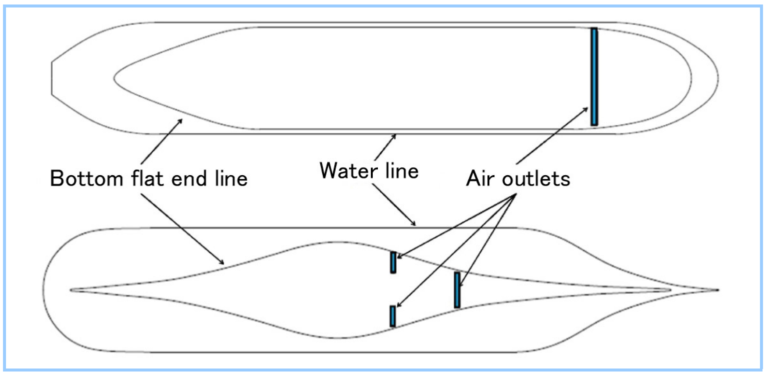

Figure 3 Location of air outlets

(2) Chamber

Air supplied from the blower is sent to the chambers located at the outlets, and then blown from the outlets on the bottom. The air immediately forms bubbles due to the shearing force of the friction against the seawater, and flows away along the hull. **Figure 4** illustrates a longitudinal cross section of a chamber. In this example, the inner bottom plating is used as the top plate of the chamber. The chamber is equipped with a manhole on the side, and can be accessed for internal maintenance. The lateral dimension of a chamber is defined in consideration of ship geometry for each ship individually.

(3) Location and shape of openings

Openings on the bottom are oval-shaped as shown in **Figure 5**. The dimension and number of openings are defined in consideration of the MALS design conditions. The gaps between openings and the distance from the longitudinal stiffeners or the wall to the openings are defined in consideration of factors such as stress concentration. The plate thickness at the openings may be increased if necessary.

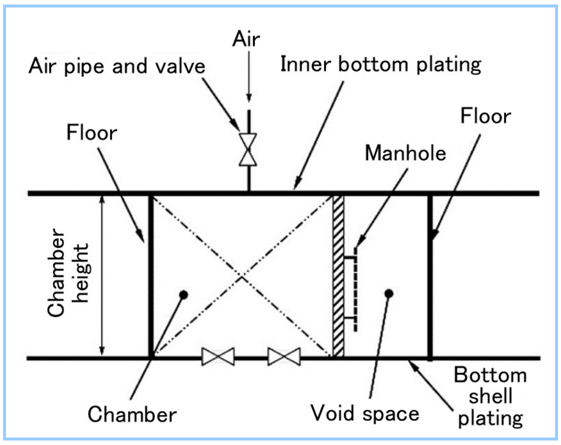

Figure 4 Example of chamber configuration

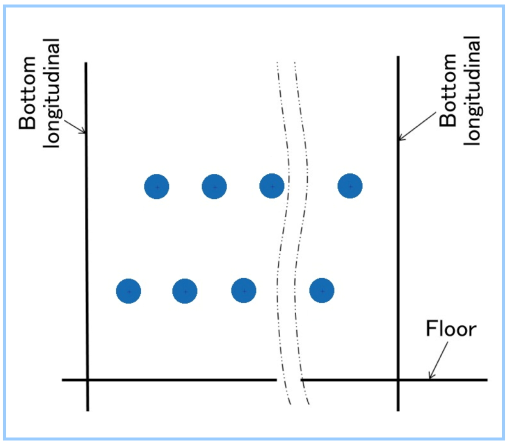

Figure 5 Arrangement and shape of opening (bottom plan)

(4) Piping diagram

Table 2 lists the components of MALS, including blowers, control valves, inverters, control panels, operation panels, etc. Air supplied by the blower is sent to the chamber at the bottom through the air piping. **Figure 6** illustrates an outline arrangement of MALS.

Table 2 MALS components

Equipment/device	Details
Blower (including air cooler and electric motor)	Electric motor driven, Turbo blower
Flow control valve	
Sea valve	
Cooler inlet valve	
MGPW [Note 1)] injection valve	
Blower inverter panel	440 V, Frequency converter
MALS control panel	
MALS operation panel (LCD)	15 inch, Touch panel type
Flow meter	

Note 1: Marine Growth Preventing Water; MGPW

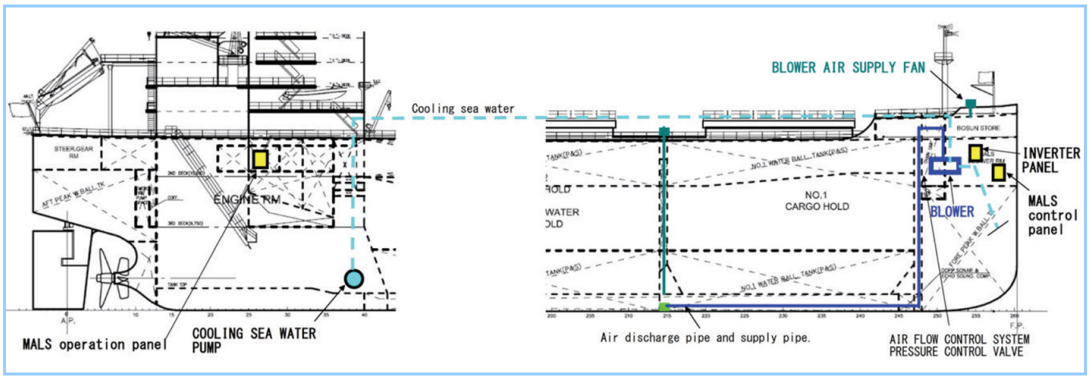

Figure 6 Outline arrangement of MALS

(5) Controls related to MALS

Controls including the MTA start/stop control system and the MALS control system have been developed and standardized. Specific explanations of this are omitted here.

3. Study examples assuming application on full-scale ship

As a preparation for offering MALS to customers in the future, design consideration is performed specifically assuming a full-scale ship. Because of the difference in cargo and service, different types of ships have substantially different internal layouts. In particular, even for a same kind of ship, it is not too much to say that no two ferries are the same except for sister ships because the required specifications differ for every customer.

Apart from installation on new ships, when retrofitting of MALS on an existing ship, sometimes modification of existing facilities may be considered in order to make space for a blower room etc. for MALS. Some examples of MALS study results for various kinds of ships are described below. Based on this study, MALS is going to be installed on a pure car and truck carrier (PCTC), a bulk carrier, and a large passenger ship.

Figure 7 illustrates an example of the layout study of a new ferry. As a result of concern for the prevention of the effects of blower noise on passengers and crews without impairing cargo space, the MALS blower room is established in the void space under the car deck, and the equipment required for air supply such as the blower, inverter, air cooler, etc., are all placed together.

Figure 8 illustrates an example of an installation study of MALS on a mega container ship at its concept design stage. On container ships, placement of the MALS blower room in the bosun store in the bow is assumed.

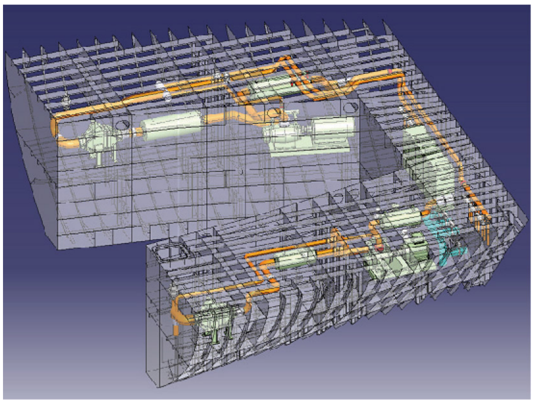

Figure 7 Example of installation of MALS on a ferry

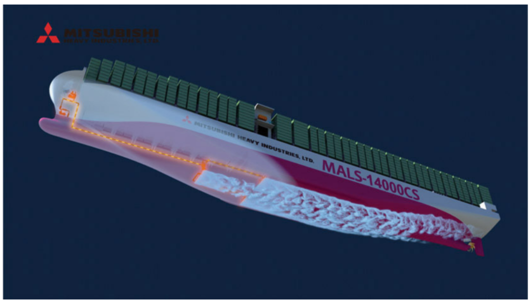

Figure 8 Example of installation study of MALS on mega container ship

For retrofitting MALS on an existing ship, in addition to equipment installing work, work planning and engineering to facilitate and enhance efficiency of the work are also important. The locations of air outlets are determined to some extent based on performance. However, it is necessary to consider the installation layout of the blower, ancillary equipment such as the control panel and accompanying pipes, wires and ducts in the limited internal space with lower construction costs and a work term as short as possible. Shortening the term of dry-dock work is advantageous also for the customer. Therefore shortening the work period not only by minimizing the work amount but also by unitizing is required.

Table 3 shows an example of dry-dock work schedule prepared during the study of retrofitting MALS on an existing bulk carrier. This project adopts a construction method where the additional equipment such as the chamber is unitized and then replaced as blocks. Because work space for conveying removed and new blocks in the bottom of the dock is limited, the block replacement work is divided into two parts. In this project, plans require the docking, modification work and undocking to take 16 days.

Table 3 Example dry-dock schedule of retrofitting MALS

D	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Dock-in and work preparation (marking etc)	■	■															
2 Removal of modification part			■	■	■												
3 Installation of new blocks etc.						#1	■	■	■								
								#2	■	■	■						
4 Inspection and testing												■	■				
5 Painting														■	■	■	
6 Ballasting and dock-out																	■

#1: Installation of center block
#2: Installation of starboard and port blocks

Figure 9 shows an example of the study of retrofitting MALS on an existing large passenger ship. Passenger ships have many pieces of equipment and electric components which are densely arranged. As a result, conveying equipment such as a blower to the installation location, and securing space for the addition of chambers for air outlets are difficult. In such cases, possible measures include changing the layout of the existing tanks. Placing equipment in the limited space efficiently and maintaining the amount of work at a low level lead to the shortening of the work period. For design concepts of retrofitting, MHI plans to gain approval in principle (AIP) from Lloyd's Register of Shipping of the UK.

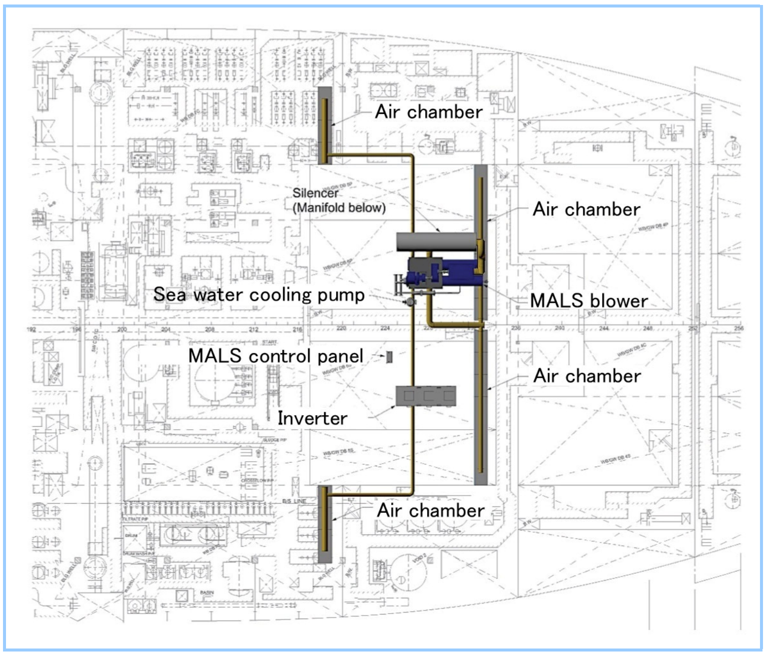

Figure 9 Example of retrofitting study of MALS on large passenger ship

4. Conclusion

MHI considered expanding the target ship types of the Mitsubishi Air Lubrication System (MALS), one of energy-saving methods, in order to promote its prevalence. Because the installation of MALS on general merchant ships such as tankers and bulk carriers was the key to attaining prevalence, layouts of MALS equipment on typical types of ships was considered. For the installation of MALS on large ships, MHI developed blowers exclusive to MALS, because few commercially available blowers with capacity suitable for MALS existed. The specific consideration of MALS installation assuming retrofitting work on existing ships in addition to installation on newly built ships was performed. Through these considerations, MHI has defined recommended standard specifications and design standard, and also has completed preparation of engineering work for not only installing MALS on ships built by MHI, but also selling MALS to other ship builders.

In the future, MHI will work on the following tasks with the aim of expanding use of MALS.

- Improvement of energy-saving effect mainly on slender ships through the optimization of air outlets.
- Offering more proper MALS packages through improvements in the estimation accuracy in the amount of propulsive resistance reduced due to air lubrication.
- Enhancement of customer benefit by enlargement of return on investment through the cost reduction of the system.

References

1. Mizokami, S. et.al, Experimental Study of Air Lubrication Method and Verification of Effects on Actual Hull by Means of Sea Trial, Mitsubishi Heavy Industries Technical Review Vol.47 No.3(2010) pp.41-47