Development of "Stability Recovery System" that Maintains Ship Stability at the Time of Damage - Ensuring Cargo Loading Capacity and Easing Restrictions on the Hull Form -

KUNIAKI YAMATO[*1] YOKI UEMURA[*2]

MASANORI ONZUKA[*1]

Due to the recent introduction of tighter damage stability regulations, requirements on the residual stability under damaged conditions have become increasingly strict. In order to meet the tougher regulations, Mitsubishi Heavy Industries, Ltd. (MHI) has developed a stability recovery system to be installed on Roll-on/Roll-off (RoRo) ships, Pure Car & Truck Carriers (PCTCs) and RoPax ferries, to which the new regulations are applied. By equipping these ships with the stability recovery system, in the event that the ship is damaged during the voyage, seawater accumulating in the lower car section is drained into the void space at the ship bottom, quickly lowering the center of gravity and restoring the stability lost as a result of the damage. This Technical Review provides an overview of the stability recovery system, its effects, and the implementation thereof.

1. Introduction

Due to the complete revision of the International Convention for the Safety of Life at Sea (hereinafter referred to as the SOLAS Convention) in Chapter II-1, the regulations on ship damage stability which came into effect on January 2009 (hereinafter referred to as the damage stability regulations) have been strengthened. To comply with the tougher regulations, MHI has developed its unique and outstanding stability recovery system which reduces the risk of ship capsize at the time of damage, and which has been patented in Japan[*1] and overseas (Korea[*2] and the U.S.A.[*3])

*1 Patent No.: 4814120 *2 Patent No.: 1152059 *3 Patent No.: 8087370

The stability recovery system is to be installed on three types of newly-built ships, to which the damage stability regulations are applied, such as RoRo ships, PCTCs and Ropax ferries. These ships have a large superstructure above the waterline in order to carry multiple cars. Their common features also include a slim shape below the waterline to achieve high-speed navigation. MHI aimed to develop a low-cost and reliable system to be installed on these types of ships. This Technical Review provides an overview of the stability recovery system, its effects, and examples of the commercialized products thereof.

2. Tightened damage stability regulations

Before the revisions, damage stability regulations based on the probabilistic concept were applied to cargo ships, including RoRo ships and PCTCs. In terms of passenger ships including Ropax ferries, damage stability regulations based on the deterministic concept used to be applied. In response to the recent revisions, the probabilistic damage stability regulations were also applied to passenger ships, ensuring the consistency of the application of the rules.

The basic concept of the probabilistic concept is that the assessment is based on the probability that only the watertight compartment or group of compartments of a ship under consideration may be flooded, and the residual stability in an equilibrium condition after the

*1 Ship & Ocean Engineering Division, Shipbuilding & Ocean Development
*2 Manager, Ship & Ocean Engineering Division, Shipbuilding & Ocean Development

watertight compartments became flooded as the probability of survival after the flooding of the compartment or group of compartments under consideration. Assuming various damage cases, the probabilistic concept demonstrates that the Attained Subdivision Index, which is a value obtained by adding the products of individual damage probabilities and survival probabilities, is greater than the Required Subdivision Index, which is obtained based on the formulae given to cargo ships and passenger ships, respectively. In the deterministic concept, the assumed damage area is predetermined, and the residual stability for every level of damage needs to satisfy the requirements. On the other hand, as the probabilistic concept assumes various damage areas, even if the level of the residual stability after damage is low in some cases, it is only necessary to present that the ultimate Attained Subdivision Index, based on all the damage conditions, is greater than the Required Subdivision Index.

The new rules based on the probabilistic concept are basically the same as the conventional damage stability regulations of the SOLAS Convention for cargo ships. However, the number of draft cases used in the calculation of the Attained Subdivision Index has been increased. Other changes include the revision of the probability of flooding, an increase in the Required Subdivision Index, and so on, in order to tighten the conventional rules even for the same cargo ships. As for passenger ships, in order to satisfy the requirements in the deterministic damage stability regulations, in addition to the probabilistic damage stability regulations, even in a worst-case scenario, in which a certain degree of damage has been done to the hull and the bow section, a sufficient level of residual stability needs to be ensured.

3. Overview of stability recovery system

The stability recovery system focuses on forcibly flooding seawater entering the hull into the void space near the ship bottom (downflooding), in the event that the ship is damaged during the voyage, quickly lowering the center of gravity and restoring the stability lost as a result of the damage.

An outline of the stability recovery system is illustrated in **Figure 1**. It consists of the void space into which seawater is drained, seawater inlets with a watertight hatch, leading to the void space provided on the car deck, and a stability monitoring and control system that monitors flooding inside the hull and controls the open-close movement of the watertight hatch.

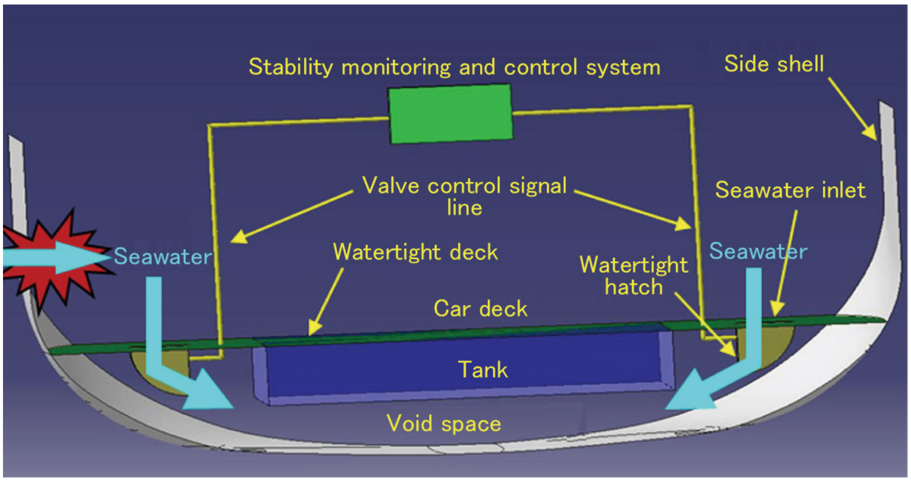

Figure 1 Conceptual drawing of stability recovery system

As shown in **Figure 2**, the void space into which seawater is drained is located at the bottom of the ship for common use with other elements such as fin stabilizer rooms, duct keels (keels laid with a duct structure), and ballast tanks with a load limit. The void space is ensured near the ship bottom by locating it in the section which also has other functions. Apart from downflooding through the seawater inlets, as shown in **Figure 3**, air vent pipes are provided as necessary inside the hull, in order to achieve quick and safe water injection and the lowering of the center of gravity at the time of damage.

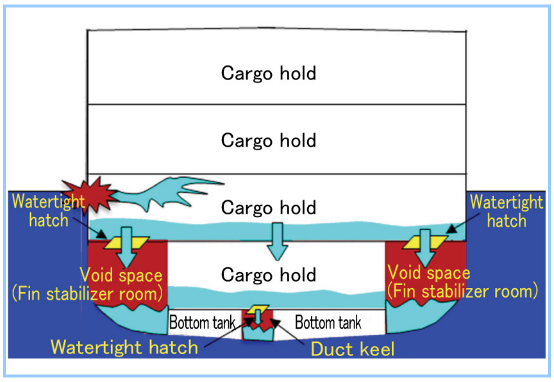

Figure 2 Downflooding through watertight hatches

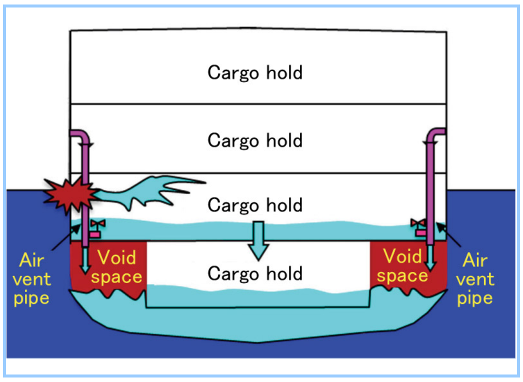

Figure 3 Downflooding through air vent pipes

Furthermore, by equipping a ship with the stability recovery system, backup stability in the case of damage is no longer necessary, avoiding the following flaws:

- A decrease in propulsion performance and fuel efficiency, due to the widening of the body for improvement of the initial stability
- A decrease in vehicle weight due to the loading of ballast water for reduction of the center of gravity
- A decrease in the number of cars on board and the blocking of the smooth flow of traffic, due to smaller subdivisions of the lower cargo hold for reduction of secondary flooding
- A limitation to the number of cars on board for keeping the center of gravity down during navigation

4. Implementation of the stability recovery system to actual ships

The ship with the stability recovery system deployed for the first time was a 170-meter-long RoRo ship, which is capable of a speed of 23 kt with a load of about 170 trailer chassis and 100 cars. Compared with the conventional type of the same grade, the energy saving ship features approximately 10% less energy consumption. It was built at MHI's Shimonoseki Shipyard (Shimonoseki, Yamaguchi Prefecture) and was delivered in March 2013. This ship is equipped with the stability recovery system, which, in addition to ensuring available cargo capacity and the smooth flow of traffic of the conventional type before the revision of rules, has achieved greater energy-saving performance by allowing increased flexibility of the hull form.

Principal particulars of the new RoRo ship are listed in **Table 1** shown below.

Table1 Principal particulars of RoRo ship with stability recovery system

Flag	Japan
Class	NK
Length (b.p.) ×Breadth × Depth (m)	158.0 × 27.0 × 23.27
Draft(scan.) (m)	6.70
Gross tonnage (International)	Approx. 23,300
Service speed (kt)	23.0
Main engine	9S50ME-C8.2×1 set 13,920kW×127.0rpm
Passenger capacity	12 persons
Cargo capacity	172 Trailer chassis 100 Cars
Other equipment	Bow thruster × 1 Stern thruster × 2 Fin stabilizer × 1 set

The whole view of the new ship is presented in **Figure 4**, and a downflooding hatch provided on the ship's lower car deck is shown in **Figure 5**.

Figure 4 RoRo ship equipped with stability recovery system

Figure 5 Downflooding hatch at the lower car deck

5. Conclusion

MHI has accumulated various technologies and experience based on considerable achievements in building RoRo ships, PCTCs and Ropax ferries. The development of the new technology, the stability recovery system, has enabled MHI to design and build ships with a higher level of safety, reliability, economic efficiency and environmental performance. MHI will strive to clearly understand customer needs and the trends of rules and regulations, which will grow increasingly diverse in the future, in order to enhance customer satisfaction and to develop new ships with high added value. MHI will also make continuous marketing efforts by proactively offering solutions based on our unique technologies underpinned by patents, such as the stability recovery system.

References

1. Development of Stability Recovery System, KANRIN,No.43(2012) pp.70
2. Shipbuilding and Marine Engineering in Japan 2013, The Japan Ship Exporters' Association
3. Masanori Onzuka, MHI’s New System Enhancing Damage Stability, INTERFERRY37th Annual Conference 2012, Dubai, U.A.E.