Study on the potential gaps and themes identified by IMO Regulatory Scoping Exercise (RSE) for the use of Maritime Autonomous Surface Ships (MASS)

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Abstract. Currently, IMO discusses to develop international standard regulations for the use of Maritime Autonomous Surface Ships (MASS), and as a preliminary work to develop these regulations, it carries out RSE work to identify measures that might arise when the existing conventions are applied to MASS. The RSE work is done by the Maritime Safety Committee (MSC), the Legal Committee (LEG), and the Facilitation Committee (FAL) for the conventions under the purview of each committee. In this paper, based on the results of the RSE work performed by each committee, a comprehensive analysis of potential gaps and themes that require further discussion and consideration in the next stage of international standard regulations for the use of MASS is presented.

1. Introduction

Along with the development of ICT technology, smart, digital and eco-friendly technologies are also a major trend even in the marine field. Reflecting this, IMO is also making efforts to develop international regulations of a new paradigm by reflecting these major trends in the existing hardware-centered international maritime conventions. Among them, MASS is currently being discussed as the most important issue in the field of IMO maritime safety.

Currently, IMO is discussing to develop unified international regulations and guidelines for the use of MASS, and as a preliminary work to develop these regulations, carrying out the Regulatory Scoping Exercise (RSE) to analyze the potential gaps and themes that could occur when the existing convention is applied to MASS.

The IMO RSE was carried out by the Maritime Safety Committee (MSC) for maritime safety conventions, the Legal Committee (LEG) for liability compensation conventions, and the Facilitation Committee (FAL) for the maritime traffic facilitation convention.

This paper comprehensively analyzes the results of the RSE conducted by IMO to identify the potential gaps and themes that should be preemptively considered before discussing regulations and technology development for the commercialization of MASS, and by classifying them into definition, ship equipment, navigation, and infrastructure sections, the potential gaps and themes are identified and analyzed, and items that need to be considered in the future are presented.
2. IMO Discussion Trend

2.1 Maritime Safety Committee (MSC)
In IMO, MSC 8 was the first meeting that the concept related to ship automation was suggested in 1965. At this Committee, the word ‘ship automation’ is stated as a word that encompasses both 'complete automation system', 'partial automation system' and 'remote control', which shows that ship automation has been discussed and reviewed from a long time ago.

Since then, with the rapid development of information and communication technology and autonomous navigation technology, the use of unmanned ships in real seas has rapidly increased, and the need for guidelines and regulations to ensure their safety has emerged. Accordingly, in MSC 95 (June 2015), starting with the information document from the UK, and in MSC 98 (June 2017), the Committee agreed to include in the 2018-2019 biennial agenda of MSC and the provisional agenda for MSC 99, an output on "Regulatory scoping exercise for the use of MASS" with a target completion date of 2020 (from MSC 99 to 102).

For RSE, IMO defined Maritime Autonomous Surface ship (MASS) as 'a ship which, to a varying degree, can operate independent of human interaction', and the degrees of autonomy were organized, rather than the autonomous level, following boarding of seafarers and remote control, with the four levels of autonomy as follows. Steps 1-2 are for the seafarers to board, and Steps 3-4 are for the seafarers not to board [1].

1. **Degree one: Ship with automated processes and decision support:** Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.

2. **Degree two: Remotely controlled ship with seafarers on board:** The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.

3. **Degree three: Remotely controlled ship without seafarers on board:** The ship is controlled and operated from another location. There are no seafarers on board.

4. **Degree four: Fully autonomous ship:** The operating system of the ship is able to make decisions and determine actions by itself.

The procedure of RSE is divided into two steps. In the first step, the regulatory scoping exercise identified provisions in IMO instruments which, as currently drafted: 1) apply to MASS and prevent MASS operations, 2) apply to MASS and do not prevent MASS operations and require no actions, 3) apply to the MASS and do not prevent MASS operations but may need to be amended or clarified, and/or may contain gaps, 4) have no application to MASS operations. [2]

A second step was conducted to analyze and determine the most appropriate way of addressing MASS operations, taking into account, inter alia, human element, technology and operation factor by: 1) equivalences as provided for by the instruments or developing interpretations, 2) amending existing instruments, 3) developing new instruments, 4) none of the above as a result of the analysis. [2]

The first step was completed at the intersessional Working Group on MASS in September 2019, and the second step is expected to be completed in MSC 102 (November, 2020).

2.2 Legal Committee (LEG) and Facilitation Committee (FAL)
In April 2018, LEG 105 decided to carry out RSE on conventions under the purview of the Legal Committee, as the necessity of considering liability and compensation conventions other than the technical conventions discussed by the Maritime Safety Committee was recognized. LEG 106 (March 2019) approved a framework for the RSE, and LEG 107 to be held in November 2020 will discuss the results of the 1st and 2nd step of RSE.

The 43rd Facilitation Committee (FAL) agreed to use the framework for RSE for the use of MASS approved by MSC 100, and the work will be finalized at FAL 44 to be held in September 2020.

3. Matters requiring clarification of terms and scope of application

3.1 Definition of remote operator, captain, seafarers, responsible person, etc.

In order for MASS to safely operate at sea, a new manpower called “remote operator” is needed to remotely control and manage them on shore. This person is a manpower that does not appear in the existing manned ships, and is a manpower necessary to realize the autonomous level of remotely controlling the ship from shore. Therefore, in order to introduce remote operators, it is necessary to consider the insertion of definition, training and education, and qualification requirements of “remote operators” to STCW 1978.

The concept of a remote operator emerges in the degrees of autonomy 2 and 3 level, and a fully autonomous ship that artificial intelligence is in charge of all decision-making will emerge in the degrees of autonomy 4 level. In this case, there will be many changes in the roles and responsibilities previously performed by the master and seafarers, so it is necessary to clearly define the roles and responsibilities of the master and seafarers by each degrees of autonomy level.

For example, the current STCW 1978 defines a master as a “person in command of the ship,” but when the autonomous navigation system makes the final decision, the role and responsibilities of the master will need to be re-established.

In addition, since the subject of responsibility according to the liability and compensation convention is determined depending on who is ultimately responsible for the ship, clarification of these terms is important.

3.2 Definition of remote operation/control center

The remote operation center is a concept that appears with the “remote operator,” and refers to a space where remote operators work on shore and remotely control and manage ships. The remote operation center will perform a function of remotely controlling a ship on land or monitoring a sailing ship through data such as sensor-based video, audio, and sea conditions sent from the ship. Since the remote operation center is closely related to the wireless communication and navigation safety of the ship, it will be necessary to review the establishment of the definition of the remote operation center, design requirements, necessary facilities, and performance standards for facilities in SOLAS 1974 Chapter 4 (Radio Communication) and Chapter 5 (Sail Safety).

3.3 Consideration on MASS application scope and subject is needed for specific types of ships

The ship type is determined according to the cargo and purpose, and the structure of the ship and the cargo management method during voyage are very different by ship type. Therefore, it will be necessary to consider whether how to include nuclear ships that can lead to large-scale accidents in the event of an accident, passenger ships with a large number of people on board, and chemical tankers that require careful tank cleaning and cargo management in the scope of application of MASS.

4. Considerations related to ship equipment and technology

4.1 Need for sensor-based approach to enable remote operation
In International Regulations for Preventing Collisions at Sea (COLREG) 1972 Rule 5, it is prescribed that 'Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision.' In addition, SOLAS Ch.5 stipulates the carriage requirements for shipborne navigational systems and equipment.

In existing ships, the final decision was made by the navigation officer based on information such as RADAR, GPS, compass, Eco Sounder, and AIS when determining the optimum route setting and any action to avoid collision, but from the degrees of autonomy 2 level, the task which was performed by humans will be done by the autonomous navigation system. Therefore, in addition to the existing navigation equipment, it will be necessary to install additional equipment such as cameras and LiDARs that can play a role equal to the visual and hearing of the navigator, and it will be necessary to consider the performance standards and mounting regulations such as the visibility of such equipment.

4.2 Technical Review Matters for COLREG
COLREG 1972 Rules 20-31 regulate that the ship's lights and shapes are differently hoisted according to the ship's size, maneuvering status, and work conditions so that the conditions of the ship could be identified through them, and in the Rules 32-37, it is regulated, through sound and light signals, to exchange control and warning signals between ships, sound signals within a limited view, and caution or distress signals.

Even if autonomous ships are used, the time when MASS and existing manned ships coexist and sail will inevitably come. Therefore, in such a case, lights and shapes indicating that the vessels are autonomously operated will be needed to distinguish whether they are manned or autonomous vessels.

In addition, in the existing manned ships, the lights and shapes of other ships are identified with the human's vision and hearing, and the sound and luminous signals are recognized, while, in regard to the degrees of autonomy 3 and 4 level without seafarers, it is necessary to find a way to identify and respond to the lighting and shapes, sound and luminous signals of other ships, by mounting a camera, LiDAR, and acoustic sensor, with the cognitive ability on the same level of sight and hearing as humans.

4.3 Radio communication and distress signals
In the case of existing manned ships, radio communication and distress signals are transmitted and received between seafarers members on board the ship and shore-based person. However, in the case of autonomous level 3 and 4 ship in which seafarers are not on board, it will be necessary to consider a plan for appropriately transmitting distress signals to shore and surrounding ships, when the ships are in distress.

4.4 Lifesaving Equipment and Lifesaving Supplies Arrangement Regulations
SOLAS Chapter 3 (Life-saving Appliances and Arrangements) provides requirements related to personal lifesaving equipment, survival craft and rescue boats, personnel assignment of survival craft in case of emergency, emergency drills and exercises. In the case of the degrees of autonomy 3 and 4 level, because the seafarers will not be on board, a large number of provisions on lifesaving equipment and equipment will not apply.

Therefore, it will be necessary to review the provisions for the arrangement of life-saving equipment and life-saving supplies for autonomous level 3 and 4 ship.

4.5 Review of fire fighting requirements and equipment
SOLAS Chapter II-2 (Construction- fire protection, fire detection and fire extinction) stipulates ship structures, facilities and training for detection of fire and extinguishing in case of fire. In the case of lifesaving equipment, since it is for seafarers members, many provisions do not apply when seafarers members are not on board, but in the case of firefighting requirements, there is always a possibility of a
fire, regardless of whether or not seafarers are on board, and since all fire extinguishing works that were performed by the seafarers must be unmanned, in the case of unmanned ships, ship structures and facilities for enhanced fire detection and fire extinguishing will be required. In particular, different types of fire extinguishing equipment should be used depending on the type of fire (Class A~E), so it is necessary to devise a plan to extinguish the fire within a prompt time in an appropriate manner by identifying the type of fire from an unmanned ship.

4.6 Design of a bridge without seafarers from the design perspective

SOLAS Chapter 5(Safety of Navigation) Regulation 15 prescribes the principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures. For example, 15.1 of the same rule stipulates that the bridge should be designed to 'facilitate the task of the mission team and pilots to fully understand the situation and to operate the ship safely in all operational conditions.'

However, in the case of autonomous level 3 and 4 ships, the seafarers are not on board, so instead of the existing bridge, a bridge design principle suitable for unmanned ships should be established. In addition, in the case of unmanned ships, equipment that can replace the sight and hearing of the navigation officer should be mounted on the vessel, and the visibility distance and mounting position of the equipment that the equipment can play an optimal role should be considered.

5. Considerations related to ship and port operation

5.1 Ship maintenance

Conventionally, many regulations related to maintenance apply to various equipment of the ship, which implicitly assumes that the seafarers are on board. Therefore, it will be necessary to establish maintenance requirements for new types of equipment that are fixed on MASS or necessary for the function of remote control center in the degrees of autonomy 3 and 4 level in which the seafarers are not on board. Moreover, new requirements for preventive maintenance and early failure detection will be needed to prevent accidents from occurring in unmanned ships. Therefore, when considering these changes, the revision of many existing provisions related to manual operation will have to be accompanied at the degrees of autonomy 3 and 4 level.

5.2 Search and rescue

International support obligations for distressed ships should also be applied to MASS, but since seafarers are not on board in the degrees of autonomy 3 and 4 level, it will be impossible to participate in search and rescue operations like existing ships. Accordingly, it will be necessary to clarify the requirements and expectations for autonomous ships to provide assistance and support to people and other ships in the long term. In addition, when rescue operations are carried out by remotely controlled or fully autonomous vessels, it is necessary to review whose actions or actions can be attributed to the “rescuer”. In the case of rescue by remotely controlled vessels, it should also be clarified whether the regulation on the cost of the person “equipment and personnel” includes on-board equipment and personnel[3].

5.3 Cargo operation

Since the current cargo operation procedure (loading, securing, etc.) is based on human supervision, it is necessary to review the applicability of these regulations in the case of unmanned ships, which should be include that to which extent onshore personnel may be required to perform some duties. In addition, it will be important to review regulations on safety and handling of cargo during voyage when dangerous goods are loaded on autonomous ships.
5.4 Pilot
The situation that ships can encounter mainly in the ocean and the situation that can be encountered in the port are very different. For example, in the case of a port, the amount of traffic is high due to the influence of ships entering and leaving the port, ships waiting for entry, and fishing vessels operating locally, and compared with the ocean, due to the influence of tide, shallow water zone, and the unique environment of the port, there are some high navigational hazards.

In the current situation, since the pilot is to board and operate the ship by oneself, it does not mean that the ship is remotely controlled by the remote control center. Therefore, from the stage of being remotely controlled, it will be necessary to discuss new regulations or other alternatives to allow remote control in relation to pilots.

In addition, in cases where autonomous level 3 and 4 ships that seafarers are not on board are docked in the port, discussion on the use of pilots should also be conducted.

5.5 Document storage and port state control
In the case of autonomous level 3 and 4, it is difficult to manage certificates, record books and other documents required by the existing rules, and therefore, in this regard, a clear regulation on appropriate digital documents, keeping in ships, and management is required. In addition, in the practical aspect of conducting inspections (especially port state control) of unmanned ships, it will be necessary to develop special guidelines and regulations, including solutions related to the detention of ships.

5.6 Safe manning and management
It will be necessary to review whether or not the regulations related to the boarding of seafarers, such as SOLAS Chapter 5/14 Regulations (Ship's Manning) and STCW regulation I/14 (Responsibilities of Companies), will be applied to shore-based persons such as remote operators. For example, whether onshore personnel should also be considered seafarers, or whether onboard personnel competency requirements stipulated in the STCW Conventions and Codes can be applied to them, and, if applicable, how to create and apply new regulations.

5.7 New certificates and procedures related to the information to be provided to the administration
In Standard 2.1, Section 2 of the FAL Convention (Arrival, Stay and Departure of the Ship), documents that the administration may request from ships are stipulated when they are entering and departing. Representatively, there are general declaration, cargo declaration, ship's stores declaration, crew list, passenger list and dangerous goods manifest, but in case of MASS, there is a need to submit additional information to the administration, such as the autonomous level, so it will be necessary to amend the general declaration to be entered or to establish a new form of entry and departure documents.

In addition, since seafarers do not board ships in the degrees of autonomy 3 and 4 level, it will be necessary to review the plan for preparing the seafarers list. [4]

5.8 consideration a new electronic format for various certificates required under the Convention
Ships engaged in international voyages shall have various certificates on board in accordance with international conventions. In addition, FAL 42 approved the guidelines for the use of electronic certificates (FAL.6/Circ.39/Rev.2), encouraging member states to use electronic certificates. In the case of autonomous level 3 and 4, an e-certificate must be used as seafarers do not board the vessel, and new regulations to safely exchange such e-certificates with various stakeholders such as administrations and ports will be required. [4]
5.9 Others
It is necessary to review procedures for responding to emergency situations to apply to unmanned ships where seafarers do not onboard, cyber security and countermeasures to prevent cyber crimes against ships, and to prepare ship security plans. In addition, the establishment of a new regulation on the treatment and treatment of stowaways on board unmanned ships is a matter to be considered.

6. Conclusion
In this paper, based on the results of the RSE conducted by IMO, the potential gaps and themes that should be considered in advance prior to future related regulations and technology development was comprehensively analyzed.

In the discussion of MASS, the review of these potential gaps and themes is considered to be a very important factor, and it is expected that IMO also will conduct detailed reviews of these potential gaps and themes in the future. Therefore, in order to lay the foundation for establishing an organized system that allows MASS to operate safely, it will be important to draw an international consensus through professional and detailed discussion and consideration on the potential gaps and themes identified in this paper.

References
[1] IMO document MSC 100/20/Add.1 “Report of the Maritime Safety Committee on its one hundredth session”, Annex 2 “Framework for the regulatory scoping exercise for the use of Maritime Autonomous Surface Ships (MASS)”
[2] IMO document MSC 100/20/Add.1 “Report of the Maritime Safety Committee on its one hundredth session”, Annex 2, Appendix 2 “Plan of work and procedures for the regulatory scoping exercise”
[3] IMO document LEG 107/8 “Summary of results of analysis of IMO instruments under the purview of the Legal Committee”
[4] IMO document FAL 44/14 “Report on the results of the regulatory scoping exercise on the FAL Convention”