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Challenges and Innovation That Will Be Brought to Maritime Education by the Rapid Development of Shipping Technology

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Abstract: The promotion of ship greening, digitization and autonomous navigation marks the vigorous development of maritime transportation, and at the same time puts forward higher requirements for seafarers' knowledge reserve and operation technology, the existing maritime education and training (MET) and supervision system will not be able to meet the demand of shipping development. Under the trend of green transformation of ships and the realization of low-carbon or even zero-carbon, the shipping world is working on the exploration of new energy sources, which requires seafarers to obtain more skills of safe operation; Ship digitalization includes the technologies of the digitalization of the ship design, manufacturing and operation process, involving computer-aided systems, manufacturing execution systems, modeling and simulation technology, product data management technology, and virtual reality technology and etc., which has the characteristics of intelligence, integration and virtualization. All those new technologies in the field of ship greening, digitization and automation will in no doubt bring new requirement to the MET, however, these new knowledge and skills have not been fully reflected in the MET courses. This paper analyzes the development of new technologies in the shipping field and the knowledge and skills required by seafarers to master these new technologies, compares with the requirements of the existing STCW convention and code for seafarers' training, finds out its shortcomings, and puts forward the challenges faced by the MET and the direction of MET innovation in the future to ensure the safe and smooth operation of ships.

Keywords: Maritime Education and Training, Ship Digitizing, Shipping Technology, MASS, Challenge and Innovation

1. Introduction

With the development of science and technology, modern navigation has entered a high-tech era and is developing in the direction of intelligence, digitalization and greening, which not only helps to reduce the workload of seafarers but also improves their safety and security. With the development and changes in the international shipping industry, international conventions are constantly raising the requirements for ship safety, environmental protection and management. Ship operators and managers are selectively applying advanced science and technology to navigation to provide reliable guarantees for ensuring safety and environment protection at sea [1]. The application of electronic navigation, electronic charts, automated operating system, low carbon fuel and so on have been changing the traditional way of ship's operation and management. The automatic system has become an integral part of the ship's operation function, providing assistance for ship operation; real-time ship-shore communication improves the shore-based monitoring and assistance to the ship. Traditional MET is no longer able to meet the needs of the new technologies.

Under the background of global emission reduction, the shipping industry responds to the call to achieve low carbon

navigation and reduce the level of greenhouse gas emissions, the operation of ships must use alternative fuels, and these new fuels have different degrees of danger because of their special properties, maritime education is committed to reducing these dangerous accidents, widely using existing alternative fuels and developing zero carbon energy. In the process of shipping intelligence, the limitations are mainly in the technical and regulatory aspects. Chinese Wang Gang et al. expressed that the process of ship digitization covers the digitization of two parties, one is ship-based and the other is shore-based, and he suggested that the process of ship autonomy, although detached from the crew, depends on the shore-based operators and cannot be separated from the data exchange and communication between ship and shore [1]. Chinese Li Xiaohui et al. expressed that MASS is a disruptive change to traditional ship navigation and STCW convention is no longer applicable, advocating the need for a new convention to regulate MASS behavior [2], Wang Deling et al. argued that new knowledge and skills are needed to manage and operate MASS, and MET for MASS involves competence, knowledge and technology in many aspects, and different automation levels have different MET requirements [3].

Based on the new technologies in shipping industry, this paper analyzes the limitations and future development of technologies related to greening, digitization and intelligence of ships, including the impact of using new energy technologies, digitization technologies and autonomous ship development on MET, and points out the future innovation direction of maritime education and training of seafarers.

2. New Requirements for MET in Ship Greening Technology

Since the end of the 19th century, the global warming trend is continuing, the dominant greenhouse gas is carbon dioxide emissions, accounting for up to 98%, of which the shipping industry accounts for nearly 3% of the total carbon emissions, in order to jointly respond to global climate change, the shipping industry should also practice greening, the International Maritime Organization (IMO) has developed a series of mandatory rules and guidance documents, and in 2018 April adopted a preliminary strategy for greenhouse gas emission reduction from ships, setting out a vision of achieving zero carbon emissions from global maritime vessels within this century. According to the STCW Convention, the minimum fitness standard for basic training of ships applying the IGF Code requires KUP table to be able to be familiar with the physical and chemical properties of fuel, to be proficient in operating the ship's fuel oil filling, storage and tethering systems, to be clear about the special hazards associated with fuel systems and fuel handling, to master the knowledge of fire-fighting devices about detecting, controlling and extinguishing fires caused by different types of fuel listed in the IGF Code. Here we will introduce the specific new fuels involved in the green transition of ships, analyze their technical advantages and disadvantages, future developments and directions for MET [4].

2.1. LNG

LNG (Liquefied Natural Gas) is a liquid of natural gas stripped of impurities and cooled to about -162°C at atmospheric pressure. The main component is methane, which is colorless, odorless, non-toxic and non-corrosive, it can reduce sulfide, nitrogen oxide and particulate emissions as an alternative fuel, and it has already achieved mature use on ships and has good prospects. Figure 1 is DNV's statistics and forecasts on the number of growth of LNG vessels in the future.

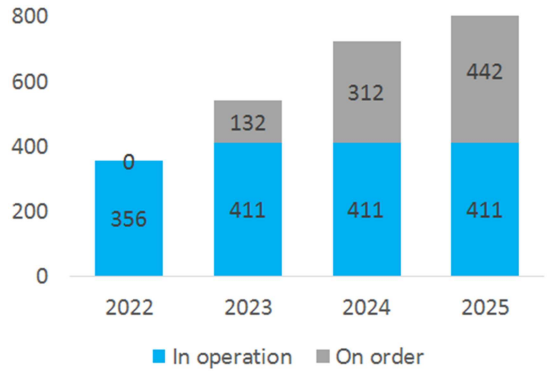

Figure 1. *Growth of LNG fueled fleet.*

The main problem of ships using LNG fuel, or the main reason for denying the future of LNG fuel, is the leakage of LNG, which is the focus of future maritime education and training [5].

1. Low temperature injury. There is a risk of low-temperature burns and frostbite with LNG. If the skin surface is wet, it will stick to the surface after contact with the surface of the low-temperature object, and improper handling will lead to skin tears.

2. Rapid phase change, Greenhouse effect. LNG leaking into the air will exchange heat with the surrounding environment and expand rapidly, resulting in a cold explosion. Besides, methane escape due to LNG leakage is also a focus of MET.

In the case of LNG, MET lies in the use of operations and the handling of methane leaks. LNG vessels have mature technologies in tank design, transport pipelines and fire-fighting systems, but it should be noted that LNG itself is colorless, and odorless, not easily detectable, and requires a set of sound training procedures with strict protective tools and ventilation during use. The secondary issue is that the solution to the escaping methane problem still needs to be deepened to further improve energy efficiency.

2.2. Hydrogen

Hydrogen is a green, efficient energy source with potential as a zero carbon fuel, and has been widely used as a mature zero carbon fuel on land, but not marine navigation, the combustion energy of hydrogen is low, so there is a shift in the form of use, and the current key technologies are hydrogen

fuel cells and hydrogen internal combustion engines, etc. Figure 2 shows the trend of the number of hydrogen internal combustion engines in recent years according to DNV statistics [6].

Future focus of hydrogen fuel in maritime training:

1. Hydrogen extraction. How to extract green hydrogen with less money and effort.

2. Storage and refilling of hydrogen. The technology development is the direction to use hydrogen on a large scale. Special ventilation and detection facilities are needed in the design of ships, and its MET should follow the IGF Code.

3. The regulatory framework and environment. At present, the 8th meeting of IMO Cargo and Container Transport Sub-Committee has considered the IGF Working Group Report on the draft Interim Guidelines for the Safety of Hydrogen Fuel Applied to Ships, and the 105th meeting of the Maritime Safety Committee held in 2022 also proposed to complete the revision of the Interim Recommendations for the Transport of Liquefied Hydrogen in Bulk in 2024, all of which will give guidance on MET [7].

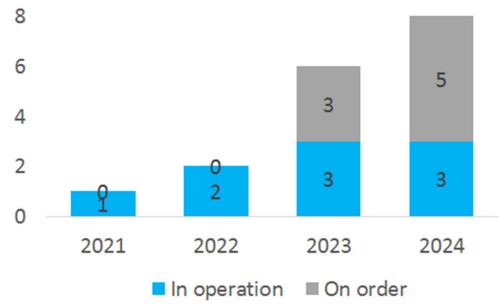

Figure 2. *Growth of hydrogen ICE fleet.*

2.3. Ammonia

Ammonia is a highly promising zero-carbon fuel that can be produced sustainably using renewable electricity and without the use of any biomass, is easier to store than hydrogen or LNG, and is relatively safe to transport. In addition, ammonia has a good combustion energy compared to hydrogen, and best meets shipboard needs.

Ammonia, as a kind of new fuel, has its own feature and risks. To ensure the safe operation of ammonia, Seafarers will in no doubt receive additional training as to following aspects:

Storage, usage and handling of ammonia. Ammonia is a toxic substance and it is necessary to set the permissible exposure limits for those who use ammonia fuel.

The use of ammonia does not comply with the International Code for the Construction and Equipment of Bulk Liquefied Gases Ships (IGC Code) which does not allow cargoes belonging to toxic goods to be used as fuel, nor does it belong to the applicable fuel of the International Safety Code for Ships Using Gas or Other Low Flash Point Fuels (IGF Code), therefore, there is a lack of corresponding technical regulations for ammonia as ship fuel. Maritime education will focus on the development and study of regulations for the use of ammonia. The 105th session of the Maritime Safety Committee held by IMO in 2022 is expected to complete the development of the Safety Guidelines for Ships Using Ammonia as Fuel in 2023, pending further study [7].

2.4. Methanol

Conventional methanol has shifted its production pathway from fossil to renewable energy sources, the clean methanol Methanol can be made from biomass or captured carbon dioxide and hydrogen, free of nitrogen oxides and sulfur, and with low particulate emissions [8]. According to DNV, methanol storage and distribution infrastructure has been established in 118 operating ports worldwide, and the current methanol ship order book is growing significantly, as shown in Figure 3.

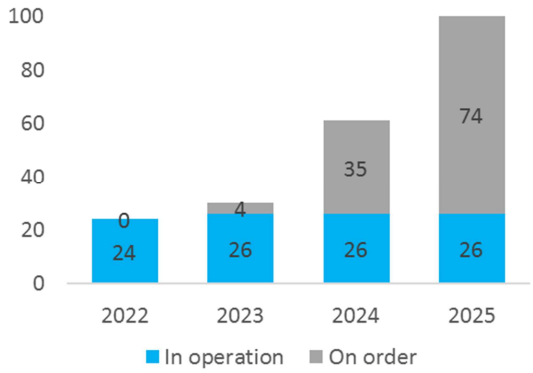

Figure 3. *Growth of methanol fueled fleet.*

The development of MET in methanol:

Storage, use, renovation and new construction of shore-based refueling stations, supervision of its production, transportation and safe use.

Processing. Such as how to solve methanol leakage? How to deal with methanol fire? How to deal with methanol poisoning?

China Classification Society (CCS) has issued the relevant regulations Interim Rules for Technology and Inspection of Alcohol Fuel Powered Ships in 2023, the safety and standardization can be guaranteed. This will also become a necessary part of maritime training.

3. New Requirements for MET in Ship Digitizing Technology

Ship digitalization is to combine digital technology with the ship manufacturing industry, can be divided into the digitalization of the ship design, manufacturing and operation process, involving computer-aided systems, manufacturing execution systems, modeling and simulation technology, product data management technology, and virtual reality technology and etc., which has the characteristics of intelligence, integration and virtualization. Digital technology refers to the use of a new generation of information technology, such as big data, communications, artificial intelligence, block chain, automation, to transform complex forms of information into data that can be

recognized and measured by computers, then establish a digital model capable of data analysis and information sharing.[9] The maturity of digital technology is the basis for the realization of ship intelligence, with the consequent increase in the level of ship autonomy and the gradual realization of maritime autonomous surface ship.

3.1. Status of Digitization in Shipping

Ship design development has evolved gradually, the traditional ship design is through two-dimensional drawings, in the initial period of computer network, data management can be in the two-dimensional space in the form of documents on the shipbuilding information for artificial storage, with the emergence of computer-aided software, 3D technology is gradually being used in the design and construction of ships on the function, there are computer-aided design software CAD, computer-aided engineering Software CAE, computer-aided manufacturing software CAM, but the various applications at different stages of the software in isolation from each other, did not form a unified integration platform, the degree of information integration is not high, thus CAD, CAE, CAM integrated system CADDS5, CATIA and Computer Integrated Manufacturing System CIMS, etc., were produced, and the current three-dimensional design software with a wide range of applications is NX Foran, Smart 3D, etc., and they are able to realize hybrid modeling for integrated construction, so as to satisfy the digitalization of the whole process of ship construction.[10] Since then, in order to improve the efficiency of ship development, reduce development costs, and achieve optimal digital shipbuilding, shipbuilding enterprises have continued to optimize the infrastructure, the equipment of intelligent ships, etc. They have implemented the product data management technology PDM, established the enterprise resource management system ERP and the manufacturing execution system MES, Digitize production units and production lines through MES to realize automated manufacturing from raw materials to finished products [11].

Analyzing the state of digitization in shipping from the ship digitization process:

Digitalization of ship design: In the ship design stage, ship models are constructed through computer virtual design systems and modeling and simulation technologies. Simulate and predict the ship design, construction and operation process from the feasibility of the ship design scheme, manufacturing cost and data indicators, and fully evaluate the ship performance and equipment status, including the diagnosis of faults, to minimize the problems of equipment operation, operation and maintenance.

Shipbuilding digitalization [12, 13]: After the digital analysis of the ship design scheme, establish a digital ship model through computer technology, then use virtual construction techniques, combined with virtual reality, processing and assembly techniques throughout the whole life cycle of ship products, to realize the integration of design and construction.

Digitalization of ship management: that is the management of product data and the administration of production, supply chain and quality data. Currently, some enterprise manufacturers apply enterprise resource planning system (ERP), supply chain management system (SCM) and other control platforms to establish a sound information management system, so as to strengthen the data transfer between the systems, the degree of information integration between the system and the overall ship, as well as the interconnection between the ships, then achieve informational standards, and realize the synergy between the design institute and the shipyard, suppliers and other parties.[14]

The process of ship digitization requires the ship design department, manufacturing department and management department to work together to improve the integration of ship systems and form a single data source, which is conducive to effective information transfer and sharing, so as to realize the integration of ship design, manufacturing and management, and to realize the integrated manufacturing of ship hull, outfitting and coating.

3.2. Future MET Focus, Based on Digital Development

1. Systematically learn database technology and establish informational standards.

To establish a product database, which contains design analysis, ship modeling, a series of methods to access the database, as well as shipbuilding-related knowledge. The information management after establishment is also a concern, as different enterprises use different information technology platforms, it is inevitable that waste occurs when resources are shared, therefore, to achieve the completeness of information, each shipbuilding enterprise should establish informational standards and strive to form a single source of data.

2. Strengthen the teaching of modeling simulation technology, visualization technology and remote sensing technology.

Modeling simulation technology is the support of simulating the actual construction process on the computer, which can help to analyze the best production plan, make timely adjustments of the existing production plan, ensure the ship construction cycle, optimize the allocation of resources and logistics management, and effectively avoid the waste of resources.

3. Strengthen the teaching of ship virtual manufacturing knowledge and skills.

It contains many technical requirements, including the establishment of three-dimensional model of the digital technology, virtual reality system interface technology, processing and assembly, logistics and other processes of simulation technology.

4. The teaching of computer three-dimensional design software.

In the process of ship design, the computer construction of three-dimensional model has not been completely separated from the two-dimensional drawings. for experienced engineering designers, the operation of three-dimensional modeling software is an obstacle, as for designers familiar

with the operation of the software, some of them they lack the experience of being able to directly design the structure and layout of the system, Therefore, MET should be committed to strengthening training in the use of existing computer-aided software, product data management systems and three-dimensional modeling software in the future, so as to enhance the researchers' knowledge and skill, and to promote the development of shipbuilding software.[15]

5. Cultivate high-quality talents.

Cultivate high-quality talents, establish a composite talent team and form a guarantee system for digital shipbuilding.[16] Organize more academic and technical exchanges and other activities to establish the awareness of cooperation and resource sharing, so that the ship manufacturing industry and digital technology are closely integrated. A powerful team of talents is the guarantee for the digital transformation of ships.

4. New Requirements for MET in Maritime Autonomous Surface Ship

4.1. Features of MASS

Autonomous navigation does not happen overnight, it is a process from personnel-assisted decision making, to crew quota reduction, and high level automation of the ship, then achieve autonomous decision making. The characteristics of MASS, in terms of crew, show the trend of the gradual reduction of crew quota, and the space on board will also change due to the reduction of crew living space and life-saving equipment, thus making the ship different from conventional ones. From the viewpoint of decision making subject, the traditional ship is a mode of decision making by the captain and execution by the crew, while MASS is a mode of autonomous decision making by the ship and remote monitoring by the shore base. From ship's operation, with the distributed storage of data and the transmission and sharing of information, the ship is gradually integrated and will transform from independent control of navigation in the past to cooperative operation among ships.[17]

4.2. Challenges in the Development of MASS

1. MASS network security. MASS cannot survive without the Internet, therefore, it is important to maintain the network environment for the development, and it is especially important to avoid network intrusion and information leakage, which should be regulated by certain laws.
2. Application of the Convention. The STCW Convention is usually considered to control and regulate the behavior of crew members, while MASS is a process of gradual transfer of seafarers to shore-based, so is the shore-based operator still defined as a seafarer? Does it still apply to the original STCW Convention? Most countries believe that it is no longer applicable and that new legislation is needed for training, licensing and duty guidelines for shore-based operators.
3. Crew competence. The STCW Convention's KUP table for seafarers' seaworthiness on ships seems to fall behind the development of new technology, and the relocation of MASS to seafarers' workplaces will bring changes in seafarers' knowledge, competence and skills, which requires new maritime training for seafarers.
4. New business operation mode. When the MASS is mature, it may be commercialized and used in military, and the new operation mode brought by autonomous ships will change the operation of multiple parties from supply chain, logistics chain to distribution channels.

4.3. Future Focus of MET on MASS

The STCW Convention use the KUP table to put forward requirements for seafarers' education and training from three aspects: Knowledge, Understanding and Proficiency, according to which, the MET for MASS is also analyzed from these three aspects: Knowledge, The main focus is on the mental health of seafarers, with the process of ship autonomy, the ship's crew is decreasing, and the long and boring voyage will definitely make the psychological problems of the crew more prominent than ever before. Understanding, Digital technologies such as Internet of Things for shipping, big data, remote control, autonomous collision avoidance, environmental awareness, artificial intelligence, etc. Proficiency, traditional knowledge of navigation, knowledge of ship automation control, etc [3]. Maritime education should be trained based on the seafarers' adjustment in the process of ship intelligence development, for example, according to the difference of workplace, seafarers are divided into shore-based operators and shipboard seafarers, the training for them is different, which are remote maneuvering technology, machine maintenance technology, navigation technology and auxiliary decision-making ability. In addition, the operation of MASS regulations also need to be adjusted, especially for the security of information data, the adjustment of the sea crew, all of these need clear regulations to specify their respective responsibilities to ensure that the problem and responsibility are traceable, it is known that IMO will introduce rules about MASS navigation in 2025 to strengthen the supervision of ship operations [18].

5. Conclusion

In the face of the development of the shipping industry, IMO and national classification societies should actively update maritime education and training programs to address these new issues in development. The KUP table in the STCW Convention standards for seafarers' competence training needs to be updated, requiring seafarers to be familiar with the physical and chemical properties of new fuels listed in the IGF Code, skilled in the operation of fuel storage, transportation and refilling, and knowledge of firefighting regarding the detection, control and extinguishing of fuel fires in new fuels. The priority of ship digitization lies in digital information technology, as for the promotion of autonomous ships, the development of regulations must keep pace with the times, so

that there is a law to follow.

From carbon reduction navigation to low carbon navigation and finally achieve zero carbon navigation, from the digitization of ships, highly integrated to the gradual intelligent realization of autonomous ships, the shipping industry still has a long way to go. Along with technological developments, it needs to rely on MET, which is for the different development directions, to build a team of high quality personnel to lead the shipping industry to achieve autonomous sustainable.

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