The Application and Development of Marine Engine Room Simulator in The Field of Maritime Training

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Abstract

According to the present status of marine engine room simulator in the field of maritime training, the concept, feature and research purpose of engine room simulator is elaborated, the functional requirements in international conventions or rules and the mandatory rules about training with engine room simulator is analyzed, the last research, theory and technology which are using in simulator is summarized. Finally, combining with the application of the latest developing technology and the special demand in new situation, a prospect for the development of the marine engine room simulator in the future is presented.

Keywords: Marine Engineering, Simulator, Maritime Training

1. Introduction

Modern marine engine room simulator (MERS) provides an integrated simulated operating platform for teaching and training of marine engineering. The external equipment which is included in the MERS and its effects such as light, sound, etc. can be designed basically as same as the parent ship, the operating mode of the system and device, working process, etc. can also be designed as close as the real ship in the greatest degree. In some respects, engine room simulator (ERS) can even overcome the existing defects of parent ship and realize overstepping. So, MERS has a strong sense of real interaction and spot experience features. To improve the level of automation, the ability of fault analysis and treating unexpected events, relevant international conventions, laws and maritime organizations have made mandatory provision for maritime colleges which training by MERS. Meanwhile, putting forward some normative requirements for MERS itself, these standards also promote the development and application of MERS in teaching and competency assessment. The contents of this paper are, namely, educed and analyzed in the background above.

2. Concept and research purpose

2.1. Concept and feature

Marine engine simulator is a kind of device which can simulate the actual equipment and system by using a pre-built mathematical model and carry out combined calculation by computer, finally, show the calculation results on human-computer interaction equipment in an information feedback form of real alike object through various media. The operator can reproduce a running state of the equipment and system in real engine room in greatest degree through a way of simulated operation and a data feedback which is generated after that interaction, so as to complete the tasks such as specialized skill training, competence appraisal, assessment for operator. Security, energy saving, environmental protection, effectiveness are the biggest advantages of marine engine room simulator, which is, of course, also determined by the meaning of "simulator" [1].

2.2. Evaluation criterion

Marine engine room simulator is a large and complex system, it is different from the simulator like ship navigation, aircraft manipulate and locomotive control, etc. which uses internal mathematical...
logic as a core to reappear simulation state rather than visual-scene effect (relative motion between object and scene). The basis of operation and the way of feedback of operator is a complex process. It can rely mainly on the data state of system and should be supplemented by sight, hearing, smell, touch and other comprehensive feelings. Therefore, the way that measuring whether a marine engine simulator is advanced or not is mainly by a standard whether the mathematical logic is consistent with the running state of real ship in the greatest degree rather than pay attention to blend in with the external visual elements, although they can polish the running effect of simulator.

2.3. Classification

Marine engine room simulator, according to the forms of operation, can be divided into different types like Full Mission (shown as Figure 1 and 2), Cooperative-distributed (shown as Figure 8), Stand-alone (shown as Figure 3) and WEB (the system interface is shown in web browser with B/S structure). According to visual effect in scene, it can be divided into types of 2D, 3D and a combination of 2D and 3D. According to properties of parent ship, it can be divided into types of general, professional and special, and the latter two types can be divided into types of Very Large Container Vessel (VLCV), Very Large Ore Carrier (VLOC), Very Large Crude Carrier (VLCC), Liquefied Natural Gas Carrier (LNG), Liquefied Natural Petroleum Carrier (LPG), Ocean Engineering Ship, River Trade Vessel (RTV), Medium Voltage, Electric Propulsion, etc. further.

2.4. Research purpose and foundation

2.4.1. Education for professional cognitive

In order to let new trainees have an initial recognition and understanding of the major they learn, they should learn main equipment and system in ship’s engine room, have a concept of Marine
Engineering Management, be familiar with the working environment and establish an ideal for their profession by overall explanation and demonstrating operation of the engine room simulator [2].

2.4.2. Assisted instruction for professional courses

For students or trainees who will join in job, in order to achieve the assisted instruction for professional courses, teachers can bring demonstrating operation of the engine room simulator into theory teaching of every professional course to improve the students' mastery of professional knowledge. To this, the author is deeply impressed. During the teaching of marine engineering automation, the author often carries out stand-alone demonstrated operation for key aspects such as remote control system of main engine (shown as Figure 3), steam system of boiler and alarm monitoring system by using engine room simulator, which is independently developed, and yields twice the result with half the effort.

![Figure 3. M/E remote control system of simulator for professional assisted instruction](image)

2.4.3. Intense professional training

It is necessary to launch an intense training which is aimed at a given device or system after professional theory course or before comprehensive training. This training can be carried out at full mission operating mode of the engine room simulator, so the students can get more authentic operating experience from the console, panel and other equipment.

2.4.4. Pre-service comprehensive training

To develop and improve students’ abilities to find, analysis, solve questions and react correctly, this training can be carried out at full mission operating mode. The training contains all of the operations of system and equipment in the engine room and it will be associated with a number of malfunctions and scenarios events. This training mode can maximize the function of engine room simulator and shorten post-suited time.

3. Requirements in international convention and code

3.1. Functional requirements

International Maritime Organization (IMO) held the 41th STCW meetings in January 2010 and completed the amendment (draft). The Party States have adopted the amendments in the international conference on International Convention on Standards of Training, Certification and Watchkeeping for Seafarers in 25th June 2010 in Manila which called "The Manila Amendments". STCW Manila Amendments provide a comprehensive review and revision for STCW78/95, the standards of training, certification and watchkeeping of seafarers which are involved in it had greater changes. The Manila Amendments has become effective since 1st January 2012, namely STCW78/10 Convention.
It divided the using and performance of engine room simulator by "mandatory standard (part A)" and "advisory standard and guidance (part B)" in the first chapter of the general rules of STCW Manila amendment. It makes a detailed list of the minimum standard for the party states to fulfill the convention fully and completely. "Advisory standard and guidance" can be interpreted as the highest standards, not mandatory, which belongs to advisory and guiding standard can be corrected constantly as the years went by or transformed into the category of mandatory standards. The standard above makes detailed regulations for the controllable, real physical level, authenticity of act, fidelity in abnormal situation of the operating environment of simulator from "general performance standards for training", "General performance standards for competence appraisal", "Training goal of simulating," "Training program", "Appraisal program", "Qualifications of the teachers and assessors" respectively. It requires that the simulator can simulate the operation of related devices on ship which including limitation, error and communication of the device. It should have enough simulation environments to achieve scheduled level for the training goal. For lack of space, please consult relevant standards of convention for more details.

In order to execute STCW convention and standard accurately, relevant certificate authorities make a detailed regulation and grade dividing explanation for the function and formation of marine engine room simulator. the certificate authority of Det Norske Veritas (DNV) ranks the simulators of different kinds of ships according to levels by grade A (full mission), grade B (multi-task), grade C (limited task), grade S (special tasks) in "STANDARD FOR CERTIFICATION No. 2.14:MARITIME SIMULATOR SYSTEMS". Relevant regulations in STCW conventions is a basis and source of the certification standard and starting point in each grade : In grade A, it requires a simulator with full mission operating mode and all the functions and systems in engine room; In grade B, it requires multi-tasking; In grade C, the functions and tasks in simulator may have some restrictions and imperfections in relative to grade B. Grade S means a simulator which only has one training system, such as ballast simulator and power station simulator.

3.2. The requirements for maritime colleges carrying training with engine room simulator

In order to keep the ship operation more standard and safety, IMO attached great importance to the role of simulator in STCW Manila amendment, and made clear mandatory and advisory provisions for the application of navigation training.

In order to adapt to the STCW Manila amendment, make the students or trainees to reach the requirements of operating standard in “Assessment Framework” by the Maritime Safety Administration (MSA) of China, the latest revision of "Competence Appraisal Outline and Provision of Seafarers in PRC" by MSA further clarified the terms in competence appraisal of marine engine room simulator. It stipulated that the chief engineer services on ship power of 3000kw and above must be assessed by the following content with engine room simulator [3]:
   a. Starting with cool ship (three terms).
   b. Engine stand-by and sailing with constant speed (six terms).
   c. Emergency operation (seven terms).
   d. Device and system malfunction analysis and troubleshooting (nine terms).

4. Research and development status

The early marine engine room simulator is only a small training machine supported by a desktop computer. With the development of computer technology, engine room simulator is innovating and evolves from single computer simulating system to large professional simulation equipment which includes multiple structures, interactive reproductions, experiences and multi-player cooperation.

Navigational advanced countries began the research of engine room simulator since the late 70s, due to the limit of computer technology, the description of mathematical model and analysis of dynamic process for the device and system is quite simple. Since the 1990s, with the development of computer technology, engine room simulator is innovating and new technology is introduced, the representative products are made by KONGSBERG company in Norway, England’s TRANSAS company in England and Dalian Maritime University in China and etc.
By the influence of background and main industries, KONSBERGB is leading in technology. Its product is mainly "universal" simulator which is the first to develop the simulator with controllable pitch propeller. It's characterized by unspecific parent ship and the design of panel and function is generality-based and focusing on the concept and expression for the simulating of engine room systems. Although this simplified the development and cost largely, the disadvantage is that some system is too abstraction (such as the ballast system in MC90-IV VLCC Simulator which only has three ballast tanks for expression). TRANSAS's engine room simulator is mainly the ERS series which can be divided into types of Cluster, Full Mission and Stand-alone. These three types can be separated or combined based on different applications. TRANSAS is the first to introduced virtual reality. The interactive operation between different platforms (system interface changes between 2D and 3D) is a light-spot. However, this series of products is not perfect in professional mathematical logic, the operating process is too simplistic and like a game, there are certain spaces to enhance and improve.

The representative research unit of China is Dalian Maritime University (DLMU). Engine room simulator of Dalian Maritime University is mainly DMS series which is characterized by the most interactive points, complete mathematical model and perfect function and so on (shown as Figure 4 and 5). The basic form of DMS series simulator is divided into three forms of Full Mission, Stand-alone and Collaborative, the parent ship including many kinds of ships such as Universal Training Ship, VLCV, VLCC, VLOC, LNG, LPG, RTV and so on [4]. The communication of this series of simulator would employ the Ethernet which is the fastest rate and largest overload capacity in similar products. To ensure the real-time and stability of the system, it passed the extreme test which including multi-player, multi-point and fast clicking at the same time successfully by Variable Channel Communication Protocol with the I/O board by independent research and development. Now, the Dalian Maritime University’s technology of Engine Room Virtual Tour, Multi-point Trigger, Pipe Network Modeling and Intelligent Evaluation develop faster and has been a leading trend.

Figure 4. M/E local control unit and power management system software interface of DMS series simulator
5. New theory and technology in research and development

5.1. Advanced network communication

Currently, a variety of network communication technology have been adopted in marine engine room simulator which including RS-232-C serial communication, RS-422 and RS-485 serial communication, Fieldbus of CAN and ProfiBus, industrial Ethernet and so on. The industrial Ethernet is widely used for the advantage of programming language supported, rich software and hardware resources and easy to connect the Internet [5]. Industrial Ethernet can certify for the accuracy and instantaneity of communication by meeting the requirements of numbers of data exchange from engine room simulation systems. In addition, industrial Ethernet can achieve wireless communication by transmission medium such as electromagnetic wave and infrared. It can transmission system information and control command in flexible space. It’s a revolutionary for the layout of simulator which makes mobile terminal, wireless control become a reality. The space utilization of control panel and console is improved, thus the arrangement will be more flexible.

5.2. Virtual reality

Virtual reality is an integrated interdisciplinary technology which is based on Computer Graphics, the Human Interface Interaction, Multimedia and Sensing Technology in recent years. It is characterized by embedded, immersion, interaction and multi-sensing. As shown as Figure 6 and 7, virtual reality technology can show a realistic effect of engine room and also achieve 3D simulation for the devices and systems [6].

Figure 5. M/E local control unit and power management system hardware interface of DMS series simulator

Figure 6. The overall of engine room virtual roaming of DMS series
5.3. Advanced auto sensing

Auto sensing is a sensing and metering progress without or need only a few manual interventions. It is an important branch of automation and is a comprehensive technology which will achieve some special functions by sensing technology such as infrared, microwave, radar, voice and laser. It will improve the level of automation and intelligence, reduce human error, and improve the efficiency of the system.

5.4. Distributed parallel processing

With the improving of function, running speed, degree of simulation, the mathematical model of devices and systems of marine engine room simulator will be more complex and refined. The system equations such as non-linear equation and sparse matrix or adjoint matrix are becoming more complex, the core CPU of system is bearing more calculating load [7]. For this problem, a new solution with Distributed Processing Units (DPU) are used, which could distribute the complex calculating process to different DPU according to system or area to finish multiple computing tasks in one clock period, so, it can improve the speed of system to a large extent.

6. Future development

With the development of shipbuilding industry and navigation technology, the engine room simulator will equip with more network, intelligent, virtualization and LCD procession. The navigation simulator and engine room simulator will join together in unified platform. Virtual devices and physical model would be tightly integrated and incorporated into the simulator. Long-distance training and teaching will come true by the use of network technology. The engine room simulator will be more advanced, flexible and intelligent in the future, its specific performance is described below.

6.1. Distributed cluster processing and cooperation mode

The system will use the structure of distributed network, and each node of this network will be regarded as a completely autonomous workstation, which has a certain role and control rights. Each station is equipped with one or more DPUs. When the system is running, the duty of each operator at each node (station) can be allocated in accordance with the functions of the real ship. So, each mission needs the cooperation of several operators (shown as Figure 8).
6.2. Malfunction simulation and intelligent diagnosis

When the simulator is running, it can reflect the active malfunction truly by introducing the mathematical description of the malfunction factors and feedback into related mathematical model and system (such as some data trends is shown as Figure 9 according with related mathematical model) [8]. The intelligent diagnosis technology is combined with the knowledge base of expert system, which can be used to carry out malfunction diagnosis. The ability of students' analyzing and solving, troubleshooting can be enhanced by the cognition and accumulation of interlocking relationship between the malfunction information.

6.3. Multi-perception and scenario reproduction

The technology of 3D virtual reality can built a highly immersed and realistic scenario of engine room. Meanwhile, human-computer interaction can be more rich and realistic by using infrared sensing, laser and radar detection, smoke releasing and lighting reproduction technology and then improve the perceived effect and scenario reproduction [9].

6.4. Intelligent evaluation and examination system

STCW78/10 Convention put forward that the engine room simulator should have a function which can cut off some processes form the others, which means that the simulator can be used to carry out a specific training and Evaluation for a specific system. Thus, intelligent evaluation system is an important research direction of engine room simulator in the future. Intelligent evaluation system can record operator’s operating steps and judge the operation by standard set before and then give reference results automatically. Another technical feature of the intelligent evaluation is tracing and deducting function, which can trace and reproduce the historical process of the evaluation operation. The system structure of examination and evaluation is shown as Figure 10.
6.5. Engine room resource management

Engine Room Resource Management (ERM) belongs to the areas of Scientific Management, the scientific and effective management can make full use of the human resource and equipment resource in the engine room, clarify the duties and responsibilities of the daily work, use and maintenance all kinds of devices in engine room correctly, ensure normal and safety voyage, reduce and eliminate the potential human error, do well in all the emergencies completely [10].

The Regulation content of “Function: Marine engineering at the operational level (see Table 1)” and “Function: Controlling the operation of the ship and care for persons on board at the management level (see Table 2)” in chapter III (Engine Department) of STCW78/10 Convention was supplemented with some “Knowledge, understanding and proficiency” for ERM. It regards the knowledge and skill of Engine Room Resource Management as a mandatory standard for the officers in engine department. It is very important for the crew to improve the ability of communication and teamwork by the relevant training items and standard operation process of ERM with the engine room simulator platform.

<table>
<thead>
<tr>
<th>Competence</th>
<th>Knowledge, understanding and proficiency</th>
<th>Methods for demonstrating competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain a safe engineering watch</td>
<td>Engine-room resource management Knowledge of engine-room resource management principle including: 1 allocation, assignment, and prioritization of resource 2 effective communication 3 assertiveness and leadership 4 obtaining and maintaining situational awareness</td>
<td>Assessment of evidence obtained from one of more of the following: 1 approved training 2 approved in-service experience 3 approved simulator training</td>
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Table 2. function: Controlling the operation of the ship and care for persons on board at the management level

<table>
<thead>
<tr>
<th>Competence</th>
<th>Knowledge, understanding and proficiency</th>
<th>Methods for demonstrating competence</th>
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</thead>
<tbody>
<tr>
<td>Use leadership and managerial skills</td>
<td>Task and workload management including:</td>
<td>Assessment of evidence obtained from one of more of the following:</td>
</tr>
<tr>
<td></td>
<td>1 Planning and coordination</td>
<td>1 approved training</td>
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<td></td>
<td>2 personnel assignment</td>
<td>2 approved in-service experience</td>
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<td></td>
<td>3 time and resource constraints</td>
<td>3 approved simulator training</td>
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<td>4 prioritization</td>
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<td></td>
<td>Effective resource management:</td>
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</tr>
<tr>
<td></td>
<td>1 allocation assignment, and prioritization of resources</td>
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<td></td>
<td>2 effective communication on board and ashore</td>
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<td></td>
<td>3 assertiveness and leadership including motivation</td>
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<td></td>
<td>4 obtaining and maintaining situation awareness</td>
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<tr>
<td></td>
<td>Knowledge and ability to apply decision-making techniques:</td>
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<tr>
<td></td>
<td>1 situation and risk assessment</td>
<td></td>
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<td></td>
<td>2 identifying and generating options</td>
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<td></td>
<td>3 selecting course of action</td>
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<td></td>
<td>4 evaluation of outcome effectiveness</td>
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6.6. Development trends of long-distance web, diversification and scalability

With the diversification of education, the development of WEB simulator or even WEB 3D simulator is an inevitable trend [11]. It can reduce the costs of installation and maintenance largely, improve system efficiency and expand the use of system. Meanwhile, the function of simulator is diversified and the parameters settings will be more flexible. The design of systems in a ship can also be verified by the simulator in order to analyze the feasibility and energy-saving effect. In addition, the scalability and secondary development of the simulator will be further enhanced. The simulator might become a design and test platform for particular system or equipment on board.

6.7. Integrated navigation training platform with navigation and engine room simulator

It is an important trend to build an integrated navigation training platform by the interconnection between navigation simulator and maritime engine room simulator. In fact, the key technology to achieve this application form is already mature and without any problem as long as both sides agree on the communication form, formulating unified communicating protocol and planning the data interaction between platforms. At present, there are two main restricted factors: firstly, there is no requirement and standard for integrated navigation training platform in general, and secondly, the management system is quite different between each department. But, it’s confirmed that an integrated training platform of navigation and engine room simulator will come true with the developing of society, unified coordination and deployment of the relevant authorities.

7. Conclusion

This paper takes the functional requirements of the ERS in international convention and the mandatory provisions, and discussed about the current situation of application of ERS and the developing direction in technology and function in the future. The new technology used in ERS can improve the level of automation and intelligence, reduce human error, and improve the efficiency of the system. With the development of shipbuilding industry and navigation technology, it is believed that the future ERS must be more advanced, more flexible and more intelligent.
8. Acknowledgement

This work was supported by “the Fundamental Research Funds for the Central Universities, No. 2012QN018”, “Liaoning Provincial Natural Science Foundation of China, No. 201202017”

9. References


