Engine Room Simulator Training for Emergency Preparedness

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ABSTRACT
Autonomous shipping demands reliable propulsion and auxiliary machinery, zero down time, low environmental footprint and intelligent operators who can make correct decisions and take appropriate actions in a timely fashion. While the first three relate to technological advancements and appropriate operational practices, the latter depends on the knowledge, skills, competencies and attitudes of the operators. This requires adequate training to ensure that operators respond effectively in all situations. Thus, the training regimes for operators must employ suitable strategies within an appropriate context to impart the required competencies. As accident investigations indicate human errors account for more than 80% of all marine accidents and thus operators must be trained with essential competencies to deal with emergency situations arising from operation, breakdown and accidents. This paper explores the potential of full mission engine simulators to train operators to handle emergency situations in autonomous ships to reduce the risk of financial losses and effects to the environment.

AUTONOMOUS SHIPS AND THE CHALLENGES AHEAD

We live in an era of transition to autonomous shipping. The maritime world has seen a surge of stakeholders take an active interest in the development and innovation of the technology of autonomous shipping. In 2017, Rolls Royce and Svitzer successfully demonstrated the world's first remotely operated commercial vessel in Copenhagen, Denmark [1]. Continuing the trend, the most discussed autonomous ship, Yara Birkland, will be delivered in the first quarter of 2020. It will initially undertake manned sailings, gradually switching to fully autonomous mode by 2022. The 120 TEU-capacity vessel will incorporate a ballast-free design and run on battery power [2]

Like most new technological inventions, autonomous shipping will also have its fair share of teething problems, but the factors demanding automation and the advancement in technology will drive the world shipping towards more autonomous ships in the near future. Although the technology takes over the human operation in normal running of ships, the emergency situations may still warrant human intervention.

An emergency is defined as a serious, unexpected, and often dangerous situation requiring immediate action [3]. In the transition to autonomous shipping, it is important to observe how the remote operators tackle the emergencies, which may have serious legal implications for ship owners, flag states, coastal states and overarching international instruments of International Maritime Organisation (IMO) and United Nations Convention on Law of the Sea (UNCLOS). In brief - Regulation of autonomous vessels and legislation dealing with their safety, manning and operation remains a particular challenge both nationally and internationally [1]. Ultimately the success and benefits of autonomy depend not by enacting new laws, but by intelligent operators, who make the correct decisions in an emergency. There is some validity in the statement when sceptics say, still the human operator can make human errors [4, 5]. Incidentally on autonomous ships, the human who makes the error is not on-board, but in a remote operating point. The fact is that the context of the situation or the role of the person who handles it has not changed. This fact leads us to believe that the training and upskilling of the remote operator to handle emergencies is crucial for future autonomous shipping.

EMERGENCIES LEADING TO CRISES SITUATIONS

The range of emergencies that could arise in an engine room during autonomous operation can be summarized as: Operational, Break-down and Accident. The operational emergencies arise mainly due to weather conditions rendering machinery malfunctions. The break-down emergencies occur due to failure of critical equipment due to design and maintenance faults or fatigue. The accidents may cause situations from fire to flood in the engine room.

Consequences of these emergency situations will be limited to financial losses and/or environmental effects if the vessel is autonomous. As there won't be any personnel on-board it is unlikely that there will be any casualties. However, in the transition when ships are operated with a skeleton crew, in addition to above, there could be casualties as well. Preparedness is the best way to handle such emergencies. The degree of preparedness for envisaged emergencies can mitigate the consequences of an event. Software-based simulators could be used to a greater extent in improving the preparedness as modern engine room simulators come with the capability of creating a raft of emergency situations without incurring any substantial cost.

SOFTWARE BASED SIMULATION FOR EMERGENCY PREPAREDNESS

Recent developments in software-based simulators revolutionised the way operators are trained. In fact, software used in these simulators are the same used in the actual plant and thus the training has become more effective. The only difference is that in real plants the software operates with real machinery while in simulators they operate virtual machinery. Nevertheless, the virtual machinery behaves in the same way as real machinery work. This is achieved with the use of mathematical models incorporating real life parameters.

Even though the best way to acquire practical experience is to learn in a real engine room, logistic issues and safety requirements are often not in favour for on-board training and thus, engine room simulators have become a popular alternative. Apart from that, decision-making

in a simulator environment opens a unique possibility to monitor the behaviour of the trainee closely and evaluate the effect of the decisions.
The opportunities to experiment on specific problems and get answers on questions such as: "what happens if ....?" without leading to wrecking of components and resulting in off- hire costs are unique advantage of simulators. In addition. a simulator gives an easy introduction and contextualisation to background theories through the realistic operation [6]. The most important advantage of a simulator exercise is the fact that it can be recorded and played back for those who participate in the exercise and de-briefed on the actions and responses. This debriefing is unparalleled in any other form of training where it is difficult to record each and every action of trainees during an exercise. Debriefing allows the trainers to analyse the thinking pattern and decision-making capability of trainees, so that trainees can be advised how appropriate and timely corrective action can be taken. On the other hand, debriefing allows trainees to review their actions and correct them as necessary. It provides a very effective pathway for learning through 'mistakes' they make in a situation so that they get a lifelong lesson.

EMERGENCY PREPAREDNESS

This is a general topic involving emergencies of any magnitude anywhere anytime. It may involve "man-made' emergency events or catastrophic events of the nature. Preparedness is one phase of management of the event to mitigate the consequences. The preparedness also goes further to response and recover phases. However, we limit our research into response only as it is what we need to train engineers in the transition and remote operators for autonomous ships.
Emergency preparedness is not a new concept for seafarers. It has been continually practised in the past as 'the Saturday Routine' on-board ships. Safety of Life at Sea (SOLAS) regulations now demands certain familiarization and safety routines to be carried out more often as appropriate. Even in the current context, the emergency preparedness involves how to fight a fire or abandon the ship. Fighting a fire involves a 'mock fire' rather than a real one. Abandoning the ship is just symbolical. The crew takes their assigned positions and duties mechanically, knowing that it is an exercise. A seafarer gets used to this routine in no time and will not tend to treat it as a serious exercise. On the other hand, we cannot create real emergencies such as a flooding of the machinery space or a crankcase explosion on a Saturday Routine. It is not feasible to create a real emergency as that is not practicable as the cost of such will be unaffordable for any shipping company. Further, even an emergency that can be created without any cost will not be exercised by the ships' personnel for the fear of the unknown. An example is the verification of the starting of emergency generator and connecting it to emergency busbar in case of a blackout. This is a normal Saturday Routine test done as explained below:
For the testing of the automatic starting and connection to the busbar of the emergency generator, in the event of a main power failure, there are two TEST buttons in the emergency generator control panel:
TEST 1: *when pressed will start the emergency generator, but it will not connect to the emergency busbar. It ensures that the emergency generator responds to a power failure.*

TEST 2: *when pressed will start the emergency generator and connect to the emergency busbar after disconnecting the main busbar connection. It ensures that the emergency generator starts up and connect to the busbar within 45 seconds of a main power failure, which is a SOLAS requirement* [7]

This operation will not cause a "blackout" of the ship if you test it under normal circumstances. There will be a momentary power loss to emergency lighting circuits and some Navigational equipment. The only precautions that the engineers must take are:

1. running the steering gear motor that is connected to the mains power.
2. informing the bridge of temporary loss of power to some equipment and lighting.

Students inquiries revealed that only half of the engineers on-board their ships agreed to press the TEST 1 button while the ship is at sea for "testing of the emergency generator during Saturday routine exercises". The alarming sign is that none of the engineers have agreed to press the TEST 2 button at sea, even though it is quite safe to conduct this test. This is a clear indication of the lack of confidence of engineers due to shortcomings in training. This lack of confidence leads to a chain reaction [8] of other erroneous actions when an operator is handling an emergency situation for the first time. Generally, marine engineers are reluctant to operate machinery if they haven't operated this equipment before for the fear of the unknown.

EMERGENCY MANOEUVRING WITH RESTRICTED ELECTRICAL POWER

A very common notion among the engineers is the amount of redundancy that a ship must have in terms of the electrical power supplying generators in an emergency. SOLAS Chapter 1 Part D states that:

"Regulation 41 - Main Source of Electrical Power and Lighting Systems"

> 1.1 A main source of electrical power of sufficient capacity to supply all those services mentioned in regulation 40.1.1 shall be provided. This main source of electrical power shall consist of at least two generating sets.
>
> 1.2 The capacity of these generating sets shall be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide normal operational conditions of propulsion and safety. Minimum comfortable conditions of habitability shall also be ensured which include at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water. [7]

In most ships there are 3 generating sets making a 200% redundancy. Students mistakenly think that ships need at least 2 generator sets for normal operation and refuse to leave / enter a port without additional tug assistance, if a generator is out of action. In an emergency if two generators are out of action, students refuse to manoeuvre the ship with one generator. Almost all students (over 400 at AMC during the past 7 years) stated that a ship cannot be run with one generator although they are aware of the SOLAS regulation to the contrary.

Facing emergencies similar to above can be best demonstrated with a full mission simulator at zero cost. The exercise designed and developed shows how to handle a critical situation when it is required to enter a port with only one main generator working. Students learn how machinery can be prepared for this emergency by following logical steps. The strategy they employ is proved capable by effective use of all the resources available in this instant.

MODERN 3-D SIMULATORS FOR EMERGENCY PREPAREDNESS

The new safety simulators for advanced firefighting have 3-D walk-through engine rooms with X-Box control that enables trainees to explore all areas of the virtual engine room or accommodation. The simulator features visual models such as equipment for the fire teams, doors, lights, fire, smoke and people. Corridors, stairs, cabins, offices, lockers, storages, emergency exits, firefighting and lifesaving equipment are all available in the 3-D environment. Exercises can be conducted allocating various tasks to each team such as firefighting and search and rescue operations. The communication between the teams is monitored by the instructor and can be recorded and debriefed for further improvement.

Another critical emergency on board a ship can be the flooding of the machinery space. The emergency preparedness involves restricting the flooding and pumping out the water. If the flooding is due to a breach of the hull it will not be possible to restrict flooding unless it is in a watertight compartment for an autonomous ship. The modern simulators can be employed to demonstrate how a major flooding is controlled by pumping out water with main seawater pumps through bilge injection suction. The simulator clearly shows the flooding rate and the pump flow rate in addition to the 3-D view of rising / falling water level. In this exercise, students learn that pumping out of water is carried out in an un-conventional manner. However, it is very effective and most probably the only way to save the ship.
Experiencing a crankcase explosion can be the worst nightmare for a marine engineer. Monitoring the progress of a hot spot in the crankcase towards an explosion can be best demonstrated by a simulator. This could be emulated by disabling certain safety features of the simulator exercise to measure the judgment and decision-making ability of the student. Students are encouraged to use trend diagrams which play a very critical role in decision-making. The emergencies of this nature need early detection and remedial action.

THE DIGITAL TWIN AND THE EMERGENCY PREPAREDNESS

A digital twin is a virtual model of a process, product or service. This pairing of the virtual and physical worlds allows analysis of data and monitoring of systems to head off problems before they even occur, prevent downtime, develop new opportunities and even plan for the future by using simulations. Digital twins are becoming a business imperative, covering the entire lifecycle of an asset or process and forming the foundation for connected products and services. Companies that fail to respond will be left behind." [9]. Current trend is to have digital twins for ships being built alongside the real ship. These digital twins will be the training models for remote operators of both autonomous and semi-autonomous ships of the future. The digital twin will represent the real ship in all aspects. This makes it even better for emergency preparedness as it represents both real hull and the machinery.

CONCLUSION

As the technology advances it is inevitable that the machines gradually take over the role of humans. It can be debated that the take over of controls by machines is better as machines do not make errors like humans. However, in the transition to autonomy and in certain emergencies human intervention is still required. In this context, a question arises as to the training of the human operator since the human element is gradually fading away in ships. In this context, with the prominent advantages, modern full mission simulators with walk-through functions will be the best solution for training future operators and engineers for emergency preparedness.

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