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A COURSE PROPOSAL FOR THE TRAINING OF MARINE ENGINEERING STUDENTS ABOUT ALTERNATIVE FUELS, RELATED SYSTEMS, AND OPERATION

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Abstract. Sea trade is an important element of international trade. There are huge number of ships at worldwide, and they emit huge amount of emissions accordingly. Stricter emission regulations are entered into force, and will be entered into force in the future by the International Maritime Organization and EU to control and reduce these emissions. To comply with these regulations, alternative fuels are in use. The alternative fuelled ship number is in increase. Despite the alternative fuel usage at maritime industry increases, there are not any alternative fuel courses at the maritime universities to educate the marine engineering students. In this study, a new course about the alternative fuels, their related systems, and operation is proposed for the training of the marine engineering students. Competences at the STCW amendments for the persons who work on alternative fuelled ships are taken into account while preparing the course topics. Each topic is paired with basic and advanced training competences of the STCW amendments, and compliance with the STCW is provided. Lastly, the course topics and sub-topics are explained for the guidance to prepare the alternative fuel course.

1 INTRODUCTION

Sea trade forms the major part of international trade. It is done with 90.917 merchant ships in various size and tonnages [1]. This high number of ships mean huge amount of fuel consumption and emission formation related to the fuel consumption. According to International Maritime Organization (IMO), global annual fuel consumption from all ships was 300 million tons [2]. Again, IMO stated that the shipboard NO_X emission was 19 million tons, the SO_X emission was 10.2 million tons, the CO_2 emission was 949 million tons, the CO emission was 936 thousand tons, and the PM emission was 1.4 million tons in 2012. The emission amounts enforce IMO and local authorities to make emission rules and regulations more stringent. Lower NO_X emission limits, less sulphur in fuel, and new CO_2 emission control and reduction strategies like MRV Regulation or IMO Data Collection System are measures to prevent higher emission amounts.

To cope with the stringent emission rules and regulations, ship owners and operators have to use emission abatement technologies or alternative fuels at their ships. Usage of the alternative fuels on ships increases in number. Liquefied natural gas (LNG), liquefied petroleum gas (LPG), and methanol is in lead at the use of the alternative fuels on ships. There are 116 LNG fuelled ships, 12 LPG fuelled ships, and 2 methanol fuelled ships in operation [3]. Alternative fuelled fleet will increase with new buildings.

IMO pays attention to the progress at the alternative fuel usage at maritime industry. In this framework, The Code of Safety Using Gases or Other Low-Flashpoint Fuels (IGF Code) was adopted, and entered into force on and after 1 January 2017 [4]. By this code, some amendments were made to Chapter II-1 and Chapter II-2 of the International Convention for the Safety of Life at Sea (SOLAS) which were also entered into force on and after 1 January 2017 [5]. Other important amendments were made to the International Convention on Standards of Training, Certification and Watch keeping for Seafarers, 1978 (STCW), and entered into force on same date with other relevant conventions.

Nowadays, education about the alternative fuels increases its importance. There are some examples for the courses in worldwide for land-based facilities and vehicles. Veer Surendra Sai University of Technology has the course named Internal Combustion Engine & Gas Turbines which includes the alternative fuels in its course plan [6]. Another course is the "Alternative Fuel" which is given at The Hong Kong Polytechnic University [7]. There is only one postgraduate program at World Maritime University (WMU), which includes the alternative fuels & renewable energy [8], but this is also not a course that contains whole aspects of the STCW.

Recent developments in both technology and legislation bring necessity of education of the ratings and especially the officers about the alternative fuels, shipboard alternative fuel systems, and operation. Maritime universities have important place in officer training, and should adapt themselves to the developments in the maritime industry. This study aims to propose a new course to give adequate knowledge to the marine engineering students about the alternative fuels, fuel systems, and the operation with the alternative fuels. For this purpose, competences part of the basic and advanced training of STCW amendments is taken as a reference. Knowledge, understanding and proficiency part related to the competences are examined in detail. A course syllabus is formed, and the course topics are explained.

2 STCW AMENDMENTS RELATED TO THE ALTERNATIVE FUELLED SHIPS

STCW has the amendments to the Chapter VI – Special training requirements for personnel on certain types of ship. New section, A-V/3 – Mandatory minimum requirements for the training and qualification of masters, officers, ratings and other personnel on ships subject to the IGF Code was added. The amendments include the basic and advanced training and qualification requirements for the ratings and the officers [9]. Table 1 shows the competences of the basic and advanced training. The basic training is for ratings, and the basic and advanced training is for officers.

Table 1: Competences of the basic and advanced training [9]

BASIC TRAINING
- Contribute to the safe operation of a ship subject to the IGF Code
- Take precautions to prevent hazards on a ship subject to the IGF Code
- Apply occupational health and safety precautions and measures
- Carry out firefighting operations on a ship subject to the IGF Code
- Respond to emergencies
- Take precautions to prevent pollution of the environment from the release of fuels found on ships subject to the IGF Code
ADVANCED TRAINING
- Familiarity with physical and chemical properties of fuels aboard ships subject to the IGF Code
- Operate controls of fuel related to propulsion plant and engineering systems and services and safety devices on ships subject to the IGF Code
- Ability to safely perform and monitor all operations related to the fuels used on board ships subject to the IGF Code
- Plan and monitor safe bunkering, stowage and securing of the fuel on board ships subject to the IGF Code
- Take precautions to prevent pollution of environment from the release of fuels from ships subject to the IGF Code
- Monitor and control compliance with legislative requirements
- Take precautions to prevent hazards
- Apply occupational health and safety precautions and measures on board a ship subject to the IGF Code
- Knowledge of the prevention, control and firefighting and extinguishing systems on board ships subject to the IGF Code

3 FORMATION OF THE COURSE STRUCTURE

This section includes proposed topics which were determined according to the competences at the STCW amendments. After the determination of the topics, these topics were explained in detail with their sub-topics, and the course structure was formed.

3.1 Determination of the course topics

The course topics were determined by taking into consideration of the basic and advanced training competences (Column 1) and their knowledge, understanding and proficiency (Column 2) section in the STCW amendments. But, due to the page number limits, only the competences were shown in this study. According to the STCW amendments, seven main topics with their sub-topics were determined. Table 2 shows the topics for the new alternative fuel course, and Table 3 shows matching of the STCW amendment competences with the proposed course topics.

Table 2: Proposed Course Topics

T1 – INTRODUCTION TO THE ALTERNATIVE FUELS
- Shipping Emissions
- Emission Abatement Technologies and the Alternative Fuels
- Maritime Industry Developments Related to the Alternative Fuels
T2 – ALTERNATIVE FUEL RULES AND REGULATIONS
- International Maritime Organization Rules and Regulations
- Class Society Rules and Guidelines
- Other Guidelines and Standards
T3 – PROPERTIES OF THE ALTERNATIVE FUELS
- Physical Properties of the Alternative Fuels
- Chemical Properties of the Alternative Fuels
- Special Properties Related to the Alternative Fuel Type
- Health Effect of the Alternative Fuels
T4 – FUEL AND STORAGE SYSTEMS OF THE ALTERNATIVE FUELS
- Tank Line and Equipments
- Fuel Supply Line and Equipments
- Main Engine and Auxiliary Engine Line and Equipments
- Safety Systems of the Alternative Fuels
T5 – OPERATIONS WITH THE ALTERNATIVE FUELS
- Bunkering Operations
- Onboard Tank Transfer Operations
- Storage and Handling Operations
- Other Onboard Operations
T6 – RISKS AND HAZARDS
- Risk Assessment About the Alternative Fuels and the Systems
- Hazard Control
- Safety Management and ISM Documentation About the Alternative Fuels and the Systems
T7 – EMERGENCY SITUATIONS
- First-aid
- Fire
- Leakage/Spillage/Venting
- Emergency Shutdowns, Emergency Escape Routes and Equipments
- Special Emergency Situations Related to the Properties of the Alternative Fuels

Table 3: Matching of the competencies with the proposed course topics

Basic Training	Notations of the Proposed Course Topics	Advanced Training	Notations of the Proposed Course Topics
Contribute to the safe operation of a ship subject to the IGF Code	T1 / T3 / T4 / T5	Familiarity with physical and chemical properties of fuels aboard ships subject to the IGF Code	T1/ T3
Take precautions to prevent hazards on a ship subject to the IGF Code	T3 / T5 / T6	Operate controls of fuel related to propulsion plant and engineering systems and services and safety devices on ships subject to the IGF Code	T4 / T5
Apply occupational health and safety precautions and measures	T2 / T3 / T5 / T7	Ability to safely perform and monitor all operations related to the fuels used on board ships subject to the IGF Code	T4 / T5
Carry out firefighting operations on a ship subject to the IGF Code	T7	Plan and monitor safe bunkering, stowage and securing of the fuel on board ships subject to the IGF Code	T4 / T5 / T7
Respond to emergencies	T7	Take precautions to prevent pollution of environment from the release of fuels from ships subject to the IGF Code	T3 / T6 / T7
Take precautions to prevent pollution of the environment from the release of fuels found on ships subject to the IGF Code	T7	Monitor and control compliance with legislative requirements	T2
		Take precautions to prevent hazards	T5 / T6 / T7
		Apply occupational health and safety precautions and measures on board a ship subject to the IGF Code	T3 / T5 / T7
		Knowledge of the prevention, control and firefighting and extinguishing systems on board ships subject to the IGF Code	T7

3.2 Explanation of the course topics

This section mentions about the basic contents of the each course topic. The contents were determined according to the competences of the STCW amendments.

T1 – Introduction to the Alternative Fuels

This topic is the introduction topic to the alternative fuel course. It is formed by the sub-topics of “Shipping emissions”, “Emission abatement technologies and the alternative fuels”, and “Maritime industry developments related to the alternative fuels”.

Shipping emissions sub-topic gives information about the shipping emission types, how they form, effect of combustion on the different emission types, and annual amount of shipping emissions. Emission abatement technologies and the alternative fuels sub-topic mentions about the emission abatement technologies, for instance exhaust gas recirculation system, selective catalytic reactor, SO_X scrubbers etc., for the different emission types. In addition to this, effect of the alternative fuels on the emissions is included in this sub-topic. Last sub-topic of this main topic gives information about the alternative fuels which have been used on ships until now, and other maritime industry related information as bunkering capabilities, engine concepts etc.

T2 – Alternative Fuel Rules and Regulations

This topic is composed by the sub-topics of “International Maritime Organization rules and regulations”, “Class society rules and regulations”, and “Other guidelines and standards”.

All sub-topics aim to give general information about the rules and regulations which determine the minimum standards of the structural requirements of the ships, and the operation necessities for the alternative fuels. This topic gives awareness about the rules and the regulations about the alternative fuels which is a requirement of the STCW amendments.

T3 – Properties of the Alternative Fuels

“Physical properties of the alternative fuels”, “Chemical properties of the alternative fuels”, “Special properties related to the alternative fuel type”, and “Health effect of the alternative fuels” are the sub-topics of this main topic. Material Safety Data Sheet information of the alternative fuels can be used to discuss properties in this topic.

Physical properties sub-topic gives necessary information about the properties of the alternative fuels, for instance, flashpoint, auto-ignition temperature, other important temperatures for storage, handling and transfer of the alternative fuels, combustion properties, viscosity etc. Chemical properties sub-topic includes reactivity properties of the alternative fuels. Ship materials which can react with the used alternative fuel should be explained in this sub-topic. Special properties related to the alternative fuels are explained, for example, frost, corrosive substance, special expansion – shrinkage at certain temperature etc. Last sub-topic is about health effect of the alternative fuels. Threshold values of daily exposure rates should be discussed, and necessity of protective clothing and equipment should be mentioned.

T4 – Fuel and Storage Systems of the Alternative Fuels

This topic is formed by the sub-topics of “Tank line and equipments”, “Fuel supply line and equipments”, “Main engine and auxiliary engine line and equipments”, and “Safety systems of the alternative fuels”.

Storage tanks of the alternative fuels are important element in the whole system. There are cooled and pressurized types and various shaped tanks for the ships. For this reason, the tank line and the equipments should be discussed in a separate sub-topic. Fuel supply lines also have low-pressure lines and high-pressure lines depend on the used system type, and valve, pump and other line elements which change with the line type. Main engine and auxiliary engine line and equipments also should be mentioned for the marine engineering students. There are additional piping, pumping and other elements depend on fuel type, system type etc. Safety systems of the alternative fuels are also important subject. It is indicated as one of the competences in the STCW amendments. This sub-topic should include double-walled pipe safety systems, fans, emergency stops, tank safety systems, gas measurement systems and alarms, and other related safety equipments.

T5 – Operations with the Alternative Fuels

“Bunkering operations”, “Onboard tank transfer operations”, “Storage and handling operations”, and “Other onboard operations” sub-topics constitute the main topic. Liquid cargo handling simulator or engine room simulators, which use alternative fuel as a fuel at main engine and auxiliary engines can be used at this section.

Bunkering operations sub-topic, mention about the bunkering procedures of the specified alternative fuels. Special precautions should be taken for the different alternative fuel type. Thus, bunkering checklists should be discussed in this sub-topic. Onboard tank transfer procedures should be mentioned at another sub-topic. Specified transfer precautions and important points of the operations should be discussed. Storage and handling operations are other important points while doing voyage. For this reason, storage and handling procedures for each operation should be discussed. These operations can be drying, inerting, purging, cooling down, stripping, draining, boiling off or rollover for gaseous fuels [5]. It can be organized for liquid alternative fuels too. The last but not the least sub-topic for this main topic is “Other onboard operations”. Other operations means that they do not related with the alternative fuels, but done on an alternative fuelled ship. These operations can be hot work, enclosed spaces and tank entry etc. Safe working knowledge for every operation should be explained in detail at this main topic.

T6 – Risks and Hazards

This topic includes “Risk assessment about the alternative fuels and the systems”, “Hazard control”, and “Safety management and ISM documentation about the alternative fuels and the systems”.

Risk and hazards should be mentioned at the risk assessment sub-topic. There can be various hazards related to the alternative fuels. These are health hazards, environmental

hazards, reactivity hazards, corrosion hazards, ignition, explosion and flammability hazards, electrostatic hazards, toxicity, sources of ignition, vapor leaks and clouds, extremely low temperatures, pressure, fuel batch differences and inert gas composition [9]. After that, basic risk assessment techniques should be explained, and class works should been done with the marine engineering students. The hazard control actions of above mentioned hazards should be stated at the "Hazard control" sub-topic. Safety management and ISM requirements should be introduced to the students to eliminate the lack at the paperwork knowledge.

T7 – Emergency Situations

This topic contains "First-aid", "Fire", "Leakage/Spillage/Venting", "Emergency shutdowns, emergency escape routes and equipments", and "Special emergency situations related to the properties of the alternative fuels" sub-topics.

At this section of the course, more advanced first-aid and fire fighting knowledge should be given to the students by taking into consideration of the properties of the specific alternative fuels. Additionally, practical fire fighting training also improves the skill of the students. Leakage/Spillage/Venting sub-topic is another important subject. Students should know how to react and how to act at these situations. Emergency shutdowns, emergency escape routes and equipments are also important things to know, when it is the worst case, and you have to leave the ship. Lastly, there are special properties of the alternative fuels, and special emergency situations can occur, for instance, extreme corrosion-reactivity, explosion, electrostatic materials, toxicity, extremely low temperatures etc. These emergency situations should be mentioned at the last sub-topic of this main topic.

12 CONCLUSIONS

This study is about improving marine engineering education by proposing a new course for alternative fuels, their related systems and operation. Firstly, STCW amendments for the alternative fuels were examined, and the competences and knowledge requirement columns of the basic training and advanced training were taken into consideration. The course topics were determined according to the competences and the knowledge requirements. Each competence was matched by the topics, so the course can cover all competence requirements of the basic and advanced training. At the last part of the study, the course topics were explained in detail.

The alternative fuel usage at the maritime industry is in increasing trend. It will be expected that more ships in number will use various type of alternative fuels in the future. Therefore, the maritime universities should be prepared to give the education about the alternative fuels to their marine engineering students. There are different types of alternative fuels with different properties, thus the marine engineering students have to learn the properties of the alternative fuels, the tank and fuel systems of them and the operations with them. This study aims both to give awareness and form a guideline to the maritime universities. It can be small pathway for the further discussions of the alternative fuel related courses at the maritime universities.

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