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AWARENESS OF THE RISK PRESENTED BY THE RADON GAS AMONG PEOPLE IN CONSTANTA COUNTY (ROMANIA)

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Abstract: During the period November 2015 - May 2016, a radon awareness survey was conducted to measure awareness and knowledge about some characteristics and health hazards of radon among residents in Constanta County, Romania. Questionnaire data consisted of knowledge and risk perception about radon. A total number of 445 participants responded to the questionnaires. The survey found that only 41% respondents had heard of radon. This study shows the necessity to inform the population about the health risk posed by radon, the necessity of monitoring and mitigation methods of it.

Key words: radon gas, health hazard, people awareness.

1. INTRODUCTION

Radon is a naturally occurring radioactive gas. It has no color, odor or taste, and is chemically inert. It comes from the disintegration of uranium. As a uranium nucleus decays to form stable lead, it changes from one radioactive element to another in a sequence known as the uranium decay cycle. Part of the way through this cycle, the element radium becomes radon gas, which moves up through the soil into the atmosphere [1]

Radon from the soil seeps through cracks in buildings' foundations, floors and walls. In some instances, the building materials can be an important source of indoor radon. If the building is not well ventilated, then the gas will concentrate in the lower floors where it is breathed in by occupants. The gas concentrations can vary significantly from place to place and indoor concentrations are affected by climate and temperature changes. This variability makes testing challenging. Additionally, studies have shown that there is no minimum threshold below which radon levels do not pose a risk to human health. Therefore, any level represents an increased risk of lung cancer [2].

Radon is estimated to cause about 21,000 lung cancer deaths nationwide per year (USA). Radon is the second leading cause of lung cancer in the United States today. Only smoking causes more lung cancer deaths. Smoking has been found to have a synergistic effect with radon in causing lung cancer [3].

Since the general public is often unaware of the risks associated with indoor radon, special risk communication is recommended [3].

The purpose of this study is to measure the extent to which Constanta County residents have information about radon gas, about the risks it posed to health and about methods to protect ourselves from the inhalation and ingestion of it.

2. METHODOLOGY

A number of 445 residents from Constanta County were asked by freshman from Constanta Maritime University, “Do you know what radon is?”. For those whose answer was “YES” the next questions were: “What do you know about radon gas?” and “Do you know how to protect against the health risk of radon?”

Figure 1 presents localities were test was applied:

Figure 1 Constanta County Map

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3. RESULTS

Figures 2, 3, 4, and 5 presents the characteristics of the respondent`s sample: sex, studies, age and residence:

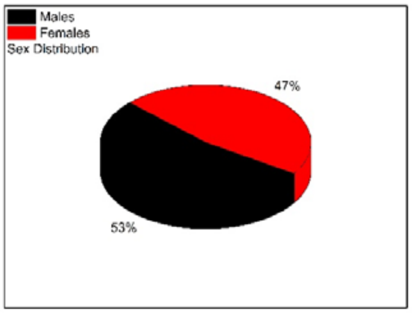

Figure 2 Sex distribution of the respondents

Figure 2 shows that the number of respondent females is almost equal to that of respondent male persons.

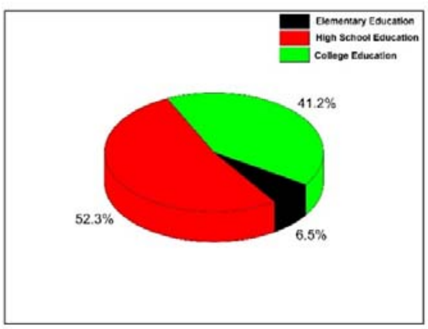

Figure 3 Educational attainment of the respondents

We observe that most respondents received an average and higher education. Those with elementary education represents only 6.5% of respondents.

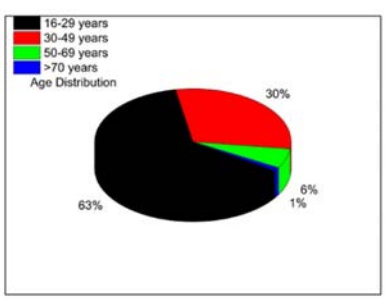

Figure 4 Age distribution of the respondents

We see that most of those who responded to the test are young people, aged between 16 and 49 years.

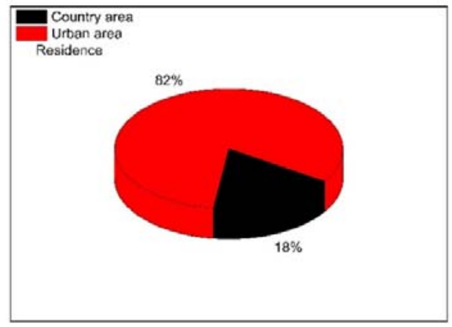

Figure 5 Residence of the respondents

Respondents live largely in urban areas.

Next, Figure 6 presents the answers to the first question: ***"Do you know what radon is?"***

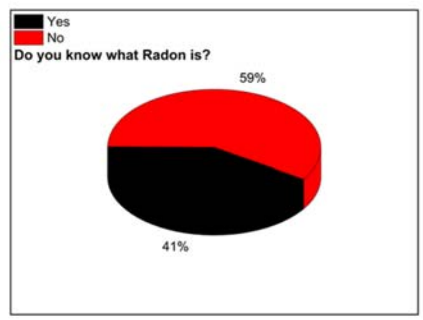

Figure 6 Who knows what Radon is?

We see that from 445 people who participated to this test, only 182 claim to have heard about radon. Now let us see what they know about radon:

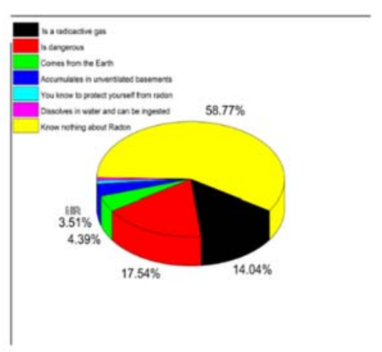

Figure 7 Answers to questionnaire

From 445 respondents 59% have not heard about radon, 14% know that radon is a radioactive gas, 18%

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know that radon is hazardous to health, 4% know that radon comes from the Earth, about 4% know that radon gas accumulates in unventilated basements, 1% know how to protect from radon and 1% know that radon dissolves in water and can be ingested.

4. COMPARISON

A similar study was conducted years ago in Colorado State, U.S.A [4].

Figure 8 Position of Colorado State on U.S.A. map

Figures 9, 10, 11, and 12 compare the distribution of ages and education levels of respondents who know about radon gas and the risk of this for health.

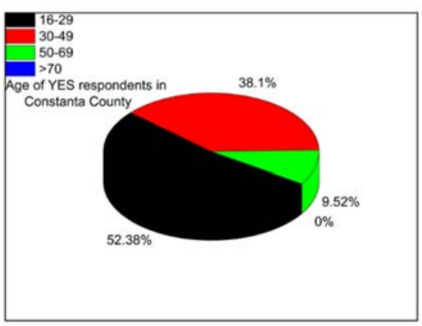

Figure 9 Age of YES (they know what Rn is and its risk for health) respondents in Constanta County

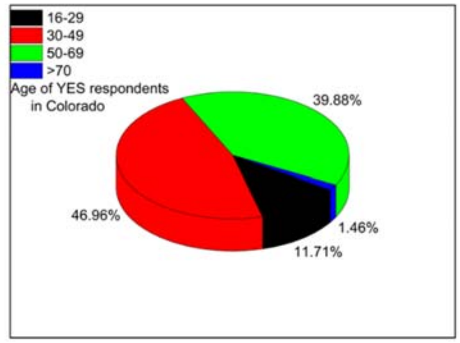

Figure 10 Age of YES (they know what Rn is and its risk for health) respondents in Colorado State [4]

We see that in Constanta County, Romania, those who have knowledge of radon are predominantly young, while in Colorado State, U.S.A., predominate the middle-aged and older people.

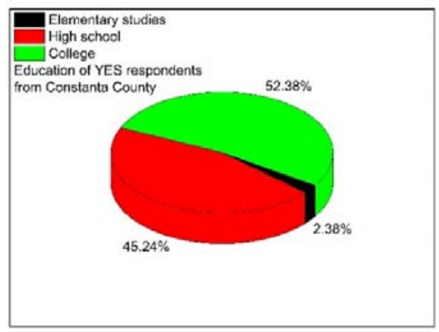

Figure 11 Education of YES respondents from Constanta County

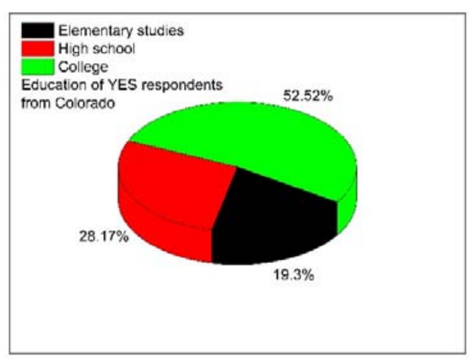

Figure 11 Education of YES respondents from Colorado State [4]

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We note that a significant percentage of respondents who are aware of the risks of radon have only basic education in Colorado State.

5. CONCLUSIONS

The study reveals that Constanta County population is less informed about the risk of radon gas on human health. Also many who know that radon is a radioactive gas are not informed about the measures to be taken to diminish its influence on human health.

The communication of radon risk and prevention messages poses serious challenges because radon is not widely known and may not be perceived as a health risk by the public.

As part of radon risk communication, the development of a set of core messages aimed at target audiences is recommended. These messages should be simple, brief, and to the point [1, 5].

The relatively low percentage of respondents who were knowledgeably aware of radon characteristics and health hazards strongly suggest that intensive efforts by the public health community, by the school and mass media, are needed to increase knowledge about radon and its health effects.

6. ACKNOWLEDGMENTS

Thanks to freshman from Constanta Maritime University who helped us in conducting this study.

7. REFERENCES

[1] Khalil M. Thabayneh, Inad M. Nawajah and Ahmad A. Ighraib, Radon Awareness Among Palestinian Population in the Southern Part of West Bank –Palestine, SDRP Journal of Earth Science & Environmental Studies, 3 August 2015;

[2] Wouter Poortinga, Karin Bronstering, Simon Lannon ,Awareness and Perceptions of the Risks of Exposure to Indoor Radon: A Population-Based Approach to Evaluate a Radon Awareness and Testing Campaign in England and Wales, Risk Analysis, Volume 31, Issue 11, November 2011, Pages 1800–1812;

[3] Wang, Ying; Ju, Carole; Stark, Alice D.; Teresi, Nicholas, RADON AWARENESS, TESTING, AND REMEDIATION SURVEY AMONG NEW YORK STATE RESIDENTS, Health Physics:June 2000-Volume 78 - Issue 6 - pp 641-647;

[4] Chrystine Kelley, Eric Brown,Radon Awareness and Household Testing: Results from the Behavioral Risk Factor Surveillance System.

[5] Suminory Akiba et al., WHO handbook on indoor radon-A public health perspective, World Health Organization, ISBN 978 92 4 154767 3, 2009.

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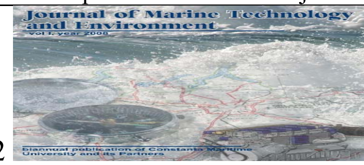

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DIGITAL AUDIO BROADCASTING FOR POSITION LOCATION AT SEA ¶

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Abstract: Position location refers to the functionality and events that estimate the location of a point of interest. Development of wireless communication technology and wide use of wireless networks have made location-aware applications possible and necessary. Object positioning location is an essential element in many applications such as navigation, tracking, emergency service, location based services and security. Position location involves the coordinates of a terminal that may be in two or three dimensions and contains information such as the latitude and longitude. The position location should ideally be available everywhere. Keeping track of objects can assist while improving safety and providing control efficiently. This paper is an overview that concerns a method of utilization of digital audio radiobroadcating technology for localization purposes while at sea. The described method relates generally to position determination and particularly to position determination using digital audio broadcasting signals (DAB). In-band On-channel (IBOC) digital audio broadcasting delivers besides enhanced fidelity and improved reception, some data services. These digital services could be utilized for position location where there's enough coverage not far from shore.

Key words: Digital audio broadcasting, position location, GPS, band allocations, pseudorange.

1. INTRODUCTION

The difficulties in positioning location and tracking estimation have been approached by many systems over the last decades such as Loran-C and global positioning system (GPS). GPS is a main example of position location with high accuracy over long distance wireless links. However GPS shows weakness in environments with distraction and interference. Positioning location system is based on the calculation of particular factors of a received signal that facilitates the position location inference of a device. The particular factors utilize measuring the supporting requirements, performance restrictions and complexity of the solutions. New opportunities using positioning location technology are therefore expected to be considered by companies and institutions experiencing convergence in their areas of business, particularly mobile and fixed communications providers and the electronic tools market.
Two-dimensional latitude/longitude position location systems using radio signals have been implemented as methods for many years. In wide usage there have been terrestrial systems such as Loran C and Omega, and a satellite-based system known as Transit. [2] Another satellite-based system enjoying increased popularity was the Global Positioning System (GPS).

Introduced in 1974, GPS is widely used for position location, navigation, survey and time coordination. GPS is based on a constellation of 24 on-orbit satellites in sub-synchronous 12 hour orbits. Each satellite carries a precision clock and transmits a pseudo-noise signal, which can be precisely tracked to determine pseudo-range. By tracking 4 or more satellites, one can determine precise position in three dimensions in real time, world-wide [4]. GPS has revolutionized the technology of navigation and position location. However in some situations, GPS is less effective. Because the GPS signals are transmitted at relatively low power levels (less than 100 watts) and over great distances, the received signal strength is relatively weak (on the order of −160 dBw as received by an omni-directional antenna). Thus the signal is marginally useful or not useful at all in the presence of blockage, distraction or interference. In general, this method features a computer-readable media for determining the position of a user terminal onboard near coastal waters. This comprises receiving, at the user end terminal, a digital audio broadcast signal and determining a pseudo-range between the user terminal and a transmitter, based on a known component of the digital audio broadcast signal.

2. ADVANTAGES OF THE PROPOSED APPLICATION OF DAB SIGNALS

Particular implementations can include one or more of the following features. The digital audio broadcast signal is selected from the group consisting of a European Telecommunications Standards Institute

ETSI) Digital Audio Broadcast (DAB) signal and an In-Band On-Channel (IBOC) audio broadcast signal. [8] The known component of the digital audio broadcast signal is selected from the group consisting of a synchronization symbol, a null symbol in a synchronization channel and a phase reference symbol in a synchronization channel. This comprises receiving a pseudo-range determined between the user terminal and a transmitter of a broadcast signal based on a known component in the broadcast signal. Determining the position of the user terminal based on the pseudo-range between the user terminal and the transmitter of the digital audio broadcast signal is also possible. The broadcast signal is selected from the group consisting of a broadcast audio, a mobile telephone cell site broadcast signal; and a Global Positioning System signal. The broadcast signal could be selected from the group consisting of the Television Standards Committee, the European Telecommunications Standards Institute (ETSI) Digital Video Broadcasting-Terrestrial (DVB-T) signal and an analog radio broadcast signal. The mobile telephone cell site broadcast signal is selected from the group consisting of a Global System for Mobile Communications (GSM) signal, a Code-Division Multiple Access (cdmaOne) signal, a WCDMA signal, a cdma2000 signal and a EDGE signal [3]. Advantages that can be seen in such method include one or more of the following. Implementations may be used to position cellular telephones onboard, wireless devices as tablets, cars, OCDMA (orthogonal code-division multiple access) transmitters and other devices. This makes use of a DAB signal which has excellent coverage near shore. The DAB signal has a power advantage over GPS of more than 50 dB, and substantially superior geometry to that which a satellite system could provide, thereby permitting position location even in the presence of blockage and indoors. The DAB signal has roughly eight times the bandwidth of GPS, thereby minimizing the effects of multipath**.** Due to the high power and sparse frequency components of the DAB signal used for ranging, the processing requirements are minimal. Implementations of the discussed method accommodate far cheaper, lower-speed, and lower-power devices than a GPS technique would require. In contrast to satellite systems such as GPS, the range between the DAB transmitters and the user terminals changes very slowly. Therefore the DAB signal is not significantly affected by Doppler effects. This permits the signal to be integrated for a long period of time, resulting in very efficient signal acquisition [5]. The frequency of the DAB signal is substantially lower that that of conventional cellular telephone systems and has better propagation characteristics. For example, the DAB signal experiences greater diffraction than cellular signals, and so is less affected by hills and has a larger horizon. Also, the signal has better propagation characteristics [1].

3. TECHNOLOGY ACKNOWLEDGEMENT

DAB utilizes OFDM (Orthogonal Frequency Division Multiplex). OFDM is a special case of multi carrier digital modulation technique in which a single data stream will be transmitted over a many narrowband closely spaced subcarriers and maintains orthogonality among subcarriers. OFDM technique may be used as either modulation or multiplexing or both. One of the main reason to use OFDM is that it offers high spectral efficiency and provides high robustness against multipath fading and narrowband interference [7] OFDM is a form of signal format that uses a large number of close spaced carriers that are each modulated with low rate data stream. The close spaced signals would normally be expected to interfere with each other, but by making the signals orthogonal to each other there is no mutual interference. The data to be transmitted is shared across all the carriers and this provides resilience against selective fading from multi-path effects. With such level of immunity, the system can operate with other digital radio transmitters operating on the same frequency without any additional effects. This means that it is possible to set up a system where all the network transmitters operate on the same frequency. This means that it is possible to set up single frequency networks throughout an area in which a common "multiplex" is used. Even though it may appear that this is a recipe for poorer reception caused by several transmitters using the same frequency, the opposite is actually true. A further advantage of this digital radio system is that it requires less power than the more traditional transmitters. For example those that carry the main FM networks from the main transmitting sites run at powers of around 100 kW for each of the four main services that are transmitted [4]

4. DESCRIPTION OF THE SETTING SCENARIO

Figure 1 is used to illustrate the aspect of the setting. The user terminal onboard could be PDA, mobile phone, tablet, car or other vehicle and any object which could include a chip or software implementing DAB position location. There’s no limitation to objects which are “terminals” or which are operated by “users.” The consequent stages are:

- Reception of multiple digital broadcast signals at the user terminal
- Determine a pseudorange between the user terminal and the transmitter of each digital broadcast signal

Determine the position of the user terminal based on the pseudoranges and a location of each of the transmitters [6].

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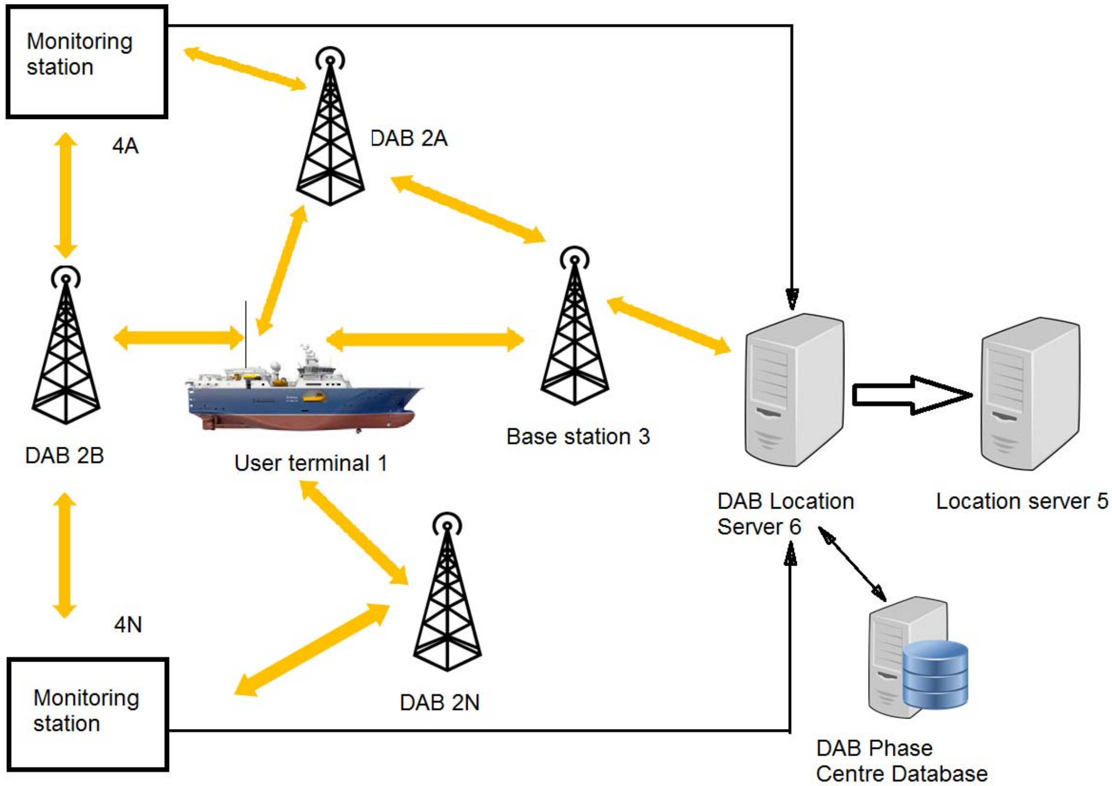

Figure1 Structure for position location using DAB base stations

User terminal 1 receives DAB signals from multiple DAB transmitters 2A and 2B through 2N. Various methods can be used to select which DAB channels to use in position location. The DAB location server 6 tells user terminal 1 onboard about the best DAB channels to monitor. The user terminal onboard 1 exchanges messages with DAB location server 6 using intermediate base station 3. Hence, the user terminal 1 onboard selects DAB channels to monitor, based on the identity of the base station 3 and a stored table correlating base stations and channels. On the other side, user terminal onboard 1 can accept a location input from the user that gives a general indication of the area, such as the name of the nearest port and uses this information to select DAB channels for processing.

First, the user terminal 1 scans available DAB channels to assemble a fingerprint of the location, based on power levels of the available frequencies received. User terminal 1 compares this fingerprint to a stored table that matches known fingerprints with known locations to select DAB channels for further processing. This selection is based on the power levels of the channels, as well as the directions from which each of the signals are arriving, so as to minimize the dilution of precision (DOP) for the position calculation. Then the user terminal determines a pseudo-range between itself and each DAB transmitter 2. Each pseudo-range represents the time difference (or equivalent distance) between a time of transmission from a transmitter 2 of a component of the DAB broadcast signal and a time of reception at the user terminal 1 of the component, as well as a clock offset at the user terminal. User terminal onboard 1 transmits the pseudo-ranges to the DAB location server 6. The DAB location server 6 consists of a general-purpose computer executing software designed to perform the operations described above. On the other side, the DAB location server is implemented an ASIC (application-specific integrated circuit). The DAB location server 6 is within or near base station 3.

The DAB signals are also received by a set of monitoring stations 4A through 4N. Each monitoring unit can be implemented as a small transceiver and processor, and can be mounted in a convenient location such as a utility pole, DAB transmitters 2 or base stations 3. Monitoring units could be installed and implemented also on satellites. For each of the DAB transmitters 2 from which it receives signals, each monitoring device 4 measures the time offset between the local clock of that DAB transmitter and a reference clock. The reference clock is derived from the GPS signals. The use of a reference clock permits the determination of the time offset for each DAB transmitter 2 when multiple monitoring stations 4 are used, since each monitoring station 4 can determine the time offset with respect to the reference clock. Thus, offsets in the local clocks of the monitor units 4 do not affect these determinations. No external time reference is needed. According to this a single monitor station receives DAB signals from all of the same transmitters as does the user terminal onboard. In fact, the local clock of the single monitor unit functions as the time reference. Each time offset is modeled as a fixed offset. So, each time offset is modeled as a second order polynomial of the form:

$$offset=a+b(t-T)+c(t-T)^2, \quad (1)$$

that can be described by a, b, c coefficients and the time period T.

Each measured time offset is transmitted periodically to the DAB location server using Internet connection, as part of the actual DAB broadcast data. The location of each monitor unit 4 is determined using GPS receivers. DAB location server 6 receives information describing the phase center (i.e., the location) of each DAB transmitter 2 from a database server 5. The phase center of each DAB transmitter 2 is measured by using the monitoring stations 4 at different locations to find the phase center directly.

One approach to doing this is to use multiple time-synchronized monitoring stations at known locations. These units will make pseudo-range measurements to a transmitter at the same time instant and those measurements can be used to inverse-triangulate the location of the transmitter phase centers. The phase center of each DAB transmitter 2 is measured by surveying the antenna phase center. Once determined, the phase centers are stored in a data base 5 (See Fig.1). The DAB location server 6 could receive also meteorological information describing the environment - air temperature, atmospheric pressure and humidity in the vicinity of the user terminal, as an option.

DAB location server 6 can also receive from base stations 3 information which identifies a general geographic location of the user terminal 1. For example, the information can identify a cell or cell sector within which a cellular telephone is located. This information is used for ambiguity resolution. DAB location server 6 determines a position of the user terminal based on the pseudo-ranges and a location and clock offset of each of the transmitters. Figure 2 depicts the geometry of a position determination using three DAB transmitters. The DAB transmitter 2A is located at a position (x1, y1). The range between user terminal 1 and DAB transmitter 2A is r1. The DAB 2B transmitter is located at position (x2, y2). The range between user terminal 1 and DAB transmitter 2B is r2. DAB transmitter 2N is located at position (x3, y3). The range between user terminal 1 and DAB transmitter 2N is r3. DAB location server 6 may adjust the value of each pseudo-range according to the tropospheric propagation velocity and the time offset for the corresponding DAB transmitter. Thus, the DAB location server 6 uses the phase center information from database 5 to determine the position of each DAB transmitter.

The user terminal onboard makes three or more pseudo-range measurements to solve for three unknowns, namely the position (x, y) and the clock offset T of user terminal. In other words, the techniques used are to determine the position in three dimensions such as longitude, latitude, and altitude, and can include factors such as the altitude of the DAB transmitters.

The three pseudo-range measurements pr1, pr2 and pr3 are given by:

$$pr1=r1+T, \quad (2)$$

$$pr2=r2+T, \quad (3)$$

$$pr3=r3+T. \quad (4)$$

The three ranges can be expressed as;

$$r1=|X-X1|; \quad (5)$$

$$r2=|X-X2|, \quad (6)$$

$$r3=|X-X3|, \quad (7)$$

where X represents the two-dimensional vector position (x, y) of the user terminal, X1 represents the two-dimensional vector position (x1, y1) of DAB transmitter 2A, X2 represents the two-dimensional vector position (x2, y2) of DAB transmitter 2B, and X3 represents the two-dimensional vector position (x3, y3) of DAB transmitter 2N. These relationships produce three equations to solve the three unknowns x, y, and T. The DAB locations server 6 solves these equations according to conventional methods. In an application, the position of the user terminal 1 is transmitted to the location server for distribution to the proper sites. The equations (2)–(4) are treating the clock offset as a function of time. Mind that, the pseudo-range measurements are also a function of time. So, it could be assumed that the ranges will remain essentially constant over a certain period. The user terminal 1 then projects all the pseudo-range measurements to some common point in time. The projected pseudo-range measurements are communicated to the location server where they are used to solve the three unknowns x, y, and T. There also other approaches to implementing this concept of projecting the pseudo-range measurements to the same instant of time. [7]

Applications comprise determining the position of the user terminal based on the pseudo-range between the user terminal and the transmitter of the digital audio broadcast signal and a location of the transmitter of the digital audio broadcast signal. The digital audio broadcast signal is selected from the group consisting of a European Telecommunications Standards Institute (ETSI) Digital Audio Broadcast (DAB) signal and an In-Band On-Channel (IBOC) audio broadcast signal.

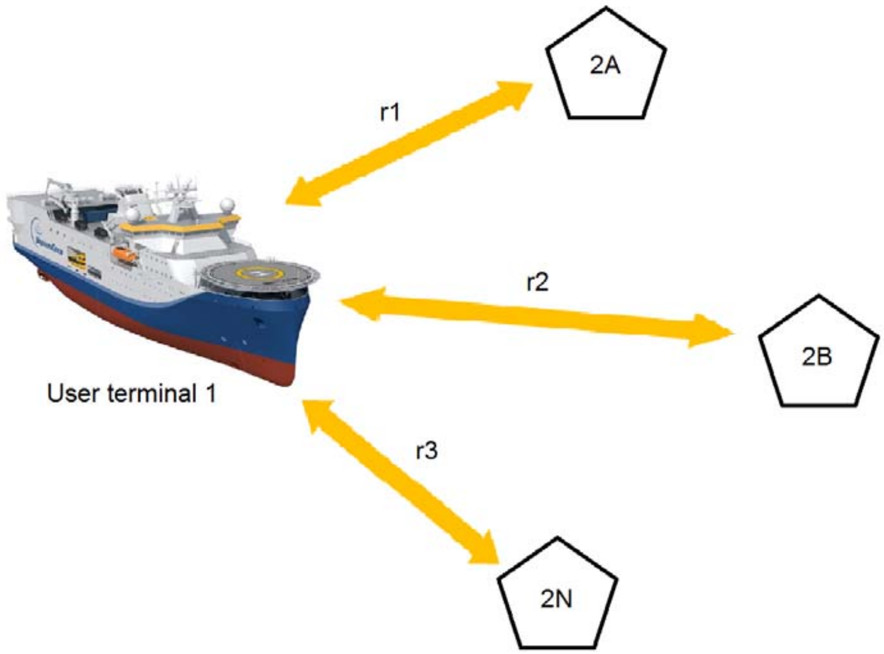

Figure 2 Implementation of DAB signals for position location

The known component of the digital audio broadcast signal is selected from the group consisting of a synchronization symbol, a null symbol in a synchronization channel and a phase reference symbol in a synchronization channel. The decribed method comprises receiving at the user terminal a broadcast signal and determining a pseudo-range between the user terminal and a transmitter of the broadcast signal based on a known component. The position of the user terminal is determined based on the pseudo-range between the user terminal and the transmitter of the digital audio broadcast signal, the pseudo-range between the user terminal and the transmitter of the broadcast signal, a location of the transmitter of the digital audio broadcast signal, and a location of the transmitter of the broadcast signal. The broadcast signal is selected from the group signal, a mobile telephone cell site broadcast signal and a Global Positioning System satellite signal. The broadcast DAB signal is selected from the terrestrial broadcasting system according to the corresponding standards committee requirements. The mobile telephone cell site broadcast signal is selected from the group consisting of a Global System for Mobile Communications (GSM) signal, a Code-Division Multiple Access signal, a WCDMA signal, an EDGE signal or 3G. The applications comprise determining the position of the user terminal based on the pseudo-range between the user terminal and the transmitter of the digital audio broadcast signal, the pseudo-range between the user terminal and the transmitter of the broadcast signal, a location of the transmitter of the digital audio broadcast signal and a location of the transmitter of the broadcast signal [8]._It is based on a known component in the digital audio broadcast signal and position is determined based on the pseudo-range between the user terminal and the transmitter of the DAB signal and a location of the transmitter of this broadcast signal.

5. CONCLUSIONS

In contrast to satellite systems such as GPS, the range between the DAB transmitters and the user terminals changes very slowly. Therefore, the DAB signal is not significantly affected by Doppler effects. This permits the signal to be integrated for a long period of time, resulting in very efficient signal acquisition. The frequency of the DAB signal is substantially lower that that of the conventional cellular telephone systems and has better propagation characteristics. For example, the DAB signal experiences greater diffraction than cellular signals, so is less affected by hills and has a larger horizon. The signal has better propagation characteristics through obstacles and constructions. One disadvantage of the OFDM signal is that it has a noise like amplitude with a very large dynamic range, therefore it requires RF power amplifiers with a high peak to average power ratio. The signal is more sensitive to carrier frequency offset and drift than single carrier systems.

Unlike the terrestrial Angle-of-Arrival/Time-of-Arrival positioning systems for cellular telephones, the method described would require no change to the hardware of the cellular base transceiver station and can achieve positioning accuracies around 1 meter. When used to position cellular phones, the technique is independent of the air interface. A wide range of UHF (ultra-high frequency) frequencies has been allocated to the DAB transmitters. Consequently, there is redundancy built into the system that protects against deep fades on particular frequencies due to absorption, multipath and other attenuating effects.

Positioning location is a key feature of future-generation wireless networks, enabling a multitude of applications in the military, public (e.g., search and rescue), and commercial (e.g., navigation) sectors. Thus, considerable research is needed to further improve the performance of such systems.

6. REFERENCES

1. Bolle M., Clawin D., Gieske K., Hofmann F., Spreitz G. *The receiver engine chip-set for digital audio broadcasting.* In Intl Symp on Signals Systems and Electronics, pp 338–342, October 1998.
2. ETSI TR 101 496-1 V1.1.1 (2000-11) Technical Report
3. ETSI**.** Radio Broadcasting Systems; *Digital Audio Broadcasting (DAB) to mobile, portable and fixed receiver*s. EN 300 401, European Telecommunications Standards Institute, April 2000.
4. Gandy C.. *DAB: an introduction to the Eureka DAB System and a guide to how it works.* Technical Report WHP-061, British Broadcasting Corp, June 2003.
5. Hoeg W., Lauterbach T. *Digital Audio Broadcasting: Principles and Applications of Digital Radio*. John Wiley, 2003.
6. Omura Jimmy K., Spilker James J. US Patent US 7042396 B2 2006 Position location using digital audio broadcast signals URL: https://www.google.com/patents/US20090175379
7. Prasad R. *OFDM for Wireless Communication System,* Artech house Inc. Boston London, ISBN 1-58053-796-0
8. Taura K., Tsujishita M., Takeda M., Kato H., Ishida M. *A digital audio broadcasting (DAB) receiver. IEEE Trans Consumer Electronics*, 42(3):322–327, August 1996.

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BEST PRACTICES FOR ESTIMATING EXTERNAL TRANSPORT COSTS

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Abstract: Transport activities give rise to environmental impacts, accidents, congestion, and infrastructure wear and tear. In contrast to the benefits, the costs of these effects of transport are not fully borne by transport users. Without policy intervention, the so called external costs are not taken into account by transport users when they make travel decisions. Transport users are thus faced with incorrect incentives, leading to welfare losses.The next study gives a perspective to what it could be done

***Key words*:** external costs, internalization.

1. INTRODUCTION

Internalization of transport external costs was a major problem for many years in Europe and the whole world regarding policy development and transport research.

A big number of research projects, including projects sustained by the European Commission, suggest that applying market instruments inspired by the economic concept of establishing the social marginal cost could bring important benefits.

The main elements considered to be part of an internalization policy of external costs in transport domain are the following:

- Internalization activation through instruments based on the market;
- Internalization facilitation through instruments based on the market;
- Building mandatory demands for market instruments;
- Other policy which contribute to cost internalization.

Shortly, internalization of external costs could be made through a combination of instruments. The main approaches recommended for internalization are:

- Costs regarding climate changes could be best internalized through fuel taxes or ETS;
- Costs connected with air pollution, accidents, noise and congestions could be internalized through differentiated taxes per kilometer, differentiated according to: the vehicle characteristics, location, hour of the day, and for the accident costs, also, driver's characteristics.

For the congestion costs, the local schemes could be a good alternative, while for the accidents 'costs these could be internalized through insurance companies, but it is preferred a tax per kilometre.

2. INTERNALIZATION OF ROAD TRANSPORT EXERNAL COSTS

The road transport is responsible for most of the external costs incoming from transport. So, the internalization policy should start with a new strategy for road transport. The differentiated kilometre taxes and the congestion taxes are two key elements in the approaches proposed for road transport. There is no legal barrier for applying the recommended internalization approaches for autovehicles and LDVs. Despite all this, for HGV, the current legislation doesn't allow fully internalization of external accidents, air pollution, noise and congestion costs.

Nr. Crt.	Type of vehicle	Costs per unit
1	Car	0.15
2	Motocycle	0.61
3	LCV	0.18
4	Bus	0.48
5	HGV < 16 tonnes	0.44
6	HGV > 16 tonnes	0.61

Chart 1. Medium costs for german highways in 2010 (euro/km)

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2.1. Arguments to amend the current directive

Internalization of road transport external costs is not permitted by the existent Eurovignette Directive 2006 / 38 / CE. The directive offers the possibility of adding costs in mountain areas and to charge taxes specific for the urban traffic, congestion taxes or regulatory taxes to combat the negative effects over the environment, including the inferior quality of the air, on any road, but especially in the urban areas. Also, the limited differentiation of taxes is permitted.

Though, the possibilities are very restricted and the full internalization of external costs is not possible. Thus, from the external costs internalization point of view, the directive modification is wanted.

The main arguments for modification of the existent directive regarding Eurovignette are the following:

1. Current taxes per km are much smaller than the marginal costs per travelled km, this thing leading to significant losses in efficiency;

2. Where there is no congestion, the highways km taxes for the HGV should be much greater to cover the infrastructure costs and the marginal external costs. In the urban area the situation is much worse because the actual system is completely free of expenses, which reflects marginal costs of air pollution, noise, accidents and, in most cases, congestion, while these costs ar much higher than the one for the highways. The current level of differentiation (the smaller taxes of 50% of the biggest expenses) is much too limited to reflect the differences of external costs in different traffic situations;

3. The incentives given through fuel taxes are perfect for costs internalization connected to climate changes, but these taxes can't internalize correctly the external costs of air pollution, noise, accidents and congestion;

4. There are no adequate incentives at the moment for the users to considerate these costs taking into account their transport decisions;

5. The current legislation is not able to assure equal playing field between different transport modes, especially between the road and rail transport. This thing is valid for the taxes level and structure, and also the differentiation possibility;

6. A first important step to more efficient prices could be a modification of the current directive, so it could allow the UE member states to charge taxes for HGV for all external costs of infrastructure costs. Taking into account the fact that the road transport is the main contributor to transports external costs, the internalization measures could be hard to be obtained in other ways as long as these are not fully activated for the road transport internalization.

A second reason for which the member states haven't yet applied the full potential of the current directive could be the fact that introducing a differentiated regime is much more sophisticated end more expensive than a paying tax system. Because of the requirement that the incomes don't exceed the medium costs of infrastructure, the complexity of an intelligent system doesn't reflect in higher incomes.

Although it wasn't used the full potential of the current directive, we have to notice that the newest introduced systems and the ones pending or still under development include differentiations, at Euro standard. Moreover, other types of differentiation are taken into account like location and hour of the day. Also, for taxes, other than the passing taxes, the number of differentiations with relevant parameters, from the Social Marginal Costs perspective, is growing.

2.2. Possible adjustments

Efficient taxing means that the prices reflect better the external marginal costs of the environment, accident costs, congestion costs and infrastructure costs. This thing needs higher levels of taxing and differentiation. Taxing levels shouldn't reflect only the infrastructure costs but also the external costs. In addition, a much more powerful differentiation for various parameters is needed, such as axle load (infrastructure costs), Euro standard, vehicles with or without particle filters, day/night, rush hour or not and location. Particular differentiation between urban and interurban areas is important because of the great differences in levels of marginal costs.

As a potential, it could be permitted a differentiation between the noise classes of vehicles. The current directive still permits some differentiations but the bandwidth is too small to reflect the real differences in costs.

For these reasons, is recommended that the directive is adapted as follows:

1. Allowing the member states to introduce differentiated taxes for marginal external costs of air pollution, noise and accident over the infrastructure taxes, to a certain level. An alternative could be ignoring the actual costs of the accident and opt for the costs internalization based on accidents through insurance companies.

2. Allowing the member states to differentiate the recovering taxes of infrastructure costs so that it reflect marginal infrastructure costs and congestion costs. This results in a more powerful differentiation regarding the location, hour of the day and type of vehicle. Another condition that could be set is that the other road users, especially the small cars, to pay the congestion tax.

3. Stating explicitly that the permitted taxes include other congestion taxes in urban and mountain areas on top of the taxes regarding infrastructure medium costs, air pollution, noise and accident costs.

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2.3. UE coordination to avoid overcharging

In the discussions that took place regarding modification of Directive 1999 / 62 / CE, there was a problem concerning overpricing. There could be a risk of overpricing when the member states are authorized to determine the price for external costs over the infrastructure costs. It is important to limit this risk because overcharging could lead to economic inefficiency. Overestimation could deflect the unwanted traffic and could obstruct a proper functioning of the internal market.

As a particular matter, there seems to be a fear from the member states situated, geographically, at the periphery of UE, because there is an overestimating risk regarding the use of infrastructure by the member states situated in the central UE. This could have an effect of redistribution from the peripheral countries to central countries.

These risks need some sort of coordination from UE. An option for this kind of coordination could be a certain limit of the taxes level which could be raised by defining a limit.

It should be noticed that a limit to strict could make the member states not to be able to establish the most efficient prices.

Generally, there could be taken into account the next options:

1. No limit.
2. A limit for each member state, for each type of vehicle regarding the tax for environment external costs and accident costs.
3. A limit for the tax per kilometer differentiated for the vehicle characteristics (i.g. Euro standard), location (i.g. urban/non-urban/metropolitan) and day / night time (i.g., rush hour or not).
4. A limit for the tax per kilometer differentiated for the vehicle characteristics (i.g. Euro standard), population density in that area, and day / night time (i.g., rush hour or not).
5. A limit for incomes from medium external costs and accidents, according to km per vehicle and a medium external cost per km.
6. A limit for incomes from medium external costs and accidents, defined as a percentage of incomes from infrastructure medium costs.

3. INTERNALIZATION OF NON ROAD EXTERNAL COSTS

Internalization of external costs in road transport is much more relevant than the other ones and that’s way has the biggest impact over the society.

However, for the other kinds of transport, internalization of external costs could lead to significant benefits. In size of external costs, maritime transport and aviation are most relevant main non-road modes of transport, but the internalization policy should be more developed also for the interior navigation and rail transport.

For the non-road transport there are some legal barriers for full internalization of external costs.

3.1 Railway transport

For railway transport, external costs charging is permitted under the conditions in which is made in competition with competing modes of transport.

Other policy initiatives which could support external costs internalization of railway transport are the following:

- The commission could encourage member states to use taxes for railway infrastructure by giving incentives for diesel trains emissions reduction and noise reduction, for example by using taxes as part of a incentive package for wagons with low noise breaks;
- The commission could encourage member states to use more the loading deficit to eliminate blockage and raise capacity.

3.2 Inland waterways transport

The main legal barriers for inland waterways navigation are the Conventions regarding Mannheim and Danube. Elimination of this type of legal barrier is a main step for inland waterway transport. This thing could make possible the external costs internalization and, also, infrastructure taxes, according to pricing model for road and railway transport. The commission, together with Central Commission for Rhine navigation could investigate the options to remove these barriers.

External costs internalization regarding inland waterways navigation should focus on air pollution costs and climate changing. A further evaluation of the instruments for costs internalization could be made focusing on km taxes and port charges for fuel costs internalization, air pollution and climate changing costs. Moreover, at present it doesn’t have a calculation method of infrastructure costs regarding inland waterways navigation. As part of an internalization strategy, the commission could propose this kind of method.

3.3 Sea transport

For maritime transport, air pollution and changing climate costs are the most relevant external costs. Port taxes seem to be the most appropriate for air pollution costs internalization. Maritime port authorities or national governments could give incentives for the least pollutant engines through further differentiation and existent port taxes. However, many harbors are reticent in introducing this kind of system because they are afraid of losing the market share. There is need for further

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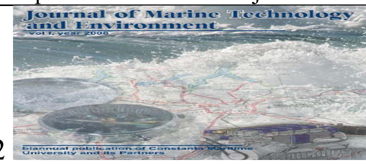

investigations regarding different alternatives for changing climate costs internalization. Especially, emissions trading options have to be analyzed, if possible, in cooperation with IMO.

Type of ship	Load	European sea area				
		Baltic Sea	Black Sea	Mediterranean Sea	North Sea	N-E Atlantic
Crude oil tanker 0-10 kt	1761	3.1	3.1	3.1	3.1	3.1
Crude oil tanker 10-60 kt	18413	0.8	0.8	0.8	0.8	0.8
Crude oil tanker 80-120 kt	49633	0.5	0.5	0.5	0.5	0.5
Products tanker 0-5 kt	810	4.1	4.1	4.1	4.1	4.1
Products tanker 5-10 kt	3150	2.7	2.7	2.7	2.7	2.7
General Cargo 0-5 kt	1527	1.4	1.4	1.4	1.4	1.4
General Cargo 5-10 kt	4174	1.5	1.5	1.5	1.5	1.5
Bulk carrier (feeder)	1440	2.7	2.7	2.7	2.7	2.7
Bulk carrier (handysize)	14300	0.7	0.7	0.7	0.7	0.7
Bulk carrier (handymax)	24750	0.5	0.5	0.5	0.5	0.5

Chart 2. Marginal costs for climate changing for sea transport in 2010 (euro/1000 tkm)

3.4 Air transport

In air transport domain, including ETS is an important step. If emission credits are auctioned and the limit is at a restrictive level than this thing could be considered as a changing climate costs internalization, except the emissions impact, other than CO2. For those to happen, the commission studies, at present, alternatives for NOx taxes.

Regarding the noise costs internalization there already are some examples of differentiated taxes for the airlines. Some airports are afraid of losing the market share in favor of competing airports, and so, it tend not to introduce this kind of noise costs elements in their charges. The commission could take the lead in this domain to search for a way to eliminate this barrier.

The most important action would be taking the lead in IACO and eliminate the legal barriers for the external costs internalization, such as adjustments for the Chicago Convention (for example, permitting fuel taxation).

Country	Airport	Outside population	Population exposed to noise
Austria	Vienna International Airport	10.8	14.8
Belgium	Brussels National Airport	59.1	76.9
Czech Republic	Prague Ruzyne International Airport	3.3	4.2
Denmark	Roskilde Airport	0.5	0.7
Denmark	Copenhagen Airport	1.2	5.8
Finland	Helsinki Vantaa Airport	0.1	0.2
France	Paris Charles de Gaulle Airport	66.3	110.6
France	Paris Orly Airport	2.8	221.3
France	EuroAirport Basel-Mulhouse-Freiburg	2.4	3.5
Germany	Hannover Langenhagen Airport	95.7	115.8
Germany	Hamburg Airport	96.2	124.1
Germany	Frankfurt am Main Airport	136.3	180.7
Germany	Berlin Tegel Airport		702.2
Greece	Athens International Airport	11.0	0.0
Hungary	Budapest Ferihegy International Airport	12.0	259.6
Italy	Milan Malpensa International Airport	36.2	43.8
Italy	Naples International Airport	85.2	385.5

Country	Airport	Outside population	Population exposed to noise
Italy	Roma Fiumicino - Leonardo da Vinci Airport	26.9	34.9
Italy	Turin International Airport	32.7	50.7
Luxembourg	Luxembourg International Airport	249.3	284.9
Netherlands	Amsterdam Schipol Airport	0.6	38.8
Poland	Warszaw F.Chopin Airport	4.1	27.1
Portugal	Lisbon Airport	5.9	205.3
Spain	Gran Canaria Airport	8.2	10.2
Spain	Madrid Barajas Airport	19.7	28.3
Spain	Bilbao Airport	44.6	53.7
Spain	Valencia Airport	100.7	170.4
Sweden	Goteborg-Landvetter Airport	1.6	1.9
Sweden	Stockholm-Arlanda Airport	1.7	2.4
UK	London Stansted Airport	14.8	19.6
UK	Southampton Airport	0.5	82.3
UK	Birmingham International Airport	2.0	160.9
UK	Bournemouth	2.4	17.2
UK	Bristol International Airport	15.3	19.5
UK	Nottingham East Midlands Airport	44.3	59.6

Chart 3 Medium cost for major airports in 2010 (euro)

4. INTERNALIZATION FACILITATION

The most efficient method of establishing the price is restricting it so there could be offered more incentives to reduce external costs. As mentioned before, this thing needs differentiated taxes for different parameters. In case of many countries opt for this kind of differentiated taxing system, harmonization is important to limit the transaction costs for the transport users. To facilitate the internalization policy by the member states, the commission could take the lead for:

- Vehicle classification (including trains, ships and airplanes) according to the environment characteristics as a differentiated taxing base. This is the best idea for Euro standard air pollution differentiating.

- Other parameters classification for differentiating such as location and the hour of the day. This type of differentiating could be made by defining some categories such as rural, urban or metropolitan; rush hour or not. Despite all this, in some cases, the local conditions could need other categories such as congestion taxes. Therefore, this type of coordination done by the commission doesn't seem to deserve the biggest priority.

- Pricing system (technology, projection and execution), such as a standard for pricing system and charging per km. Developing a European standard is very necessary to avoid an excessive number of different systems. To ensure that the future board units are capable of learning the main cost factors, should include the necessary demands to differentiate the taxes, such as the capacity to see the difference between location, hour of the day and Euro standards.

- Occasional and border treatment. Developing a new electronic taxing system confronts the problem of in which way the occasional users should pay. This problem is mostly connected to foreign traffic.

An important connection should be done with the policy in climate changing domain. From the economic point a view, raising fuel prices (CO2 taxation) and/or including transport sector in an emission trading system seems to be an optimal first solution. Including it in EU and ETS is the best way to follow for the maritime and air transport; for the road and railway transport, both fuel taxes and ETS could be taken into consideration. At a global level, orientation is onto measures to address the problem of CO2 emissions and, at a local level, the focus is on the measures to counteraction the local external effects which should be different in future internalization strategies.

Fuel	kg CO_2 per litre of fuel	g CH_4 per litre of fuel	g N_2O per litre of fuel	Climate changing costs, € per litre of fuel
Gasoline	2.25	0.81	0.26	21.1
Diesel (roads and railways)	2.66	0.14	0.14	24.3
Marine diesel oil	2.99	0.27	0.08	27.2
Kerosen	2.86	0.02	0.08	26.0
LPG (50% propane + 50%	1.77	1.74	0.01	16.3
CNG (methane)	1.57	2.58	0.08	14.9

Chart 3. Climate changing costs per unit of fuel consumption in 2010

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5. MANDATORY REQUIREMENTS FOR INSTRUMENTS BASED ON THE MARKET

Another element which could be part of a UE policy is to apply mandatory requirements for member states for internalization through market based instruments.

An example for this kind of mandatory requirements is that each member state to perceive a minimum share (with a growth up to 100% in time) of marginal external costs for each mode (marginal taxes and taxes). Considering different types of cost drivers, it is recommended to make a difference between km taxes and fuel taxes and taxes. Additional requirements could be that fuel taxes for changing climate costs for internalization should be based on the carbon content of fuel. Another additional requirement for km taxes would be that it would be differentiated at least regarding the location (urban/interurban), emission class, noise class (where is possible) and time of day.

These types of requirements could be applied for road, railway and inland waterways transport. It can contribute to harmonize the transport prices in different member states.

Establishing mandatory requirements needs a clear definition in which taxes can be considered internalization measures. However, the choice regarding the way of evaluation fuel taxes is more a policy measure than a scientifically one.

These requirements could be hard to apply because it will interfere with the taxing individual policy of the member states. This could be considered as being in conflict with the subsidiary principle.

Costs internalization regarding changing climate should be considered as part of a climate global policy. Both taxes, ETS and fuel are excellent instruments of external costs internalization regarding changing climate. Including aviation in ETS is a policy proposal and the electric railway transport is already part of ETS. Also, other modes of transport could be under the ETS. Another option could be putting surface transport in a different trading system, except ETS.

Also, fuel excises could be used for changing climate costs internalization. As mentioned before, this could be done by raising the existent excises or by designating a part of the existing excises as CO2 tax. However, more transparency is needed when it comes to internalize the changing climate costs. So, for each mode, is recommended a marketing strategy for the emissions or a CO2 tax.

6. CONCLUSIONS

The analysis of the important factors shows that it is important to destinguish the following types of taxes and expenses: the fix ones (which have no connection with the transport activity), fuel taxes and km taxes. External costs internalization is recommended through the use of a combination of instruments. The main recommended approaches for internalization are:

- taxes based on fuel which contents carbon or including in ETS for the internalization of changing climate costs;
- differentiated km taxes for the air pollution costs internalization, noise and congestion. These taxes should be differentiated according to vehicle characteristics (including Euro standard and particle filters), location and hour of the day. Accidents costs could be internalized through a km tax (differentiated for relevant parameters such as: location, type of vehicle and driver characteristics) or through taxes for insurance companies based on accidents. The last option is prefered, but it needs forward analysis. For congestion costs, local road pricing system could be a good alternative for the differentiated km taxing. For aviation and maritime transport, a good taxing basis could be the number of visits in ports or airports.

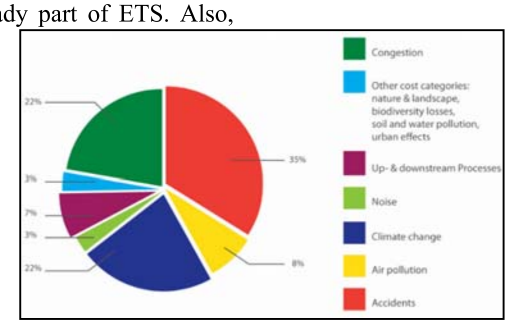

Figure 1 Total external costs of transport by externality in 2010

6. REFERENCES

[1] European Commission – *Update of the Handbook on External Costs of Transport*, January 2014;
[2] European Commission – *Internalization measures and policy for the external costs al transport*, June 2008;
[3] Beziris Anton, Bamboi Gh., *Transportul maritim*, Editura Tehnica, Bucuresti, 1988.
[4] Bombos Sever G., *Transportul intern de marfuri*, Editura Tribuna Economica, Bucuresti, 1999.

[5] Gh. Turbuţ , I Boicu , E Spirea , *Sisteme de transport,* Editura Tehnică , Bucureşti ,1978
[6] Caraiani Gh., *Tratat de transporturi*, Editura Lumina Lex, 2001.
[7] Caraiani Gh., *Transporturile si expeditiile rutiere*, Editura Lumina Lex, Bucuresti, 1998.
[8] Caraiani Gh., Stancu I., *Transporturile feroviare*, Editura Lumina Lex, Bucuresti, 1998.

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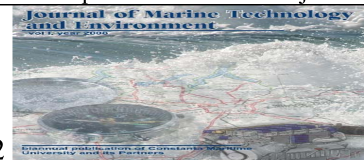
ISSN (Online): 1884-6116 http://www.cmu-edu.eu/jmte



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GREEN ENERGY PROPULSION

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Abstract.Emissions from the shipping sector must be curbed in order to reduce air pollution and climate change impacts. The International Convention for the Prevention of Pollution from Ships (MARPOL) has stipulated mandatory technical and operation measures, which require more efficient maritime energy use and, simultaneously, less emissions. These regulations came into force in 2013. The industry itself has set targets to reduce carbon dioxide emissions by 20% by 2020 and 50% by 2050. Ship operators, therefore, need to consider cleaner fuel and power options, including the use of renewables, to meet these targets. Furthermore, rising bunker fuel prices, amid a globally volatile market, provide another compelling reason to scale up modern shipping solutions based on renewable sources and technologies.

Key words**:** LNG, fuel cell, hybrid, electric, scrubber.

1. INTRODUCTION

During the past 150 years, shipping propulsion underwent a significant transformation from renewable energy (sails) to steam (coal), heavy fuel oil (HFO) and marine diesel oil (MDO), the latter two being high emissions fuels that are now the dominant source of power for propulsion in this sector. Over this period, the performance of merchant ships powered by diesel engines has improved with thermal efficiency approaching 55% for slow speed engines.

Renewable power applications in ships of all sizes include options for primary, hybrid and/or auxiliary propulsion, as well as on-board and shore-side energy use.

Shipping is vital to the world economy. It is a critical part of international import and export markets and supports the global distribution of goods. As for all industries, concerns about climate change require the reduction of greenhouse gas emissions from the shipping sector. This entails higher fuel prices for low sulphur fuels. It means that the industry must prepare for the new future and investigate alternative, more economic ship propulsion systems.

2. GROWTH AND INNOVATION

For many years, purely mechanical propulsion systems have been the norm in naval vessels. The last decade saw some applications of all-electric power and propulsion but, because of the sheer amount of power as well as the level of power density required, these systems were very expensive to acquire and very challenging for the ship designer to successfully integrate. The past few years, however, have seen considerable evidence of a shift amongst major combatants and naval auxiliaries from mechanical and all-electric toward a hybrid-electric power and propulsion system.

2.1. Combatants

With Japan and the US now adopting hybrid electric, most major navies have now moved from all-mechanical to a hybrid-electric system with some having passed through all-electric systems on the way.Time will tell how accurate this is, but with some of the most significant future combatatnt programmes (such as Australia, Canada, Brazil and Spain) most likely being based on existing designs, the prospect of a more hybrid future seems very strong.

HMS Queen Elisabeth is the world's largest all-electric combatant and uses two MT 30 Gas Turbine Alternators, together with four Wartsila W 3 DGs to power twin-shaft Rolls-Royce Adjustable Bolted Propellers, with each shaft having tandem GE Advanced Induction Motors. The trend for the latest combatants is towards a hybrid mechanical-electrical P&P system – gas turbines providing mechanically geared higher ship speed, while an integrated electrical system provides the ship's electrical load, as well as driving a lower-power high-torque motor provided loiter and cruise speeds.

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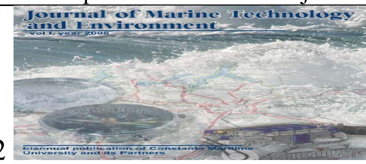

Figure 1 HMS Queen Elizabeth aircraft carrier

The UK Royal Navy's Type 26 continues the hybrid propulsion trend set by the T23, but adopts a single MT30 GT cross-connected gear set by David Brown and uses high-torque electric motors for loiter and cruise speeds. T26, like FREMM, F125 and FFXII, uses the most power-dense naval diesel generators currently available, the MTU4000. In the T26 each MTU20V4000 will deliver 2.9 MWe even at very high ambient air and seawater temperatures. Propellers are expected to be Rolls-Royce Fixed Bolted Propellers FBP, a low noise variant of the built-up ABP delivered to both T45 AND QE-Class ships, and shaft-lines will be provided by DCN.

In 2014, Italy has approved a class six of 140 m, 5000 tonne displacement multi-role ships, designated PPA. PPA will have a maximum speed of 35 kts, a range of 6000 n-miles at 15 knots and accommodation for 200+. The design is a twin shaft propeller driven ship, which for 35 knots and 5000 tonne displacement indicates perhaps an installed power of around 60-70MW, or twice that of FREMM, and in similar length but significantly slimmer hull (17 m instead of the 20m beam of FREMM).

In the near future, the following Combatant classes are most likely to be based on one or more of the latest 5000-7000 tonne displacement existing European frigates:

- The Spanish Navy's F110 frigate designed to replace the six ageing Santa-Maria (FFG7) ships from about 2020 onwards, fitting in between the innovative BAM and the F 100 air warfare destroyer. The preferred design is 143m and 5,450t. A hybrid propulsion system provides a maximum speed of 26 knots and a range of 4,100 nm. The F110 design may form the basis for Australia's SEA5000 future Frigate.
- Canadian Surface Combatant CSC, initially to replace the three Iroqois destroyers then later to replace the Halifax frigates, will be built by Irving Shipbuilding in Halifax.
- Despite Turkey's indigenous Milgem-Class frigate, it seems most likely that, for the larger and more capable TF2000, Turkey will seek to base the design on a current European design and to incorporate Turkish weapons wherever possible.
- Brazil's future frigate is part of the larger Pro-Super programme.
- Australia's SEA5000 replacement for the Anzac Class is expected to be ordered around 20121, with the first delivered 2026.

Whilst conventional combatants are adopting hybrid electric power and propulsion, fast combatants lack the weight or space available for such a system. The USA LCS was expected to be achieved by using exchangeable mission modules. Changing mission modules allows surface warfare, mine warfare, littoral Anti-Submarine Warfare and special-forces operations to be undertaken from a common hull.

2.2. Naval auxiliary vessels

Two of the latest naval auxiliary vessels, one Class for the UK and the other for the Norway, are based on BMT DSL's Aegir family and both were built at Daewoo Shipbuilding and Marine Engineering (DSME) in Korea. For both navies, these are their first Auxiliary/Logistics Vessels with diesel-electric hybrid power and propulsion system and this probably marks a shift, likely to be followed by many navies, from all-mechanical and all-electric system to a hybrid system. Main machinery for both vessels are similar and is provided by Wartsila. For LSV there are two 6L46F main engines and two 6L32 for diesel generators, gearboxes are SVC110-PDCT65 and 4E1300 CPP's.

One of the last major navies to replace their ageing single-skin tankers, France's BRAVE (Batiment RAVitalleur d'Escadre) multipurpose underway replenishment ships will provide dry goods, munitions, fuels and at-sea repair and maintenance capabilities. Although the BRAVE programme has now been delayed until at least 2019 (and hence France is relying on naval exemption to MARPOL regulation), DCNS showed its latest design at the Euronaval show. . The design, from aft to forward, has clear zones for aviation/VERTREP, ammunition, solids, liquids and accommodation; the accommodation so far forward being possible due to the novel (for a naval auxiliary vessel) wave piercing bow, which significantly reduces pitching motion as well as reducing ship resistance. Early machinery arrangements featured simple CODAD system but exhaust uptakes impacted on the flight deck and aviation capabilities and this has led to a new all-electric design with generating machinery (and exhausts) in the forward part, a solution that draws upon the potential (but rarely seen) innovation allowed by an all-electric power and propulsion system.

2.3. The Arctic navies

The Arctic's melting ice caps holds the key not only to significant oil and minerals, but also to quicker transportation of goods and equipment from the Far East to Europe and the Eastern Americas. It therefore holds a

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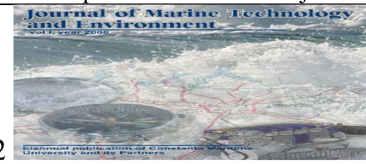

growing interest for many countries either for exploitation of the seabed or for Sea Lanes of Communications (SLOC) and, in an area where sovereignty, under UNCLOS, has not yet been settled, it seems inevitable that naval vessels will be seen more often in these regions.

The arctic nations include Russia, USA, Canada, Norway, Denmark and Iceland and for most of these nations the building of armed arctic-capable naval vessels is well underway.

Norway has a very capable 18 knots Polar-10 classed KV Svalbard, an all-electric 5 MW azipod propelled vessel, the hybrid-electric KV Harstad and the KV Bergen, Sortland and Barentshav all of which are powered by Wartsila dual-fuel engines.

Iceland has received two ships for patrolling the Arctic waters ICGV Thor and ICGV Oinn. Both vessels are hybrid electric with Bergen main propulsion engines and are Classed Ice-1C.

Denmark has the Knud Rasmussen class patrol ships capable of breaking first year ice up to 80 cm.

With the Canadian National Shipbuilding Procurement Strategy now in place and a thirty-month definition phase underway, construction of the first Arctic Offshore Patrol Ship A-OPS is expected to start at Irving Shipbuilding in Halifax in 2015 with deliveries beginning from 2018 onwards. Canada has designed the A-OPS to be a flexible platform for patrol and sovereignty enforcement in the country's three oceans: the Atlantic, the Arctic and the Pacific. A-ops is 98m, 5874 tonne displacement and classed to PC5 (year round operation in medium first-year ice that may include old ice inclusions). All-electric power and propulsion provides a range of at least 6800 n-miles at 14 knots and a maximum speed of 17 knots. A-OPS has twin shaftlines and 3,8 m diameter bolted fixed pitch propellers, four diesel generators and two GE 4,5 MWe induction motors, capable of 150 per cent overtorque during icebreaking.

2.4. Offshore patrol vessels OPV's

The first Irish OPV, LE Samuel Beckett (P61) was commissioned into service in May 2014. The OPVs have a diesel electric propulsion integrating two W26 5440Kw Wartsila diesel engines and two five-bladed controllable pitch propellers. The vessel uses a hybrid-electric P&P system with the power take in (PTI) motor powered by the ship's alternators allowing low speed operation at speeds up to 8 knots. A 450kW bow thruster and high-manoeuvrability rudders are included as well as a dynamic positioning (DP) system to a maximum speed of 23 knots, a range of 6000 n-miles at 15 knots and is capable of conducting autonomous mission for up to 21 days.

The Mozambique vessels are 43m and crewed by just 13 people. The vessel has twin-CPP CODAD using four Scania diesels to provide a total of 1600Kw of for30 knots. Remarkably, the vessel on patrol can achieve 236 n-miles from just one tone of fuel.

3. LNG OR FUEL CELL CONSUMPTION

3.1. Gas boosts medium speed development

With so much of the research and development budget of engine manufacturers having necessarily beend directed towards efficiency gains and emissions abatement, medium speed engines appear to have benefited significantly aver recent years. A fascination with LNG has seen several dual-fuel variants of well-proven engines being developed and commercialised.

Medium speed engines have never been the engine of choice for large vessels, where low-speed two-strokes reign supreme. But they come into their own for small cargo vessels, in which they are used in direct configuration through a gearbox, and for diesel-electric power systems.

For medium speed dual-fuel engines the major obstacle to greater take up – beyond the most obvious one of there being no bunkering infrastructure - was developing the containment and delivery systems for the LNG fuel. This is still being addressed, with IMO now moving forward in adopting the draft International Code of Safety for Ships using Gases or other Low flashpoint Fuels (IGF Code).

The basic philosophy of the IGF Code is to provide mandatory provisions for the arrangements, installation, control and monitoring of machinery, equipment and system using low flashpoint fuels such as LNG and possibly ethyl or methyl alcohol at some future point and also to minimise the risk to the ship, in crew and the environment, having regard to the nature of the fuels involved. It addresses all area based on a goal-based approach, with goals and functional requirements specified for each section forming the basis for the design, construction and operation of ships using this type of fuel.

MaK's M 43C engines have become very popular choice for cruise ships and the company's dual –fuel M 46 DF has been a logical development. It shares the same footprint features and the same system interfaces as the M 43C and boasts a power rating of 900kW per cylinder at 500 and 514 rpm in diesel and gas modes. As suggested by its label, the engine has a bore of 460mm and shares the same long stroke of 610mm as the conventional M 43C type.

Although designed for unlimited operation on LNG, marine diesel oil and heavy fuel oil, it can alternate from gas to diesel mode during operation and MaK's parent company Caterpillar claims that in gas mode it features industry-leading fuel consumption and complies with both IMO Tier III and EPA Tier 4 regulations. The engine has been designed to allow retrofitting of current M 43 C.

One aspect of the engine's performance highlights the improvement in dual-fuel engines in the ten years since the first was fitted. Wartsila claims that, for LNG carrier applications, the 46 DF offers fuel savings of around 20 tonnes/day compared with the original DF engines. As an example of the virtues of the 46 DF, Wartsila cites the cruise ferry Viking Grace which is powered by four eight-cylinder Wartsila 50 DF engines. That ship could achieve the same power output and speed if fitted with four seven-cylinder 46 DF engines, it reported. As well as a fuel saving of around US 10000 per year, there would also be savings in maintenance and spare part costs through the lifecycle.

Two versions of a new part-load kit for Carterpillar Marine's MaK M 32 E were introduced at the SMM exhibition in 2014. Developed specifically for offshore vessels where engines are frequently required to operate in off-load and part-load mode because of DP and similar operations, the M 32 E part-load kits are available for both constant speed and variable speed operations. Both kits combine lowest possible fuel consumption in part load range with highest possible power output at full load.

Figure 2 Part load kit for the MaK M 32 E platform

The part-load kit enables all vessels operating M 32 E engines primarily in the part –load range to improve fuel efficiency and load acceptance performance while reducing smoke. Key components in the variable speed part-load kit include a modified turbocharger, a cylinder bypass valve and waste gate.

Also in September 2014, MAN Diesel & Turbo announced it had been awarded a Tier III- compatibility certificate buy DNV GL for a MAN 8L21/31 four stroke engine on DFDS Seaways Petunia Seaways with a retrofitted selective catalytic reduction (SCR) system. While the engine alone meets IMO Tier II emission criteria, the SCR system for NOx reduction raises the whole system to the standard demanded by IMO Tier III rules.

MAN Diesel & Turbo's main efforts in dual fuel have been directed at the two-stroke sector but it does have two medium speed engines as well – the 51/60 DF and the 35/44 DF, the latter being based on the 32/44 CR oil engines, existing models of which can be converted to the dual-fuel configuration. Several of the 51/60 DF type have been ordered for LNG carriers operated by Sovcomflot and more recently Teekay LNG Partners.

The SCR system has consistently allowed the engine to meet the required NOX reduction level. MAN Diesel &Turbo claims it is the first company to succeed in making four-stroke marine engines IMO Tier III compliant, based on a fully modular SCR-kit that covers the entire MAN Diesel & Turbo four-stroke engine portfolio.

Another big constructor, Rolls-Royce, is widely recognized for its ship design and system solutions for a broad range of vessels. Systems comprising propellers and thruster, engines, stabilizers, deck machinery rudders, steering gear, automation and control systems. Rolls-Royce supply gas-powered propulsion solutions that reduce emissions significantly. Compared to diesel engines that meet IMO Tier 2 emission levels, Bergen gas engines give E2 weighted emission reduction of 92%NOx, close to 22% in CO2 and virtually eliminate Sox and particulates, already meeting enforced and future IMO Tier 3 requirements.

3.2. Fuel cell consumption

It is accepted that future ship power will come from green fuels, reducing the reliance on diesel, if ship owners are to meet regulations. However, choosing the fuel of the future is taxing owners.

Both LNG and fuel cell technologies have now been put through tests and installed onboard vessels, with the uptake of both propulsion types looking to be made by ship owners for future vessels. Norway is backing the development of LNG as the future fuel, with DNV announcing its support for the use of the fuel. It stated that LNG was the way forward for short sea shipping due to the cut in emissions and the ease of use of the technology. DNV was the first classification society to class an LNG powered vessel in 2001 and since then has classified a further 20 vessels.

In Germany the first fuel cell-powered inland river vessel was developed and launched back in 2008, under the Zemshipps banner, the European Union founded-project's aim was to produce zero emissions.

The main issue with fuel cells is the handling and management of fuel cell technology. There are incidents or previous historical incidents with hydrogen deter some of the people from using this as a form of propulsion. At the moment the market already has the combustion engine as a proven technology that works. Now it needs to show that the fuel cell is a viable option for owners, which is a difficult task. The problem is that people think that hydrogen is dangerous. The risk factor

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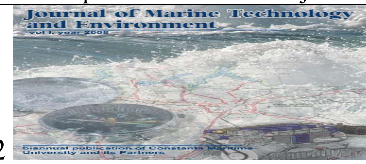

is subjective. If it is done the right way and handled correctly then there is no problem.

The hydrogen is stored in fuel cells and kept at a low pressure because of this it gives the gas less density and so less combustible. Adding to this the use of the correct battery type, correct ventilation and handling of fuel makes the fuel cell a safe option. Adapting this form of technology into larger vessels types will be different due to cruising cycle, loading and offloading.

Fuel cell technology is a viable option for smaller vessel at the moment due to the load pattern of inland vessels such as ferries. The added advantage to the fuel cell is that it can use any type of fuel and also has higher efficiency than that of LNG, which has 43% efficiency compare to fuel cell that has in the region of 60-70% fuel savings.

LNG is the buzz word as the next step in propulsion for ships, with Norway in full support of this form of fuel for ships. It has been shown that engines that run on LNG instead of marine diesel fuel emit 99.9% less sulphur (Sox), 90% less nitrogen (Nox) and 97% less particulates and 25% less carbon dioxide (CO_2).

4. ELECTRIC SHIPS OPT FOR HYBRID

The world's first boat powered with an ultra low emission microturbine was launched in Netherlands in June 2014. The prototype craft is owned by Electric Ship Facilities in The Netherlands, developer of a hybrid-electric propulsion system for ships that can operate on multiple forms of power generation. The ship features the innovative onboard energy system a Capstone C30 diesel fuelled microturbine.

The Capstone C30 microturbine comes in 30, 60 and 200 kW with a single or multiple ESF that can be integrated to a hybrid energy system, adding to this is the microturbine's ability to switch between main components. The microturbine can operate on different fuels, as demonstrated by the prototype vessel can operate on (bio) diesel, with gas such as CNG or LNG also possible.

The emissions from the micro turbine are very minimal for that of the very high combustion temperatures that it operates. In addition, virtually no wear was reported on the tests and no additional lubricants were included. Maintenance of the micro turbine is a fraction of a conventional combustion engine. Both environmentally and commercially sound, this is a strong, effective step forward.

Micro turbines are ideal for power generation in marine applications because of their ultra low emissions and maintenance, small footprint, ease of installation, quiet operation and lack of lubricants and coolant.

Current diesel-electric technology is unfeasible for small and mid-sized vessels that start and stop often at various ports, or that work harder when travelling against river currents. In a battery supported hybrid system, Capstone microturbines efficiently address both emission and efficiency issues that arise in smaller craft not suited for diesel-electric technology.

Reducing emissions pollution from marine vessels is a key issue for the International Maritime Organization, which in 1997 adopted an international convention protocol to reduce air pollution from ships and this is why Capstone microturbines are an excellent solution in marine application; low emissions, low noise, high efficiency and extended maintenance benefits.

Figure 3 World's first boat powered with an ultra low emission Capstone C30 microturbine launched in the Netherlands

5. AN ALTERNATIVE TO LOW SULPHUR FUEL

5.1. The project phase

At a presentation of the achievements of eight partners from the UK, Italy and Poland in a project termed Innovative After Treatment System for Marine Diesel Engine Emission Control (known as DEECON), Francesco Di Natale contrasted their approach with conventional scrubber technology, which has been derived from chemical engineering. Instead, one of the concepts underpinning this project was that scrubbers could be optimized for marine applications by using electrostatic forces.

Mike Jackson, the project manager set out the project's objective: to use higher technology to remove the primary pollutants from ship diesel engines. Putting numbers to that broad aim, he said that the goal was to reduce NOx and Sox by 98 per cent while reducing particulate matter (PM), especially damaging to health and which are not adequately dealt with by current scrubber technology. It will also deal with volatile organic compounds (VOCs), which are not currently covered by legislation.

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The mission is to create a system that uses less of the ship's power than existing systems and will deal with NOx without needing any chemical additives, such as urea or ammonia, as required in current selective catalytic reduction systems.

To achieve all this, the partners have developed two innovative pieces of equipment that they have tested in an installation near Southampton in the UK. These are an electrostatic sea water scrubber (ESWS), to deal with Sox and PM, and a non-thermal plasma reactor (NTPR) to address NOx and VOCs. The initial results are promising. NOx and Sox have been reduced by 95%, while PM has been cut by 50% overall, but by 80% for the sub-micron nano particles. But there is more that could be done. The NTPR is not sufficiently stable, so was not in operation during the demonstration, and the ESWS must be reduced in size for practical installations.

There are also promising areas for further work that are outside the scope of the project's initial brief. For example, the NTPR operates at lower temperatures than selective catalytic reduction (SCR) systems. This gives the potential to recover more waste heat from exhaust than is currently achieved by waste heat recovery system, which typically take exhaust down to 180^0C to avoid corrosion.

The ESWS also provides an opportunity to deal with black carbon, which is considered to be second most important greenhouse gas after CO_2.

Summarising their achievements, the project team's members said in a briefing note that it had broadly achieved its objectives and made significant gains in knowledge and expertise.

5.2. Prototype scrubber system

A prototype scrubber system that has been in operation since 2013, in 2014 received class society approval.

Germany's Saacke Marine Systems uses a dry soot separation technique in its hybrid systems. It installed a unit on Carl Buttner's 14,999 dwt chemical and product tanker Levana during 2013. The unit had operated under certain restriction until October 2014 when it was granted certification by class society DNV GL.

Saacke Marine Systems claims that its system has a sulphur filtration rate of up to 99%. It consists of a sulphur scrubber and an upstream soot separator, known as the VentSep. This arrangement is said to result in significantly less sludge formation from soot residue in the washing water than other systems. The VentSep also reduces pollution in the exhaust gas boilers.

A spokesman for DNV GL explained that the 'special permits' under which some scrubbers operate are issued by class societies on behalf of flag states during the test phase of an installation.

During this test phase, the engines must be operated with low sulphur fuel in designated areas. So, official classification of the scrubber allows use of HFO.

5.3. Swapping silencers for scrubbers

Two 8MW diesel engines on a bulk carrier in North America were due to have their silencers replaced with scrubbers in January 2015. The ship burns 2% sulphur fuel and still operates within the North America emission control area (ECA).

CR Ocean Engineering (CROE) is supplying a pair of its closed loop units for the installation, which are of a size that makes it possible to fit them inside the funnel by replacing the existing silencers. They used the structure that previously supported the silencers, so no major modifications to the funnel are needed. They each were delivered in four sections that were lifted into place for final assembly.

The system is lighter, smaller, more efficient and more cost-effective than most competing scrubbing systems. The system requires low back-pressure, no bypass and can run dry.

Being a closed loop system, it needs a supply of fresh water, for which two tanks are being built in the ship's void spaces to avoid losing deck space. A wash water treatment system is also included as part of the scrubbing system.

Figure 4 OPTIMA SEAWAYS with its newly installed scrubber, which is located behind the existing funnel casing

6. CONCLUSIONS

To achieve effective improvements in efficiency and reductions in emissions for ships, an integrated systems engineering approach is required. This must embrace all of the elements of naval architecture, marine and control engineering alongside operation practices. Moreover, a systems approach must include all of the stakeholder requirements to achieve a sustainable and optimal design solution. With any propulsion option it is essential that the overall emission profile of the propulsion method and the fuel used is properly assessed, so that reductions in exhaust emissions from ships are not at the cost of increasing harmful emissions in land-based sectors that produce either the propulsion machinery or the fuel.

Liquid natural gas (LNG) can be used in reciprocating engine propulsion systems and is a known technology with classification society rules for the fuel systems already in existence. Service experience with dual fuel and converted diesel engines, although limited at the present time, has been satisfactory and currently LNG is considerably cheaper than conventional fuels. LNG, while not free of harmful emissions, has benefits in terms of CO_2, NOX, SOX emissions, given that methane slip is avoided during the combustion and fuelling processes.

Fuel cells offer potential for ship propulsion with good experience gained in auxiliary and low-power propulsion machinery. For marine propulsion, the high-temperature solid oxide and molten carbonate fuel cells show most promise, while for lower powers the low temperature proton exchange membrane fuel cells are more suitable. While hydrogen is the easiest fuel to use in fuel cells, this would require a worldwide infrastructure to be developed for supply to ships.

The industry must switch to low sulphur, cleaner fuels. After this, it needs to look a mix of technologies on-board: SCR catalyst and filters – not scrubbers. It’s a controversial point, but although scrubbers are an answer to some of the upcoming legislation, it will simply prolong the use of heavy fuel oil.

7. REFERENCES

[1] The Royal Institution of Naval Architects – *Shiprepair & conversion technology*, 3rd Quarter 2009;
[2] The Royal Institution of Naval Architects – *The Naval Architect*, November 2010;
[3] MARIN’s news magazine for the maritime industry, *Report,* December 2014;
[4] The journal of ships’ engineering systems, *Marine propulsion & auxiliary machinery*, December/January 2014/2015;
[5] The Royal Institution of Naval Architects – *Warship technology*, January 2015;
[6] LNG Industry, March 2015.

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STOCHASTIC APPROACH TO OPTIMIZE THE SETTING OF RADIOLOCATION STATIONS AT REPAIR

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Abstract: The structure of stochastic approximation methods is appropriate for realization in linear and non-linear stationary processes. Their application in optimization of pulses from radiolocation stations (RLS) is determined by the actual conditions of uncertainty (presence of noise and incomplete information about output data). Stochastic models of optimization are usually more adequate to real conditions with their choice of solution than determinate formulations of the extreme tasks.
It applies to the optimization of impulse parameters that have static mode of operation of the electronic stage i.e., the circuit function is an algebraic equation.
There is a simple and reliable algorithm enough to link the circuit function to the setting area of the existing element. Taking into account the nature of the respective real phenomena it is found that the most convenient method is the stochastic approximation.
Practically, the degree of influence of the individual elements on the parameter of the set pulse, as well as the order of variation of the radio elements (**R* and C***) is determined, which facilitates the practical realization of the algorithms at repair.

Key words: Adaptive algoritms, stochastic approximation; optimal impulse; optimization algorithm; stochastic inputs**.**

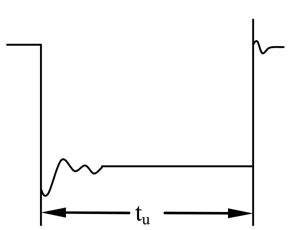
1. FORMULATION OF THE PROBLEM

This is the dependence (the desired circuit function) of the pulse given in Fig.1.

It is: $t_u = \alpha \cdot R^* \cdot C^*$ where: (1)

coefficient $\alpha = \text{constant}$

The aim is to look for the tuning area of the electronic components after entering the input data and the type of the circuit function.



Range (Nm)	t_u(μs)
0.25÷0.75	14±1
1.5	28±3
3	65±5
6	135±15
12	235±15
24	370±20

Figure 1 Impulse for tuning

The general appearance of the iterative stochastic procedure, which is applied specifically, is represented by the ratio [4], [6]:

$X_{n+1} = X_n - a_n \cdot F(X_n) \cdot \text{sign}F'(X)$, where: (2)

a_n – correction factor, $F(X_n)$ – rated function.

The sequence (a_n) is chosen freely within a sufficiently wide range and characterizes the length of the step. Here $a_n = (\frac{1}{n})$,

$X_n \to \overline{X}$ at $n \to \infty$ with probability one. $(\text{Lim}\, X_n = \overline{X})$ (3)

The procedure of stochastic approximation guarantees a greater probability of movement in the desired direction than in an undesirable. For a large number of iterations, an approximation to the desired optimal point is provided (for a single solution to the task). The recurrent sequence is selected so that the probability of the parameters is approximated to the required optimal values. The task is to minimize the mathematical expectation by a certain iterative method

$$\mathrm{Lim}\left[X_i - \overline{\overline{X}}\right] = 0 \quad \text{at} \quad i = \infty \tag{4}$$

Analytical approach to getting set up:

1. The convergence of the method is ensured by satisfying weak and general conditions pertaining to the type of $\mathbf{a_n}$.
2. The optimization procedure does not assume convergence in the middle quadratic sense and therefore the convergence is achieved over a large interval of time.
3. It is a method of consecutive gradient convergence.

A gradient-proportional setting is performed, and the gradient convergence methods used in this algorithm can be considered as a development of Newton's classic method for calculating the roots of the equation and are applicable in real-world conditions [6].

4. This method is distinguished by its low convergence in static mode (minimizing the maximum deviation from the reference value).
5. In static mode, one-dimensional demand significantly determines the performance of the entire minimization procedure. Therefore, an arbitrary complication of the tactic is justified if it ultimately leads to a decrease in the number of points considered.

The criterion is the condition for a minimum deviation from the optimum of the pulse:

$$J = J(\alpha_1, ..., \alpha_n) \to \min \tag{5}$$

Where: $J = \max|\delta_i|$ $\alpha_1, ..., \alpha_n$ – parameters .

When evaluating the quality of the points of the space according to this criterion, the best point will be the point with the smallest deviation δ_i and the target function corresponding to the criterion whose extreme values indicate the points that best satisfy the equation:

$$\Phi(X_1, ..., X_n) = \max\left|\Phi_i(X_1, ..., X_n) - A_i\right| \to \min$$

$$i=1,...,n \tag{6}$$

The solution is to request such a set of numerical values of the variables in which the function evaluated reaches an extreme value.

2. ANALYSIS

Static mode of operation is considered.

1. When only one parameter needs to be set up, a one-dimentional demand is applied.
2. If it is necessary to set up two or more paramters, an interrupted scheme is used.

The relationship between the circuit function and the setup method is to be based on the decomposition of the Taylor formula for a function of two variables: (7)

$$F(R_1, C_1) = F(R_0 + \Delta R, C_0 + \Delta C) = F(R_0, C_0) + \frac{\partial F}{\partial R}\Delta R + \frac{\partial F}{\partial C}\Delta C + ...$$

An algorithm is proposed, to which are the following comments.

1. It is set $C^0 1$ which belongs to the set of values from Table 2.

$\varepsilon = 10^{-4}$ – accuracy; ρ_1 – factor

An initial condition is set:

$R1 = R^0 1; C^0 1;$ α_1 – factor; $T3 = t_{standard1}$;

2. A moment is determined:

$t_{measured} = F(C^0 1)$ according to Table 2 .

A step is determined:

$$\Delta C1 = \rho_1\left[t_{standard1} - t_{measured}(C1')\right]. \tag{8}$$

3. It is obtained:

$$C^1 1 = C^0 1 + \rho_1\left[t_{standard1} - t_{measured}(C1')\right]; \tag{9}$$

$$\rho_1 = a_{n1} = \frac{1}{R1 \cdot \alpha_1 \cdot J}; \; J \text{ - counter} . \tag{10}$$

4. A cycle is formed until:

$\left|t_{standard1} - t_{measured}(C1')\right| < \varepsilon \,|$

The second part of the procedure (**if applicable**) is analogous to points 1 to 4.

5. An initial condition is set:

$C^0 1$; $R^0 1$ which belongs to the set of values from Tab. 1;

$T5 = t_{standard2}$; ρ_2 – factor

6. It is determined:

$t_{measured} = F(R^0 1)$ according to Table 1 .

7. It is determined:

$$R^1 1 = R^0 1 + \rho_2\left[t_{standard2} - t_{measured}(R1')\right]; \tag{11}$$

$$\rho_2 = a_{n2} = \frac{1}{C1 \cdot \alpha_2 \cdot G}; \; G \text{ - counter} . \tag{12}$$

8. A cycle is formed.

3. PRELIMINARY EXPERIMENTS (INPUT DATA)

The studies are given in tabular form.
The nomogram is taken at:

$R_{const} = 3800\ \Omega$, $C_{const} = 2$ nF

The steps ΔC and ΔR follow the row of elements R and C.

Table 1. Nomogram T_u =F(R)

R (Ω)	0	120	270	680	910	1000	1200	1400	1750	2000	2150
Tu(μs)	12,3	12,4	12,6	13,0	13,2	13,4	13,8	14,0	14,4	14,8	15,0
	1	2	3	4	5	6	7	8	9	10	11
	2400	2500	2650	2800	3000	3200	3350	3500	3700	3800	**C=2nF**
	15,4	15,8	16,0	16,3	16,6	17,0	17,3	17,6	18,0	18,2	
	12	13	14	15	16	17	18	19	20	21	

Table 2 Nomogram T_u =F(C)

C (nF)	1,6	1,8	2,0	2,4	2,7	3,2	3,3	3,4	3,6	3,8	4,0	4,2	4,4	4,6	4,8	5,0	5,2
Tu (μs)	10,2	11,0	12,4	14,2	16,6	20,0	21,0	21,5	22,5	24,0	25,5	26,5	27,5	28,0	28,5	30,5	32,0
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	5,4	5,6	5,8	6,0	6,3	6,5	6,8	7,0	7,2	7,4	7,6	7,8	8,0	8,3	8,5	8,7	9,0
	33,0	34,0	35,0	36,0	38,0	41,5	43,0	44,0	45,0	45,5	46,5	47,5	48,5	50,0	53,0	54,0	55,0
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
	9,2	9,4	9,5	10,0	11,2	11,6	12,0	12,6	13,0	13,6	14,0	14,4	15,0	15,6	16,0	16,6	17,0
	56,0	58,0	59,5	62,0	68,0	70,0	72,0	76,0	83,0	86,0	88,0	90,0	95,0	95,5	97,0	100	105
	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
	17,4	18,0	18,5	19,0	19,5	20,0	20,5	21,0	21,5	22,0	22,5	23,0	23,5	24,0	24,5	25,0	25,5
	108	110	115	119	122	126	128	130	133	136	139	143	146	150	152	154	157
	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
	26,0	26,5	27,0	27,5	28,0	28,5	29,0	29,5	30,0	30,5	31,0	31,5	32,0	32,5	33,0	33,5	34,0
	159	161	164	167	172	175	179	182	184	185	186	187	187	188	188	192	196
	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
	34,5	35,0	35,5	36,0	36,5	37,0	37,5	38,0	38,5	39,0	39,5	40,0	40,5	41,0	41,5	42,0	42,5
	200	204	207	210	214	217	220	223	226	228	230	234	237	240	243	246	248
	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102
	43,0																**R=3800Ω**
	252																
	103																

4. ALGORITHM

A. Adjustment is made on C according to Tab. 2.

(**R** - Constant with a specified value).

1. Initial condition:

C1, R1, T3 = $T_{standard}$, A1 = α - factor, ε – accuracy, J & I-counters.

2. It is determined:

$$t_{measured} = F(C^{0}1) = T1(I) = F(R^{0}1, C^{0}1). \qquad (13)$$

$$\Delta C^1 1 = \rho\left[t_{standard} - t_{measured}(C^0 1)\right]; \quad (14)$$

$$\rho = \frac{1}{R1 \cdot A1 \cdot J}; \ \rho \text{ - factor}. \quad (15)$$

3. It is determined:

$$C^1 1 = C^0 1 + \frac{T3 - T1}{R1 \cdot A1 \cdot J}, \quad \text{where:} \quad (16)$$

$$T1 = T(I) + \frac{T2 - T1(I)}{C2 - C(I)}\left[C1 - C(I)\right] =$$

$$= T1(I) + \frac{T1(I+1) - T1(I)}{C(I+1) - C(I)}\left[C1 - C(I)\right] \quad (17)$$

4. Discretization: The largest interval t_u contains 100 measured points. This also covers the error of the selection elements according to the different pulses for distances from 0.25 to 24 Nm. Accuracy are 10^{-4}, which is highly accurate at repair.

A cycle is formed until:

$$\left|t_{standard1} - t_{measured}(C1')\right| < \varepsilon \,| \quad (18)$$

B. Combined adjustment is made on R* and **C***, which applies only to small distances.

The algorithm is the same. It has been developed in two versions.

First version – "incomplete step"

1. It is determined $t_{measured} = f\left(R^0, C^0\right)$;
2. It is determined "incomplete step" $\alpha_1 \cdot R^0 \cdot \Delta C$;
3. It is determined "incomplete step" $\alpha_2 \cdot C^0 \cdot \Delta R$;
4. A cycle: point 2, point 3, point 2, point 3 …etc.

Disadvantage: It is more difficult to manage the process of global optimization at repair.

Second version – "complete step"

1. It is determined $t_{measured} = f\left(R^0, C^0\right)$;
2. A cycle is formed at $t_{standard1}$ and determined

$$C^1 = C^0 + \Delta C; \quad (19)$$

3. A cycle is formed at $t_{standard2}$ and determined

$$R^1 = R^0 + \Delta R. \quad (20)$$

Disadvantage: Additional adjustment may be required.

When the circuit function has only one variable electron element, the setting is performed by algorithm **A**.

When the circuit function has two or more variable electronic elements, the setting is performed by a complex algorithm in which the **A** and **B** algorithms alternate according to the situation.

5. CONCLUSIONS

1. The developed algorithm has been tested with real operational data.
2. An attempt is made to introduce standardization (unification) of applied algorithms - only with change of input data to be feasible in another radiolocation system.
3. These algorithms make it possible to exclude the "active" participation of a person.
4. The developed algorithms - "instrumentation" - can be used to repair RLS.

6. REFERENCES

[1] R. Sharma, "*Stochastic Analysis of the ∑ Δ Modulator and Differential Pulse Code Modulator*", CIRCUITS AND SYSTEM, 1997.
[2] A. Benveniste, "*Algorithm for Adaptive Parameter Estimation*", CIRCUITS AND SYSTEM, 1995.
[3] A. Benveniste, "*Adaptive Algorithms and Stochastic Approximation*", CIRCUITS AND SYSTEM, 1997.
[4] Д. Б. Юдин, "Задачи и методы стохастического программирования", МОСКВА, 1979.
[5] К. Спиди, "Теория управления", МОСКВА, 1973.
[6] Н. Н. Калиткин, "Численные методы", МОСКВА, 1978.

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AN ANALYSIS OF UNDERUTILISATION OF INLAND WATERWAY TRANSPORT IN NIGERIA

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Abstract: This research analyzes the effects of underutilization of inland waterway transport on Nigerian economy. It also scrutinized critically, the challenges negating the utilization of the inland waterway transport and its relative impacts on the Nigerian economy. Primary data were obtained from staff of Nigeria Inland Waterways Authority (NIWA) and Nigeria Port Authority (NPA). Data received, from 60 respondents identified constraining variables were subjected to Principal Component Analysis using the Principal component and orthogonal varimax rotation. The student t-test was used to test the statistical significance of the hypotheses, and they were all found to be not statistically significant, thus the null hypothesis were rejected. From our findings, the 15-item variables optimally weighted and summed based on the Kaiser criterion of eigenvalue cut-off of 1.0, there were 6 components that explained a cumulative variance of 91.917%, leaving 8.083% to other variables not included in the analysis. In conclusion, a well-developed and integrated inland waterway transport is a vital tonic for the economic development of Nigeria. With a better managed inland waterways, Nigeria can develop a regional trade within the West African sub-region as the River Niger cut across Nigeria, Benin, Mali, and Guinea and emptied into the Atlantic Ocean. She can also boost her tourism potentials, through waterway recreational activities. This will definitely contribute to the Nigerian GDP and has the capacity to support the economy in the wake of dwindling oil prices.

Key words: Inland waterways, transport, river, port, underutilisation.

1. INTRODUCTION

Nigeria has the second longest length of water-ways in Africa. It has 8,600km of inland waterways and an extensive wetland of about 852km. Nigeria's waterways center on its longest rivers, River Niger and Benue, which dissect the country into East, West and North sections. The two rivers run into each other at Lokoja and flow into the Atlantic Ocean. The costal waterways extend from Badgerys through Warri to Calabar. Most of the activities on the countries waterways especially by larger powered boats and for commerce in the Niger Delta and all along the coast from Lagos lagoon to Cross River.

However, water transport scores a distant second to road transport with an average share of about 1.6% of Nigeria's gross domestic product. Water transport is slow and while unsuitable for passenger movement, an efficient coastal and inland waterway system can relive pressure on a country's rail and road transport infrastructure, inland water transport is advantageous in terms of costs of moving heavy traffic, especially where speed is less important than cost. A single 15-barge tow is equivalent to about 225 rail road cars or 870 tractor-trailer trucks. This would be advantageous in the transportation of tonnes of agricultural products from the middle belt areas to the delta areas through the waterways and vice versa, and hopefully bring about a fall in commodity prices in the region.

The Nigeria inland waterway despite its great potentials are underutilized and underdeveloped. The federal government hopes to reverse this and has

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recently signed N34.8bn contract for the dredging of the Lower Niger. The project covers about 572km of waterways that stretches from Warri in Delta to Baro in Niger State. To maximize the potentials of the Inland waterways, the federal government also plans to restructure the Inland Waterways Authority so it can focus on regulatory duties and concession its other activities. Under the current plans, the inland waterways will be responsible for the following.

- Provide regulation for inland navigation
- To ensure the development in infrastructural facilities for a national inland waterways network, connecting the creeks and the rivers with economic countries, using the river-ports as nodal points for inter modal exchange
- Undertake capital and maintenance of dredging
- Undertake hydrological and hydrographic surveys.
- Design ferry routes.
- Issuance and control of licenses for inland navigation, piers, jetties and dockyard
- Granting of designs to private water crafts.
- Approval of designs and construction of Inland River crafts.
- Survey, remove and receive derelicts, wrecks and other obstruction from inland waterways and among others.

The restructured Nigeria Inland Waterways Authority will look unto the private sector to assist it in revitalizing the inland waterways.

1.1 Objectives of Study

The research aims at investigating the impact of underutilization of inland waterways transport in Nigeria. In order to achieve the above aim, the following objectives are hereby stated;

1. To investigate the impact of underutilization of Nigeria inland waterways on Nigeria's economy.

2. To determine the effects of government policies on the inland waterways transport sector.

2. REVIEW OF RELATED LITERATURE

National Inland Waterways Authority [13] explained that, the word "waterways" means navigable water course, which includes navigable canal, drain or rivers, "inland waters", refers to lakes, streams, rivers, canal waterways, inlets etc. Inland watering can therefore be described as water inland which is navigable by vessel, which could be river, canal, and lake or titan inlet. Anyaoku [6] stated that transport is the movement or conveyance of people, goods, idea and information from one place to another. This is because not all areas are equally enforced, hence the need for interaction through transport. It involves the use of vessels like barges, speed boats, lighter or ships authorized to navigate in restricted areas, canals are built to link two navigable areas, examples are the Suez Canal which links the Atlantic ocean with the Pacific Ocean. Throughout the countries, rivers has provided an obvious means of transportation to meet the demand for import and export and resulting from trade expansion. Inland water transport in Nigeria has had a long history of neglect by both Government and the private sector, little efforts were made to develope inland water transport facilities prior to the 1980s. This stems largely from policy inconsistency and limited private sector involvement [4].

The movement of freight by waterway is one of the oldest means of transporting cargoes from one point to another [10] this is largely due to the fact that inland water transport offers, the most economical, energy efficient and environmental friendly means of transporting all types of cargo from place to place [17]. It also offers safer and cheaper rates in areas where water exist actually. This facilitates commerce, promotes wealth creation, environmental sustainability, poverty alleviation and creates job opportunities for youth within such regions. The ancillary sector of boat building industry generates several employment opportunities through active engagement of the youths in welding and fabrication process [12].Recently, [15] asserts that there has been a considerable decline in the use of inland water transport in Nigeria. This was attributed to several physical constraints impeding growth and performance in the inland water transport sector in Nigeria. This creates an urgent need for innovations and strategies which are radically to improve the sector so that it continues to remain the bedrock of trade, industrial and economic growth.

Abams [1] claims that the Niger River, after which the country was named, are the main rivers whose channels provide the longest waterways into the hinterland of the country. Both rivers Niger and Benue, rise outside the country but meet at Lakoja confluence and later enter the Gulf of Guinea through a large network of creeks and distributaries which form the Niger Delta. They also noted that rapids and falls are common along many Nigerian rivers and that these are partly responsible for non- navigability along certain part of these rivers. In another study [1] found that the capacity of the Nigerian navigable waterways has increased to about 852.km based on this, he noted that the country has a huge potential to move freight and passengers from the coast to the hinterland by water. Also [16] regretted that the immense opportunities which the Nigerian inland waterways provide for business is yet to be harnessed by potential investors. He reported

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that despite her enormous potentials, inland water transport is yet to become an alternative means of transportation to road and an such that passengers and cargo can sustainably and efficiently by moved to their destination through waterways. Similarly, [2] lamented that inland water transport is yet to receive the deserved attention from the Federal Government particularly, in the twin areas of funding channel dredging and other infrastructural development. He outlined the constraints to improved performance in the sector to include non-channelisation and dredging of navigable rivers inadequate construction and rehabilitation of river ports, limited water transport infrastructures, safety and security concern along the navigable waters.

Ezenwanji [8] focused on the poor use of inland rivers and transport routes in Nigeria. He compared the percentage share of transport modal choice in Nigeria to others elsewhere. He noted that in Bangladesh, water transport constitutes 32% of the transport sector [19] 20% in Philippines [10], 3% in Sierra Leone [13], 0.15% in India [20] and only 0.0% in Nigeria despite the country's rich endowment of Inland Waterways. He established, like earlier researchers [4] that several economic factors negatively affected the utilization of inland waterways as a means transport routes in Nigeria.

Akali and Idoko [5], quoting [7],[18] states that inland water transportation plays a key role in the socio-economic and political development in Nigeria as a factor of exchange, mixing of population and sub-regional integration. They posits that this mode of transport enhances the movement of bulky goods over long and short distances and that it is better acknowledged when the source and destinations are water front location. These authors summarized by observing that inspite of the enormous advantages associated with inland water transport, there has been a remarkable downturn in its use in Nigeria. In a recent study, [15]established that the unique benefits which inland water transport offer to investors include facility management, jetty operations and boat building, he concurred with an earlier observation that security concerns discourage potential investors from benefitting from the able business opportunities, which the Nigeria inland water transport provides. There have also been several report of consultancies by development agencies and firms, aspects of which have dealt with diverse inland water transport developing and maintenance, private sector involvement in the water transport sector, construction and rehabilitations of security boats, building of channels buoys and other projects.

Globally, the use of inland waterways for the purpose of transporting freight has come a long way; it has contributed immensely to trade across the globe. One pertinent thing about inland waterways transportation is its development hinged on trade expansion (import and export) activated waterways hence cannot be over emphasized especially in a developing nation like Nigeria. The role of Nigeria inland waterways cannot be over emphasized considering its main objectives of.

I. Improving and developing inland waterways for navigation
II.Promoting an alternative mode of transportation for the evacuation of economic goods and persons
III.Executing the objectives of the national transport policy as they concern inland waterways.

In the light of the foregoing, the Inland waterways Department (IWD) station were grouped into three;

Table 1: (IWD) Stations

Group 1	Group 2	Group 3
Lagos Area	Onitsha	Lokoja
Igbokorda	Port Harcourt	IDAH
Warri	Calabar	Shintaku
Agenebode	Oron	Yauri

Source: NIWA [14]

Apart from its relative cheapness and safety among other modes, water transportation can be relied upon for pleasurable and relaxing journey when good quality services are provided.The inland waterways system has for a longtime service the needs of Nigerian economy by providing main communication routes. Prior to Trans – Atlantic trade, the inland waterways provided the main channels of trade between the coastal communities and the Trans – Sahara trade countries of the North [3].

Furthermore, inland water transportation in Nigeria has the potential of contributing immensely towards developing existing economic and industrial centres and creating new ones in the riverine communities. The multifaceted nature of its present contribution touches virtually all other sectors of the economy and ensures its status as a basic service sector. It however, cannot be overemphasized that in order to derive maximum benefits from inland waterways transport as a veritable tool for National developments, it has to be properly organized and harnessed. It is on pursuit of this objective that the federal government embarked on National River ports, most especially in the riverine areas has been completed. The plan for the sitting of river ports has therefore been focused mainly along the shores of the Niger/Benue river system and creek routes choice of particular sites for the location of river ports apart from being informed by topography, geotechnical, hydrographic and infrastructural sectors were also influenced by economic, political and historical considerations. The coming of the European traders to

Nigeria shores brought to the fore the dominant role of the inland waterways system, the early expatriate companies of United African Company (UAC), John Holt etc made extensive use of the inland waterways systems from the Delta creeks to the Niger and Benue systems for the movement of Agricultural products meant for the foreign markets and manufactured goods meant for the local markets.

Figure1 Map of Nigeria Showing Inland Waterways [13]

The River stations such as Onitsha, Idah, Lokoja, Ibi, Numan, Yola, and Baro which were used as transshipment stations flourished, annual transport in the inland waterways in the country at the time reached 300,000 tonnes in the best year. However, the inland water transportation would at times be the only available mode of transportation especially where the topography of an area does not support other modes. This is a case of riverine communities and the Islanders.

2.1 Nigerian Inlands Waterways Fund

The fund will be similar to the US's inland waterways trust fund, which funds half the costs of new construction and major rehabilitation of the inland waterways infrastructure. The fund will be registered as a company limited by guarantee and operate independently of the Nigeria. Inland Waterways Authority. The fund will be administered and managed by a board of trustees representing various interests in the private and public sector and will be completely isolated from the management of the Nigerian Inland Waterways Authority. The fund will be required to release quarterly reports on how much of its funds are being spent and how is being spent on any of the operations he it financing. The fund will be financed by :

- Grants from governments, organized private sector and international donors.
- Concessions of jetties and dockyards owned by the Nigerian inland Waterways Authority.
- Sale of vessels and other non-operatory assets of the inland waterways authority.
- A fuel tax paid directly to the fund by commercial operators along designated inland waterways
- Returns on investments made in the capital and money markets.

The fund will be used to finance:

- Developing and maintaining the inland waterways infrastructure
- Property development in riverside towns and construction of roads and rail links to existing and new river ports and inland depots
- A vessel tracking system for the inland waterways
- Provision of communication and navigational aids along the various routes of the inland waterways.

3. RESEARCH METHODOLOGY

The data obtained were edited to eliminate errors, the data were then coded and grouped according to the study to ease analysis. It was then analyzed using Principal Component Analysis (PCA) algorithm with the aid of the Statistical Package for Social Sciences (SPSS V. 20).

Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. The number of principal components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it is orthogonal to the preceding components. The resulting vectors are an uncorrelated orthogonal basis set. The principal components are orthogonal because they are the eigenvectors of the covariance matrix, which is symmetric. PCA is sensitive to the relative scaling of the original variables.Research hypotheses were tested using the statistical student t- test of the regression model and t results were obtained.

4. PRESENTATION OF RESULTS AND DISCUSSIONS FROM THE PCA OUTPUT

Data were subjected to Principal Component Analysis using the Principal component and orthogonal varimax rotation, using the Statistical Package for Social Scientist (SPSS V.20).The descriptive statistics gave us the averages of the 60 respondents sampled. The non-development of waterway infrastructural facilities to

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connect with other economic centers variable has the highest mean score of 2.75. This implies that, it is the most important variable.From the correlation matrix, the variables have a 100% correlation with each other. Non-development of effective transport policy by the government to drive inland waterway transport sector has a strong positive correlation of 63.4% with the Dearth of human capital to implement government regulatory functions in the waterway transport variable. This implies that the variables have direct proportionate relationship with each other.

The Bartlett's test conducted proved to be statistically significant (Sig-value=0.000< 0.001). The Kaiser-Meyer-Olkin (KMO) measure was approximately 0.40, indicating the data were sufficient for principal component analysis (PCA). The Bartlett's test of sphericity X^2 (105) = 1206.821, P < 0.001 showed that there were patterned relationships between the variables.From the 15-item variables optimally weighted and summed based on the Kaiser criterion of eigenvalue cut-off of 1.0, there were 6 components that explained a cumulative variance of 91.917%. The Scree plot confirmed the findings of retaining 6 components.From the components matrix, the components with eigenvalues greater or equal to 1.0 is said to be significant. Therefore components 7, 8, 9, 10, 11, 12, 13, 14 and 15 were insignificant, while components 1, 2, 3, 4, 5 and 6 were significant. The scree plot is a visual representation of how much the eigenvalue explained the components identified, the last point of inflexion. The last point of inflexion at component 7, signifies that only 6 components should be retained.Correlations that are above r = +/- 0.90 indicate that our data may have a problem of multicollinearity, however large number of low correlation coefficient (r < +/- 0.05) were removed as they indicate lack of patterned relationships.

Total variance explained in table 2, PCA has assisted as to identify six underlying components explaining 91.917% of the common variance.

Component 1**:** Component I which explains 34.626% of the total variance and has Eigen value of (5.1944) is the major component. Among the variables that correlated positively with component one include, Non-development of indigenous human capital to meet the challenges of modern inland waterway transport systems, Inadequate skilled and qualified human capital to man waterway transport facilities, Dearth of human capital to implement government regulatory functions in the waterway transport sector . These variables relate to human capital development problems that characterize the underutilization of inland waterway transport in Nigeria. This implies that the major factor undermining the utilization of inland waterway transport in Nigeria is lack of human capital to take charge of inland waterway transport in Nigeria. Thus, this component can be identified as Human capital factor. One of the four pillars of Cabotage Act in Nigeria is that; Vessels involved in coastal shipping in Nigeria must be manned by Nigerian crews. From our findings, lack of skilled manpower to man waterway transport infrastructural facilities in Nigeria is statistically significant. Implying, that for Nigeria to succeed in the utilization of waterway transport, Nigeria must develop and train an adequate human capital to man these infrastructures which will result to improving her economic growth.

Component 2**:** Component 2 which explains 15.818% of the total variance and has Eigen value of (2.373) is the next major component. Among the variables that correlated positively with component two include, High operation costs of water transport infrastructures discourages potential investors, High interest rate by commercial banks discourages private sector investment in inland waterway transport. This variables validate the fact that, none participation of the private sector in inland waterway transport has negated the utilization of the inland waterways. This implies that if the private sector has access to credit facility with low interest rate, they can afford to invest in the inland waterway sector at minimal financial risk. Thus this component can be named, economic factors.

Component 3**:** Component 3 which explains 13.548% of the total variance and has Eigen value of (2.032). Among the variables that correlated positively with component three include, Poor safety and security concern along navigable waterways, Lack of safety regulations for inland waterway navigation systems. These variables validate one of the core reasons for the underutilization of the inland waterways. The gulf of Guinea as well as Nigerian coastal waters has been adduced as high risk areas, due to pirate activities and armed robbery within these areas. Thus, this component can be named; Risk and Safety factors.

Component 4**:** Component 4 which explains 11.897% of the total variance and has Eigen value of (1.785). Among the variables that correlated positively with component four include; Lack of political will by the government to make the river ports viable, The provision of road highway infrastructure negates patronage of waterway transport. These variables are complex to be named a common factor. The Lack of political will by the government to make the river ports viable variable has a high correlation or factor loading of 0.915 on component four, thus this component can be named; poor political will by the government.

Component **5:** Component 5 which explains 8.965% of the total variance and has Eigen value of (1.345). Among the variables that correlated positively with component five include; Low investment in inland waterway transport by private sector due to over-concentration on other transport modes. This variable validates the non-competitive nature of the inland waterway transport, as the investment apathy by the private sector in inland waterway transport negates the optimal utilization of inland waterway transport in

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Nigeria. Also the over concentration on other modes of transport such as road and air ways negates the utilization of waterway transport in Nigeria. Thus, this component relates to Investment apathy by the private sector.

4.1 Test for Hypothesis One

Ho1: There is no statistically significant effect of human capital development on the underutilization of Nigerian inland waterway transport.

From the regression output, the coefficient of Human capital development (X_1) is 0.000 and the standard error is 0.135, therefore;

$T_1 = 0.000 /0.135= 0.00$

This value corresponds with the Human capital development (X_1) 't-stat' value of the regression output; the sig – value of Human capital development variable is 0.000. Since the sig- value (1.000) is greater than 0.05, then we accept the null hypothesis, i.e., There is no statistically significant effect of human capital development on the underutilization of Nigerian inland waterway transport.

Table 2: Total Variance Explained by the PCA

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.194	34.626	34.626	5.194	34.626	34.626	3.289	21.925	21.925
2	2.373	15.818	50.444	2.373	15.818	50.444	2.639	17.593	39.518
3	2.032	13.548	63.992	2.032	13.548	63.992	2.360	15.731	55.249
4	1.785	11.897	75.889	1.785	11.897	75.889	2.283	15.220	70.469
5	1.345	8.965	84.854	1.345	8.965	84.854	1.616	10.772	81.241
6	1.059	7.063	91.917	1.059	7.063	91.917	1.601	10.676	91.917
7	.359	2.392	94.309						
8	.282	1.881	96.190						
9	.203	1.352	97.542						
10	.135	.897	98.439						
11	.108	.721	99.160						
12	.088	.590	99.749						
13	.027	.177	99.927						
14	.011	.071	99.998						
15	.000	.002	100.000						

Extraction Method: Principal Component Analysis.

4.2 Tests for Hypothesis Two

Ho2: There are no statistically significant effects of government policy variables on the underutilization of the Nigerian inland waterway transport.

From the regression output, the coefficient of government policy variable (X_2) is 0.000 and the standard error is 0.135, therefore;

$T_2 = 0.000 /0.135= 0.00$

This value corresponds with the government policy (X_2) 't-stat' value of the regression output; the sig – value of government policy variable is 0.000. Since the sig- value (1.000) is greater than 0.05, then we accept the null hypothesis, i.e., There are no statistically significant effects of government policy variables on the underutilization of the Nigerian inland waterway transport.

4.3 Tests for Hypothesis Three

Ho3: There are no statistically significant effects of private sector non-investment in Nigerian inland waterway transport sector.

From the regression output, the coefficient of private sector non-investment (X_3) is 0.000 and the standard error is 0.135, therefore;

$T_3 = 0.000 /0.135= 0.00$

This value corresponds with the private sector non-investment (X_3) 't-stat' value of the regression output; the sig – value of private sector non-investment variable is 0.000. Since the sig- value (1.000) is greater than 0.05, then we reject the null hypothesis, i.e., There are no statistically significant effects of private sector non-investment in Nigerian inland waterway transport sector.

4.5 Tests for Hypothesis Four

Ho4: The Cabotage Act has no statistically significant effect on the Nigerian inland waterway transport sector.

From the regression output, the coefficient of Cabotage Act implementation variable (X_4) is 0.000 and the standard error is 0.135, therefore;

$T_4 = 0.000 /0.135= 0.00$

This value corresponds with the Cabotage Act implementation variable (X_4) 't-stat' value of the regression output; the sig – value of private sector non-investment variable is 1.000. Since the sig- value is greater than 0.05, then we accept the null hypothesis, i.e., The Cabotage Act has no statistically significant effect on the Nigerian inland waterway transport sector.

5. CONCLUSIONS

In conclusion, the port is the gateway to the nation's economy, aside from the international trade and revenues generated; it leads to the economic growth as well as economic development of the nation. From safety perspective, the inland waterways if optimized will reduce the rate of road accidents on our highways. In the wake of high costs of transporting petroleum products, due to the economies of scale of shipping, large volume of these products can be freighted through the inland waterways at a cheaper rate. This will save the nation quite a lot of costs ranging from; accidents to regular maintenance of the roads and will open up the tourism potentials of the riverine areas, enhance the sustainability of our environments and contribute to the GDP of the nation. From the literatures reviewed, the Nigerian inland waterways has been grossly underutilized;

leading to neglect of the waterways as a mode of transportation and over dependence on other transport modes. A well developed and integrated inland waterway transport is a vital tonic for the economic development of Nigeria. With a well-developed inland waterways, Nigeria can develop a regional trade within the West African sub-region as the River Niger cut across Nigeria, Benin, Mali, Guinea and emptied into the Atlantic Ocean.

From our findings, human capital development, inadequate government transport policy, investment apathy by private sector and poor implementation of the cabotage Act are the major components discovered with the aid of principal component analysis (PCA) as the factors facilitating the underutilization of the Nigerian inland waterway transport. About ₦1,392,879,889.99 was internally generated by NIWA in 2013 from Baga, Calabar, Eket, Lagos, Lokoja, Igbokoda, Makurdi, Onitsha, PortHarcourt, Warri, Yauri, Yenagoa, Yola and Kaduna inland waterways. This implies that in the wake of dwindling oil prices, Nigeria can input more resources into developing the transport sector as this sector can be a major contributor to the gross domestic product (economic growth) of the nation

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6. REFERENCES

[1]. Abams, T.K.S (1999) "Dynamic and Quality of Water Resources in Niger Delta" In Bryan Ellis (ed). Impacts of Urban Growth on Surface Water and Groundwater Quality.

[2]. Abams, T.K.S (2004) Geohydrology with Application to Environmental Management. Charisma Graphic Pub, Port-Harcourt, pp.126-127.

[3]. Abimbola, S. (2000).The Niger River dredging controversy, *Nature Watch.*

[4]. Aderemo, A.J.& Mogaji, S.A (2010): "Rural Transportation of public Facilities in Nigeria: a case study of Edu Local Government Area of Kwara State" J Human Ecology, Vol. 29 no. 3, pp 171-179.

[5]. Akali, K.E, & Idoko, O. (2010): River Transport and Economic Empowerment; An Assessment of Lokoja Crossing Port on the Niger Being a Paper Delivered at the 53rd annual Conference of Association of Nigerian Geographers (ANG) at Lagos State University, Lagos Between Nov. 21st -Nov. 25th 2011

[6]. Anyaoku, B. O., (2001) Overview of Inland Waterways Transportation in West and Central Africa: The Nigerian Experience. Paper presented at the International Conference on Navigation Activities within the River Basin in the West and Central Africa sub-region Abuja.

[7]. Anyaoku,B., (1997).Inland Water Development in Nigeria: Ineffective Capital Development of the Nigeria Shipping Industry.Edited by Mu via Ja'afaru and Olu Akinsoji,Published by Maritime Academy of Nigeria, Oron.

[8]. Douglas, I.E. (2001) "Impact of Navigation on Socio-economic Development of West and Central Africa sub-region and as a veritable tool for the promotion of tourism and sports". A paper presented at a 3-day International Conference on Navigation activities within the Niger River Basin West and Central Africa Sub-region, held at Abuja on the 26th-28th June, 2001.

[9]. Ezenwaji, E.E. (2010) Constraints on Effective Water Transportation in some Riverine Communities of Old .Anambra L.G.A., Anambra State". A Paper delivered at the 2010 Rural Development Seminar with the theme Rural Transportation in Nigeria. Imo State University, Owerri, 31st March to 1st April, 2010

[10]. Fellinda, L. (2006) "World's Water Transport needs further Development". Transport and Development, pp 68-72

[11]. Gray, L. (2004) "An examination of the problems of water transportations in old Degema Province, Nigeria". J Waterways, *Africa*, No. 33, pp 20-26.

[12]. Kimba, G. (2008) "Development of inland waterways in Freetown Sierra Leone". Journal of African Integration, Vol. 3, pp 91 - 100.

[13]. NIWA, (2005) Harnessing the inland Waterways Advantages for
Natural Development NIWA publishing Lokoja.

[14]. NIWA, (2012) National Inland Waterways Authority. News bulletin. http://www.niwa.gov.ng/

[15]. Obed, B.C.N (2013) "A Critical Assessment of the Inland Waterways Operations and Management of the Development of Nigerian Maritime Industry" Greener J environmental management and public safety Vol. 2, No 2 Pp 99-17

[16]. Obeta, M.C (2014) The Characteristics of Inland Water Transport in Nigeria J Humanities And Social Science (IOSR-JHSS) Volume 19, Issue 3, Ver. IV (Mar. 2014), PP 119-126

[17]. Ojile, M. O. (2006) Draft Report of the Socio-Economic Characteristics for the Idealization of the Port Harcourt Warri Roads Submitted to Messer allots Nigeria. Limited on behalf of the Federal Ministry of Works, Abuja. P60

[18]. Onuche, H. A. (2007); Assessment of Inland water transport at the Lokoja Crossing Port. An M.Sc. thesis submitted to the Department of Geography, Benue State University, Makurdi.

[19]. Rahman, M. (1994) "National Transport System in Bangladesh". Asian Transport Journal, vol. 21, pp 18-23. [30].

[20]. Raphuram, G. (2004) "Integrating Coastal Shipping with National Transport Network in India". Proceedings of the International Association of Maritime Economics Annual Conference. Vol. 11, No. 1, pp 39-48.

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REPAIRING PISTON STEEL HEAD IN INTERNAL COMBUSTION SHIP ENGINE MITSUBISHI 60 LS BY MEANS OF FLUX-CORED ARC BUILT UP WELDING

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Abstract: The proposed article describes the process of reparing piston steel head in internal combustion ship engine MITSUBISHI 60 LS by means of flux-cored arc built up welding.
The technological sequence, of the recovery process, is completely described, the used consumables are listed, as well as the technological modes of welding. The main steps of the process are illustrated.

Key words: repairing of piston steel head in internal combustion ship engine, build up welding, flux-cored arc built up welding, welding power source, Welding wire - chemical composition, welding of the piston head.

1. INTRODUCTION

In practice built up welding is used mainly for repairing worn out machinery parts, fixing defects, and industrial production of new bimetal parts.

The main characteristic of welding materials is hardness; however, due to the complex chemical composition and structure of the welded metal created by the various alloying elements, it does not unequivocally reflect the resistance to different types of wear. Therefore, when choosing materials used for welding, consideration should be given to the following [2]:

- initial materials and hardness of the worn parts
- operating conditions, friction pairs, types of friction and wear;
- the dimensions of the parts, the degree of wear and the required thickness of the welded layer;
- The need for preliminary and final mechanical as well as thermal treatment.

In built up welding we use materials that have the properties required primarily on the basis of operating conditions, friction and wear.

For built up welding, all basic ways of melt welding can be used. In essence, the flux-core arc welding is a welding process in which the arc burns between a non-coated electrode (welding wire) and the welded article under a protective layer of flux. This method is used for the restoration of flat and cylindrical surfaces whose diameters are above (50 ÷ 60) mm. [1, 2]

Automatic built up welding is a high-performance method. The efficiency of the process is determined by the amount of molten metal per unit of time, which depends directly on the power of the current. The combination of high current density with the presence of flux protection causes static pressure on the liquid metal, prevents spraying and allows to increase the process performance 6 ÷ 12 times compared to manual built up welding [2, 5].

The type of flux is essential for the physical and mechanical properties and the quality of the welded metal. The main tasks of the flux are to protect the seams in metal from the impact of atmospheric air as well as to ensure: proper formation of seams; the required mechanical properties of the seam metal and the corresponding chemical composition; sufficient arc resistance; easy separation of the crystallized slag crust.

Achieving a high degree of alloying through a dense electrode wire is a relatively expensive process. For these reasons, it is advisable to use batch electrodes with welding surfaces that require a high degree of alloying. This allows the unlimited alloying of the welded metal and makes it possible to obtain coatings with different physical and mechanical properties. As a disadvantage of the batch electrodes it can be stated that the larger the diameter of the electrode, the more unevenly the batch melts, which affects the physical and mechanical properties of the welded metal [5]. Improving the uniformity of melting of the core from the batch material is achieved by reducing the thickness of the batch layer or by increasing its conductivity. For welding parts with a diameter greater than 200 mm, it is advisable to use strip electrodes [2]. The advantages of strip electrodes over electrode wires are expressed in: smaller depth of penetration; possibility of obtaining seams of different width; possibility of adjusting the layer thickness for transition within a sufficiently wide range; obtaining welded metal with a smooth surface; high performance; distributed heat input which creates favorable conditions for the flow of structural transformations and reduces the thermal influence on the parent metal; simplification of the traction process and more.

The main advantages of welding under the layer of flux are as follows: the arc burns in a gas bubble surrounded by liquid slag and flux, which prevents contact with the air and ensures excellent protection; high quality metal seam is obtained not only due to good protection but also due to maintaining constant values of the mode parameters and the delayed cooling of the metal [4]; reduced heat losses increase the efficiency ratio to 0.9, while in open arc welding it is 0.6 - 0.8 [3]; In the flux-core arc welding higher current densities or higher yields can be used; the covered arc not only provides good protection for the metal but also reduces spillage losses during the welding process; an opportunity to achieve high smoothness of the welded metal; an opportunity of obtaining a welded metal with high degree of alloying; good working conditions associated with the absence of light radiation.

2. PRESENTATION

2.1. Repairing piston steel head in internal combustion ship engine MITSUBISHI UEC 60 LS by means of flux-cored arc welding.

The processed parts are the steel piston heads made of low carbon chrome-molybdenum steel brand 15XM, 25XM, 40XM, with highly worn grooves on the piston rings.

The repair has been performed by means of by flux-core arc welding technology according to the requirements in the following sequence:

1) *Preliminary mechanical treatment* –The removal of the burnt surface layer in the region of the piston ring grooves is performed on a lathe. The individual cracks and dents are smoothened with a manual abrasive tool.
2) *Welding of the piston head* is carried out by the method of flux-core arc welding (pic.1).
3) *Used equipment* – welding machine (welding column) ESAB-A6; welding power source – ESAB 1250A (pic.2.)
4) *Welding materials:*
   - ✓ Welding wire - OK 13.12 *Φ*2.0 mm., EN12070, chemical composition- C=0.10%; Mn=1.0%, Si=0.7%, Cr=1.1%, Mo=0.5%, made by ESAB – Sweden;
   - ✓ Welding flux – 230, EN760 – made by Lincoln Electric – USA; electrodes for repairs OK 48.00 Φ3.2mm –ESAB, chemical composition - C=0.06%; Si=0.5%; Mn=1.15%.
5) *Welding mode:*
   - ✓ Polarity - reverse;
   - ✓ Strength of the current – (350÷400) A;
   - ✓ Voltage – (30÷32) V;
   - ✓ Wire deviation – (25÷30) mm.;
   - ✓ Welding speed – (350 ÷ 450) mm/min;
   - ✓ Temperature of preliminary heating - 150°C;
   - ✓ Temperature during welding process – (150÷200)°C.
6) *Heat treatment to remove residual pressure* – 1.5 hours, at 570°C in a shaft furnace.
7) *Final mechanical processing* – lathing (Fig.4) and polishing of the completed part.
8) *Chemical and thermal treatment* (Fig.5) – Gas carbo nitrification (saturation with carbon and nitrogen). A diffusion layer is obtained, (0.3÷0.4) mm deep, surface hardness – (750÷850) HV10.

After the completion of the technological operations, the quality of the repaired surfaces is checked.

Figure1. Welding of the piston head under a layer of flux

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Figure 3 Completed welded part

Figure 4 Lathing of a welded part

Figure 5 View after chemo-thermal treatment

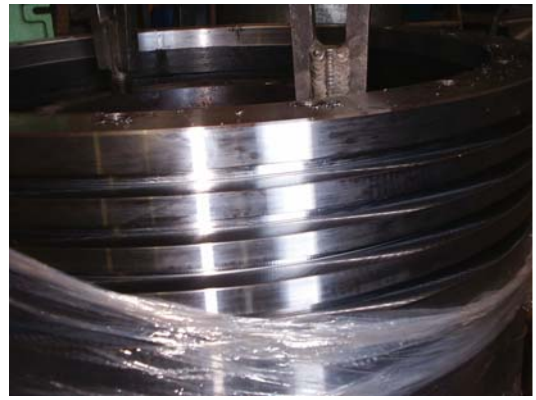

Figure 6 Grooves after final treatment

3. CONCLUSIONS

1. Repair of the crankshaft parts by built up welding has been widely used in ship repair practice.

2. An outline of steel cylinder head restoration technology for the MITSUBISHI UEC 60 LS engine has been proposed;

3. Repair has been completed by means of flux-core arc built up welding in the following modes: reverse polarity, I=350÷400A, U=30÷32V, welding speed = 350÷450mm/min, temperature of preliminary heating =150 °C, temperature during welding process =150÷200 °C;

4. The proposed technology, with slight changes, can be applied to repairing piston heads of other types of engines.

3. REFERENCES

[1] ESAB, *“Manual for repair and recovery by welding”*, 2001.
[2] PETEX, *“Reference book for welders and technologists”*, 1999.
[3] Benadsky V.N. et al., “*Welding industry in modern Germany. Automatic welding*”, № 11, 2000.
[4] Wladislav Sudnik, *“Arc welding”*, Intech publisher, 2011.
[5] Klas Weman. *“Welding processes handbook”,* Woodhead Publishing Ltd, 2003.

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REPAIRING WORN-OUT RUDDER BEARING HUB AND PROPELLER BY MEANS OF BUILT UP WELDING

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Abstract: The proposed article describes the process of repairing worn-out rudder bearing hub by means of built up welding by the electrode subfusion welding method, as well as, the repair of propeller blades by semi-automatic MIG welding. The technological sequence of the recovery process is described, the used consumables are listed, as well as the technological modes of welding. The main steps of the process are illustrated.

Key words: Repairing propeller, build up welding, flux-cored arc built up welding, welding power source, Welding wire - chemical composition, semi-automatic MIG built up welding.

1. INTRODUCTION

The experience of repair works shows that many machinery parts, restored with the aid of modern methods, are not inferior to brand new parts in their durability and reliability, and in some cases even exceed them. The quality of repairs satisfies technical requirements for the strength characteristics of recovered parts.

The use of significant quantities of repaired parts in major repairs of aggregates turns out to be very economical: the cost of spare parts is reduced and more rational use of metals as raw materials is achieved.

The choice of repair method for specific parts depends on their technological characteristics, wear, working conditions, physical and chemical properties of the coatings, determining the durability of the repaired parts and the cost of their repair.

Materials used in built up welding process should have properties required primarily on the basis of operating conditions and types of friction and wear.

For built up welding, all basic ways of melt welding can be used:

- Manual arc welding;
- Flux-cored arc welding;
- Plasma welding;
- Arc welding in protective gas medium
- Short-circuited arc welding.

Built up welding is characterized by high productivity, mobility and lack of constraints regarding the welded surfaces, as well as relative freedom with respect to the spatial orientation of the work piece [4].

It facilitates application of coatings to worn-out surfaces while making a wide range of changes in their thickness and geometry [4].

Electric arc methods and in particular welding in a protective gas medium or under a layer of flux and their varieties are implemented most frequently [3].

2. PRESENTATION

2.1. Repairing worn-out bearing hub of rudder by means of flux-cored arc built up welding.

The repair has been performed meeting the technical requirements, by means of flux-cored arc welding in the following sequence [1]:

1) *Preliminary mechanical treatment* – lathing of the worn-out hub till clean metal surface is obtained. Performing capillary defectoscopy.

2) *Welding upon worn-out surface* – method: flux-cored automatic built up welding. Figure.1 and 2 show the way of fastening the part and the welding process.

3) *Equipment* – welding machine, bearing spars and welding power source ESAB LAE 800.

4) *Welding materials*:
   - ✓ Welding wire - ESAB OK16.12-Φ1.2mm - chemical composition - 0.01%C, 20%Cr, 10%Ni; welding flux

Zelezarna Jesenice FB CR –NI for stainless steel. Both materials are of class 3YM GL.

- ✓ Welding flux – 230, EN760 – made by Lincoln Electric – USA; electrodes OK 48.00 *Φ*3.2mm –ESAB, chemical composition - C=0.06%; Si=0.5%; Mn=1.15%.

5) *Welding mode:*
   - ✓ Polarity - reverse;
   - ✓ Strength of the current – 250 A;
   - ✓ Voltage – (28÷30) V;
   - ✓ Wire deviation – (20÷25) mm.;
   - ✓ Welding speed – (0.5 ÷ 0.7) m/min;
   - ✓ Preliminary heating temperature – 60÷70)°C;
   - ✓ Temperature during welding process – 200°C.
   - ✓ Final mechanical treatment:
   - ✓ Processing up to nominal sizes according to the factory drawing;
   - ✓ Capillary defectoscopy of the restored surface;
   - ✓ Ultrasound control;
   - ✓ Control of the dimensions of the restored surfaces.

Figure 1 Flux-cored built up welding of the worn-out bearing hub

Figure 2 Method of fastening the part

Figure 3 The power source

Figure 4 Additional wire used in the process

2.1 Repairing propeller defects by means of semi-automatic MIG built up welding.

Repair of defects of the propeller is done by the method of semi-automatic MIG built up welding, in compliance with technological requirements to the process, in the flowing sequence [1]:

1) *Measuring the dimensions of the blades, before and after repairs;*

2) *Straightening bent sections by heating with propane blowlamps;*

3) *Building up by welding the missing sections according to the following welding procedure:*
   - ✓ Main material: NiAlBronze;
   - ✓ Welding process: Argon arc welding (MIG), position – bottom, gas flow rate – (16÷20) dm3/min;
   - ✓ Additional materials: AMPCO 46 - NiAlBronze, SFA 5.7, AWS: ER CuNiAl.
   - ✓ Heating temperature: (100÷200) °C, with the aid of propane burners. Temperature gradient in the time of heating (100÷200) °C, Figure 5;

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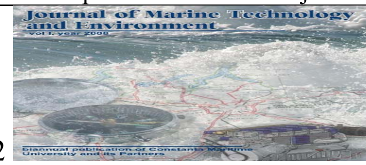

(All thermic operations during the repair are performed with propane blowlamps and heating panels [4])

- ✓ Welding seams are applied as the diagrams above show (pic.7. and pic.8.);
- ✓ Mechanical treatment: Polishing of the welded sections is done with an abrasive tool till the actual dimensions and shape of the blades are achieved;
- ✓ Static balancing of the propeller;
- ✓ Nondestructive testing is performed by color defectoscopy of the straightened and welded sections, as well as of the roots and edges of all the blades (Figure 11).

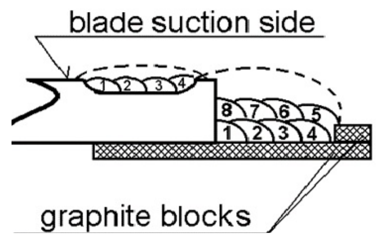

Figure 7 Diagram showing the usage of graphite blocks

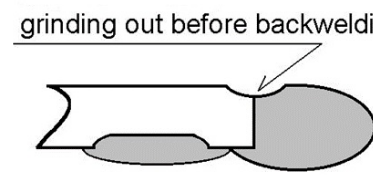

Figure 8 Diagram showing intermediate processing

Figure 5 Heating the blade

Figure 9 Processing with an abrasive tool

Figure 6 Building up missing sections

Figure 10 The part after the repair

Figure 10 Defectoscopy

3. CONCLUSIONS

1. Recovery of worn-out parts of crank-shaft mechanism by welding is widely used in repair practice.
2. Automatic arc welding under a layer of flux and MIG welding facilitate recovery of worn-out surfaces with a wide range of changes in their thickness and geometry.
3. The above mentioned welding methods allow to repair parts with a high degree of wear and a variety of defects, such as loss of structuring integrity, cracks, various types of wear, deformations, etc.

4. REFERENCES

[1] ESAB. *"Manual for repair and recovery by welding"*, 2001.
[2] PETEX. *"Reference book for welders and technologists"*, 1999.
[3] Benadsky V.N. et al. "*Welding industry in modern Germany. Automatic welding*", № 11, 2000.
[4] Wladislav Sudnik. *"Arc welding"*, Intech publisher, 2011.

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ENERGY EFFICIENCY IMPROVEMENT OF SHIPS BY APPLICATION OF ALTERNATIVE FUELS

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Abstract: The purpose of this paper is to show opportunities for improvement of ship energy efficiency and reduction of Greenhouse Gas Emissions through the implementation of an alternative fuels and energy sources. Biofuel and LNG as a fuel in shipping have great potential for the future. The use of alternative fuels in maritime transport is not only a good solution for environmental protection but also provides low fuel consumption and reduction of operational costs. Biofuels contain no sulphur and reduce carbon emissions. LNG is high-energy fuel with lower carbon content. These energy sources are suitable alternative and an environmentally friendly solution for replacing fossil fuels in the transport sector. Please use **first-name** for correspondence.

Key words: alternative fuels, biofuels, energy efficiency, improvement, Liquefied Natural Gas

1. INTRODUCTION

Environmental protection and sustainable use of natural resources are key priorities of the world transport policy over the last decade. Implementation of various technical and economic measures will ensure energy efficiency improvement and environmental protection. The International Convention for the Prevention of Pollution from Ships (MARPOL) provides mandatory technical measures that require more efficient use of energy while emitting less greenhouse gas emissions. These provisions entered into force in 2013. There are targets to reduce carbon dioxide emissions by 20% by 2020 and 50% by 2050. Therefore, shipping companies should consider using cleaner fuels and innovative technologies, to meet these goals. In addition, the rising fuel prices provide another good reason to search for alternative solutions for energy efficiency improvement.

2. APPLICATION OF ALTERNATIVE FUELS FOR SHIPS

2.1 Liquefied natural gas (LNG)

Rising fuel costs and the issue of reduce Greenhouse gas emissions are the main reasons for using LNG as an alternative fuel for all types of ships. Natural gas engines compared to diesel engines produce less than 92% of nitrogen oxides (NOx) and 98% of particulate matter. Sulphur oxides (SOx) emissions are negligible (decreases by 95-100%). These engines work with zero smoke; low unburned fuel slip and reduced maintenance costs. [10]

The lower carbon content of LNG compared to standard marine fuels provides a 20-25% reduction in CO_2 emissions. LNG has higher energy content than diesel and heavy fuel oil, and can provide up to 20% fuel savings.

Table 1 presents the energy content of various types of fuels. [4]

Ships can be powered by LNG fuel only or with combination of diesel and LNG. Dual fuel engines use natural gas as the primary source of energy and a small amount of diesel fuel usually called the pilot is injected to start combustion. These engines can work with 80% to 99% of natural gas fuel. They provide a high level of propulsion reliability and safety.

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Table 1 The energy content of fuels

	Energy source	kJ	kgoe	kWh
1	1 kg hard coal	17200 — 30700	0,411 — 0,733	4,778 — 8,528
2	1 kg brown coal	5600 — 10500	0,134 — 0,251	1,556 — 2,917
5	1 kg residual fuel oil (heavy oil)	40000	0,955	11,111
6	1 kg light fuel oil	42300	1,010	11,750
7	1 kg motor spirit (petrol)	44000	1,051	12,222
8	1 kg liquefied petroleum gas	46000	1,099	12,778
9	1 kg natural gas	47200	1,126	13,10
10	1 kg liquefied natural gas	45190	1,079	12,553
11	1 kg wood (25 % humidity)	13800	0,330	3,833
12	1 kg pellets/wood bricks	16800	0,401	4,667
13	1 kg waste	7400 — 10700	0,177 — 0,256	2,056 — 2,972
14	1 MJ derived heat	1000	0,024	0,278
15	1 kWh electrical energy	3600	0,086	1

Source: Eurostat

The main advantage of LNG is the lower price compared to other marine fuels (Figure 1 - Prices of marine fuels for the period 2006-2012 [12]), which is expected to stay at this level and decline gradually. The specific LNG fuel consumption is lower than standard marine fuels. In Fig.2 it is listed for different fuels and different engine load. [12]

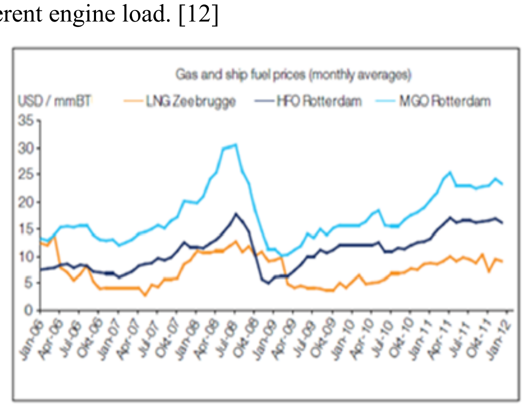

Figure 1

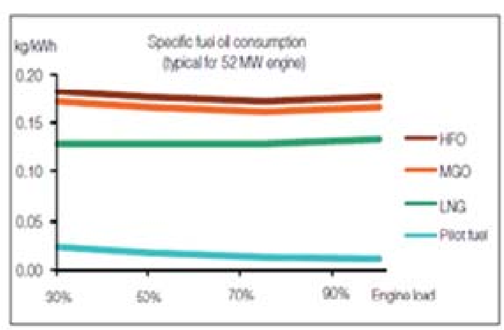

Figure 2

LNG as a fuel in shipping is suitable for short range ships (ferries, tugs and coastal boats) sailing in areas with low emission requirements and the ability for bunkering.

A major disadvantage of this alternative fuel is the need for significant initial investments (for tanks, gas preparation systems, gas lines, main engines and generators).

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The payback period for investments depends on the prices of LNG. It is shorter for smaller vessels due to lower investment costs for LNG systems.

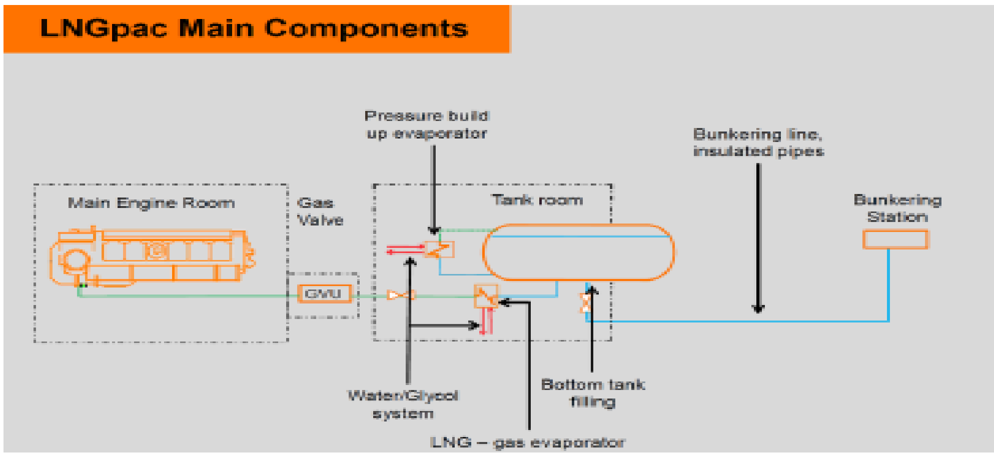

Figure 3 LNG fuel system (Wartsila) [8]

For assessment of the performance of engine fuelled with LNG we study a 2200 TEU container carrier.

The surveyed vessel is equipped with a low-speed main diesel engine, type: HYUNDAI-MAN B & W 8S70MC, MCR 30560 BHP (22477,53 kW), 91 RPM. Low-speed engines are the most efficient engines. They use chemical energy of the fuel and convert about 40-50% into mechanical energy for ship propulsion. Part of the energy is lost as waste heat from the exhaust gases or losses in the cooling system.

The daily fuel consumption (FOC) of the main engine (ME) of the surveyed vessel is calculated:

$$FOC_{ME} = \frac{P_{installed} \times LF \times SFC \times h}{\text{g/t}}, [\text{t}] \qquad (1)$$

$P_{installed}$ = 22477,53 kW - is the nominal power of the ME;
SFC_{ME} = 169 g / kWh - specific fuel consumption of main engine;
LF - load factor of ME when sailing (assumed to be 80% of payload);
h = 24 - transit hours per day;
g / t = 1000000 - grams per metric ton;

$$FOC_{ME} = \frac{22477,53 \times 0,8 \times 169 \times 24}{1000000} = 72,94\,[\text{t/day}]$$

The useful energy flow (mechanical energy) obtained from the main engine per day $E_{ME/day}$ has a value:

$$E_{ME/day} = P_{installed} \times LF \times h = 22477 \times 0,8 \times 24 = 431558,4\,kWh \qquad (2)$$

The useful energy received by the ME for one year (292 days - sailing mode) is:

$$E_{ME/year} = E_{ME/day} \times 292 = 126015\ MWh \qquad (3)$$

In order to calculate the thermal efficiency of the main diesel engine, it is necessary to determine the amount of heat flow (combustion power) emitted during combustion of the fuel in the engine:

$$Q_f = m_f \times C.V. \qquad (4)$$

m_f - fuel burned per second [kg / s];

The term Calorific Value (C.V.) is the thermal energy emitted by burning 1kg of fuel [MJ / kg]. The thermal energy of marine diesel oil (MDO) is 42.7 [MJ / kg] and of LNG is 54.7 [MJ / kg].

The amount of fuel consumed per day at 80% load is 72.94 T / Day. The fuel consumption value per second is:

$$m_f = \frac{72,94}{24 \times 3600} \times 1000 = 0,844 kg / s. \qquad (5)$$

The thermal flow of ME with marine diesel oil (MDO) has a value:

$$Q_f = m_f \times C.V. = 0,844 \times 42705,4 = 36043,36 kW. \qquad (6)$$

The total energy flow (energy content of the fuel consumed) passing through the ME per year (292 days) is:

$$E = 36043,36 \times 24 \times 292 = 252591,9 MWh \qquad (7)$$

The thermal energy of LNG is C.V. = 54.7 [MJ / kg] and the thermal flow of ME is:

$$Q_f = m_f \times C.V. = 0,844 \times 54700 = 46166,8\ kW \qquad (8)$$

The total energy flow passing through the ME (LNG as fuel) per year is:

$$E_{LNG} = 46166,8 \times 24 \times 292 = 323\,536,9\ MWh \qquad (9)$$

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Compared to MDO the energy received per year from LNG is 70 945MWh larger:

$$E_{LNG} - E = 323536{,}9 - 252591{,}9 = 70\ 945\ MWh \qquad (10)$$

Since LNG has high energy content, a lower amount of fuel is needed to obtain the required amount of energy. Therefor application of this alternative fuel will provide fuel savings and reduction of emissions.

A new mandatory code for ships using gases or other low-flashpoint fuels enters into force on 1 January 2017.

As the use of LNG as a fuel in shipping is gaining popularity IMO Maritime Safety Committee (MSC) adopted this safety rules. Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code) aims to minimize the risk for ships, their crews and the environment, given the nature of the fuels involved. [11]

Three big companies are developing different LNG technologies for ship engines - Rolls-Royce, Wärtsilä and MAN. Wärtsilä has delivered more than 330 dual-fuel diesel engines for 90 ships. These engines consume about 0.6% less energy than marine diesel engines and 5% less than scrubbed fuel oil engines. Rolls-Royce has also sold more than 500 LNG engines. These engines provide a reduction in fuel consumption and increased thermal efficiency. [7]

Glosten Associates announced the completion of a study on 144-Car Ferry LNG fuel conversion feasibility. The company's study found that the payback period of the initial cost of switching to liquefied natural gas fuel is three to ten years, depending on the LNG prices. Glosten has developed a conceptual design for the use of dual-fuel and LNG engines. Operational savings per vessel is expected to be between $ 0.9M and $ 1.25M per year, after a $ 8.5M to $ 10M initial investment. [5]

Japanese shipbuilding company Kawasaki Kisen is working on a cargo ship with LNG as a fuel to reduce carbon emissions by 40%. The Kawasaki Kisen ship will have a capacity of 5000 tons and will be able to transport 2000 cars. The Kawasaki Heavy Industries gas engine has a 90% lower nitrogen oxide emission profile compared to conventional diesel engines. [1]

Sea-Cargo AS in 2010 ordered the Indian shipyard "Bharati Shipyard" the first ship powered by LNG with a simple mechanical propulsion system. The new ship, 132.8 m in length, has a load capacity of 5600 tons, 94 TEU containers and 1,140 linear meters of RoRo capacity. The important result achieved is a large reduction in emissions compared to the same oil-fuelled vessels. CO_2 emissions will be reduced by about 20%, NOx emissions by about 90%, and particulate matter and SOx will be zero. [2]

On-board energy consumption is reduced by 4% when using LNG as a fuel. Switching from conventional fuels to liquefied natural gas will provide energy efficiency improvement, reduction of operational costs and environmental protection.

2.2 Biofuels

Biomass is a broad term used for living biological materials that can be used as energy sources. Biogas is a combustion gas and an alternative ecological fuel produced by anaerobic digestion of organic waste material such as plant, animal and municipal waste, sewage sludge or other biodegradable materials. By parameters and utilization biogas is close to natural gas.

The methane content of biogas is 50 to 85%. It also contains carbon dioxide from 15 to 40%, nitrogen, hydrogen, oxygen and hydrogen sulphide. The energy content of biogas is about 22,600 KJ / m or 5400 ccal / m (1 KJ = 4,185 ccal). The calorific value of 1 kg of methane corresponds to 1.18 kg of fuel oil.

The energy generated from biomass can be used in transport sector. Bio diesel and bio ethanol are substitutes for conventional diesel and gasoline fuels. Bio Diesel is produced by processing fresh or used vegetable oils as well as other fats. Bio ethanol is produced by converting carbohydrates of biomass into sugar, which is then converted to ethanol through a fermentation process similar to beer brewing. Ethanol is the most widely used biofuel today, based on starch crops such as corn.

Biofuel could be produced from algae. The conversion of rape and other crops into biofuels is at a more advanced stage than that of algae diesel. The biomass from algae can also be burned or anaerobically digested to produce methane biogas to generate heat and electricity. Algal biomass can also be treated by pyrolysis to generate crude bio-oil. Production of biodiesel by growing algae can lead to significant cost savings, according to Solix Biofuels, with about 90-95%. [9] Algae in bioreactors need only water, nutrients and CO_2 to feed and grow. They absorb sunlight and convert solar energy into chemical. Compared to soy, their productivity is 30 to 100 times greater.

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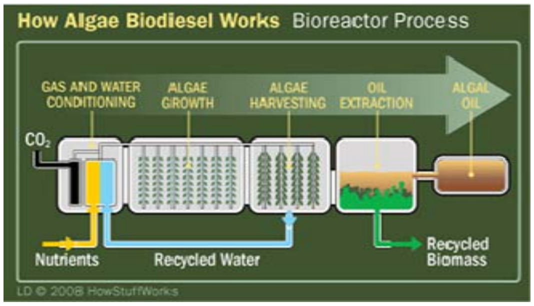

Figure 4 Biofuel from algae

The technology could be called waste-free, since after the extraction of biodiesel, the residue of carbohydrates can be used to produce ethanol or as feed for farm animals. Algae biofuels contain no sulphur, are non-toxic and are biodegradable.

The United States has launched warship using biofuels. The US Navy's first biofuel powered ship - Spruance-class destroyer completed a successful trip along California's coast. (17 hours from San Diego, California to the naval base in Port Wine). The US Navy plans to use alternative fuels on a number of small ships, destroyers, cruisers, aircraft and submarines and, by the beginning of the next decade, to meet 50% of its electricity needs from renewable sources. [3]

The energy generated from biomass used in transport sector is shown on Figure 4.

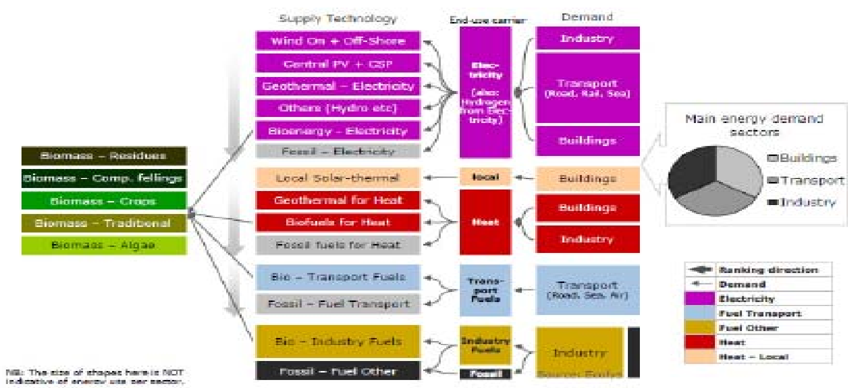

Figure 5 Biofuels Opportunities [The Energy Report, Ecofys / WWF, 2011]

Table 2 presents the most important features of six selected biofuels compared to ship fuel characteristics as quoted in the ISO 8217 technical standard for marine fuels. [6]

Table 2

Fuels	Cetane number	Higher Heating value (MJ/kg)	Kinematic viscosity (mm2/s at 40 °C)	Cloud point (°C)	Pour point (°C)	Flash point (°C)	Density at 15 °C (kg/m3)
IFO 380 (ISO8217-RMG)	not specified	not specified (~ 42,8) [41]	<380	not specified	<30 (~ 6-18) [41]	>60 (~90) [41]	< 991 (~963) [41]
Straight Vegetable Oil	37 – 42	39.5 -39.7	32 – 37	-4 - +7	-32 – -12	246 - 274	900
Raw pyrolysis bio-oil	10	22.7	14.5	-21	-33 – -12	40-100	1100-1250
HDO pyrolysis bio-oil	"high"	45.2	2.8	unknown	unknown	35-39 [42]	900
MDO (ISO8217 DMB)	> 35	not specified (~45,3 [43])	2 – 11	not specified	0 - +6	> 60	< 900
MGO (ISO8217 DMA)	> 40	not specified (~45,3 [44])	2 – 6	not specified	-6 – +0	> 60	< 890
Biodiesel	49 – 58	37.3 -39.8	4.2 - 4.5	-1 – +8	-4 – +5	110 - 195	880-920
Di-methyl ether (DME)	55 – 60	29.8	0.2 – 0.25 [45]	unknown	unknown	-41	665 (5 bar)
Bio-methane	0 [46]	55	n/a	n/a	n/a	-188	0.66
Bio-ethanol	8	29.8	- - 1.2	n/a	n/a	12	791

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According to the data, it can be concluded that straight vegetable oil and biodiesel are the options closest to marine fuels (in green) in accordance with the ISO standard. Bio-methane and bioethanol should not be compared to an ISO standard fuel, as they will be applied to different types of engines.

Fuels that work in Diesel engines: diesel, biodiesel, vegetable oil, DME (Dimethyl ether), GTL (gas-to-liquid), BTL (biomass-to-liquid), FAME (Fatty Acid Methyl Ester) and HVO (Hydro treated Vegetable Oil).

Fuels that work in Otto engines: Gasoline, Ethanol, methanol, natural gas; Biogas (compressed natural gas (CNG) and in liquid natural gas (LNG)) and hydrogen. [6]

MAN B & W Diesel states that it is possible to retrofit existing engines for operation on liquid biofuels. The cost of conversion is relatively small compared to fuel costs. They states that the retrofitting of an existing engine to run on biofuels is less than 5% of the engine cost. [6]

When using biofuels, it is also necessary to modify other ship systems - fuel tanks, pipelines, processing systems, etc., which is also a cost. But the main obstacle to the widespread use of biofuels is difference in price between heavy fuel oil and liquid biofuels.

The use of biofuels improves the quality of the environment and energy production. Methane is one of the most powerful greenhouse gases with 21 times greater impact on global warming than carbon dioxide. The effect of methane combustion is also expressed in the substitution of the derivatives of petroleum fuels.

3. CONCLUSIONS

Optimization of ship's energy efficiency can be achieved through the technological improvement and use of high-energy fuels. The presented alternative fuel solutions can provide energy savings and low levels of Greenhouse Gas Emissions. LNG engines produce less CO_2, NOx, SOx emissions compared to diesel engines. Engines running on biofuels discharge no sulphur emissions and reduce carbon emissions, so they have lower impact on climate change.

Switching from conventional fuels to LNG and biofuels would provide reduction of fuel consumption and operational costs this will ensure optimization of ship energy efficiency and environmental protection.

3. REFERENCES

[1] *A liquefied gas vessel reduces CO2 emissions*, 31.07.2011, http://www.greentech.bg,

[2] *Advancing the state of the art* – Sea-Cargo orders LNG-fuelled multipurpose RoRo vessels using Rolls-Royce technology, 10.12.2011, 16:55, http://www.shortsea.nl

[3] *Danko P.* - U.S. Naval Landing Craft Gets Biofuel Boost, 2011

[4] *Eurostat*, Directive 2006/32/EC of the European Parliament and of the Council of 5.04.2006, on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC, ANNEX II, Energy content of selected fuels for end use — conversion table

[5] *Feasibility study points to benefits of LNG use in ferries*, http://www.marinelog.com, 23.08.2011

[6] *Florentinus A., Hamelinck C.*, Arno van den Bos , Winkel R., Cuijpers M., Potential of biofuels for shipping, Ecofys 2011, January 2012, Project number: BIONL11332

[7] *International Council on Clean Transportation*, White paper, Assessment of the fuel cycle impact of liquefied natural gas as used in international shipping, May 2013

[8] *LNG as Ship Fuel*, TRB AW010(1) – New Technologies for the Marine Highway – 14.01.2013

[9] Mc Dermott M., 90-95% Cost Reduction in Algae Production Claimed by Solix Biofuels, November 24, 2008, http://www.treehugger.com/renewable-energy

[10] *Odd Magne Horgen* - Rolls Royce Bergen Engines Presentation- SNAME GL&GR Meeting - Cleveland, Ohio - February 23-24, 2012

[11] Safety For Gas-Fuelled Ships – New Mandatory Code Enters Into Force, 02.01.2017, http://www.marineinsight.com

[12] *Sames P. C., Clausen N. B., Andersen M. L.,* Costs and Benefits of LNG as Ship Fuel for Container Vessels, GL and MAN Diesel & Turbo, 2011, http://www.mandieselturbo.com

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INCREASING THE FRETTING AND FATIGUE RESISTANCE OF Ti-6Al-4V THROUGH PLASMA PROCESSING IN NONAUTONOMOUS PLASMA GLOW

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Abstract: Titanium alloys possess unique combination of good mechanical properties and excellent corrosion resistance which make them an attractive material for application in marine engineering. Along with these properties there are some disadvantages. The most important of them is the low hardness and poor tribological properties, which leads to poor fretting and fatigue resistance. These drawbacks limit the application of titanium alloys in production of machine parts, which are subjected to friction and surface contact loads. They can be successfully eliminated using numerous of surface treatment methods. One of the most commonly used is plasma treatment processes in nonautonomous plasma glow. These methods usually include plasma thermochemical treatment and afterwards plasma spraying of large variety of materials to the surface of the treated sample, which will eliminate the drawbacks of the titanium alloys and will increase the area of their application in marine engineering.
This article presents investigation of the results obtained from plasma nitriding and plasma spraying of titanium alloy Ti-6Al-4V in nonautonomous plasma glow using TiO_2 powder. The quality assessment and morphology of the plasma sprayed layer is made using micro structural analysis, EDS analysis, XRD analysis, SEM analysis and microhardness measurements.
Key words: Plasma spraying, surface modification, titanium alloys, Ti-6Al-4V, TiO_2 coatings.

1. INTRODUCTION

Pure titanium and its alloys have great potential for application in marine industry and marine engineering because of their remarkable mechanical properties over other constructional materials. One of the most perspective and widely used titanium alloy in modern engineering is Ti-6Al-4V. It possesses low elastic modulus, excellent corrosion resistance and high strength-to-density ratio. It is already known that about few nanometres thick TiO_2 layer is naturally formed on the surface of Ti-6Al-4V spontaneously in any oxidative environment. In recent studies is indicated that this amorphous layer does not provide sufficient long-term corrosion protection and wear resistance and therefore it is not an efficient barrier for preventing the fretting and fatigue wear on the surface. These drawbacks limit the application of Ti-6Al-4V in production of machine parts, which are subjected to friction and surface contact loads. To eliminate this disadvantages a variety of surface treatment methods can be used. Some of them are PVD, CVD, sol-gel method, electrochemical deposition etc. One of the most perspective and widely used method for surface modification of titanium alloys is plasma surface treatment. This method usually combines two plasma surface treatment techniques – plasma nitriding followed by plasma spraying of TiO_2 [1,2,4,6].

The plasma equipment which is used for this duplex surface modification provides treatment in nonautonomous plasma glow, which ensures the electrical neutrality of the treated sample and provides more sufficient results in terms of mechanical characteristics of the sprayed layer TiO_2. The phases which are formed using surface plasma treatment process are TiN and TiO_2. These phases will generally change the initial Ti-6Al-4V surface mechanical properties and will increase fretting and fatigue wear resistance on the surface [1,3,5,6].

In recent studies there is not enough information about the microstructure and the mechanical properties of the surface layer of Ti-6Al-4V alloy after duplex plasma surface modification treatment. The aim of the current paper is to characterize the microstructure and the microhardness profile in terms to give enough information of the mechanical properties of duplex coating deposited on Ti-6Al-4V alloy surface. The investigation of the results for surface microhardness, surface morphology and elemental composition will be conducted using SEM, EDS and XRD analysis.

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2. EXPERIMENTAL DETAILS

2.1. Sample preparation

Some important properties of the investigated Ti-6Al-4V are given it table 1 [3,5,6].

Table 1. Main properties of titanium alloy Ti-6Al-4V

Property	Value
Density, g/cm^3	4,4
Melting point, °C	1650
Thermal conductivity, W/m.K	7
Thermal expansion	9,0
Heat capacity, J/kg.K	530
Elastic modulus, GPa	110
Poason's coefficient	0,36
Tensile stranght, MPa	1000
HV	350
Corrosion resistance	High
Oxygen reactivity	High

Commercially available Ti-6Al-4V (90% Titanium, 6% Aluminium, 4% Vanadium) samples are used for the experimental procedure conduction. The cylindrical samples used are with dimensions d=10mm, h=35mm. The calculated total surface, subjected to plasma treatment process for each sample is S=314mm^2. Samples preparation include surface treatment with nitric and hydrofluoric acid solution for 20s and further cleaning with acetone liquid. The final surface preparation is rinsing in running water for 3 minutes followed by drying.

2.2. Plasma treatment process

For duplex plasma surface modification of Ti-6Al-4V the prepared samples were subjected first to plasma nitriding process. The plasma nitriding equipment consists of PPN-80 set with nonautonomous direct current plasma torch PN-80. The initial parameters for plasma nitriding process are shown in table 2. After plasma nitriding treatment the surface of the prepared samples of Ti-6Al-4V were subjected to plasma spraying process.

The powder which is used for this stage is TiO_2. It was deposited on the substrate's surface using low pressure plasma computerized equipment set PPS-80 with direct current plasma torch PS-80. The parameters for conduction of the plasma spraying process are given in table 3. The first and the second stage of plasma treatment process of Ti-6Al-4V samples were performed with fixed parameters.

Table 2. Processing parameters for plasma nitrating

Parameter	Value
Current, A	550
Voltage, V	50
Power, kW	27,5
Main plasma forming gas flow rate (Ar), lpm	20
Additional plasma forming gas flow rate (N), lpm	8
Distance from plasma torch to the substrate surface, mm	80
Linear plasma torch speed, mm/min	35
Rotation speed of the sample, min^{-1}	300

Table 3. Processing parameters for plasma spraying

Parameter	Value
Current, A	450
Voltage, V	50
Power, kW	22,5
Main plasma forming gas flow rate (Ar), lpm	22
Additional plasma forming gas flow rate (N), lpm	4
TiO_2 powder feed rate, g/min	45
Distance from plasma torch to the substrate surface, mm	100
Linear plasma torch speed, mm/min	20
Rotation speed of the sample, min^{-1}	300

The rotor type powder supply equipment is used for plasma spraying process. The equipment is electronically controlled through a central programmed control panel. Powder spraying is performed at variable rotor speed from 0 to 300rpm with linear speed of plasma torch 20mm/min and substrate rotation velocity of 300rpm. The surface temperature of the substrates during plasma spraying process is within limits 180÷220ºC.

The main plasma forming gas is argon with purity 99,9% and the additional plasma forming gas is nitrogen with purity 99,9%. The pressure of plasma forming gasses is 3 bars.

2.3. Coating characterization

The microstructure of plasma processed samples is investigated using optical microscope Nikon Eclipse

L150. For microstructural analysis conduction, the samples' cross sections are grinded and polished using grinding machine Mecatech 350. The morphology of the coatings is examined using scanning electron microscope Joel JSM 6060-LU. The elemental distribution is measured by energy dispersive spectroscopy Joel JSM 6060-LU. The phase constitution is determined with X-ray diffraction Rigaku 600 X-Ray Diffraction D/MAX/2200, using Cu-Kα radiation in 20÷100º 2θ. The microhardness profile of the plasma treated substrates is defined using Metkon MH-3 hardness testing machine with a load of 50g for 10s. Each microhardness data is average of three measurements.

3. RESULTS AND DISCUSSION

3.1. Microstructural analysis and microhardness profile

The microstructure profile of the plasma treated samples of titanium alloy Ti-6Al-4V is shown on figures 1 and 2. The surface of the samples after plasma nitriding process are shown on Fig. 1. After plasma nitriding process the surface colour of the samples changed into yellow. That suggests presence of phases TiN through plasma nitriding modification. The depth of the plasma nitriding layer formed on the surface of the samples varies in the limits between 7÷11μm.

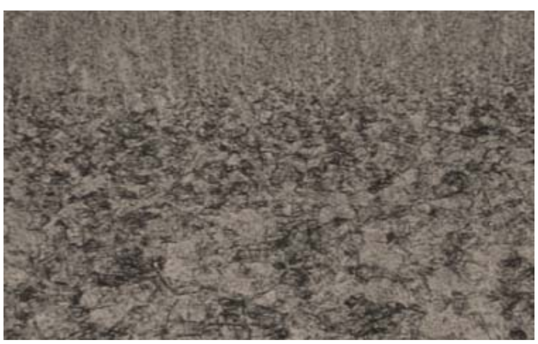

Figure1 Cross-section optical microscopic image of plasma nitrided sample of titanium alloy Ti-6Al-4V

The microstructure along with the microhardness profile of the treated samples after plasma spraying modification is shown on Figure 2. After plasma spraying process the surface colour of the treated samples changed from yellow into white. The investigation of the cross-sectional morphology shows presence of duplex layer with possible composition TiN followed by coating of TiO_2. The cross-sectional view of the coating indicates that its thickness varies between 10÷12μm and the coatings adheres well to the Ti-6Al-4V substrate. The plasma treated samples demonstrate very good adhesion between the nitrided layer and the TiO_2 coating on Ti-6Al-4V with no presence of cracks. This is a proof for high quality of the bonding process between these two layers and it's an evidence for very good performance of the coting in zones, subjected to friction and surface contact loads.

Microhardness profile measured in the cross sectional plane of the duplex coating of the plasma treated samples is shown in Fig. 2. The TiO_2 coating, formed by plasma spraying process on previously plasma nitrided Ti-6Al-4V substrate demonstrate hardness in the range of 690÷710HV0.05 at the surface. The microhardness measured in the depth of the cross-section of the sample decreases at the end of the plasma sprayed region to the beginning of the nitrided layer from 700 to 390HV0.05. The hardness of the nitrided layer prodused by plasma nitriding process is within limits 390÷410HV0.05. Further in the depth of the sample the microhardness of the nitrided layer decreases and reaches the base hardness of the sample of Ti-6Al-4V which is between 270÷290HV0.05. It is obvious that the surface hardness increases approximately 3 times after the plasma treatment process.

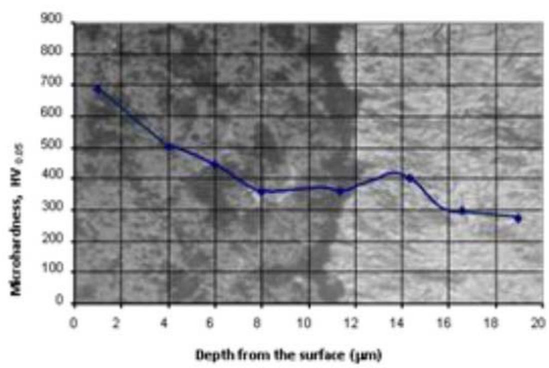

Figure 2 Cross-section optical microscopic image and microhardness profile of plasma sprayed sample of titanium alloy Ti-6Al-4V using TiO_2 powder

3.2. SEM, EDS and XRD analysis

The surface morphology results from investigation with SEM of the duplex TiN/TiO_2 coating, produced by plasma treatment of Ti-6Al-4V substrate are shown on Fig 3. The micrograph of the sample's internal area is shown on Fig. 3 (a). The processed Ti-6Al-4V sample's external area is shown on Fig. 3 (b). Both images show that after surface treatment with plasma spraying process of TiO_2 powder, porous surface layer can be formed. It could be determined that the TiO_2 coating's roughness of the internal area is higher compared to the external area. This variation in roughness of the porosity of the coating is due to different cooling speed between the layers of TiO_2. After plasma spraying process the external layer cools down more rapidly compared to the substrate's internal layer. The difference between the cooling speed will result in less rough structure on the surface of the treated sample and more rough structure at the internal

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part of the sample's TiO_2 coating. Surface roughness of TiO_2 coating plays a major role in the performance of the layer in case of surface contact load. This directly will affect to the tribological properties of the treated sample's surface and will increase significantly its fretting and fatigue resistance.

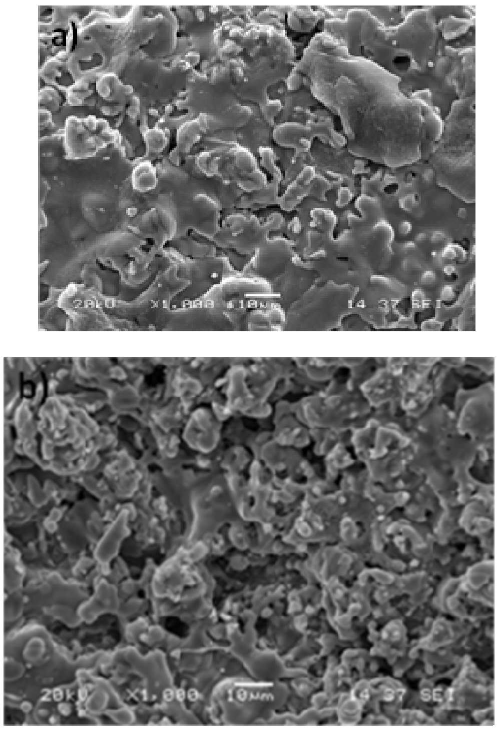

Figure 3 SEM micrographs of plasma sprayed coating on Ti-6Al-4V substrate using TiO_2 powder

a-cross-section image of TiO_2 sprayed coating internal area

b-cross-section image of TiO_2 sprayed coating external area

On Figure 4 are shown results from elemental distributions on the external area surface of the duplex TiN/TiO_2 coating determined by EDS. The elemental distribution is investigated in 3 zones of the cross-section of the sample. The results from EDS analysis show that Ti and O demonstrate a uniform distribution character on the surface of the plasma treated Ti-6Al-4V samples. The uniformity of the distribution is very important to the mechanical characteristics, the performance of the coating and its longevity, therefore higher fretting and fatigue resistance of the substrate can be expected.

The results from the EDS analysis of the internal side of the plasma sprayed TiO_2 coating on Ti-6Al-4V substrate are shown on Fig. 5 and table 4. The EDS analysis is conducted in 3 sections. The results show that the concentration of Ti is higher in the micro pores which are situated near to the surface of beforehand plasma nitrided Ti-6Al-4V substrate. This can be explained with the trend high energy active particles of the plasma sprayed TiO_2 powder to interact with the surface of the treated Ti-6Al-4V sample.

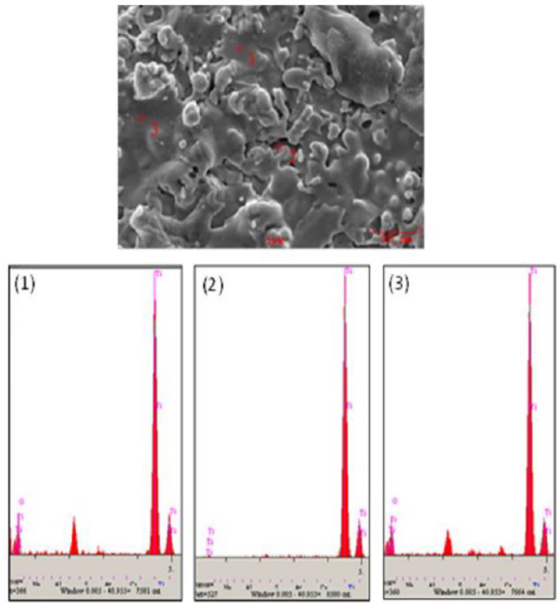

Figure 4 Cross-section SEM image and results from EDS analysis of the external layer of plasma sprayed TiO_2 coating

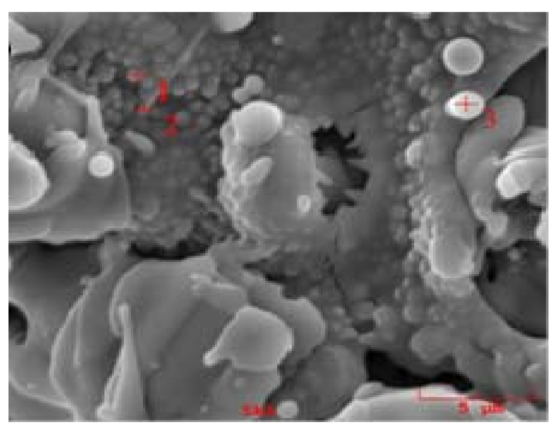

Figure 5 SEM image internal section of plasma sprayed TiO_2 coating on Ti-6Al-4V substrate

Table 4. Results from EDS analysis of elemental distribution of the internal part of Ti-6Al-4V sample's TiO_2 coating after plasma spraying process

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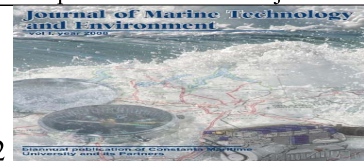

Spectrum	Oxygen, at. %	Titanium, at %
1	55	45
2	77	23
3	64	36

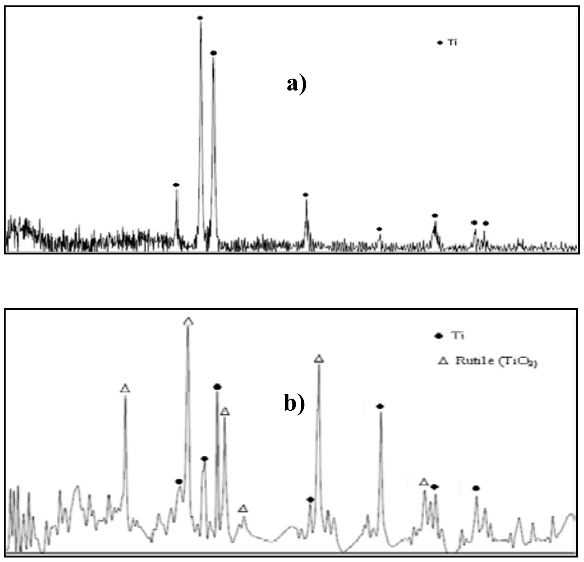

Figure 6 Results from XRD analysis of uncoated Ti-6Al-4V plasma nitrided sample (a) and plasma sprayed TiO_2 coating on Ti-6Al-4V substrate (b)

The results of performed XRD analysis of plasma sprayed with TiO_2 powder Ti-6Al-4V sample and plasma nitrided one are shown of Fig. 6. The diffraction pattern for the plasma nitrided sample shows presence of peaks with element Ti. As it was previously discussed in the introduction part of the current paper there is presence of a thin naturally formed TiO_2 layer as a result of plasma nitriding process and the interaction of the surface of the sample with the oxygen from the atmospheric air. This is the reason that any nitrogen was not detected through the XRD analysis of the nitrided Ti-6Al-4V sample (Fig. 6 (a)). The XRD analysis of plasma sprayed with TiO_2 powder Ti-6Al-4V sample are shown on Fig. 6 (b). The diffraction peaks on the surface of the duplex TiN/TiO_2 coated Ti-6Al-4V sample show presence of rutile or modified TiO_2. Peaks and therefore presence of TiN on duplex TiN/TiO_2 coating is not detected on XRD patterns of the coated Ti-6Al-4V specimen.

4. CONCLUSIONS

Surface treatment of titanium alloy Ti-6Al-4V specimens with plasma nitriding and plasma spraying process using TiO_2 powder is performed in order to change the mechanical properties and to increase fretting and fatigue wear resistance on the surface. The results from the investigation shows, that plasma nitriding process leads to change in the surface colour of the treated substrate from white to yellow. This can be explained with the formation of new phases TiN through plasma nitriding modification. The depth of the plasma nitriding layer, investigated using microstructural analysis varies in the limits between 7÷11μm. The hardness of the nitrided layer is within limits 390÷410HV0.05.

The SEM analysis reveals that the TiO_2 coating's roughness of the internal area is higher compared to the external area. This variation in roughness of the porosity of the coating will affect to the tribological properties of the treated sample's surface and its fretting and fatigue resistance. The EDS analysis shows that Ti and O demonstrate a uniform distribution character on the surface of the plasma treated Ti-6Al-4V samples, which affects to the performance of the coating and its longevity. The XRD analysis of the duplex TiN/TiO_2 coated Ti-6Al-4V sample show presence of rutile or modified TiO_2. Peaks and therefore presence of TiN on duplex TiN/TiO_2 coating is not detected on XRD patterns of the coated Ti-6Al-4V specimen.

The dual plasma surface treatment of Ti-6Al-4V leads to a change in surface morphology and formation of a duplex TiN/TiO_2 coating on the surface of the substrate. The performed microstructural analysis reveals that the produced duplex TiN/TiO_2 coating adhere very good, the produced layers are uninterrupted, without any cracks. The TiO_2 coating is with thickness 10÷12μm and microhardness in the range of 690÷710HV0.05. The dual plasma surface treatment of Ti-6Al-4V leads to increasing the surface hardness from 270÷290HV0.05 of the Ti-6Al-4V base to 690÷710HV0.05, which is 245%. This dual plasma surface treatment of Ti-6Al-4V will affect directly in improving the tribological properties of the samples and will increase significantly their fretting and fatigue wear resistance.

5. REFERENCES

[1] Guo Z., Sha W., 1999, *Phase evolution of pure titanium and ti-6v-4al alloy during continuous heating process,* 9th World Conference on Titanium - St. Petersburg, Russian Federation, pp 1-7.

[2] Kostadinov K., Alexandrov Ch., Sivkov J., Tsvetkov M., 2010, *Network centric based radar in maritime surveillance systems*, Black sea 2010, Varna, ISSN 1314-0957, pp 415-418.

[3] Malinov S., Zhecheva A., Sha W., 2003, *Modelling the nitriding in titanium alloys*, International Surface Engineering Congress - Proceedings of the 1st Congress., pp 344-352.

[4] Malinov S., Sha W., Voon CS., 2002, *In situ high temperature microscopy study of the surface oxidation and phase transformations in titanium alloys*, Journal of Microscopy, Vol.207, pp 163-168.

[5] Manov M., Skulev H., 2010, *Investigation of titanium alloys after surface hardening with plasma nitriding*, Journal of mechanical engineering and technologies, Vol.1, Varna, ISSN 1312-0859, pp 32-36.

[6] Manov M., Skulev H., 2010, *Titanium and titanium alloys – an overview*, Journal of mechanical engineering and technologies, Vol.2, Varna, ISSN 1312-0859, pp 34-49.

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HOW TO APPROCH THE OTTO CYCLE THEORY DURING THE UNDERGRADUATE THERMODYNAMICS COURSE IN CMU

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Abstract: The approach presented in this paper refers to the study of the effect of specific heat of working fluid and heat loss on the performance of an Otto cycle, using finite time thermodynamics- as a powerful thermodynamic tool in the hand of specialists. Traditionally, Otto cycle performance issue was presented to the students in the case of constant specific heat, available only if it is assumed that the working fluid behaves as a perfect gas, meaning for relatively small temperature differences.
Since in the practice are met large temperature differences, should be considered the case of variable specific heat, in this paper the adiabatic exponent being taken as a liniar function of temperature.
For the both situations discussed in the paper are given formula for the calculation of the total energy of the fuel, the heat added to the working fluid, the heat leakage, the compression and expansion efficiencies, the work output and the thermal efficiency.
The calculus is based on the cycle shown in temperature- entropy diagram, in which are also indicated the irreversible adiabatic compression and expansion.

Key words: Otto cycle, specific heats, constant, variable

1. INTRODUCTION

Maritime Education and Training is the path towards a successful career in shipping industry, which despite of the present global economic crises, is asking for highly qualified marine engineers in the context of the world's fleet growth [1].

Developments in marine engineering, found in new and future ships, offer major benefits in terms of fuel consumption, maintenance, carrying capacity, environmental behavior, etc.

All these aspects must be reflected in the education and training of future marine engineers [2].

In Constanta Maritime University (CMU), an important educational outcome of its engineering programme is the capacity of graduates to design a component or a system.

Taking into account that population of the world is increasing and the natural resources are depleting, future marine engineers will face the energy efficiency challenge. In this context, future graduates will deal with the problem related to the increase of the efficiency of power systems.

Thermodynamics is an important component of mechanical engineering curricula, as well as of marine engineering curricula. In Constanta Maritime University, future marine engineers, encounter the Otto cycle during Thermodynamics 1 course, delivered in their second year of study.

Because large temperature differences exist in the practical cycles, the constant specific heat assumption is not valid; therefore this topic should be extended when it is delivered to students.

The analysis of the performance of an Otto cycle with heat transfer and constant / variable specific heat of working fluid leads to enhance the understanding of specific concepts and principles.

In the following, will be presented approaches revealing the influence of specific heat of working fluid and heat loss on the performance of the Otto cycle, with the involvement of finite – time thermodynamics.

The aim of these algorithms is to provide to future marine engineers guidance for the design of practical Otto engines, by choosing the optimal situation for the desired use.

2. METHODS AND MATERIALS

The air standard Otto cycle is shown on temperature – entropy coordinates in Figure 1. The closed

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thermodynamic cycle 1-2_t-3-4_t consists of four internally reversible processes:

- reversible adiabatic compression (1-2_t),
- constant volume heat addition (2_t-3),
- reversible adiabatic expansion (3-4_t)
- constant volume heat rejection (4_t-1).

In the mentioned figure, it is possible to be seen the processes 1-2 and 3-4, which are the irreversible adiabatic processes – in which internal irreversibility in the real compression and expansion processes are considered.

The Otto cycle analysis, which is developed on the assumption that the working fluid behaves as an ideal gas with constant specific heat, is viable for relatively small temperature differences; but in the practice of thermal machines, the temperature differences are important, making useful the examination of the variable specific heat case [3].

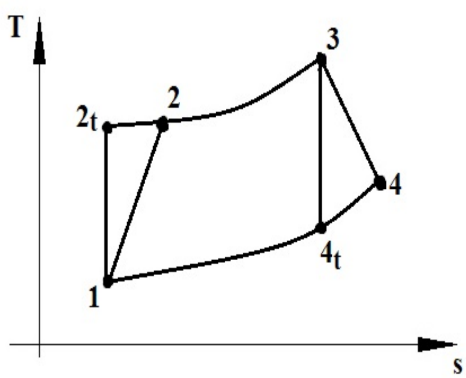

Figure 1. (T-s) diagram for the air standard Otto cycle.

In this study, dealing with the performance of the irreversible Otto cycle, it will be used Finite Time Thermodynamics, which is a tool able to reveal the optimal time path of any cyclic process with friction and heat leakage and to offer a clear image of how irreversibility influences the performance of thermal processes [4].

The performance of the analyzed air standard Otto cycle is evaluated with:

$$\eta = \frac{W_{out}}{Q_{in}} \tag{1}$$

meaning the ratio between the work output and the heat added to the working fluid.

2.1 Constant specific heat case:

When working with an ideal gas for which are known its initial conditions, the maximum temperature and minimum volume, it is easy to find the other states, the heat input, heat rejected and the work output in the analyzed cycle, by the use of ideal gas laws and the first principle of thermodynamics [5].

For the isentropic compression process (1-2_t) and isentropic expansion process (3-4_t) are written the following equations:

$$\frac{T_{2_t}}{T_1} = r^{k-1} \tag{2}$$

$$\frac{T_{4_t}}{T_3} = r^{k-1} \tag{3}$$

where:

r – the compression ratio for the engine ($r = V_1 / V_2$),
V_1 – the total volume of the cylinder,
V_2 – cylinder clearance volume,
k –ratio of the specific heats ($r = c_p / c_v$),

The investigation is focused on reversible and irreversible processes, thus it is requested the definition of the compression and expansion efficiencies, which describe the internal irreversibilities of the adiabatic processes [6]):

$$\eta_c = \frac{T_{2_t} - T_1}{T_2 - T_1} \tag{4}$$

$$\eta_E = \frac{T_3 - T_4}{T_3 - T_{4_t}} \tag{5}$$

The total energy of the fuel (Q_{fuel}), the heat added to the working fluid (Q_{in}), the heat leakage (Q_{ht}) and the work output (W_{out}) are evaluated with [7]:

$$Q_{fuel} = \eta_{com} m_f Q_{LHV} \tag{6}$$

$$Q_{in} = Q_{fuel} - Q_{ht} \tag{7}$$

$$Q_{ht} = m_t B(T_2 + T_3) \tag{8}$$

where:

m_f – fuel amount,
m_t – air-fuel amount inducted into the cycle,
η_{com} – combustion efficiency,
B – constant,
Q_{LHV} – the lower heating value of the fuel.

$$m_t = m_f \left[1 + \frac{1}{(m_a / m_f)_s \phi}\right] \tag{9}$$

Above, Φ is the equivalence ratio and “s” refers to stoichiometric conditions.

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$$Q_{in} = \frac{R_{air}\, m_t}{k-1}\left(T_3 - T_2\right) \quad (10)$$

$$W_{out} = \frac{R_{air}\, m_t}{k-1}\left(T_1 - T_2 + T_3 - T_4\right) \quad (11)$$

where:

R_{air} – characteristic gas constant of air.

2.2 Variable specific heat case:

Having in view the existence of large temperature difference in the practical cycles, the specific heat with constant pressure and the specific heat with constant volume depend on temperature, resulting that the adiabatic exponent "k", depends on temperature also.

A reversible adiabatic process, between states i and j, for which k is variable, can be divided into infinitesimally small processes, each of them with constant k. For any of these processes, when occur infinitesimally small changes in temperature (dt) and in volume (dV) of the working fluid, the equation for reversible adiabatic process with variable k is written as [8]:

$$TV^{k-1} = \left(T + dT\right)\left(V + dV\right)^{k-1} \quad (12)$$

According to Ebrahimi [9]:

$$k = k_0 - k_1 T \quad (13)$$

Above, T is absolute temperature and k_0, k_1 are constants.

In this respect, from equation (12) results:

$$T_j\left(k_0 - k_1 T_i - 1\right)\left(\frac{V_j}{V_i}\right)^{k_0 - 1} = T_i\left(k_0 - k_1 Tj - 1\right) \quad (14)$$

In addition, Ebrahimi gives formulas for the heat added to the working fluid during combustion (Q_{in}), the heat rejected during evacuation (Q_{out}) and the work output (W_{out}) [9] as:

$$Q_{in} = m_t\int_{T_2}^{T_3} c_v\, dT = m_t\int_{T_2}^{T_3}\left(\frac{R_{air}}{k_0 - k_1 T - 1}\right) dT = \frac{m_a R_{air}}{k_1}\left[1 + \frac{\phi}{\left(m_a/m_f\right)_s}\right]\ln\left(\frac{k_0 - k_1 T_2 - 1}{k_0 - k_1 T_3 - 1}\right) \quad (15)$$

$$Q_{out} = m_t\int_{T_1}^{T_4} c_v\, dT = m_t\int_{T_1}^{T_4}\left(\frac{R_{air}}{k_0 - k_1 T - 1}\right) dT = \frac{m_a R_{air}}{k_1}\left[1 + \frac{\phi}{\left(m_a/m_f\right)_s}\right]\ln\left(\frac{k_0 - k_1 T_1 - 1}{k_0 - k_1 T_4 - 1}\right) \quad (16)$$

$$W_{out} = \frac{m_a R_{air}}{k_1}\left[1 + \frac{\phi}{\left(m_a/m_f\right)_s}\right]\ln\left[\frac{\left(k_0 - k_1 T_2 - 1\right)\left(k_0 - k_1 T_4 - 1\right)}{\left(k_0 - k_1 T_3 - 1\right)\left(k_0 - k_1 T_1 - 1\right)}\right] \quad (17)$$

3. RESULTS AND DISCUSSION

A performance analysis was carried out in terms of thermal efficiency of an irreversible Otto cycle.

In the presented calculation procedure was considered the case of constant specific heats, available for relatively small temperature differences, and also the case of variable specific heats, met in practice because of the large temperature differences.

For both cases are given formulas for the calculation of the heat added to the working fluid during isochoric combustion, the work output and the thermal efficiency of the air standard Otto cycle.

Were introduced the compression and expansion efficiencies for the two adiabatic processes of the cycle, used to describe the irreversibility of these processes.

For the first case in discussion, T_{2t} can be found if are known r, η_c, η_E and T_1 by the use of relation (2).

By introducing T_{2t} in equation (4), results T_2.

The temperature at the end of combustion is calculated by replacing equation (7) in equation (10).

T_{4t} results from equation (3); when it is introduced in equation (5), it is possible to get T_4.

With T_1, T_2, T_3 and T_4 evaluated, are used equations (11) and finally (1), to have a theoretical basis of the cycle performance analysis.

For the second case in discussion, T_{2t} can be calculated if are known r, η_c, η_E and T_1 from equation (14). Then, T_{2t} is introduced in equation (4), to be found T_2. The temperature at the end of the combustion is calculated by replacing equation (7) in equation (15).

T_{4t} results from equation (14); when it is introduced in equation (5), it is possible to get T_4.

With T_1, T_2, T_3 and T_4 evaluated, are used equations (17) and (1), to finalize the theoretical basis of the cycle performance analysis.

4. CONCLUSIONS

An important outcome of marine engineering program in CMU is the ability of future professionals to deal with engineering design

In this paper a standard Otto cycle had been shortly reviewed in order to serve as a basis for the theoretical exposure in discussion.

In the context of new technologies penetration in the maritime sector and of the need for highly qualified marine engineers, thermodynamics course in CMU was updated. Such an aspect is demonstrate through this article.

The classical approach related to the performance of Otto cycles was based on the influence of the constant specific heat.

This situation is available only when considering small temperature differences; in practice, because of the large temperature differences, the above mentioned should be reconsidered.

As a result, when delivered to the students, this topic was extended to the analysis of the effect of variable specific heats on the performance of the irreversible Otto cycle.

The model presented may provide guidelines for evaluation of optimal design and operating conditions of real Otto cycles.

5. REFERENCES

[1] Baylon A.M., Ma R. Santos V.E., 2011, *The challenges in Philippine Maritime Education and Training, International* Journal of Innovative Interdisciplinary Research, Issue 1, pp.34-43

[2] Saharuddin , O.O. Sulaiman A.H., Kader A.S.A., Wan Nick W.B., August 2011, *Marine Engineering as future career in Malaysia*, Business Management Dynamics, Vol.1, No.2, pp.01-10

[3] Anwar Beg O., Rashidi M.M., Mehr N.F., 2014, *Comparative thermodynamic study of air standard cycles with heat transfer and variable specific heats of the working fluid*, Int. J. Appl. Math. and Mech 10 (2), pp.41-60

[4] Mehta H.B., Bharti O.S., 2012, Performance analysis of an irreversible Otto cycle using Finite Time Thermodynamics, *Proc. of the World Congress on Engineering*, Vol. II, London, U.K., pp.5, July 1-3, 2009

[5] M. Huleihil, G. Mazor, *Irreversible performance characteristics of air standard Otto cycle with polytropic processes*, Applied Mechanical Engineering, Vol. 1, Issue 3, pp.6

[6] Ust Y., Sahin B., Safa A., 2011, *The effects of cycle temperature and cycle pressure ratios on the performance of an irreversible Otto cycle*, Acta Physica Polonica A, Vol. 120, pp.412-416

[7] Ebrahimi R., 2010, *Theoretical study of combustion efficiency in an Otto engine*, Journal of American Science, 6 (2), pp.113-116

[8] Ge Y., Chen L., Sun F., Wu C., 2005, *Thermodynamic simulation of performance of an Otto cycle with heat transfer and variable specific heat of working fluid*, International Journal of Thermal Sciences, 44, pp.506-511

[9] Ebrahimi R., 2010, *Effects of variable specific heat ratio on performance of an endoreversible Otto cycle*, Acta Physica Polonica A, Vol. 117, pp.887-891

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AN EVALUATION OF THE ENERGY EFFICIENCY DESIGN INDEX BASELINE FOR PASSENGER VESSELS OF BANGLADESH

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Abstract: Energy Efficiency Design Index (EEDI) was introduced since 2013 for new ships as a measure to improve energy efficiency of sea going ships. This factor already has created a great influence on global maritime industry. However, any requirement related to the energy efficiency of inland vessels does not exist. This paper attempts to evaluate EEDI for inland passenger vessels of Bangladesh. According to the results of this analysis, which has been based on 90 existing inland passenger vessels, EEDI that was introduced for seagoing ships cannot be applied for proper evaluation of inland passenger vessels due to limitation of carrying capacity and installed main engine power. So, the main objective of this paper is to provide EEDI reference line for inland passenger vessels of Bangladesh.

Key words: Inland Cargo Vessel, $C0_2$ emission, IMO, Reference line, Energy Efficiency Design Index (EEDI).

In order to reduce $C0_2$ emission, Marine Environment Protection Committee (MEPC) at its 62nd session adopted Resolution MEPC.203(62) (MEPC, 2011a) which includes amendments to MARPOL Annex VI. It introduces new chapter 4 which intends to improve energy efficiency for ships through a set of technical performance standards. The amendments, which entered into force on 1 January 2013, require that every ship has the International Energy Efficiency (IEE) Certificate on board. In order to obtain the IEE Certificate a ship has to comply with the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). The EEDI is mandatory for all new ships and SEEMP for all ships of 400 GT and above engaged in the international shipping. The EEDI is a simple formula that estimates $C0_2$ output per ton-mile at one design condition.

Due to geographical advantages, waterways are the cheapest mode of transport for transporting passengers and cargoes in Bangladesh. Although, there are more than 500 passenger vessels plying all the year round in Bangladesh, but performance of these ships in terms $C0_2$ emission is not known and any regulations related to the energy efficiency for inland passenger vessels still does not exist. Several attempts have made to establish a reliable tool for seagoing vessels with respect to energy efficiency that can be found in various papers & reports but there are no suggested benchmarks that could be used for assessment of the energy efficiency of inland passenger vessels for Bangladesh. A Simic [2] has proposed a reliable tool for benchmarking energy efficiency and carbon emissions of inland waterway self-propelled cargo ships for UK, which should be similar to already accepted approach for seagoing ships. Having in mind the significance of energy efficiency benchmarking, which already has a huge influence on the global marine shipbuilding industry, this study has been performed based on available data of 90 existing inland passenger vessels of Bangladesh. From this perspective, this research will seek to review the present scenario of inland passenger vessels in terms of EEDI, analyze the results and propose some reliable tool for benchmarking energy efficiency and carbon emission of inland cargo vessels considering existing socio-economic and technical factors in Bangladesh. Originally, existing ships are not been targeted in EEDI regulation however, this study has been presented in order to investigate the conformity of existing designs with the new regulation for illustration purposes and take precautions for adopting EEDI methodology to new designs.

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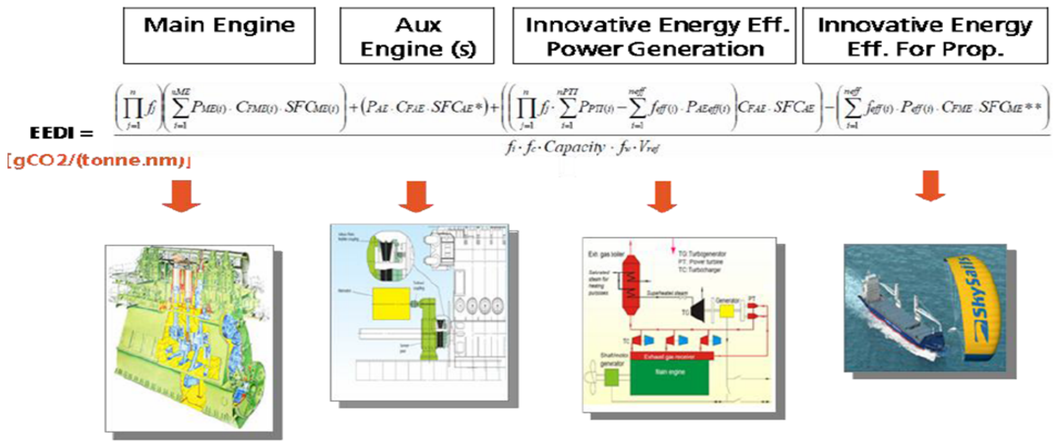
2. OVERVIEW OF ENERGY EFFICIENCY DESIGN INDEX (EEDI)

The Energy Efficiency Design Index has been developed by the IMO over the past several years through a series of submissions to MEPCs 57-59 and the 1st and 2nd Working Groups on Greenhouse Gases. After the 2nd intersessional meeting of the Working Group on Greenhouse Gas Emissions from Ships, the equation was refined to the following form,



2.1. Explanation of terms

C_F is a non-dimensional conversion factor between fuel consumption measured in g and CO_2 emission also measured in gram based on carbon content. The subscripts *MEi* and *AEi* refer to the main and auxiliary engine(s) respectively. C_F corresponds to the fuel used when determining SFC listed in the applicable EIAPP Certificate. The values of the conversion factors, C_F are given in table 1.

Table 1. C_F values for different types of fuel

Type of fuel	Reference	Carbon content	C_F (t-CO2/t-Fuel)
Diesel/Gas Oil	ISO 8217 Grades DMX through DMC	0.875	3.206
Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.86	3.15104
Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.85	3.1144
Liquefied Petroleum Gas (LPG)	Propane Butane	0.819 0.827	3.0 3.03
Liquefied Natural Gas (LNG)		0.75	2.75

V_{ref} is the ship speed, measured in nautical miles per hour (knot), on deep water in the maximum design load condition (Capacity) at the shaft power of the engine(s) and assuming the weather is calm with no wind and no waves. The maximum design load condition shall be defined by the scantling draught with its associated trim, at which the ship is allowed to operate. This condition is obtained from the stability booklet approved by the administration.

Capacity is defined as

- For dry cargo carriers, tankers, gas tankers, containerships, ro-ro cargo and general cargo ships, deadweight should be used as Capacity.
- For passenger ships and ro-ro passenger ships, gross tonnage in accordance with the International Convention of Tonnage Measurement of Ships 1969, Annex I, regulation 3 should be used as Capacity.
- For containerships, the capacity parameter should be established at 70% of the deadweight.

Deadweight means the difference in tonnes between the displacement of a ship in water of relative density of 1.025 kg/m^3 at the deepest operational draught and the lightweight of the ship.

'P' is the power of the main and auxiliary engines, measured in kW. The subscripts ***ME*** and ***AE*** refer to the main and auxiliary engine(s), respectively. The summation on ***i*** is for all engines with the number of engines (***nME***).

$P_{ME(i)}$ is 75% of the rated installed power (MCR) for each main engine (***i***) after having deducted any installed shaft generator(s):

$$P_{ME(i)} = 0.75\times (MCR_{MEi} - P_{PTOi})$$

$P_{PTO(i)}$ is 75% output of each shaft generator installed divided by the relevant efficiency of that shaft generator.

$P_{PTI(i)}$ is 75% of the rated power consumption of each shaft motor divided by the weighted averaged efficiency of the generator(s).In case of combined *PTI/PTO*, the normal operational mode at sea will determine which of these to be used in the calculation.

$P_{eff(i)}$ is 75% of the main engine power reduction due to innovative mechanical energy efficient technology.

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Mechanical recovered waste energy directly coupled to shafts need not be measured.

$P_{AEeff(i)}$ is the auxiliary power reduction due to innovative electrical energy efficient technology measured at ***$P_{ME(i)}$***.

P_{AE} is the required auxiliary engine power to supply normal maximum sea load including necessary power for propulsion machinery/systems and accommodation, e.g., main engine pumps, navigational systems and equipment and living on board, but excluding the power not for propulsion machinery/systems, e.g., thrusters, cargo pumps, cargo gear, ballast pumps, maintaining cargo, e.g., reefers and cargo hold fans, in the condition where the ship engaged in voyage at the speed (***V_{ref}***) under the design loading condition of Capacity.

For cargo ships with a main engine power of 10000 kW or above, P_{AE} is defined as:

$$P_{AE(MCRME>10000kW)} = \left(0.025 * \sum_{i=1}^{nME} MCR_{MEi}\right) + 250$$

For cargo ships with a main engine power below 10000 kW P_{AE} is defined as:

$$P_{AE(MCRME<10000kW)} = 0.05 * \sum_{i=1}^{nME} MCR_{MEi}$$

For ship types where the PAE value calculated by the above two equations is significantly different from the total power used at normal seagoing, e.g., in cases of passenger ships, the PAE value should be estimated by the consumed electric power (excluding propulsion) in conditions when the ship is engaged in a voyage at reference speed (Vref) as given in the electric power table, divided by the weighted average efficiency of the generator(s).

V_{ref}, Capacity and ***P*** should be consistent with each other.

SFC is the certified specific fuel consumption, measured in g/kWh, of the engines. The subscripts ***ME(i)*** and ***AE(i)*** refer to the main and auxiliary engine(s), respectively. For engines certified to the E2 or E3 duty cycles of the NO_x Technical Code 2008, the engine Specific Fuel Consumption (***$SFC_{ME(i)}$***) is that recorded on the EIAPP Certificate(s) at the engine(s) 75% of MCR power or torque rating. For engines certified to the D2 or C1 duty cycles of the NO_x Technical Code 2008, the engine Specific Fuel Consumption (***$SFC_{AE(i)}$***) is that recorded on the EIAPP Certificate(s) at the engine(s) 50% of MCR power or torque rating.

fj is a correction factor to account for ship specific design elements. For ice-classed ships are determined by the standard ***fj*** in Table 2.For other ship types, ***fj*** should be taken as1.0.

Table 2. Correction factor for power f j for ice-classed ships

Ship type	fj	Limits depending on the ice class			
		IC	IB	IA	IA Super
Tanker	$\frac{0.516 L_{PP}^{1.87}}{\sum_{i=1}^{nME} P_{iME}}$	{max 1.0 $\min 0.72 L_{PP}^{0.06}$}	{max 1.0 $\min 0.61 L_{PP}^{0.08}$}	{max 1.0 $\min 0.5 L_{PP}^{0.1}$}	{max 1.0 $\min 0.4 L_{PP}^{0.12}$}
Dry cargo carrier	$\frac{2.15 L_{PP}^{1.58}}{\sum_{i=1}^{nME} P_{iME}}$	{max 1.0 $\min 0.89 L_{PP}^{0.04}$}	{max 1.0 $\min 0.78 L_{PP}^{0.04}$}	{max 1.0 $\min 0.68 L_{PP}^{0.06}$}	{max 1.0 $\min 0.58 L_{PP}^{0.08}$}
General cargo ship	$\frac{0.045 L_{PP}^{2.37}}{\sum_{i=1}^{nME} P_{iME}}$	{max 1.0 $\min 0.85 L_{PP}^{0.08}$}	{max 1.0 $\min 0.7 L_{PP}^{0.04}$}	{max 1.0 $\min 0.54 L_{PP}^{0.1}$}	{max 1.0 $\min 0.39 L_{PP}^{0.13}$}

fw is a non-dimensional coefficient indicating the decrease of speed in representative sea conditions of wave height, wave frequency and wind speed (e.g., Beaufort Scale 6), and should be determined as follows:

It can be determined by conducting the ship-specific simulation of its performance at representative sea conditions. The simulation methodology should be prescribed in the guidelines developed by the organization and the method and outcome for an individual ship shall be verified by the administration or an organization recognized by the administration.

In case that the simulation is not conducted, f_w should be taken from the "Standard f_W"table/curve. A "Standard f_W"table/curve, which is to be contained in the guidelines, is given by ship type (the same ship as the "baseline" below), and expressed in a function of the parameter of Capacity (e.g., DWT). The "Standard f_W"table/curve is to be determined by conservative approach, i.e. based on data of actual speed reduction of as many existing ships as possible under representative sea conditions.

f_w should be taken as one (1.0) until the guidelines for the ship-specific simulation or f_W table/curve becomes available.

$f_{eff(i)}$ is the availability factor of each innovative energy efficiency technology. ***$f_{eff(i)}$*** for waste energy recovery system should be 1.

fi is the capacity factor for any technical/regulatory

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limitation on capacity, and can be assumed one (1.0) if no necessity of the factor is granted.

fi for ice-classed ships are determined by the standard f_i in Table 3. For other ship types, ***fi*** should be taken as 1.0.

Table 3. Capacity correction factor fi for ice-classed ships

Ship type	*fi*	Limits depending on the ice class			
		IC	IB	IA	IA Super
Tanker	$\frac{0.00115 L_{PP}^{3.36}}{capacity}$	max $1.31\,L_{PP}^{-0.05}$ min 1.0	max $1.54\,L_{PP}^{-0.07}$ min 1.0	max $1.8\,L_{PP}^{-0.09}$ min 1.0	max $2.1 L_{PP}^{-0.11}$ min 1.0
Dry cargo carrier	$\frac{0.000665 L_{PP}^{3.44}}{capacity}$	max $1.31\,L_{pp}^{-0.05}$ min 1.0	max $1.54\,L_{PP}^{-0.07}$ min 1.0	max $1.8\,L_{PP}^{-0.09}$ min 1.0	max $2.1 L_{PP}^{-0.11}$ min 1.0
General cargo ship	$\frac{0.000676 L_{PP}^{3.44}}{capacity}$	1.0	max 1.08 min 1.0	max 1.12 min 1.0	max 1.25 min 1.0
Container ship	$\frac{0.1749 L_{PP}^{2.29}}{capacity}$	1.0	max $1.25\,L_{PP}^{-0.04}$ min 1.0	max $1.6\,L_{PP}^{-0.08}$ min 1.0	max $2.1 L_{PP}^{-0.12}$ min 1.0
Gas tanker	$\frac{0.1749 L_{PP}^{2.33}}{capacity}$	max $1.31\,L_{pp}^{-0.04}$ min 1.0	max $1.6\,L_{PP}^{-0.08}$ min 1.0	max $2.1\,L_{PP}^{-0.12}$ min 1.0	1.0

Length between perpendiculars, L_{pp} means 96 % of the total length on a waterline at 85 % of the least moulded depth measured from the top of the keel, or the length from the foreside of the stem to the axis of the rudder stock on that waterline, if that were greater. In ships designed with a rake of keel the waterline on which this length is measured shall be parallel to the designed waterline. The length between perpendiculars (L_{pp}) shall be measured in meters.

3. FORMULATION OF THE GUIDELINES OF EEDI FOR INLAND PASSENGER VESSELS IN BANGLADESH

3.1. Establishment of the Reference line Regression Model

In this study the reports of MEPC 60 were used as the basis for the calculations. MEPC 60 has been working on the mandatory treaty text for implementing the EEDI method on new building vessels within MARPOL Annex VI. The Energy Emission Design Index adopted by the IMO in 2011 will affect most of these new ships. Phase 1, 2 and 3 will force an EEDI reduction of respectively 10%, 20% and 30% relative to the reference line for the ship type. The design of the new buildings in the different phases must take the EEDI into account – this will affect the whole chain from naval architects to the ship owners to the yards. The attained EEDI shall be specific to each ship and shall indicate the estimated performance of the ship in terms of energy efficiency, and be accompanied by the EEDI technical file that contains the information necessary for the calculation of the attained EEDI and that shows the process of calculation.

The attained EEDI shall be as follows:

Attained EEDI ≦ Required EEDI = (1-X/100) × Reference line value

Where X is the reduction factor specified in Table 4 for the required EEDI compared to the EEDI Reference line.

Table 4. Phase in scheme for reduction of required EEDI for different ship types

Ship Type	Size (DWT)	Phase 0 1 Jan 2013–31 Dec 2014	Phase 1 1 Jan 2015 –31 Dec 2019	Phase 2 1 Jan 2020–31 Dec 2024	Phase 3 1 Jan 2025– and onwards
Bulk Carrier	≥20000	0	10	20	30
	10,000-20,000	n/a	0-10*	0-20*	0-30*
Gas tanker	≥10000	0	10	20	30
	2,000 – 10,000	n/a	0-10*	0-20*	0-30*
Tanker	≥20000	0	10	20	30
	4,000 – 20,000	n/a	0-10*	0-20*	0-30*
Container ship	≥15000	0	10	20	30

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Ship Type	Size (DWT)	Phase 0 1 Jan 2013–31 Dec 2014	Phase 1 1 Jan 2015 –31 Dec 2019	Phase 2 1 Jan 2020–31 Dec 2024	Phase 3 1 Jan 2025–and onwards
	10,000–15,000	n/a	0-10*	0-20*	0-30*
General Cargo ships	≥15000	0	10	15	30
	3,000 – 15,000	n/a	0-10*	0-15*	0-30*
Refrigerated cargo carrier	≥5000	0	10	15	30
	3,000 – 5,000	n/a	0-10*	0-15*	0-30*
Combination carrier	≥20000	0	10	20	30
	4,000 – 20,000	n/a	0-10*	0-20*	0-30*

*Reduction factors should be linearly interpolated between the two values dependent upon vessel size. The lower value of the reduction factor is to be applied to the smaller ship size.

This attained EEDI must be less than the reference EEDI or reference line. The Average Index Values are used as the basis for calculating an exponential regression line. The regression line expresses the baseline value, which can then be calculated by using the following formula:

Reference line value = a ×b^{-c}

From figure 1 we observe that the value of a is 42477 and c is 1.015 where b indicates capacity. The reference line is based on the vessel database of Department of Shipping (DOS) in Bangladesh.

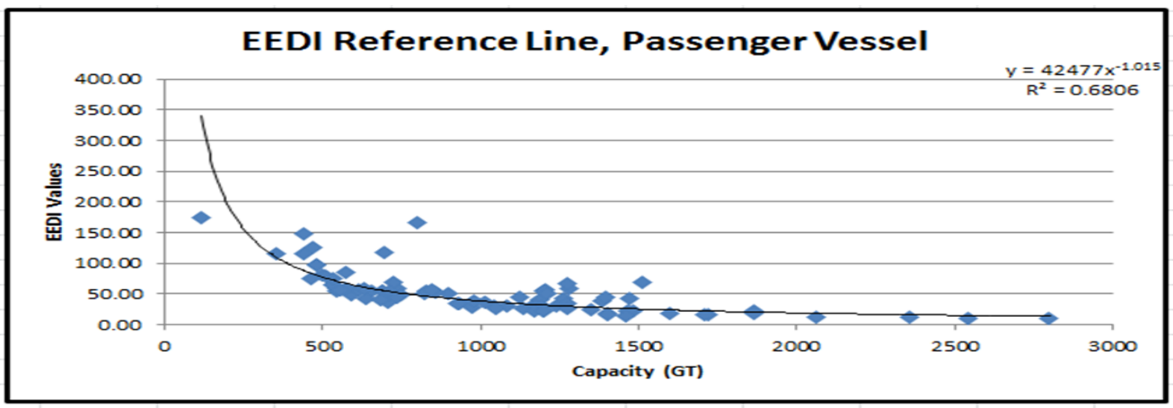

Figure 1 EEDI Reference line for Inland Passenger Vessel of Bangladesh

Here R^2 describes the correlation of the baseline value. A correlation close to 1 or -1 represents a high degree of correlation. Outliers which are more than two standard deviations from the regression line are removed, and a new regression line is calculated. This ensures that special ships and erroneous data are excluded from the calculation. From figure 1, it has been observed that the number of Passenger vessels smaller than 1500 GT in the dataset is limited. The regression line of passenger vessels is higher than the IMO baseline. The correlation of the regression line is high.

3.2. Verification of Reference line formula

The verification of mathematical model with capacity as independent variable data is shown in table 5.

Table5. Validation of mathematical model with capacity as independent variable

Ship Name	Capacity (GT)	Attained EEDI	Required EEDI	Error
MV Parabot-2	1864	22.05	20.35	-8.4%
MV Achol-2	1137	26.89	33.62	20.0%
MV Jahid-4	1044	30.49	36.66	16.8%
MV Jahid-3	1080	31.88	35.42	10.0%
MV Sundarban-2	824	49.18	46.61	-5.5%
MV Shampad	1175	33.07	32.51	-1.7%
MV Mitali-6	718	47.72	53.54	10.9%
MV Karnafuli-1	651	55.85	59.21	5.7%
MV Sharandip-7	612	57.96	63.04	8.1%
MV new Sabbir-2	1270	33.68	30.05	-12.1%

It has been observed from table 5 that, error is within the permitted range between reference line value and actual EEDI value, so this reference line formula can provide a reference for EEDI calculation of inland passenger vessels of Bangladesh.

4. PRESENT SITUATION OF INLAND VESSELS OF BANGLADESH WITH RESPECT TO EEDI

More than four years have been passed since IMO regulations regarding the required energy efficiency of seagoing ships became mandatory. These regulations introduced massive application of already existing technologies, which were neglected without proper incentives, and also initiated development of new solutions for reduction of unnecessary energy dissipation during ship navigation. As it turned out, in some cases even simple (well known) solutions in combination with already existing technologies can provide significant increase of energy efficiency of a ship. Moreover, the absence of appropriate energy & emissions benchmarks for IWW SP ships is a large impediment to performance improvements of these ships. In this paper, a considerable effort has been devoted to this matter; so far there are no suggested benchmarks that could be used for assessment of IWW cargo ship efficiency during design stage or for comparison of existing ships with respect to energy & emission efficiency.

4.1. Present situation of EEDI with respect to vessel's length

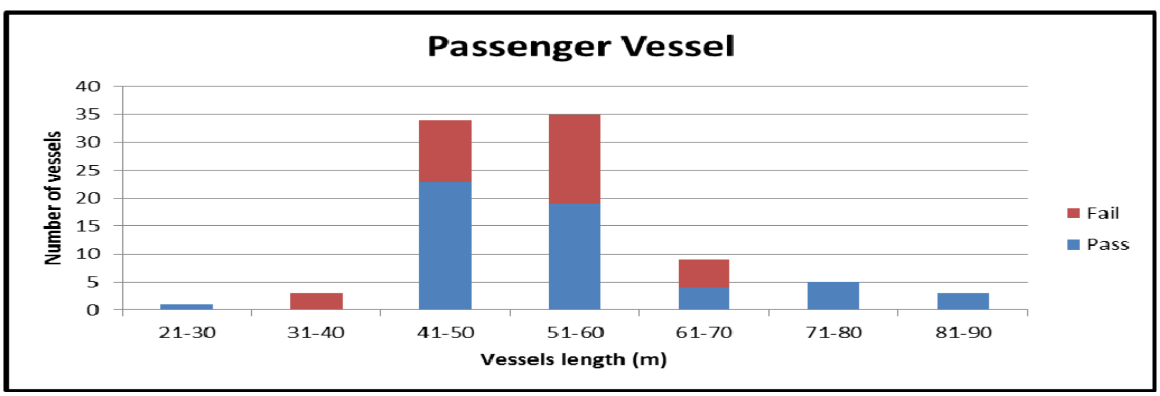

Figure 3 Present situation on EEDI with respect to vessel's length

From figure 45 it has observed that in Bangladesh most of the inland passenger vessels length is between 41to 60m. In this range there are presently 69 vessels out of them 42 vessels pass in terms of EEDI and the rest of the vessels EEDI exceed the required value. It has been also observed that larger length vessels EEDI lies below the reference line. In this case in vessels length range between 71 to 90m, there is no such vessel which does not meet EEDI reference line.

4.2. Present situation of EEDI with respect to vessel's Capacity

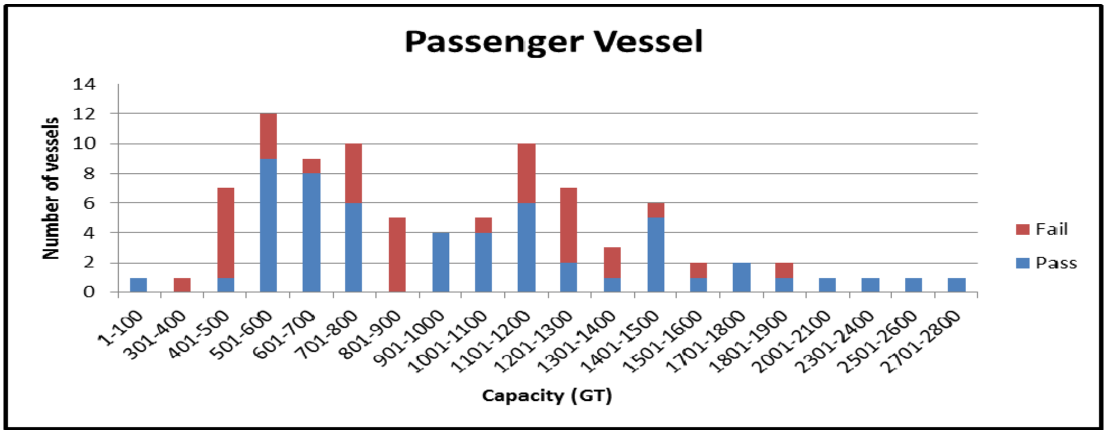

Figure 4 Present situation on EEDI with respect to vessel's Capacity

From figure 4 it has observed that in Bangladesh most of the inland passenger vessels capacity is between 501to 800GT. In this range there are presently 31 vessels out of them 23 vessels pass in terms of EEDI and the rest of the vessels EEDI exceed the required value. In vessel's capacity between 801 to 900 GT, all of the vessels EEDI exceed the reference line. It has been also observed that larger capacity vessels EEDI lies below the reference line. In this case in vessels capacity range between 2001 to 2800 T, there is no such vessel which does not meet EEDI reference line.

4.3. Present situation of EEDI with respect to vessel's Main engine power

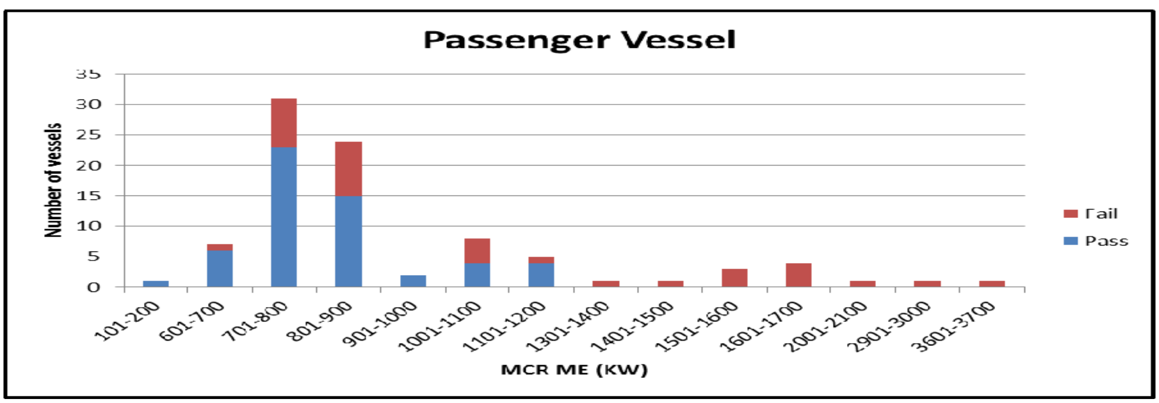

Figure 5 Present situation on EEDI with respect to vessel's Main Engine Power

From figure 5 it has observed that in Bangladesh most of the inland passenger vessels main engine power is between 701 to 900 KW. In this range there are presently 55 vessels out of them 38 vessels pass in terms of EEDI and the rest of the vessels EEDI exceed the required value. It has been also observed that larger main engine power vessels EEDI lies above the reference line. In this case in vessels main engine power range between 1301 to 3700 KW, there is no such vessel which does not meet EEDI reference line.

5. SENSITIVITY ANALYSIS OF EXISTING INLAND VESSELS WITH RESPECT TO EEDI

According to the EEDI, the energy efficiency of ships is defined as the ratio of the mass of CO_2 emissions from main, auxiliary engines and additional shaft per unit of transport work for a particular ship design. Therefore detailed design data, such as speed, engine power, fuel oil consumption, deadweight etc., are required in order to calculate the correct EEDI values which are closely related to the economic performance of the ship. The price of fuel has been the primary driver

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for improved efficiency and reduced fuel consumption on commercial ships. The highly competitive nature of the maritime industries meant that efforts to bring down fuel consumption were cost effective solutions, leading to overall optimization of the transport system. The IMO is developing the Energy Efficiency Design Index (EEDI) for new ships, which is a gauge of a ship's CO_2 efficiency. During the design stage of the vessel, for known demands, hull form should be determined at the beginning. Based on principal ship parameters, it is possible to estimate the attained EEDI and to compare it with the required value.

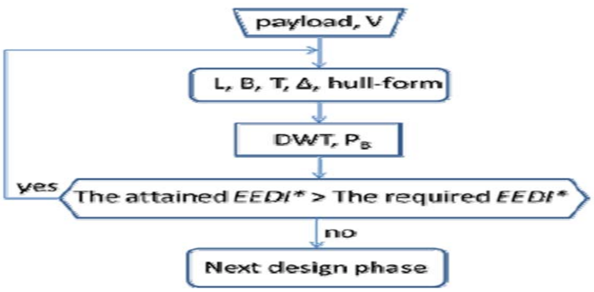

Figure 6 Procedure for evaluation of energy efficiency of a new ship during design stage

If a criterion described in Figure 6 is fulfilled, something should be changed (improved) within the project, otherwise it is allowed to proceed to the next design stage. Naturally, results should be confirmed during the speed trials as is recommended to be done for the seagoing ships.

Sample Case Ship (Passenger vessel):

Sensitivity of EEDI has been exemplified through set of calculations for a case passenger vessel. For demonstration purposes, an existing design of 754 person carrying capacity passenger vessel has been used as an example.

Principal particulars of the Sample Case Ship:

Table 6. Ship Specifications of Passenger vessel

Length (O.A)	75.6m	DWT	2700
Length (B.P)	73.25m	Main Engine (Yanmar)	2X600 BHP@100% MCR
Breadth (mld)	12.5m	SFC (ME)	190 g/KWh
Depth (mld)	3.0m	Main Generator	2X40KW
Draft	1.6m	SFC (AE)	210 g/KWh

For calculation of EEDI for the Case Ship, exact and ship specific model test data has been used and the calculation has been made according to the latest calculation guidelines as described in IMO MEPC.1/Circ.68.Calculated EEDI for the Case ship is 22.23 gCO_2/tnm. According to the formulated passenger vessel baseline, the requirement for 1743T passenger vessel is 21.7gCO_2/tnm, thus the Case Ship is about 2.44% above the baseline. However actual EEDI of the case ship would need to be improved by 2.44% to match with the requirement. When the speed of the vessel reduces to 9.5 knot from parent 10 knot then attained EEDI of the vessel is to be 20.33gCO_2/tnm which reduces the EEDI value of the vessel about 8.54% from the parent ship.

Change in Length of the vessel:

Table 7. Optimization *of ship's length with respect to EEDI (passenger vessel)*

Condition	Length (m)	P_{ME} (KW)	Total Resistance (KN)	EEDI (Attained)
Basis	73.25	592.4	72.17	22.2
5% less	69.5875	588.9	71.75	23.1
10% less	65.925	578.2	70.44	25.69
5% more	76.9125	600.85	73.19	20.54

From table 7, it has been observed that EEDI (attained) decreases with the increase of length at 10 knot speed, but increases with the increase of length at higher speeds. From this table it has been also observed that, Total resistance and Main engine power (P_{ME}) increases with the increase of length.

Change in Breadth of the vessel:

Table 8. Optimization of ship's breadth with respect to EEDI (passenger vessel)

Condition	Breadth (m)	P_{ME} (KW)	Total Resistance (KN)	EEDI (Attained)
Basis	12.25	592.4	72.17	22.2
5% less	11.6375	571.6	69.63	23.44
10% less	11.025	550.55	67.07	25.65
5% more	12.8625	613.15	74.69	21

From table 8, it has been observed that EEDI (attained) decreases with the increase of breadth at 10 knot speed. From this table it has been also observed that, Total resistance and Main engine power (P_{ME}) increases with the increase of breadth.

Change in Speed of the vessel:

Table 9. Optimization of ship's speed with respect to EEDI (passenger vessel)

Condition	Speed (Knot)	P_{ME} (KW)	Total Resistance (KN)	EEDI (Attained)
Basis	10	592.4	72.17	22.2
5% less	9.5	514.95	66.03	20.33

10% less	9	442.23	59.86	18.43
5% more	10.5	433.2	80.2	24.7

From table 9, it has been observed that EEDI (attained) increases with the increase of speed. It has been also observed that, Total resistance and Main engine power (P_{ME}) increases with the increase of speed. It can be decided easily that low speed gives the better performance in terms of EEDI.

Change in block coefficient of the vessel:

Table 10. Optimization of ship's block coefficient with respect to EEDI (passenger vessel)

Condition	Cb	P_{ME} (KW)	Total Resistance (KN)	EEDI (Attained)
Basis	0.85	592.4	72.17	22.2
5% less	0.8075	527.1	64.21	19.7
10% less	0.765	482.7	58.81	18.1
5% more	0.8925	649.1	81.25	28.1

From table 10, it has been observed that EEDI (attained) increases with the increase of block coefficient. It has been also observed that, Total resistance and Main engine power (P_{ME}) increases with the increase of block coefficient. It can be decided easily that, at any speed it is better to have small block coefficient.

Change in engine of the vessel:

Table 11. Optimization of ship's engine with respect to EEDI (passenger vessel)

Engine Name	SFC (g/Kwh)	Price (USD)	EEDI (Attained)
Cummins	165	700000	19.32
Yanmar	190	650000	22.2
Weichai	200	480000	23.39
Nigbo CSI	210	350000	24.55

From table 11, it has been observed that EEDI (attained) increases with the increase of specific fuel consumption value. It has been also observed that, the price of engine increases which has low SFC value. It can be decided easily that low SFC gives the better performance in terms of EEDI. But considering the economic factor in Bangladesh, if the EEDI values between two engines are nearer then the engine which has high SFC would be used.

6. HULL FORM OPTIMIZATION

In the process of ships, the determination of hull lines is complicated and pivotal, in respect that ships main performance of the rapidity (resistance and propelling), maneuverability and seakeeping would be influenced directly. However to obtain the hull shape of the minimum resistance is the primary goal of designers. Formerly, the hull lines design which refers excellent original hull is finished by competitive method of the deviser's experience and ship model testing. However, such method requires a great amount of time and labor and also suffers from some limitations. Nowadays, the shipbuilding capacity of our country is in the front of world; however the shipbuilding technology is unenlightened slightly. In order to increase competitiveness and ability of ship form development in international market, an optimization design method of excellent hull lines with the resistance performance and to development of program of ship lines of optimal design with the independent intellectual property is in urgent need.

In this paper, the S60 hull form is selected as the original hull to be optimized.

The principal particulars of the existing passenger vessel are shown in table 12.

Table 12. Ship Specifications of Passenger vessel

Length (O.A)	75.6m	GT	1743
Length (B.P)	73.25m	Main Engine (Yanmar)	2X750 BHP@100% MCR
Breadth (mld)	12.5m	SFC (ME)	190 g/KWh
Depth (mld)	3.0m	Main Generator	2X200KW
Draft	1.6m	SFC (AE)	210 g/KWh

According to the specifications, we have found that the EEDI value for this vessel is 46.16 g CO_2/ton mile and the maximum EEDI value for this vessel is 11.4 g CO_2/ton mile. So, this vessel exceeds it's EEDI value and needs the optimization of hull form.

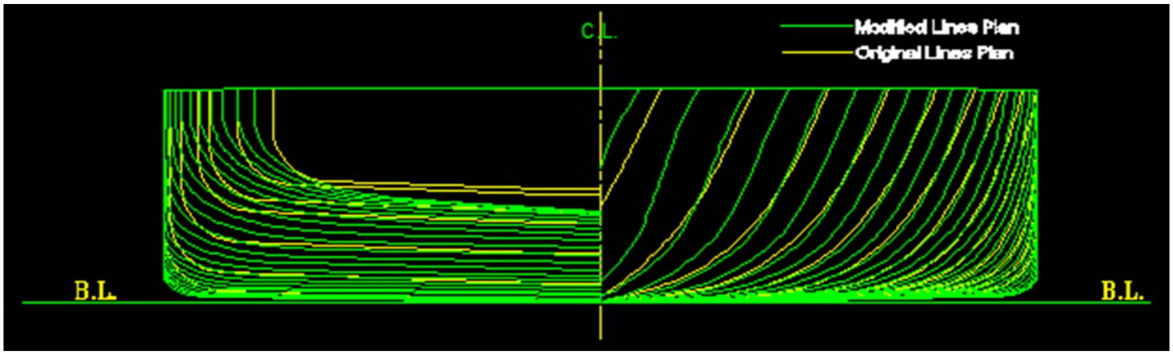

Figure 7 The comparison of body plans between the original hull form and the modified hull form (Passenger vessel)

The comparisons of body plans between the modified hull form and the original hull are shown in figure 7 and in this figure yellow line shows the original body plan & green line shows the modified body plan. In this comparison ship's hull has been optimized by keeping the passenger carrying capacity same.

Resistance Vs Speed graphs:

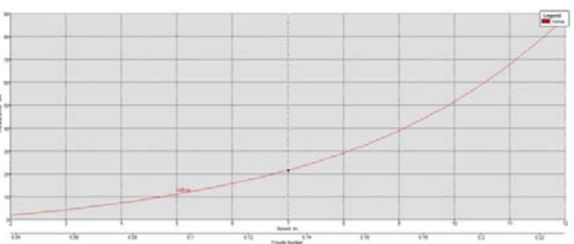

Figure 8 Resistance Vs Speed Graph –Original lines plan (Passenger vessel)

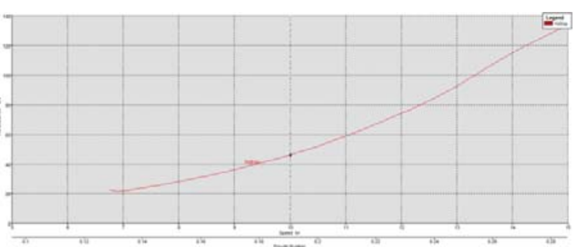

Figure 9 Resistance Vs Speed Graph –Modified lines plan (Passenger vessel)

From figure 8 & 9 we have seen that whereas in original lines plan resistance have found 51.5KN but in modified lines the resistance value is 46.2KN at 10 Knot service speed.so, the modified lines has given less resistance than the original one.

<u>Power Vs Speed graphs:</u>

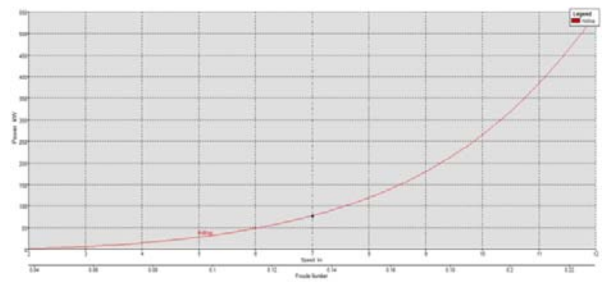

Figure 10 Power Vs Speed Graph –Original lines plan (Passenger vessel)

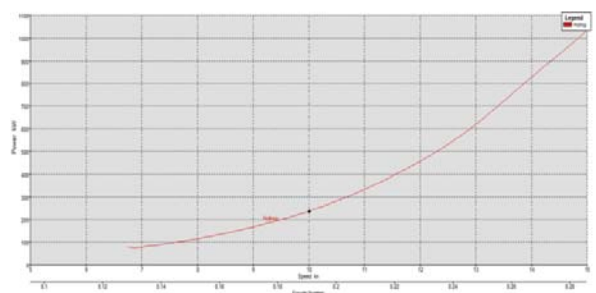

Figure 11 Power Vs Speed Graph –Modified lines plan (Passenger vessel)

From figure 10 & 11 we have seen that whereas in original lines plan required main engine power is 265KW but in modified lines the required power is 240KW. By original lines plan we have found the EEDI value for the vessel is 11.19 g CO_2/ton mile but the modified lines plan we have found the EEDI value 10.2 g CO_2/ton mile. Though originally 1100 KW power has been provided in this vessel but this vessel needs 265KW. So, we can say that a better and smooth hull design gives lesser resistance and hence gives better EEDI values.

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6. CONCLUSIONS

Having in mind the significance of energy efficiency benchmarking, which already has a huge influence on the global marine shipbuilding industry, this study has performed, based on available data of existing inland cargo vessels in Bangladesh and the following could be concluded:

- The EEDI introduced by IMO for evaluation of energy efficiency of passenger vessels can't be used for proper evaluation of energy efficiency of IWW passenger vessels. The reason for this is the limitation of carrying capacity and installed main engine power for inland waterways vessels.
- Formulated baseline equations for EEDI of Bangladesh lies much above than other countries like Denmark & Netherlands and one of the reasons for that is inappropriate engine selection of most of the inland passenger vessels in Bangladesh.
- Comparatively longer vessel is favorable from the EEDI point of view. A slender hull form, which will create a smaller pressure difference between bow and stern, is favorable.
- Lower main engine power vessels are more effective in terms of EEDI.
- A better and smooth hull design gives lesser resistance and hence gives better EEDI values.

7. REFERENCES

[1] IMO (2014), *Guidelines of the Method of Calculation of the Attained energy Efficiency Design Index for New Ships,* Resolution MEPC. 245(66).

[2] A Simic (2014*), Energy Efficiency of Inland Waterway Self-Propelled Cargo Ships,* Conference on Influence of EEDI on Ship Design, London, UK.

[3] K. Frouws (2016), *Is reducing speed the right mitigating action to limit harmful emissions of seagoing RoRo cargo carriers?,* Journal of Shipping and Trade, DOI 10.1186/s41072-016-0014-2.

[4] Tien Anh Tran (2015), *Calculation and Assessing the EEDI Index in the Field of Ship Energy Efficiency for M/V Jules Garnier*, Journal of Marine Science: Research & Development, DOI: 10.4172/2155-9910.1000212.

ISSN (Print): 1844-6116
ISSN (Online): 1884-6116 http://www.cmu-edu.eu/jmte

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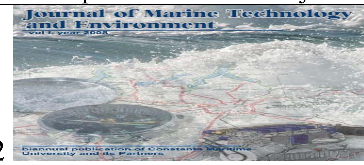

USING A NAVIGATION SIMULATOR IN THE DEVELOPMENT OF A COLREGS E-COURSE

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Abstract: Acquisition of skills to apply the International Regulations for Preventing Collisions at Sea (COLREGs) is one of the basic abilities of students from the Navigation specialty. Further training is a global requirement as well as self-improvement of students worldwide. Training institutions have no opportunity to do so; moreover, the creation of new centers would require a large financial resource, which necessitates flexible approaches to the training while taking into consideration the current situation. The build-up of electronic resources in the environment of the global network for a complementary or further training with assessment of performance is entirely in the spirit of modern standards for providing relevant training.

Application of navigation simulators is a new approach to creating training content for the electronic courses. It has a gradual transition between university education and the need for additional COLREG training. One of the main advantages of using simulations is the different angles in which a given situation is presented and the possibilities for re-pass. The comparison of what is visually observed from the bridge and the radar screen with a "bird eye-view" gives learners additional skills to read real situations in their practice.

Key words: navigation simulator, simulations, e-course, COLREGs, visualizations.

1. INTRODUCTION

COLREGs training is one of the major courses of the Naval Academy in the Bachelor program for Navigation. Each student must acquire a certain volume of knowledge and skills that they will be able to apply in their work [4,7,8]. The use of graphic presentation of the rules and their application, by illustrating specific situations, is one of the most commonly used methods of presenting the study material during the training in the academic subject [2,5]. The latter is combined with visualizations designed specifically for the courses that complement static two-dimensional diagrams without any opportunity for interactive change of conditions, which in turn imposes certain constraints.

The practical drills on the other hand are carried out in the environment of simulation on navigation simulators with a visualization of 180° to 360° or during navigational practice within the training period [1]. The navigation simulator has the following advantages:

- an opportunity for invariance of the assigned task, as well as for a change of the drill in its course;
- a large number of ships, on which it is possible to conduct the drill;
- an option to record and analyze the performance of the task;
- multiple coverage of same-type tasks for better training of students.

It also has some disadvantages, such as:

- a high cost of construction;
- a limited number of trainees;
- a need for a trained instructor;
- the trainee must be in a training center or university equipped with the necessary equipment;
- a high cost of training;
- a difficult access to further or recurrent training.

When training is used during navigational practice, we have the following advantages:

- training in a real situation;
- supervision by an in-service navigational officer.

In this case, we have the following disadvantages:

- no opportunity to cover the same situation many times;
- no option, in general, to record and analyze the performance of the task;
- a limited, in view of time, period for carrying out the training;
- no opportunity for further or recurrent training;
- combining the COLREGs training with other elements of practice;

- lack of opportunity to solve problems of certain types.

Despite these disadvantages in both approaches, they are the preferred and the best ones at the moment. By complementing them with other training approaches, such as self-teaching through training facilities or using e-learning, some of the existing disadvantages can be removed [2].

2. PRESENTATION

The use of e-learning is one of the modern approaches, giving very good results whether applied alone or in combination with the above-mentioned [7].

Applying it to COLREGs training will provide the following benefits and advantages for students or learners:

- opportunities to learn regardless of place: we avoid the restriction on the learner to be in a training center, or at home or on a ship;
- multiple coverage of a certain task for perfection of skills;
- recording the entire learning process with the ability to evaluate the results;
- an option to interrupt the training in the process of a certain task and to continue later;
- no need for an individual instructor;
- continuous updating and enrichment of the available tasks;
- low cost of resources.

Having appreciated the benefits mentioned above, a team of six countries (Bulgaria, Croatia, Slovenia, the UK, Turkey and Spain), involving university lecturers, practitioners and e-learning specialists, created the eColregs platform (www.ecolregs.com)[2]. The implementation was carried out within the framework of a European research project under the Leonardo program [3] funded by the European Commission for the period 2013-2015.

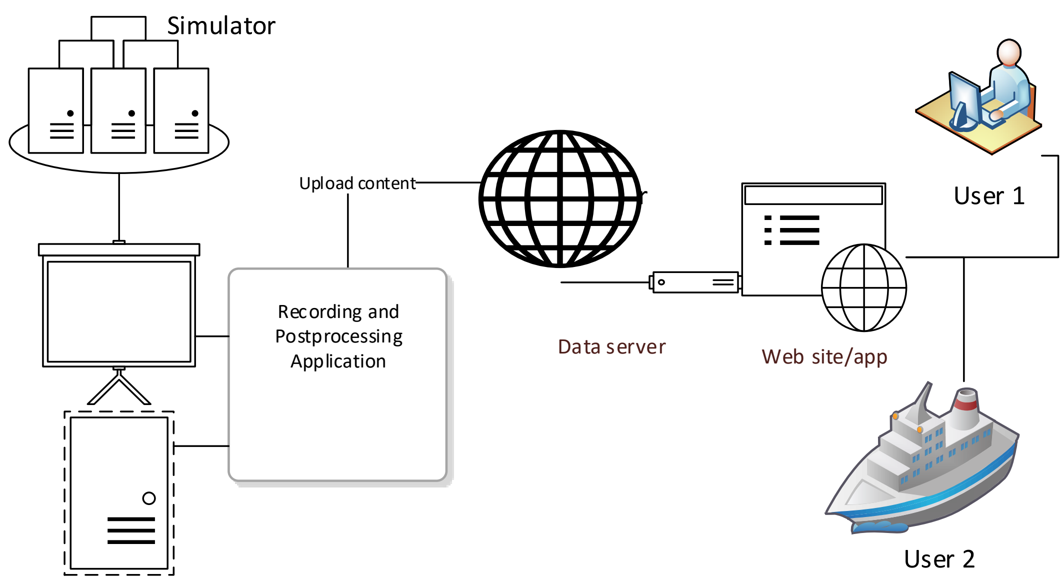

Figure 1 Operative diagram

To design an electronic system, it is necessary to select several basic characteristics: a platform for providing, a way of providing the contents, a methodology for contents creation, and the targeted results from training.

The following criteria were used when analyzing the possible platforms for implementation:

- a log-in system with an access control option;
- a stable operation with a large number of users;
- an opportunity to add contents without changing the source code;

- an opportunity to add photo, video and audio material;
- an option to define different levels of access to the contents of the course;
- modularity that allows the system to be upgraded without changing the current contents;
- an option to add test questions with assessment and analysis;
- an option to record the process of training and its analysis;

operation in the environment of the global network.

The Joomla system was chosen as it meets the needed criteria in full and provides the required stability and security. It is also very popular and has a wide range of developers.

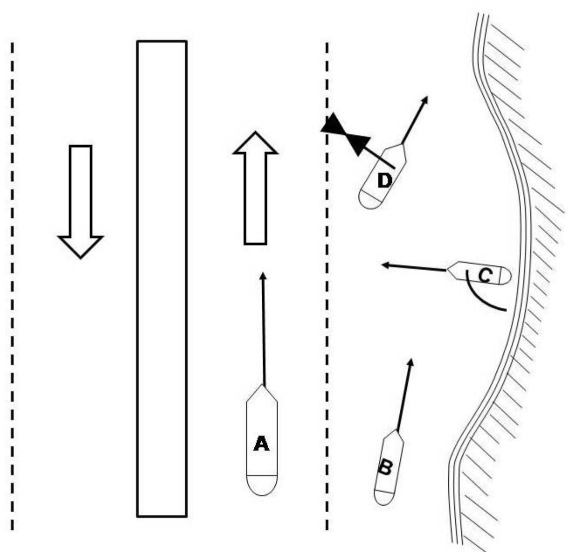

Figure 2 Task diagram

In order to provide a methodology for the creation of contents and to define the targeted results in the training process, a number of workshops were held in four countries with representatives from universities and maritime business, with navigation experts and representatives of maritime administrations, where the major targets and methods to achieve them were discussed.

On the basis of this analysis, university lecturers and experts have developed over 200 standard tasks to provide adequate presentation of the material described in the collision prevention regulations, such as contents and practical implementation, as well as a test control for self-assessment by the trainee.

One of the major problems is the visual presentation of the tasks under consideration, which should provide sufficient information by use of a personal computer. Appreciating the functional capabilities of modern equipment and the needs of students for visualization, the Transas 4000 Navigation Simulator has been used, which provides the necessary presentations of the tasks. This is an unconventional use of the simulator, which was originally designed to train navigational officers during maneuvering, teamwork, etc., but it does not have any built-in functionality for recording the visualization presented to the trainees, nor for presenting the information separately for the needs of the COLREGs training. These disadvantages have been overcome by using special programs to record the screen images and their subsequent processing (Figure 1).

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Figure 3 Bird's-eye view image

Each task is developed in a unified format, where each of the visualizations is described in advance and presented as a diagram (Figure 2). Then an exercise is made on the Transas 4000 Navigation Simulator available at the Naval Academy, in the Department of Navigation [1]. For the recordings that the project team made, an agreement was signed between the team and Transas for the use of the simulation facility.

In order to develop an informative environment, an analysis was carried out by experts from different fields at different stages (trainees, lecturers, experts form maritime administrations, HR of maritime companies, etc.) on how the tasks should be presented and how the trainees as expected to perceive them. The conclusions from the workshops were that it was necessary to visualize several sources for creating a situation as close as possible to the real environment.

Four sources were identified as the main elements of the visualization:

- from bird's-eye view: for an overview of the situation and its development;
- from the bridge: presenting the visualization as the navigational officer would see it during the watch;
- from a radar screen: presenting the situation in progress as observed on the naval radar screen;
- from the screen of an electronic map system: presenting the situation in progress using the data from the AIS system .

While developing visualizations with adequate synchronization, some of the constraints of the simulator had to be overcome, such as: impossibility to record the movement of the ships from bird's-eye view at large distances. This constraint was mainly imposed by the very small size of the ships or their absence from screen over a long period of visualization caused by the need for a high altitude observation point at a distance of more than 6 nautical miles. To solve this problem, additional tasks were developed on the simulator so as to obtain synchronous maneuvering at closer distances only for the needs of the bird's-eye view visualization.

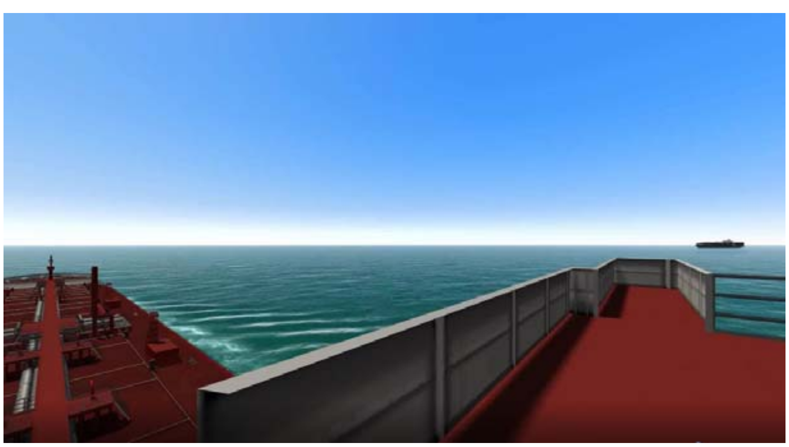

Figure 4 View from bridge

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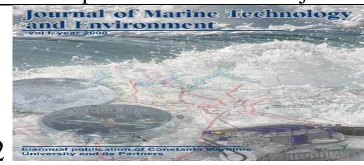


In the course thus developed, the full text of COLREGs is included in six languages, and each of the regulations is clarified in several different situations (over 200 for the whole course), with a description of the situation, a diagram of the situation (Figure 2), three or four visualizations (from bird's-eye view, from the bridge, from the radar screen, and from an electronic map), with high-resolution, all of them time-synchronized and accompanied by a short test to enhance knowledge. This means that the course is situationally based, its main purpose being to acquire knowledge through gaining experience of common problems in practice and handling a large amount of information from different sources.

The main advantage of this kind of learning is the quick and easy access to contents, obtaining current, up-to-date contents, as well as avoiding the need for specialized software or presence at a specific location and time.

The visualization was carried out at the Nikola Vaptsarov Naval Academy, where more than 330 hours of simulations were recorded in more than 257 situations, which, after due processing, were used in the making of the eColregs.com e-learning course [2].

Following the completion of the project, the course was first evaluated for its area and included, as a model e-course, in the system of eLearning Education by the European Commission in the European Union Register, which includes 14 courses in different fields (https://ec.europa.eu/digital-single-market/en/content/avoiding-collisions-sea)[3].

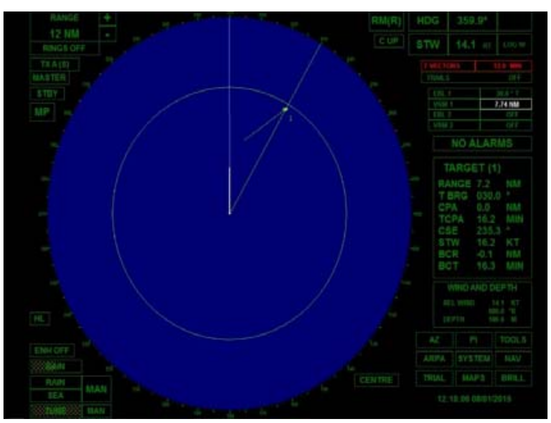


Figure 5 View from radar screen

Figure 5 View from ECDIS

5. CONCLUSIONS

E-learning is one of the most promising aspects of education, especially useful in the maritime field. With the current seafarer dynamics, the use of resources that do not require presence at a specific location will generate a great deal of interest, and the educational institutions will place the emphasis on building online platforms, which will prove to be crucial for their presence on the market.

One of the main advantages of the course presented here, is the large set of situations and the extensive use of a navigation visualization simulator, already recognized in marine training throughout the world, which facilitates easy adaptation to the learning contents. Last but not least, the localization in six different languages should also be pointed out, one of them being Bulgarian.

The further development of the project should involve completing the developed course with situations by including a larger number of ships and combining the application of a larger number of regulations. The added situations will aim to cover common situations in practice

As a suggestion for further development of the training, the introduction of a concept for virtual reality and the addition of 360° visualization should be noted, as well as complementing them with interactive functionalities.

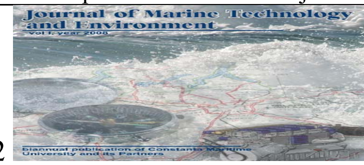
6. REFERENCES

[1] Transas. Maritime simulation & training [Electronic resource]. 2017. URL: http://www.transas.com/products/simulation.

ISSN (Print): 1844-6116
ISSN (Online): 1884-6116 http://www.cmu-edu.eu/jmte

[2] eColreg team. Colreg online course [Electronic resource]. 2017. URL: http://www.ecolregs/com.
[3] Leonardo Programme. Lifelong Learning Programme [Electronic resource]. 2017. URL: http://ec.europa.eu/education/lifelong-learning-programme_en.
[4] Alexandrov, Ch., Kostadinov K., Tsvetkov M. „Applications of TCP/IP based radar-computer interface", International Symposium SIELA '2009, ISBN 978-954323560-5.
[5] Alexandrov Ch., Draganov A., Kostadinov K., Tsvetkov M. A radiolocation image laid over an e-map with application in river and sea navigation, Research Works, Volume 40, series 1.2 Electrical Engineering, Electronics, Automation, Angel Kanchev University of Ruse, Ruse, 2003, ISSN 1311-3321 (in Bulgarian);
[6] Dimitrov D., Implementation of innovative methods for studying COLREG rules, Journal of Marine Technology and Environment, vol. 2, 2014, Constanta Maritime University, Constanta, Romania, ISSN 1884-6116;
[7] Kalinov K., Mednikarov B., Kanev D., Tsvetkov M. and oth. Opportunities for development of the system for maritime education, Nikola Vaptsarov Naval Academy, Varna, Bulgaria, 2015, ISBN 978-954-8991-79-7 (in Bulgarian).
[8] Tsvetkov, M., Alexandrov, Ch. Software simulator of marine monitoring platform, 19th International Symposium on Electrical Apparatus and Technologies, SIELA 2016, p.209-215.

ISSN (Print): 1844-6116
ISSN (Online): 1884-6116 http://www.cmu-edu.eu/jmte



ONE WAY TO PROTECT THE INFORMATION OF THE SHIP'S SENSORY NETWORK FROM EXTERNAL INTERFERENCE AND CYBER ATTACKS

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Abstract: This paper represents a study for information security of ship's navigational sensory network and possibilities for protection of the data streams on it. The current state and future evolution of basic protocols and standards for communication between marine electronic devices are described. It is found, that the data on the ship's sensory network is not protected from cyber-attacks and external interference. An approach is proposed for securing the ship's sensory network using micro-crypto devices for encryption of the navigational data between different sensors, indicators and systems. Every micro-crypto device is consisting of programmable microcontroller, which uses symmetric-key algorithms for encryption/decryption of the data with 128 bits key size. In addition, every micro-crypto device has a unique identification number (ID) and they are programmed to communicate with exactly defined sensors, indicators or systems in the network. The proposed solution falls under the domain of technical information protection measures. The implementation and the use of the proposed cybersecurity solution and increasing of the level of protection of marine navigation information will significantly enhance the safety of navigation and, respectively, the safety of human life at sea.
Key words: Cybersecurity, NMEA Protocol, Ship's sensors, Ship's navigation.

1. INTRODUCTION

Cyber technologies have become a natural complement to the operation and management of a wide range of systems that are part of industrial technology. As they progress, the requirements for maritime transport evolve with emphasis on cost reductions, increased levels of control and environmental measures. In order to meet these requirements, the means of maritime transport are equipped with information and operational technologies, providing constant monitoring and opportunities for timely appropriate action. Much of these technologies are created a few decades ago and they do not equipped with cyber security systems and systems for information protection.

Cyber security in the 21st century is in constant evolution and change to respond to modern threats. The maritime industry is no different from each other and is threatened by cyber-attacks against it.

In December 2013, the steering committees of the EU Council underlined the importance of protecting strategic interests in the field of maritime security against the many available risks and threats. The 2012 EU Limassol Declaration highlighted the "importance of improved maritime management, including more active cooperation".

Despite the absence of attacks with significant effects, the existence of attempts to devastate the maritime industry, confirm the elevated thesis. Data erasure with sensitive and economically valuable information owned by ship owners in Iran and Japan are among the evidence to support this claim.

Cyber-attacks against the maritime industry are taking place at an ever-increasing frequency. However, most of the attacks are unreported or unchecked due to lack of effective control measures, cyber security, and inadequate awareness of the real threats posed by ship owners and crews. Despite the large number of studies showing that the maritime industry is vulnerable, action in this direction is either non-binding or lacking in completeness or efficiency.

The International Safety Management Code (ISM) and the International Ship and Port Facility Security Code (ISPS) do not refer to Cybersecurity measures, but are only relevant to the means of information protection and physical security.

By increasing the capabilities of the information and operational technologies on board a vessel are increasingly interconnected and interdependent on both

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the ships and shore-based control systems. In order to ensure a great level of connectivity, a publicly accessible environment is used, which further creates the conditions for a malicious act.

Analyses indicate that among the potentially vulnerable shipping systems are:

- Navigation systems;
- Systems ensuring management of the loading and unloading activity;
- Machine monitoring systems;
- Power management systems;
- Access control systems;
- Passenger vessel entertainment systems;
- Internet access provision systems;
- Communication systems.

This paper tries to identify the weakness of ship's navigational sensors network and offer a way to protect navigational information.

Nowadays, the bigger part of merchant ships are equipped with at least one navigational sensors or indicators from the following: GPS or DGPS (positioning systems); gyro compass; magnetic compass; log; echo sounder; wind sensor; temperature sensor; ARPA; Radar; AIS receiver; autopilot; rate-of-turn indicator; yeoman; navtex; etc.

They usually communicate with each other using the standard NMEA-2000 or NMEA-0183.

NMEA-0183 description

The National Marine Electronics Association (NMEA) is a non-profit association of manufacturers, distributors, dealers, educational institutions, and others interested in peripheral marine electronics occupations. The NMEA-0183 standard defines an electrical interface and data protocol for communications between marine instrumentation. NMEA 0183 is a voluntary industry standard, first released in March of 1983. It has been updated from time to time [1].

NMEA 0183 devices are designated as either talkers or listeners (with some devices being both), employing an asynchronous serial interface with the following parameters: Baud rate: 4800; Number of data bits: 8 (bit 7 is 0); Stop bits: 1 (or more); Parity: none; Handshake: none

NMEA 0183 allows a single talker and several listeners on one circuit. The recommended interconnect wiring is a shielded twisted pair, with the shield grounded only at the talker. The standard dos not specify the use of a particular connector. There are a 0183-HS standard (HS means high speed) introduced in version 3.0 uses a 3-wire interface and a baud rate of 38400 [1].

All data is transmitted in the form of sentences. Only printable ASCII characters are allowed, plus CR (carriage return) and LF (line feed). Each sentence starts with a "$" sign and ends with <CR><LF>. There are three basic kinds of sentences: talker sentences, proprietary sentences and query sentences [1].

Talker Sentences. The general format for a talker sentence is: $ttsss,d1,d2,....<CR><LF>

The first two letters following the „$" are the talker identifier. The next three characters (sss) are the sentence identifier, followed by a number of data fields separated by commas, followed by an optional checksum, and terminated by carriage return/line feed. The data fields are uniquely defined for each sentence type [1]. A sentence may contain up to 80 characters plus "$" and CR/LF. If data for a field is not available, the field is omitted, but the delimiting commas are still sent, with no space between them. The checksum field consists of a "*" and two hex digits representing the exclusive OR of all characters between, but not including, the "$" and "*" [1].

Proprietary Sentences. The standard allows individual manufacturers to define proprietary sentence formats. These sentences start with "$P", then a 3 letter manufacturer ID, followed by whatever data the manufacturer wishes, following the general format of the standard sentences [1].

Query sentences. A query sentence is a means for a listener to request a particular sentence from a talker. The general format is: $ttllQ,sss,[CR][LF] The first two characters of the address field are the talker identifier of the requester and the next two characters are the talker identifier of the device being queried (listener). The fifth character is always a "Q" defining the message as a query. The next field (sss) contains the three letter mnemonic of the sentence being requested [1].

NMEA-2000 description

NMEA has also established a working group to develop a new standard for data communications among shipboard electronic devices. The new standard, NMEA-2000, is a bi-directional, multi-transmitter, multi-receiver serial data network. It is multi-master and self-configuring, and there is no central controller [1].

In NMEA-2000 the data is shared across all devices; all devices connected to the bus have instant access to all the data on the bus; no multiplexers or buffer amplifiers are required; all devices have electrically isolated interface circuitry; a binary encoded message structure is used, using "PGNs", which are identifiers for data packets sent over the bus; baud rate is 250,000 bits/s [2].

NMEA-2000 is an 'open' network system based on "CAN" bus (Controller Area Network). NMEA-2000 added the following specifics: marine manufacturers collaborated to create an 'open' network environment; data rate of 250 Kbit/s (50x NMEA-0183); standard connectors were specified; isolation in the interfaces was added to prevent ground loops; no need for multiplexers as used in NMEA 0183 – the bus itself is the multiplexer [2];

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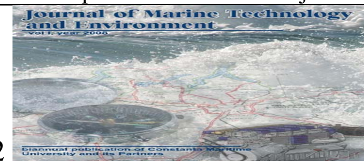

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Gateway Definition: A network gateway is an internetworking device capable of joining together two networks that use different base protocols; a network gateway can be implemented completely in software, completely in hardware, or as a combination of both; because a network gateway, by definition, appears at the edge of a network, related capabilities like firewalls tend to be integrated with it [2].

Description: Just like the general gateways described on above, an NMEA 2000 gateway operates on the edge of the NMEA 2000 network [2].

Certification requirements: As the NMEA 2000 network has specific timing requirements in the Network management layer, it is a requirement that NMEA gateways are provided as certified hardware devices on the bus [2].

Using nonstandard hardware: The requirement for dedicated hardware precludes the use of devices such as Personal Computers using a standard CAN interface to be used directly on the bus as gateways, as the tight timing requirements could not be met [2].

The Gateway operates at the "edge" of the network An NMEA 2000 network will have many edges, where the core network interacts with the outside world in different ways. Typical edges of an NMEA 2000 network are where NMEA 2000 connects to: legacy NMEA networks, e.g. NMEA-0183; analogue sensors – e.g. engines, trim tabs, fuel levels; personal computing devices – directly via USB or via TCP/IP over Ethernet or Wi-Fi.

NMEA OneNet

In recent years, there are initiative for creation of a new standard for communication between ship's navigational sensors, indicators and systems. The name of the new standard is NMEA OneNet. The idea is to provide transport of standard NMEA-2000 messages using standard ethernet protocol in a common non-proprietary format.

The OneNet development committee comprises 25 manufacturer members of NMEA. OneNet committee members are representatives of manufacturers of ship's radioelectronic equipment like: Airmar, Garmin, Furuno, KVH, Flir, Mercury Marine, Navico, Actisense, Hemisphere GPS, Offshore Systems, Digital Yacht, Humminbird, Fugawi, Azimut, etc. In addition, in OneNet committee are represented and US Coast Guard, Microsoft, Cisco and NMEA [4]. OneNet has support from the US Coast Guard, Canadian Coast Guard and by Radio Technical Commission for Maritime Services (RTCM). International Electrotechnical Commission (IEC) has not yet declared a position on OneNet but have expressed interest.

Advantages of NMEA OneNet Network. An NMEA-2000 network has a capacity for 50 devices, whereas an OneNet Network has capacity for more than 65,000 devices which will meet future integration demands for many more interconnections and bandwidth. OneNet will supports high bandwidth applications such as video, using standard Ethernet video protocols. OneNet data rate is 100 Megabits to 10 Gigabits (from 400 to 40,000 times faster than NMEA 2000). OneNet will continue to advance with the evolution of Ethernet based applications and supports the most current networking innovations by Internet architects. OneNet will evolve with the onset of higher speed physical cables such as fiber optics [3].

Figure 1 Cyber security awareness

2. THE PROBLEM

As can be seen from the above, the ship's sensory network and the information flowing on it is not protected from external interference and manipulation. On the other hand, there are still no assigned persons on-board of the merchant ships which to be responsible for information security and the protection of critical information resources such as data on the ship's sensory network. The continued delay of the implementation of administrative and technical measures to protect critical shipboard information may affect over safety of navigation and the protection of human life at sea. Recently, in various international conferences connected with the subject of this article was introduced the possibility of application of ISO 27000 for shipboard information protection.

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3. OUR APPROACH

Based on cyber security awareness shown on figure 1, we propose a decision in domain of technical measures to protect the informational streams in ship's sensory network, connected with safety of navigation and the protection of human life at sea.

It is proposed to implement a low-coast system for increasing confidentiality, by encrypting the navigational information and ensuring the identity of sensors, indicators and users in ship's sensory network. The system is based on micro-crypto devices, connected directly to input and output ports of the navigational sensors and systems in one side and to NMEA-2000 network in opposite side.

Micro-crypto devices can be powered directly from the NMEA-2000 network or via autonomous adapters connected to the ship's power supply. Each micro device has its own unique identification number (ID) and is programmed to work with specific micro-crypto devices by programming their unique ID numbers in its BIOS. Example of implementation of the idea is shown on Figure 2.

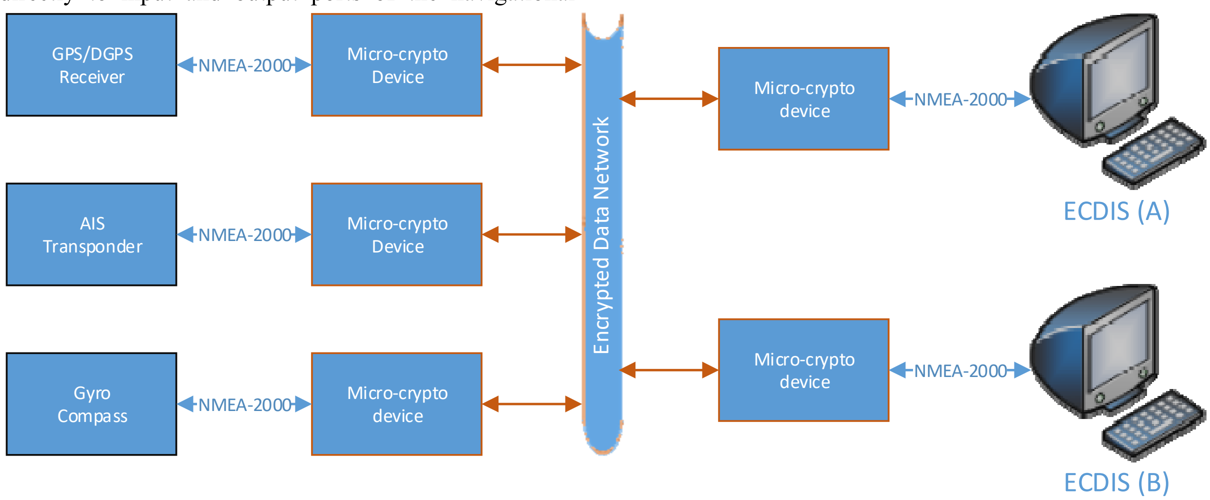

Figure 2 Example of implementation of the micro-crypto devices over ship's navigational sensory network

The micro-crypto devices are consist of programmable micro-processors, supported RS-232 and CAN bus communication protocols [9, 10, 11]. Micro-processors will be programed to use symmetric-key algorithms for encryption and decryption of the data streams. Symmetric-key algorithms are algorithms for cryptography that use the same cryptographic keys for both encryption and decryption. The keys may be identical or there may be a simple transformation to go between the two keys. The keys, in practice, represent a shared secret between two or more parties that can be used to maintain a private information link. This requirement that both parties have access to the secret key is one of the main drawbacks of symmetric key encryption, in comparison to public-key encryption (also known as asymmetric key encryption) [6]. Symmetric-key encryption can use either stream ciphers or block ciphers. Stream ciphers encrypt the digits (typically bytes) of a message one at a time. Block ciphers take a number of bits and encrypt them as a single unit, padding the plaintext so that it is a multiple of the block size. Blocks of 64 bits were commonly used. The Advanced Encryption Standard (AES) algorithm approved by NIST in December 2001, and the GCM block cipher mode of operation use 128-bit blocks. Examples of popular symmetric algorithms include: Twofish, Serpent, AES (Rijndael), Blowfish, CAST5, Kuznyechik, RC4, 3DES, Skipjack, Safer+/++ (Bluetooth), and IDEA [6, 7].

Symmetric-key algorithms require both the sender and the recipient of a message to have the same secret key. All early cryptographic systems required one of those people to somehow receive a copy of that secret key over a physically secure channel. This can be done from the operator [6]. Nearly all modern cryptographic systems still use symmetric-key algorithms internally to encrypt the bulk of the messages, but they eliminate the need for a physically secure channel by using Diffie–Hellman key exchange or some other public-key protocol to securely come to agreement on a fresh new secret key for each message (forward secrecy) [6]. When used with asymmetric ciphers for key transfer, pseudorandom key generators are nearly always used to generate the symmetric cipher session keys. However, lack of randomness in those generators or in their initialization vectors is disastrous and has led to cryptanalytic breaks in the past. Therefore, it is essential that an implementation uses a source of high entropy for its initialization [6].

4. CONCLUSIONS

Cyber-attacks are constantly evolving. It is absolutely necessary to protect ship's navigational sensory network and information streams on it. The presented approach is useful, low-cost decision, for securing the navigational data on board of the ship. The solution is to use different keys to encode the different data channels. For example, for data stream in channel GPS-ECDIS(A) to use one key, for data stream in channel GPS-ECDIS(B) to use another key, etc. If the key size is 128 bits, the number of alternative keys will be 3.4×1038, and average time required for exhaustive key search at one decryption will be 5.4×1024 years [8].

5. REFERENCES

[1] The NMEA 0183 Protocol, National Marine Electronics Association: http://www.nmea.org
[2] Actisense, NMEA Gateway session, NMEA Conference&Expo, San Diego, 2013
[3] OneNet Summary for NMEA Board of Directors Steve Spitzer, Technical Director, July, 2013
[4] https://www.nmea.org/Assets/2014%20onenet%20committee%20list.pdf
[5] https://www.storagecraft.com/blog/5-common-encryption-algorithms/
[6]https://en.wikipedia.org/wiki/Symmetric-key_algorithm
[7] Contel Bradford, 5 Common Encryption Algorithms and the Unbreakables of the Future, https://www.storagecraft.com/blog/5-common-encryption-algorithms/
[8] William Stallings, Cryptography and network security principles and practice, 5th edition, ISBN10:0-13-609704-9
[9] Sivkov, Y.A., Kostadinov K.G., Tsvetkov M., A system for transmitting and receiving data from self-floating platforms with sensors, Nikola Vaptsarov Naval Academy, Varna, Integrated Coastal Zone Management through establishment of an integrated informational system, 2016, ISBN 978-954-8991-89-6, pp. 89 - 96.
[10] Sivkov, Y.A., Kostadinov K.G., Tsvetkov M., An Approach for data collection from sensors in self-floating platform, Varna, Nikola Vaptsarov Naval Academy, Integrated Coastal Zone Management through establishment of an integrated informational system, 2016, ISBN 978-954-8991-89-6, pp. 97 - 101.
[11] Kostainov K., Aleksandrov Ch., Sivkov Y. Web Services for Maritime Applications, Collection of scientific reports dedicated to the 105th anniversary of the pioneers of computer equipment John Atanasov and John von Neumann, Konstantin Preslavsky Uniersity of Shumen, 2009, ISBN 987-954-577-539-0

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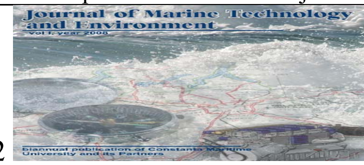

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ONE APPROACH FOR INTEGRATION AND VISUALIZATION OF MARINE AND AIR TRAFFIC DATA IN COMMON GIS

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Abstract: This paper represents a study on the possibilities for integration marine and air traffic data into a common geographic information system (GIS) display in the interest of better monitoring and management of transborder transport corridors. The maritime automatic identification system (AIS) technology, the automated reporting system for aviation transport (Automatic dependent surveillance – Broadcast, ADS-B) technology and the corresponded data transmition protocols are presented and analysed.

***Key words*:** AIS, ADS-B, NMEA, Marine, Air, Traffic,GIS

1. INTRODUCTION

The Automatic Identification System (AIS) is a system for the exchange of information between ships. Vessels, equipped with AIS automatically share and regularly updated information about their position, course, speed, and its identification with other ships that have the necessary equipment [1].

In the early 90s the International Association of Lighthouses services and navigational aids (International Association of Lighthouse Authorities, IALA) initiated a discussion of the possibility of using transponders for transmitting identification signals in VHF.

The use of the Automated Identification System (AIS) functionalities in the navigation systems provides many benefits both for coastal services ensuring shipping safety in coastal areas and ports, as well as for ship's crews.

The information exchanged in the AIS system can be divided into four categories: static data, dynamic data, voyage-related data and shipping safety information (safety - related data).

Static information includes: Vessel identification given in 4 fields as follows: Name, Call Sign, IMO number, Maritime Mobile Number; Maritime Mobile Service Identification number (MMSI); Dimensions of the ship (Length and Beam); Position of the receiving antenna of the used navigation system (position-fixing antenna); Vessel type.

Dynamic information includes: Ship's Position with Accuracy Indication; Universal Time Coordinated, UTC; Course Over Ground, COG; Speed Over Ground, SOG; Heading; Navigational Status; Rate Of Turn, ROT.

Voyage-related data includes: Draught; Hazardous cargo, Type; Destination and ETA; Route Plan.

Regardless of the type, the information in the AIS system is exchanged in the form of messages with a certain content and volume. 24 different types of messages are used, and three are in test period. Examples of raw, parsed and decoded AIS data messages is shown on Figures 1, 2 and 3.

Table 1. Types of AIS messages

AIS message	Usage
1, 2, 3: Position Report Class A	Reports navigational information
4: Base Station Report	Used by base stations to indicate their presence
5: Static and Voyage Related Data	Gives information on a ship and its trip
6: Binary Addressed Message	An addressed point-to-point message with unspecified binary payload.
7: Binary Acknowledge Message	Sent to acknowledge the reception of a message 6
8: Binary Broadcast Message	A broadcast message with unspecified binary payload.
9: Standard Search and Rescue Aircraft Position Report	Used when an airplane is lost at sea.
10: UTC/Date Inquiry	Obtain time and date from a base station
11: Coordinated universal time/date response	Response from message 10
12: Addressed Safety-Related Message	Used to send text messages to a specified vessel
13: Safety related acknowledge	Response from message 12

AIS message	Usage
14: Safety related broadcast message	Identical to message 12, but broadcast
15: Interrogation	Used by a base station to get the status of up to 2 other AIS devices
16: Assigned mode command	Used by a base station to manage the AIS slots
17: Global navigation-satellite system broadcast binary message	Used by a base station to broadcast differential corrections for GPS
18: Standard class B equipment position report	A less detailed report than types 1-3 for vessels using Class B transmitters
19: Extended class B equipment position report	For legacy class B equipment
20: Data link management message	Used by a base station to manage the AIS slots
21: Aids-to-navigation report	Used by an (AtN) aid to navigation device (buoys, lighthouse)
22: Channel management	Used by a base station to manage the VHF link
23: Group assignment command	Used by a base station to manage other AIS stations
24: Static data report	Equivalent of a Type 5 message for ships using Class B equipment
25: Single slot binary message	Used to transmit binary data from one device to another
26: Multiple slot binary message with communications state	Used to transmit binary data from one device to another
27: Long-range automatic identification system broadcast message	This message is used for long-range detection of AIS Class A and Class B vessels (typically by satellite).

```
!AIVDM,1,1,,B,14`Uu5P0262CEB@H9iGqhoml06RH,0*33,9/3/2017 8:38:45 PM
!AIVDM,1,1,,A,B01vlOP008P@sm6:5M003wtUkP06,0*5F,9/3/2017 8:38:45 PM
!AIVDM,1,1,,A,142Lcr0PAa2784jH?9NWUn5n0@R:,0*40,9/3/2017 8:38:45 PM
!AIVDM,1,1,,B,15U3sL00001w?v:Hf3;7:;=l08R=,0*6B,9/3/2017 8:38:45 PM
!AIVDM,1,1,,B,13Q;7D001vR5g6lGdd@uoc7n2D7h,0*2D,9/3/2017 8:38:45 PM
!AIVDM,1,1,,A,13<@T<001fR53FBH>UbMac?j0<4T,0*00,9/3/2017 8:38:47 PM
!AIVDM,1,1,,B,335RIB00001wirTHe`fS`Rsh202P,0*71,9/3/2017 8:38:47 PM
!AIVDM,1,1,,B,1:0Nup801U28GabG`gtSARen0D4a,0*29,9/3/2017 8:38:47 PM
!AIVDM,1,1,,B,15V6EL101@28BcjG`GPCBRcp0`Rm,0*66,9/3/2017 8:38:47 PM
!AIVDM,1,1,,B,19NSCjPvh3R5PdvGe<in`Usn0<4k,0*23,9/3/2017 8:38:47 PM
!AIVDM,1,1,,A,4h1vGRQv6AIW01wrldHdnlA026RL,0*0A,9/3/2017 8:38:47 PM
!AIVDM,1,1,,A,19NWu=@0262=4DPH4:D9TWcn0p0@,0*21,9/3/2017 8:38:47 PM
!AIVDM,1,1,,A,13U7I2001RR<j`0H2FR9M7al00SP,0*29,9/3/2017 8:38:47 PM
!AIVDM,1,1,,B,13b`Jj001k26i9THGflP@P@2080K,0*3E,9/3/2017 8:38:47 PM
!AIVDM,1,1,,A,15@4fV001K27iGDGW<bCKjb20@0a,0*2E,9/3/2017 8:38:48 PM
!AIVDM,1,1,,B,14akwn0008244FtGfcPccQMp0D7A,0*47,9/3/2017 8:38:48 PM
!AIVDM,1,1,,A,3815>B@0j:205fPHe0aDol9n00w0,0*20,9/3/2017 8:38:48 PM
!AIVDM,1,1,,A,401vl8iv6AIW1Qwh6tHeGdW00@0t,0*27,9/3/2017 8:38:48 PM
!AIVDM,1,1,,A,13ku8f001gR>DHNH5cCalWP42L8`,0*7C,9/3/2017 8:38:48 PM
!AIVDM,1,1,,A,13lol60wRhR5EUvH>wT=ebv420Se,0*18,9/3/2017 8:38:48 PM
```

Figure 1 Raw AIS messages

!AIVDM	215521000	1				ADELINA	Position Report Class A (Scheduled)
!AIVDM	477631300	1				TIGER NORTH	Position Report Class A (Scheduled)
!AIVDM	677075500	1				SELIM 1	Position Report Class A (Scheduled)
!AIVDM	538005065	1				SEDEF	Position Report Class A (Scheduled)
!AIVDM	636016319	1				ADASTAR	Position Report Class A (Scheduled)
!AIVDM	248961000	1				TURKAN SAYLAN	Position Report Class A (Scheduled)
!AIVDM	256767000	1				HUNGARY	Position Report Class A (Scheduled)
!AIVDM	271043022	3				DUZGIT ENDEAVOUR	Position Report Class A (Special)
!AIVDM	002070819	20					Data Link Management
!AIVDM	002070819	20					Data Link Management
!AIVDM	353852000	1				MSC ANNAMARIA	Position Report Class A (Scheduled)
!AIVDM	538006996	1				HELEN M	Position Report Class A (Scheduled)
!AIVDM	538003910	1				GAS GROUPER	Position Report Class A (Scheduled)
!AIVDM	538003910	1				GAS GROUPER	Position Report Class A (Scheduled)
!AIVDM	273420740	1				VIZANTIN	Position Report Class A (Scheduled)
!AIVDM	312338000	1				ABK TRADER	Position Report Class A (Scheduled)
!AIVDM	207133000	1				AGAMEMNON	Position Report Class A (Scheduled)

Figure 2 Parsed AIS messages

Description	Value	Value Description
Creation Time Local	03/09/2017 23:40:37	
Creation Time Unix UTC	1504471237	03/09/2017 20:40:37
Nmea Sentence	!AIVDM,1,1,,B,14`Uu5P	
Received Time UTC	03/09/2017 20:38:45	1504471125
Talker	AI	Mobile class A or B
Sentence	VDM	AIS VHF data-link message
AIS Sentence	!AIVDM	Mobile class A or B
Fragments in this message	1	
Fragment No	1	
Sequential Message ID		(blank)
Radio Channel	B	
Payload	14`Uu5P0262CEB@H9	168 bits (28 6-bit words)
Fill bits	0	
CRC check	33	
AIS Payload	14`Uu5P0262CEB@H9	168 bits (21 8-bit words)
Vessel Name	AFRICAN RAPTOR	
AIS Message Type	1	Position Report Class A (Scheduled)
Repeat Indicator	0	Repeatable
MMSI	311000342	
MID	311	Bahamas (Commonwealth of the)
Navigation Status	0	Under way using engine (Rule 23(a) or Rule 25(e))
Rate of Turn (ROT)	0	0°/min
Speed Over Ground (SOG)	13.4	Knots
Position Accuracy	0	low (>10m)(default)
Longitude	32.1853	32° 11.118' E
Latitude	42.2099	42° 12.592' N
Course Over Ground (COG)	249.9	° (degrees)
True Heading (HDG)	250	° (degrees)
Time Stamp	58	Second of UTC timestamp
Manoeuvre Indicator	0	not available (default)
Spare	0	3 bits
RAIM Flag	0	RAIM not in use
Communication	0	SOTDMA
Sync State	0	UTC Direct
Slot Time-out	1	Slots Left
Hour UTC	20	
Minute UTC	38	

Figure 3 Decoded AIS message

Automatic dependent surveillance – broadcast (ADS–B) is a surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it, enabling it to be tracked. The information can be received by air traffic control ground stations as a replacement for secondary radar. It can also be received by other aircraft to provide situational awareness and allow self-separation [2, 3].

ADS-B provides many benefits to both pilots and air traffic control that improve both the safety and efficiency of flight [2, 3].

Traffic – When using an ADS-B In system, a pilot is able to view traffic information about surrounding aircraft if those aircraft are equipped with ADS-B out. This information includes altitude, heading, speed, and distance to aircraft. In addition to receiving position reports from ADS-B out participants, TIS-B [USA-only] can provide position reports on non ADS-B out-equipped aircraft if suitable ground equipment and ground radar exist. ADS-R re-transmits ADS-B position reports between UAT and 1090 MHz frequency bands [4, 5, 6].

Weather – Aircraft equipped with universal access transceiver (UAT) ADS-B In technology will be able to receive weather reports, and weather radar through flight information service-broadcast (FIS-B) [4, 5, 6];

Flight information – Flight information service-broadcast (FIS-B) also transmits readable flight information such as temporary flight restrictions (TFRs) and NOTAMs to aircraft equipped with UAT [4, 5, 6];

Expense - ADS-B ground stations are significantly cheaper to install and operate compared to primary and secondary radar systems used by ATC for aircraft separation and control [4, 5, 6];

Squitter (DF-11)

The structure of the common data transmission protocol in the "from air to ground" direction, also called "Downlink Format" 11 is shown on Table 2 [7, 8, 9].

Table 2. ADS-B Structure of Downlink Format (DF-11)

DF	CA	AA	PI

The "response" message according to the general data transmission protocol in the direction of "from air to land" consists of 56 bits, such as:

Table 3: Response message (DF-11)

Abbreviation	Description	Bits	Start-End Bits
DF	Downlink Format	5	1-5
CA	Capability (additional identifier)	3	6-8
AA	ICAO aircraft address	24	9-32
PI	Parity/Interrogator ID	24	33-56

Extended squitter (DF-17)

Extended squitter format messages from the ADS-B Extended Automatic Identification System have a fixed length of 112 bits. Each message consists of five main parts, shown in the corresponding sequence on Table 4.

Table 4: ADS-B „Extended squitter format" (DF-17)

DF	CA	AA	ME	PI

Compared to the DF-11 format, the DF-17 contains an additional sequence of 56 bits, positioned immediately after the bits showing the address section.

Table 5. Response message (DF-17)

Abbreviation	Description	Bits	Start-End Bits
DF	Downlink Format (17)	5	1-5
CA	Capability (additional identifier)	3	6-8
AA	ICAO aircraft address	24	9-32
ME	**Data payload**	**56**	**33-88**
[TC]	**Type code**		**[33-37]**
PI	Parity/Interrogator ID	24	89-112

Description of sequence fields.

DF: The field consists of 5 bits and shows the number or the type of the transmitted message, respectively. Coded according to the distribution shown in Figure 4 [14, 15, 16].

The figure shows that the total number of message types is 24, of which 14 are reserved for use in a special regime, including for military use.

CA: The field consists of 3 bits. It serves to identify the level of technical capabilities of the transponder installed on the aircraft. Coded according to the distribution shown on Table 6, using the data transmission formats DF-11 and DF-17.

When the conditions for CA code 7 are not satisfied, aircraft with Level 2 or above transponders:

a) that do not have automatic means to set the on-the-ground condition shall use CA code 6; and

b) with automatic on-the-ground determination shall use CA code 4 when on the ground and 5 when airborne.

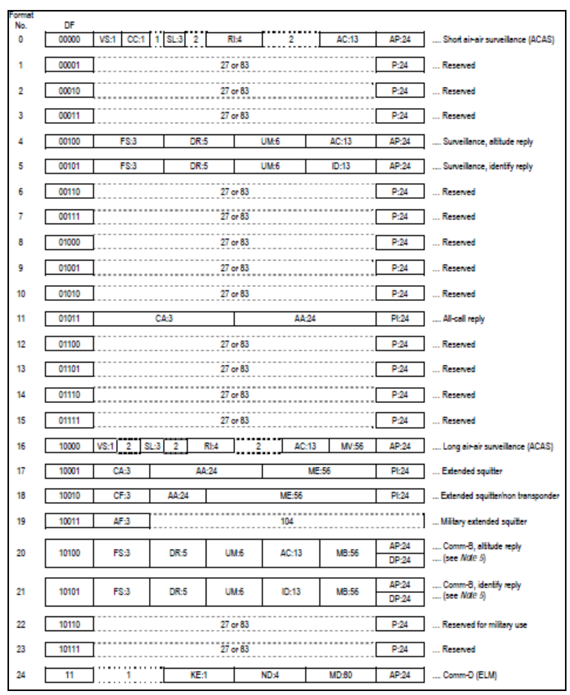

Figure 4 Codes, structure and description of "downlink format (DF)" messages

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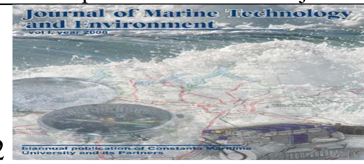

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Table 6. CA field codes

„0“ signifies Level 1 transponder (surveillance only), and no ability to set CA code 7 and either airborne or on the ground
„1“ reserved to maintain backward compatibility
„2“ reserved to maintain backward compatibility
„3“ reserved to maintain backward compatibility
„4“ signifies Level 2 or above transponder and ability to set CA code 7 and on the ground
„5“ signifies Level 2 or above transponder and ability to set CA code 7 and airborne
„6“ signifies Level 2 or above transponder and ability to set CA code 7 and either airborne or on the ground
„7“ signifies the DR field is not equal to 0 or the FS field equals 2, 3, 4 or 5, and either airborne or on the ground

AA: The field consists of 24 bits (from number 9 to 32) and contains the address (s) of the aircraft that must provide its unambiguous identification. This is usually the aircraft number of the International Civil Aviation Organization (ICAO).

PI: The field consists of 24 bits (from number 33 to number 56 or from number 89 to 112). The message must contain information about the respondent. The verification bits are combined with address encoding or encrypting the identifier of the requester. The resulting combination then forms the "parity identifier" field. Used in Mode S, All-Call Response, DF-11 and DF-17 or DF-18.

ME: Additional bits are designed to transmit the so-called "Broadcast messages".

The 56-bit (33-88) field (DF = 17) of the extended message is used to transmit data that must support registers 05, 06, 07, 08, 09, 0A {HEX} and 61-6F {HEX}, as well as the message formats version 0, version 1 or version 2.

Version 0. The extended message format and related requirements provide information on the quality of the observed data through the navigation uncertainty category (NUC), which may be an indicator of the accuracy or integrity of the data used by ADS-B. However, there is no indication as to which of these NUC values are indicated and transmitted.

Version 1. The format of the extended message and its related requirements provide information on the accuracy and integrity of the survey separately: navigation accuracy category (NIC), navigation integrity category (NIC) and surveillance integrity level (SIL).

Version 2. The format of the extended version 2 release and its associated requirements contain the provisions of version 1 but additionally puts requirements to improve integrity and parameter reporting. In version 2 of the expanded message, the data integrity of the location / position data source data integrity is considered separately from the integrity of the ADS-B transmission equipment. Version 2 also verifies vertically the accuracy and horizontal accuracy of location determination as well as additional GNSS / GPS antenna spacing data. Version 2 also refines the data to include the selected altitude, the selected position, and the Barometric Pressure Sensor setting.

Guidance material and specifications for transponder register formats and data sources are outlined in "Technical Provisions for Mode S Services and Extended Squitter". The formation and characteristics of ADS-B messages are shown on Figure 5.

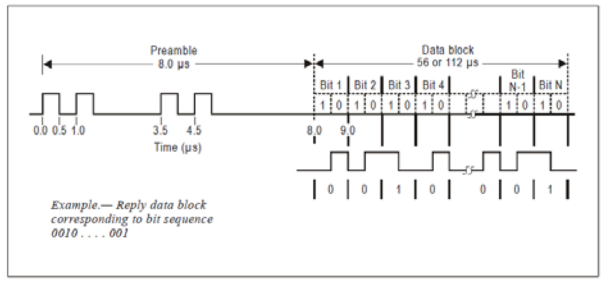

Figure 5 Characteristics of ADS-B messages

Examples of decoded ADS-B messages are shown on Table 7.

Table 7. Decoded ADS-B messages

MSG,5,,,896385,,,,,,,39000,,,,,,,,,
MSG,6,,,3C6498,,,,,,,,,,,,7713,0,0,0,0
MSG,6,,,89639A,,,,,,,,,,,,7647,0,0,0,0
MSG,5,,,896385,,,,,,,39000,,,,,,,0,0,0,0
MSG,3,,,896385,,,,,,,39000,,,43.54478,27.77723,,,0,0,0,0
MSG,4,,,06A095,,,,,,,,454,155,,,0,,0,0,0,0
MSG,3,,,8963D7,,,,,,,35000,,,43.24456,27.80685,,,0
MSG,4,,,3C6DCF,,,,,,,,456,126,,,0,,0,0,0,0
MSG,4,,,896385,,,,,,,,489,121,,,0,,0,0,0,0
MSG,5,,,3C6DCF,,,,,,,32975,,,,,,,,,
MSG,3,,,89639A,,,,,,,41000,,,43.31877,27.83872,,,0,0,0,0
MSG,3,,,3C6DCF,,,,,,,32975,,,43.19939,28.11848,,,0,0,0,0
MSG,4,,,89639A,,,,,,,,499,125,,,0,,0,0,0,0
MSG,3,,,06A095,,,,,,,31000,,,43.14136,28.11166,,,0,0,0,0
MSG,6,,,8963D7,,,,,,,,,,,,7111,0,0,0,0
MSG,6,,,06A095,,,,,,,,,,,,5402,0,0,0,0
MSG,6,,,3C6DCF,,,,,,,,,,,,7662,0,0,0,0
MSG,3,,,8963D7,,,,,,,35000,,,43.24333,27.80946,,,0,0,0,0
MSG,3,,,896385,,,,,,,39000,,,43.54358,27.77989,,,0,0,0,0
MSG,4,,,06A095,,,,,,,,454,155,,,0,,0,0,0,0
MSG,3,,,40058C,,,,,,,39000,,,43.09476,28.43785,,,0,0,0,0
MSG,6,,,8963D7,,,,,,,,,,,,7111,0,0,0,0
MSG,4,,,3C6DCF,,,,,,,,456,126,,,0,,0,0,0,0
MSG,4,,,896385,,,,,,,,489,121,,,0,,0,0,0,0
MSG,3,,,89639A,,,,,,,41000,,,43.31760,27.84092,,,0,0,0,0

2. OUR APPROACH

Using decoded data streams from real hardware AIS and ADS-B receivers we prepare a software module for processing, merging and visualizing the data in real time in common geographical information system on single display. The basic algorithm is shown on Figure 6.

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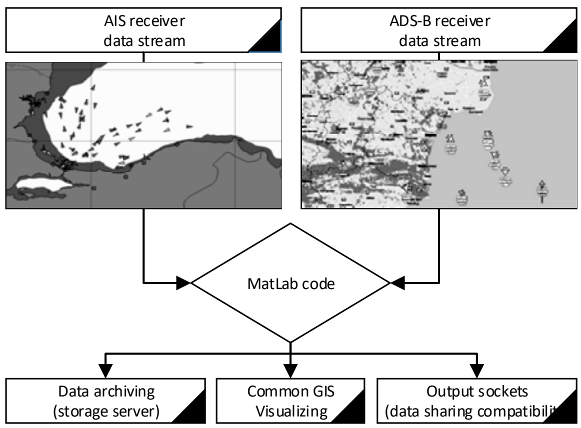

Figure 6 Basic algorithm for integration and visualization of marine and air traffic data in common GIS

3. CONCLUSIONS

The research study reviews and analyses the current state of the AIS and ADS-B systems and the possibilities of integrating different types of information in the form of an information layers to the common geographical information system [13].

For integration of AIS and ADS-B data in a real-time, was used 162.025 MHz AIS receiver and 1090 MHz ADS-B receiver, as well as own build software application in MatLAb [10, 11].

In addition, the proposed approach has capabilities to manage output sockets to share the data streams [12] and archives the data after compressing in data storage server.

4. REFERENCES

[1] Alexandrov Ch., Surveillance Sensors in Vessel Traffic Management and Information Systems, Monography, Varna, 2017, ISBN 978-619-7428-00-1;

[2] Junzi Sun, ADS-B Decoding Guide, Release 0.3, 2016;

[3] Automatic dependent surveillance-broadcast will transform air traffic control, Technical White Paper – ADS-B (AT), Honeywell Aerospace;

[4] Aeronautical Telecommunications, Volume IV, Surveillance and Collision Avoidance Systems, Annex 10 to the Convention on International Civil Aviation, Fifth Edition, July 2014, International Civil Aviation Organization;

[5] Greg Dunstone, Surveillance Program Lead, Airservices Australia, ADS-B Introduction;

[6] Lima, Peru, Guide on technical and operational considerations for the implementation of ADS-B in the SAM region, International Civil Aviation Organization, South American Regional Office;

[7] Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B);

[8] Surveillance and Broadcast Services Description Document, SRT-042, Rev. 01, FAA, USA, 2011;

[9] TERMS OF REFERENCE, Special Committee (SC) 186, Automatic Dependent Surveillance Broadcast (ADS-B), Revision 17;

[10] Sivkov, Y.A., Kostadinov K.G., Tsvetkov M., A system for transmitting and receiving data from self-floating platforms with sensors, Nikola Vaptsarov Naval Academy, Varna, Integrated Coastal Zone Management through establishment of an integrated informational system, 2016, ISBN 978-954-8991-89-6, pp. 89 – 96;

[11] Sivkov, Y.A., Kostadinov K.G., Tsvetkov M., An Approach for data collection from sensors in self-floating platform, Varna, Nikola Vaptsarov Naval Academy, Integrated Coastal Zone Management through establishment of an integrated informational system, 2016, ISBN 978-954-8991-89-6, pp. 97 – 101;

[12] Kostainov K., Aleksandrov Ch., Sivkov Y. Web Services for Maritime Applications, Collection of scientific reports dedicated to the 105th anniversary of the pioneers of computer equipment John Atanasov and John von Neumann, Konstantin Preslavsky Uniersity of Shumen, 2009, ISBN 987-954-577-539-0;

[13] Dachev Uri, Maritime charts, Steno, Varna, 2017, ISBN 978-954-449-910-5;

[14] https://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/;

[15] https://en.wikipedia.org/wiki/Automatic_identific-ation_system;

[16] https://en.wikipedia.org/wiki/Automatic_depen-dent_surveillance_%E2%80%93_broadcast.

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DESIGNING THE SCREW-NUT ASSEMBLY ON A COMPUTER-AIDED RATCHET PRESS

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Abstract: By introducing the Mathcad software in design of machine is made interactive and easier data processing. In application created can be modified easily input data to obtain more rapid project results.
The main source of AutoCAD is the ability to develop specialized applications running in the same graphical environment. The market for software developers under AutoCAD environment is immense. Basically, any care theme involves designing and finding somewhere more or less elaborate.
This paper proposes the design of the screw-nut assembly to a ratchet press with Mathcad and AutoCAD software.

Key words : autocad software*,* mathcad program, screw-nut assembly, ratchet press.

1. INTRODUCTION

Raising the technical and qualitative level of production and products is a major objective in the broad integration policy of the European Union. This has led to the emergence of a diverse range of products that are increasingly performing and competitive.

In industry, especially in the machine building industry, the most recent and most important discoveries of science and technology are related to increasing the complexity of the machines to increase their value and to optimally use the productive potential.

The precision of the machine depends on the precision of the components, the precision of their installation and adjustment works, and the way the maintenance and repair works are organized and carried out.

To increase machine performance, builders are trying to increase their performance and power. Each piece that is part of the assembly is calculated, drawn and simulated working conditions with specialized programs.

Finally, that piece is made that will have to work in optimal conditions within that system. This operation involves moving in contact with other parts, under certain conditions of speed, power and efficiency.

This paper proposes the design of the screw-nut assembly to a ratchet press with Mathcad and AutoCAD software.

The Mathcad interface allows users to combine a variety of different elements (mathematics, descriptive text, and supporting imagery) into the form of a worksheet, which is naturally readable. Because the mathematics are core to the program, the math is inherently live, dynamically recalculating as upstream values are altered. This allows for simple manipulation of input variables, assumptions, and expressions, which in turn update in real-time.

AutoCAD, created by Autodesk, is the most widespread program for drawing technical drawings anywhere in the world. According to Autodesk, CAD is the acronym for "computer-aided design", but also for "computer-aided drafting" or "drawing".

2. DESIGNING THE RATCHET PRESS MOTION MOVEMENT SCREW

2.1. Technical specifications of the ratchet press

Consider a ratchet press with the following technical caracteristics:

- → The maximum applied force $F = 12000\,N$
- → The maximum travel for the screw $H = 170mm$
- → External span of the press $D = 170mm$

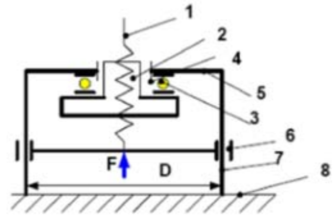

Figure 1 Scheme of the ratcheting press

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In the Figure 1:

1. Screw
2. Rotating nut
3. Axial ball bearing
4. Ratchet device
5. Actuation mechanism
6. Pressure plate
7. Column
8. Base plate

2.2. Choosing the materials for Screw and Nut

The screw is made out of steel (subjected to full annealing) with the following mechanical
Characteristics:

Yielding Strength: $\sigma_c = 410 N/mm^2$

Ultimate strength: $\sigma_r = 630 \div 800 N/mm^2$

σ_r - has a value in between 630 and 800 $\mathrm{N/mm^2}$since several test pieces were tested having diameters

$d = 16 \div 40mm$

This type of steel is our first choice since its yielding strength is high enough for the screw to resist to all the loads susceptible to appear during functioning. In order to have $\sigma_c = 410 N/mm^2$ the screw after machining is quenched and annealed.

The nut is made of antifriction grey cast iron with the following mechanical proprieties:

- Bending strength: $\sigma_i = 390 N/mm^2$ (minimum);
- Compression strength: $\sigma_{comp} = 880 N/mm^2$
- Young modulus: $E = 2.1 \cdot 10^5 MPa$.

This type of grey cast iron is used mainly for its content in platlike graffite good for enabling it to resist wear.

2.3. The diagrams of loads in the main components of the press

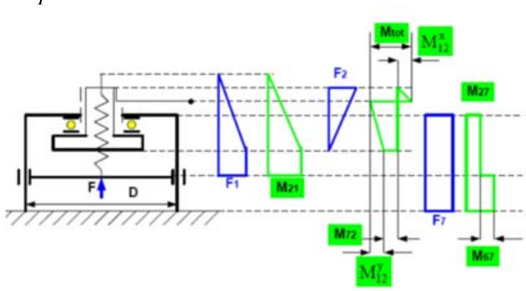

Figure 2 The diagrams of loads in the main components of the press

$F_1 = F_2 = F_7 = F$

$M_{21} = M_{67}$

$M_{12} = M_{12}^x + M_{12}^y$

$M_{tot} = M_{12} + M_{72}$

$M_{72} = M_{\text{roll bearing}}$

2.4. Choosing the type of threat

We'll choose the ACME screw thread for its combination of strength and rigidity and an acceptable efficiency (just 4-5% lesser that that of the square thread). This type of thread is allowing the control of the axial clearance due to wear and its manufacturing price is low.

2.5. Pre-dimensioning of the screw

The Pre-Dimensioning of the screw is done out of the condition to resist to the combined loads.

This type of dimensioning is taking into account the following types of loads:

The compression load where the load is a calculation-load

$$F_c = \gamma \cdot F \tag{1}$$

Where:

F - is the real load action on the screw (project input data) and

$\gamma (\gamma > 1)$ is a correction factor taking into account the torsion load

We'll choose γ =1,2 in order to have a conservative approach:

$$A_{nec} = \frac{F_c}{\sigma_a} = \frac{\gamma \cdot F}{\sigma_a} = \frac{\pi d_3^2}{4} \tag{2}$$

$$\Rightarrow \quad d_3 = \sqrt{\frac{4\gamma \cdot F}{\pi \cdot \sigma_a}} \tag{3}$$

Where:

$$\sigma_a = \frac{\sigma_c}{c_c}; \tag{4}$$

d_3 – is the inner diameter of the screw;

σ_a – allowable strength to compression;

σ_c – yielding strength;

c_c – safety factor for yielding.

For pre-dimensioning the safety factor (c_c) may be big enough in order to ensure the resistance to buckling and a reasonable amount of fillets in contact.

We will have $c_c = 3$, as an

Intermediate value.

It is also recommended

$\sigma_a = (0.25 \div 0.4)\sigma_c$ for d_3< 30 mm.

$F_c = 1.2 \cdot 12{,}000 = 14{,}400 N$

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$$\sigma_a = \frac{410}{3} = 136.666 N/mm^2$$

$$d_3 = \sqrt{\frac{4 \cdot 14{,}400}{3.14 \cdot 136.666}} = 11.583mm$$

Now bearing in mind that in real world the types of loads can be of various types, we will choose

$d_3 = 15.5mm$

We'll derive the main dimensions of the Tr 15.5 × 4 thread type as:

- Inner diameter: $d_3 = 13.5mm$
- Nominal diameter: $d = 20mm$
- Medium nominal diameter: $d_2 = 18mm$
- Pitch: $p = 4mm$

$$H_1 = 0.5 \cdot p = 2mm$$
$$D_1 = d - P = 16mm$$
$$a_c = 0.25mm$$
$$D_4 = d + 2a_c = 20.5mm$$
$$R_{1\max} = 0.5 \cdot a_c = 0.125mm$$
$$H_4 = h_3 = H_1 + a_c = 2.25mm$$
$$R_{2\max} = a_c = 0.5mm$$
$$\alpha = 30°$$

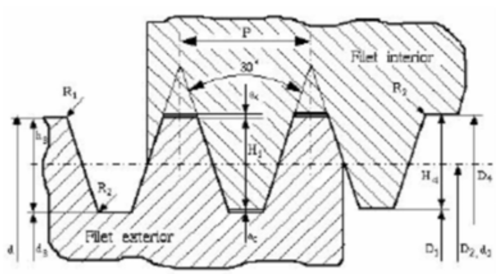

Figure 3 Trapezoidal threat

2.6. Checking the self-blocking condition

In the manual actuated mechanical systems is preferred that the self-blocking to be ensured by the thread itself. In general, the threads are ensuring the self-blocking when the angle of the thread (ψ) is smaller than the friction angle (φ') $\psi \leq \varphi$ ', where:

$$tg\psi = \frac{p}{\pi \cdot d_2} \tag{5}$$

$$tg\varphi' = \mu' = \frac{\mu}{\cos\frac{\alpha}{2}} \tag{6}$$

In which:

α - Angle of the thread profile;

μ - The friction coefficient depending on the combination of the materials for screw-nut, surfaces roughness and the lubrication.

In our specific case the materials combination of screw-nut is steel-grey iron so that $\mu = 0.08 \div 0.18$.

For the worst case scenario we'll choose $\mu = 0.08$.

$$\left.\begin{array}{ll} tg\psi = \dfrac{4}{3.14 \cdot 18} = 0.071 & => \quad \psi = 4.061° \\ tg\varphi' = \dfrac{0.08}{\cos 15°} = 0.082 & => \quad \varphi' = 4.734° \end{array}\right\}$$

$\Rightarrow$ $\psi < \varphi'$, So that the self –blocking condition Condition is satisfied

2.7. Checking the buckling behavior

The buckling scheme is given in the figure below (the screw is deemed to be with fixed ends to both sides) since the nut will have enough fillets and a clearance enough small to approximate that the screw is fixed inside the nut.

Figure 4 The buckling scheme

The same approximation goes for the connection between screw and the pressure plate. In order to be conservative we will take $l_c = 1.35 \cdot H = 270mm$.

This calculation crew length comprises the contact zone between nut and screw.

In general, for screws used in transmissions is mandatory to conduct a buckling check since buckling is a major failure mode that may happen in functioning.

The first step is to calculate the slenderness ratio with the following formula:

$$\lambda = \frac{l_f}{i_{\min}}, \tag{7}$$

Where:

l_f - is the buckling length

$$l_f = K \cdot l, \tag{8}$$

l - is the length of the screw,

K - is a coefficient depending on the buckling scheme (K=2 if the lifted load is prone to move horizontally and K=0.5 if the screw is deemed fixed inside the lifted load).

$I_{\min}$ – minimum inertia radius is:

$$i_{\min} = \sqrt{\frac{I_{\min}}{A}} = \sqrt{\frac{4\pi d_3^4}{64\pi d_3^2}} = \frac{d_3}{4}. \tag{9}$$

Knowing the slenderness ratio one may calculate the buckling domain:

if $\lambda \geq \lambda_0$ - then buckling is within elastic range

if $\lambda < \lambda_0$ - is within plastic range

The coefficient λ_0 for normal steel is:

λ_0= 105 (OL 37)

λ_0 = 89 for higher strength steels (OL 50 and OL 60).

Generally for steels

$$\lambda_0 = \sqrt{\frac{\pi^2 \cdot E}{\sigma_p}} \tag{10}$$

Where:

$E = 2.1 \cdot 10^5 MPa$ is the Young modulus

and $\sigma_p \cong 0.8 \cdot \sigma_{02}$

Is proportionality limit (the strength which is limiting the proportionality domain of the test piece subjected to normal loads where the load is proportional with the displacement of the test-piece).

If $\lambda < 20$

Then it is impossible to have buckling $\lambda \geq 250$

The buckling is more than sure to happen.

The stress developed during buckling is depending on the buckling domain:

• When buckling is within elastic range, as per Euler formula $\lambda \geq \lambda_0$

$$\sigma_f = \frac{F_f}{A} = \frac{\pi^2 E I_{\min}}{l_f^2 A} \tag{11}$$

and taking into account

$$\lambda^2 = \frac{A l_f^2}{I_{\min}} \tag{12}$$

Will result

$$\sigma_f = \frac{\pi^2 E I_{\min}}{\lambda^2} \tag{13}$$

• Within plastic range, $\lambda < \lambda_0$

The stress to which the screw will support buckling is given by the following relations

$\sigma_f = 310 - 1.14 \cdot \lambda$ - for soft steels OL 37;

$\sigma_f = 335 - 0.62 \cdot \lambda$ - for hardened stee

Generally, for any other types of steels to which the yielding strength for compression loading is equal to that for traction loading:

$$\sigma_f = \sigma_{02} - \left(\sigma_{02} - \sigma_p\right)\left(\frac{\lambda}{\lambda_0}\right) \cdot 2 = \sigma_{02}\left[1 - 1.2\left(\frac{\lambda}{\lambda_{02}}\right) \cdot 2\right] \tag{14}$$

The safety coefficient for buckling is:

$$c = \frac{\sigma_f}{\sigma_c} \geq c_a \tag{15}$$

Where:

c_a - is the allowable safety coefficient for buckling;

$c_a = 3...6$ - for elastic domain

$c_a = 2...4$ - for plastic domain.

When buckling is unavoidable the pre-dimensioning may be done directly by considering this type of phenomena:

$$d_3 = \sqrt{\frac{64 \cdot c_a \cdot F \cdot l_f^2}{\pi^3 \cdot E}} \tag{16}$$

And choosing the standard thread dimensions.

In this case $c_a = 8...8$

Proceeding to our press project, the slenderness ratio λ is:

$$\lambda = \frac{l_f}{i_{\min}} \tag{17}$$

Where:

$l_f = 0.5 \cdot l_c = 114.75mm$ - is the buckling length

$i_{\min} = \sqrt{\frac{I_{\min}}{A}} = 3.875mm$ - is the minimum inertia radius

For an conservative approach

$$A = \frac{\pi d_3^2}{4} = 188.692mm^2$$

$$i_{\min} = \frac{\pi \cdot d_3^4}{64} = 2.833 \cdot 10^3 mm^4$$

That is

$$\lambda = \frac{114.75}{3.875} = 29.613 < 85 = \lambda_0 \quad \Rightarrow$$

So that the buckling will happen within the plastic

Domain and for the steel we considered we have ($\lambda_0 = 85$)

We will calculate the safety buckling coefficient (C_f)

$$C_f = \frac{F_f}{F} \geq C_{fa} \tag{18}$$

Where:

C_{fa}= 3 ÷ 5 is the allowable safety coefficient and

$F_f = \sigma_f \cdot A$ is the critical load for buckling

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$$\sigma_f = a - b \cdot \lambda \tag{19}$$

Where:
a= 449 N/mm^2 and
b =1.67 N/mm2

$$\sigma_f = a - b \cdot \lambda = 449 - 1.67 \cdot 29.613 = 399.546 MPa$$

$$\Rightarrow F_f = 399{,}546 \cdot 188{,}692 = 7.539 \cdot 10^4$$

$$c_f = \frac{7.539 \cdot 10^4}{12000} = 6.283 > 3 = C_{fa}$$

⇒ The screw will resist buckling

2.8. Calculation of the Number of Fillets for Nut

The calculation for the minimum number of fillets of the nut results from the condition of wear resistance.

For low speed actuators the first parameter, which influences the wear intensity, is the contact pressure between screw-nut spires. In the hypothesis of uniform distribution of load on each and every fillet and neglecting the thread angle, one may use the relation:

$$z = \frac{F}{\frac{\pi}{4}\left(d^2 - D_1^2\right) \cdot \sigma_{as}} \tag{20}$$

Where:
σ_{as} - is the allowable contact pressure

For the combination of materials in question (steel-grey iron) the allowable contact pressures
Are σ_{as}= 10 ÷ 15 MPa.
We will pick σ_{as}= 13 MPa.

$$\Rightarrow z = \frac{12000}{\frac{3.14}{4}\left(20^2 - 16^2\right) \cdot 13} = 8.162$$

We will choose $z = 9$ taking into account a small clearance between screw and nut/spire

2.9. Checking the Fillet of Screw

Modeling the fillet of screw as a one end fixed beam, the resulting loads acting upon the fillet will be bending and shearing. Since both loads types are determining stresses in the fixed end area, the combined effects of the two loads are to be considered for both screw fillet and nut fillet.

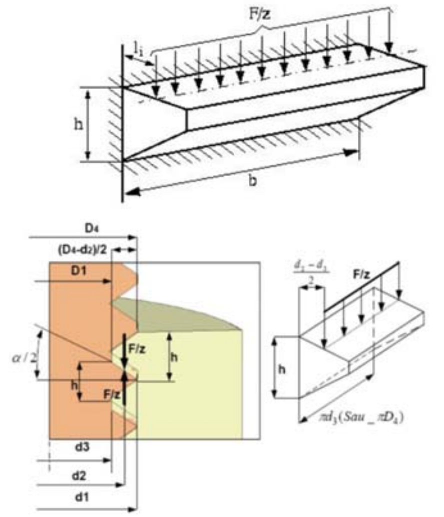

Figure 5 Calculation model

a) Checking the Nut:

- Bending load:

$$\sigma_i = \frac{M_i}{W} = \frac{\frac{F}{z} \cdot l_i}{W} \tag{21}$$

$$l_i = \frac{H_1}{2} + a_c \tag{22}$$

$$\Rightarrow l_i = \frac{2}{2} + 0.25 = 1.25 mm$$

$$W = \frac{\pi D_4 \left(\frac{p}{2} + 2 l_i \cdot tg15°\right)^2}{6} \tag{23}$$

$$\Rightarrow W = \frac{3.14 \cdot 10.5 \left(\frac{4}{2} + 2 \cdot 1.25 \cdot 0.267\right)^2}{6} = 39.099$$

$$\Rightarrow \sigma_i = \frac{\frac{12000}{9} \cdot 1.25}{39.099} = 42.636 N/mm^2$$

- Shearing load:

$$\tau_f = \frac{\frac{F}{zKm}}{A} \tag{24}$$

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$$A = \pi D_4\left(\frac{p}{2} + 2l_i tg15°\right) \quad (25)$$

$$A = 3.14 \cdot 10.5\left(\frac{4}{2} + 2 \cdot 1.25 \cdot 0.267\right) = 171.947mm^2$$

K_m =0.55 ÷ 0.75 is the correction factor taking into account the non-uniform distribution of stresses.

We will pick K_m =0.6 in order to be conservative resulting thus

$$\Rightarrow \tau_f = \frac{\frac{12000}{9 \cdot 0.6}}{171.947} = 12.924N/mm^2$$

The equivalent stress may be calculated using an equivalency stress theorem:

$$\sigma_{ech} = \sqrt{\sigma_i^2 + 4\tau_f^2} \le \sigma_a \quad (26)$$

Where:

$$\sigma_a = \frac{\sigma_r}{c_r} \quad (27)$$

for grey iron $\sigma_r = 250N/mm^2$

and $c_r = 2.5 \div 5$

We will pick $c_r = 5$ for the worst scenario.

$$\sigma_r = \frac{250}{5} = 50N/mm^2$$

$$\Rightarrow \sigma_{ech} = \sqrt{21.783^2 + 4 \cdot 12.984^2} = 33.802 \le 50 = \sigma_a$$

=> So that the nut fillets are resisting combined stresses

b) Checking the Screw

- Bending load:

Replace the formulas (21), (22) and (23)

$$\Rightarrow l_i = 1.25mm$$

$$\Rightarrow W = \frac{3.14 \cdot 15.5\left(\frac{4}{2} + 2 \cdot 1.25 \cdot 0.267\right)^2}{6} = 57.719$$

$$\Rightarrow \sigma_i = \frac{\frac{12000}{9} \cdot 1.25}{57.719} = 28.875N/mm^2$$

- Shearing load:

Replace the formulas (24) and (25)

$$\Rightarrow A = 130.009mm^2$$

$$\Rightarrow \tau_f = 17.093N/mm^2$$

The equivalent stress may be calculated using an equivalency theorem

$$\sigma_a = \frac{\sigma_c}{c_c} \quad (28)$$

For steel $\sigma_c = 430N/mm^2$

and $c_c = 1.5 \div 3$

We will pick $c_c = 3$ for the worst scenario.

Replace the formulas (26) and (28)

$$\Rightarrow \sigma_a = \frac{430}{3} = 143.33N/mm^2$$

$$\Rightarrow \sigma_{ech} = \sqrt{28.975^2 + 4 \cdot 17.093^2} = 40.536 \le 143.33 = \sigma_a$$

=> so that the screw fillets are resisting combined stresses.

2.10. *Preliminary Design of the Screw and Nut*

The nut has the role to support the load coming from the screw via the fillets. The load is then transmitted from nut to columns via an axial roll bearing in order to have a better efficiency. To the upper part of the nut, we will have the Ratchet device actuating the nut. In out constructive solution the ratchet gear is independent for the nut.

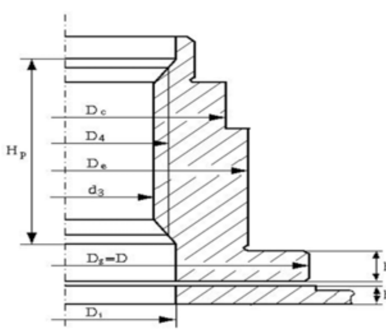


Figure 6 The structural elements of the nut

a) Nut

The height of the nut is calculated with

$$H_p = z \cdot p + \Delta \quad (29)$$

Where:

Δ=5mm - is the dull edge of the nut fillet so that

$$\Rightarrow H_p = 9 \cdot 4 + 5 = 41mm$$

Since during rotating the nut the torque M21 is generated and tends to rotate the screw, in order to prevent this, a blocking pin is deployed. The designing process of the nut starts from inner side to the outer side.

The inner minimum diameter ($D_{i\,min}$) of the unthreaded part of the nut has to ensure the free motion of the screw so that:

$D_{i\,\min} = d = 20mm$

We will pick D_i= 22 mm.

For the outer area of the nut, the outer diameter (D_c) corresponds to the mounting area between nut and the ratchet gear where the developed loads are traction and twisting.

Let us consider the calculating force:

$F_c = \gamma \cdot F$ - formula (1)

where γ is a factor counting for twisting effects. Making γ = 1,2 we will have:

$F_c = 1.2 \cdot 12{,}000 = 14{,}400N$

$$A = \frac{\pi}{4}\left(D_c^2 - D_4^2\right) = \frac{F_c}{\sigma_{at}} \tag{30}$$

Where:

$$\sigma_{at} = \frac{\sigma_r}{c_r} \tag{31}$$

and $c_r = 5 \div 6$

for grey iron we will pick $c_r = 5.5$

$$\Rightarrow \sigma_a = \frac{250}{5.5} = 45.454MPa$$

$$D_{c\,\min} = \sqrt{\frac{4\gamma F}{\pi \cdot \sigma_{at}} + D_4^2} \tag{32}$$

$$\Rightarrow D_{c\,\min} = \sqrt{\frac{4 \cdot 1.2 \cdot 12000}{3.14 \cdot 45.454} + 20.5^2} = 28.699mm$$

We will pick

$D_c = 38mm < D_e = 45mm$

after which from standards we will choose the right axial ball bearing which should have $C_0 \geq$ F and d $\geq D_{e\,\min}$, where C_0 is the static loading capacity of the bearing and F is the axial load. For the given case, the ball bearing will have the dimensions (out from the standards):

$d = 45mm$

$D = 85mm$

$D_1 = 52mm$

$T = 18mm$

$r = 1mm$

$C_0 = 62$

The nut collar supports bending loading and shearing as well.

The height of the collar (h_g) may be calculated considering the bending loads only with a conservative selection of the allowable stress σ_{ai}. Using a similar model we have:

$$W_{\min} = \frac{\pi D_e h_g^2}{6} = \frac{M_i}{\sigma_{ai}} \tag{33}$$

Where:

$$\sigma_{ai} = \frac{\sigma_r}{c_r} \tag{34}$$

for grey iron $c_r \approx 5$

$$\Rightarrow \sigma_a = \frac{250}{5} = 50N/mm^2$$

$$M_i = F\frac{D_G - D_e}{4} \tag{35}$$

$$\Rightarrow M_i = 12000\frac{85-45}{4} = 120{,}000N \cdot mm$$

$$h_{g\,\min} = \sqrt{\frac{6 \cdot M_i}{\pi \cdot D_e \cdot \sigma_{ai}}} \tag{36}$$

$$\Rightarrow h_{g\,\min} = \sqrt{\frac{6 \cdot 12000}{3.14 \cdot 45 \cdot 50}} = 7.047mm$$

We will choose $h_g = 12mm$

The height h_f is calculated considering the contact pressure. Since the torque loading the assembly is $M_t = 0.5 \cdot M_{12} = 8{,}355N \cdot mm$ where M_{12} is the friction torque between screw-nut fillets.

We may adopt

$\sigma_{as} \approx 20 \div 40MPa$ (for mobile contact)

$$\varphi' = arctg\mu' = arct\left(\frac{\mu}{\cos\frac{\alpha}{2}}\right) \tag{37}$$

Where $\alpha = 30°$

$$M_{12} = F \cdot \frac{d_2}{2} \cdot tg(\psi + \varphi') \tag{38}$$

$$M_{12} = 12000 \cdot \frac{18}{2} \cdot tg(4.061° + 4.734°) = 1.671 \cdot 10^4 N \cdot mm$$

$$W_{\min} = \frac{\pi \cdot D_e \cdot h_f^2}{6} = \frac{M_t}{\sigma_{as}} \tag{39}$$

$$\Rightarrow h_f = \sqrt{\frac{6 \cdot M_t}{\pi \cdot D_e \cdot \sigma_{as}}} \tag{40}$$

Where σ_{as}= 30MPa

$$\Rightarrow h_f = \sqrt{\frac{6 \cdot 1.671 \cdot 10^4}{\pi \cdot 55 \cdot 30}} = 3.438mm$$

We pick $h_f = 5mm$

b) Screw

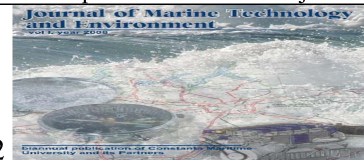
We estimate the total minimum length of the threaded portion of the screw as:

$$L_f = H_p + H \tag{41}$$

Where:

a) H –the imposed maximum travel

b) H_p – the previously calculated portion of the screw which is inside the nut



c) $L_{f\,min} = 41 + 200 = 241$ mm.
We pick $L_f = 260mm$

Since the screw is not supposed to rotate at its lower end there is a hole for a pin.

3. MATHCAD SOFTWARE APPLICATION FOR DESIGNING THE SCREW-NUT ASSEMBLY

The calculation program MATHCAD initial design data is entered. Enter formulas and standards chosen dates thereafter. The program calculates and generates results.

MATHCAD application program looks like this:

Introduce your data in the yellow fields

Pre-dimensioning of the screw

VARIABLE

$F := 12000$

$\gamma := 1.2$

$\sigma c := 410$

FORMULAS

$Fc := F \cdot \gamma$

$$\sigma a := \frac{\sigma c}{3}$$

$$d3 := \sqrt{\frac{4 \cdot Fc}{\pi \cdot \sigma a}}$$

REZULTS

$Fc := 1.44 \cdot 10^4$

$\sigma a := 136.667$

$d3 := 11.583$

Checking the self-blocking condition

VARIABLE

$\mu := 0.08$

$$\alpha := \frac{\pi}{6}$$

$p := 4$

$d2 := 18$

FORMULAS

$$\psi := a\tan\left(\frac{p}{\pi \cdot d2}\right)$$

$$\phi := a\tan\left(\frac{\mu}{\cos\left(\frac{\alpha}{2}\right)}\right)$$

REZULTS

$\tan\psi := 0.071$

$\tan\phi := 0.083$

$\psi := 4.061$

$\phi := 4.734$

Checking the buckling behavior

VARIABLE

$H := 170$

$d3 := 15.5$

$E := 2.1 \cdot 10^3$

$F := 12000$

$a := 449$

$b := 1.67$

FORMULAS

$$i\min := \frac{d3}{4}$$

$$A := \frac{\pi \cdot d3^2}{4}$$

$$I\_\min := \frac{\pi \cdot d3^4}{64}$$

$lc := 1.35 \cdot H$

$$lf := \frac{lc}{2}$$

$$\lambda := \frac{lf}{i\min}$$

$\sigma f := a - b \cdot \lambda$

$Ff := \sigma f \cdot A$

$$cf := \frac{Ff}{F}$$

REZULTS

$i\min := 3.875$

$A := 188.692$

$I\_\min := 2.833 \cdot 10^3$

$lc := 229.5$

$\lambda := 29.613$

$\sigma f := 399.546$

$Ff := 7.539 \cdot 10^4$

Calculation of the Number of Fillets for Nut

VARIABLE

$d := 20$

$D1 := 16$

$\sigma as := 13$

$F := 12000$

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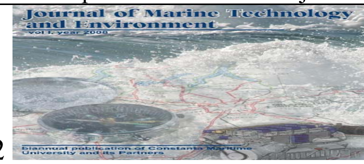

FORMULAS

$$z := \frac{F}{\frac{\pi}{4}\left(d_2 - D_1^2\right)\sigma as}$$

REZULTS

$z := 8.162$

We will choose z=9 taking into account a small clearance between screw and nut/spire

Checking the Fillet of Screw

VARIABLE

$H1 := 2$

$z := 9$

$D4 := 20.5$

$p := 4$

$Km := 0.6$

$\sigma r := 250$

$CT := 5$

$d3 := 15.5$

$\sigma c\_steel := 430$

$Cc := 3$

$F := 12000$

FORMULAS

$$li := \left(\frac{H1}{2}\right) + ac$$

$$W := \frac{\pi D4\left(\frac{p}{2} + 2 \cdot li \cdot \tan\left(\frac{\pi}{12}\right)\right)^2}{6}$$

$$\sigma i := \frac{\frac{F}{z} \cdot li}{W}$$

$$Aria := \pi D4\left(\frac{p}{2} + 2 \cdot li \cdot \tan\left(\frac{\pi}{12}\right)\right)$$

$$\tau f := \frac{\frac{F}{z \cdot Km}}{Aria}$$

$$\sigma ech := \sqrt{\sigma_i^2 + 4 \cdot \tau_f^2}$$

$$\sigma a := \frac{\sigma f}{CT}$$

$$Wscrew := \frac{\pi d3\left(\frac{p}{2} + 2 \cdot li \cdot \tan\left(\frac{\pi}{12}\right)\right)^2}{6}$$

$$\sigma i := \frac{\frac{F}{z} \cdot li}{W}$$

$$Aria := \pi D4\left(\frac{p}{2} + 2 \cdot li \cdot \tan\left(\frac{\pi}{12}\right)\right)$$

$$\tau f\_screw := \frac{\frac{F}{z \cdot Km}}{Aria\_screw}$$

$$\sigma ech\_screw := \sqrt{\sigma_{i\_screw}^2 + 4 \cdot \tau_{f\_screw}^2}$$

$$\sigma a\_steel := \frac{\sigma c\_steel}{Cc}$$

REZULTS

$li := 1.5$

$W := 140.025$

$\sigma i := 23.805$

$Aria := 254.294$

$\tau f := 14.565$

$\sigma ech := 37.619$

$\sigma a := 50$

$\sigma ech < \sigma a$ so that the nut fillets are resisting combined stresses

$W\_screw := 105.733$

$\sigma i\_screw := 31.526$

$Aria\_screw := 192.018$

$\tau f\_screw := 19.288$

$\sigma ech\_screw := 49.82$

$\sigma a\_steel := 143.333$

$\sigma ech\_screw < \sigma a\_steel$ so that the screw fillets are resisting combined stresses

Preliminary Design of the Screw and Nut

VARIABLE

$\Delta := 5$

$\gamma := 1.2$

$z := 9$

$p := 4$

$F := 12000$

$\sigma r := 250$

$Crl := 5$

$D4 := 20.5$

$d2 := 18$

$\tan\_\Sigma\_\angle = \tan(a + b)$

$\sigma as := 30$

$Dc := 50$

$Dg := 70$

$De := 55$

$H := 200$

$Hp := 50$

$hg := 10$

$Lf\,\min := 250$

FORMULAS

$$Hp = z \cdot p + \Delta$$

$$Fc := F \cdot \gamma$$

$$\sigma at := \frac{\sigma r}{Cr}$$

$$Dc\min := \sqrt{\frac{4\gamma F}{\pi \sigma at} + D_4^2}$$

$$\sigma ai := \frac{\sigma r}{Crl}$$

$$Mi := \frac{Dg - De}{4}$$

$$hg\,\min := \sqrt{\frac{6Mi}{\pi De \sigma ai} + D_4^2}$$

$$M12 := F\left(\frac{d2}{2}\right)\tan\_\Sigma\_\angle$$

$$Mt := \frac{M12}{2}$$

$$hf := \sqrt{\frac{6Mt}{\pi De \sigma as}}$$

$$Lf\,\min := H + Hp$$

REZULTS

$Dc\min := 35.672$

$hg\,\min := 7.217$

$Hp := 50$

$Fc := 2.4 \cdot 10^4$

$Mi := 7.5 \cdot 10^4$

$M12 := 3.393 \cdot 10^4$

$hf := 4.431$

$hg := 10$

$Lf := 261$

$\sigma ai := 50$

4. DESIGN OF SCREW-NUT ASSEMBLY WITH THE AUTOCAD PROGRAM ASSISTANCE

In the current stage of the evolution of informatics, a polarization of the fields of activity is increasingly being observed. Thus, we can see the formation of specialized groups in databases, multimedia, network/ communications / system applications, DTP, CAD and so on.

AutoCAD, created by Autodesk, is the most widespread program for drawing technical drawings anywhere in the world. According to Autodesk, CAD is the acronym for "computer-aided design", but also for "computer-aided drafting" or "drawing".

The first version of AutoCad, running under MS-DOS, was launched on the market in 1982. AutoCad was the first noteworthy CAD program to run on an office computer. At that time, most of the other drawing programs were running at high-performance workstations.

The success of AutoCad has been attributed to its renowned architecture and the existence of programming languages (such as AutoLISP and Visual Basic for Applications) designed specifically for the end user to be able to program in AutoCad.

As a result, AutoCad is the most flexible design software available, which can be applied in all areas of activity. Support provided by AutoCad turns it into a program that does not face serious competition outside of the United States. Therefore, AutoCad is used in all disciplines in over 150 countries.

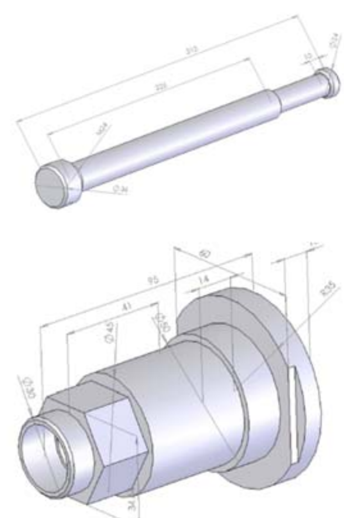

Figure 7 Screw and nut generated in CAD

5. CONCLUSIONS

By introducing the Mathcad software in design of machine is made interactive and easier data processing. In application created can be modified easily input data to obtain more rapid project results.

Engineering graphics has been and remains a fundamental area of engineering knowledge. The representation of the ideas for solving the main solutions of the designed parts and assemblies is one of the most important tasks of the designer. The importance of design as an effective means of communicating information is universally recognized at all stages of the design and manufacturing process. The ability to use this ability by the computer, a revolutionary way they are used today in all areas.

The present paper realise the design by using Mathcad and AutoCAD software of screw-nut assembly for a ratchet press.

6. REFERENCES

[1] Ciortan S., Bologa O., Ioniță B., *Mathcad, proiectare interactivă*, Ed. Zigotto, Galați, 2003.

[2] Drăghici I. ş.a., *Îndrumar de proiectare în construcţia de maşini,* Vol. I,II Editura Tehnică,1982, 1983.

[2] Gafiţanu M. ş.a., *Organe de maşini*, Vol I,II, Ed. Tehnică, 1982, 1983.

[3] Pavelescu D. ş.a., *Organe de maşini,* Ed. Didactică şi Pedagogică Buc., 1986.

[4] Rădulescu Gh. ş.a., *Îndrumar de proiectare în construcţia de maşini,* Vol. III Editura Tehnică.

[5] Zidaru N., *Transmisii mecanice,* Ed. Printech, Bucureşti, 2004.

[6] T9 - Maritime and Coastguard Agency (MCA), Code of Safe Working Practices for Merchant Seamen, London. The Stationery Office Publications Centre, Consolidated Edition, 2009 (ISBN 9780115530784)

[7] T13-Pritchard, R.T. Technician Workshop Processes and Materials. London, Hodder and Stoughton, 1979 (ISBN 0-34022-100-3) OUT OF PRINT, 1999

[8] Machines elements-CAD Induction/ Organe de Masini-Elemente de proiectare asistata de calculator/-Ediţie bilingva engleza-romana-2013-Editura Nautica-Ioan Calimanescu , Lucian Grigorescu, Viorica Popa.

[9] http://en.wikipedia.org/wiki/Matchcad

[10] http://en.wikipedia.org/wiki/AutoCAD

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EVALUATING THE IMPACT OF MARPOL SULFUR EMISSIONS CONTROL REGULATIONS ON EUROPEAN SHORT SEA SHIPPING

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Abstract: Short sea shipping industry of the European Union is a vital part of the European transportation networks. The present article analyses the recent trends in the development of European short sea shipping (SSS) and the economic impact of Annex VI of Marpol Convention regarding regulations on sulphur emission control. The IMO and the EU regulations related to sulphur emissions control have been studied in detail to outline the main issues concerning the feasibility of regulations compliance. The results from the empirical data analyses have shown that European SSS shipowners and operators have several alternatives in order to abide by these regulations. Compliance with regulations leads to higher operating costs that impede the competitiveness and further development of the industry.

Key words: maritime transportation, short sea shipping, Marpol Annex VI, sulphur emissions control in shipping.

1. INTRODUCTION

European short sea shipping industry has undergone significant changes during the last three decades. The latter are the outcome of increased competition, specific policies and regulations and stakeholders' response to environmental regulations. As per MARPOL, Annex VI, and EU Directive 2012/33/EU, limits on sulfur oxides (SOx) emissions from ships exhausts are imposed. The present paper analyses the effect on European short sea shipping of the available options for shipowners in compliance with sulfur emissions control regulations. Specific study has been carried out on the basis of empirical data and data available from EU projects reports on this matter. The results prove that any of the adopted options, in compliance with MARPOL Annex VI, are either highly intensive as investment or lead to loss of competitiveness and loss market share for the European short sea shipping shipowners operators. The higher operating costs will inevitably result in modal shift to road transport and potentially decrease the growth rate of the European short sea shipping industry.

2. SHORT SEA SHIPPING IN EUROPE: ISSUES AND CHALLENGES

European short sea shipping (SSS) has undergone significant changes during the last three decades. The latter are the outcome of increased competition, specific policies and regulations and stakeholders' response to environmental regulations.

According to the officially adopted definition SSS is "the movement of cargo and passengers by sea between ports situated in geographical Europe or between those ports and ports situated in the non-European countries having a coastline on the enclosed seas bordering Europe". SSS consists of several sub-groups: carriage of containerized or non-containerized cargo, passengers, feeder services, cabotage, etc. The main purpose of the European SSS policy is to promote shifting from road to multimodal transportation involving maritime transport to allow for decreased environmental impact of transportation. The volume of good transported between main EU-28 ports and Mediterranean ports amounted to 577 million tons in 2015. This accounts for about 29% of the total SSS tonnage declared by the main EU-28 ports (Figure 1). SSS within the North Sea and the Baltic Sea followed, with 506 and 421 million tons, respectively (22% and 26% of the total).

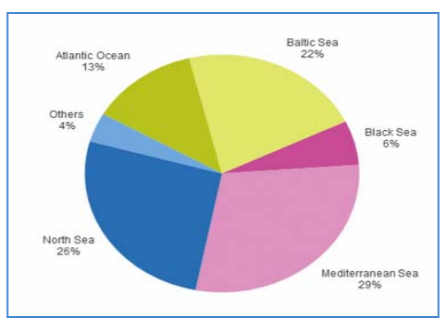

Figure 1. EU-28 Short Sea Shipping of goods by sea region in 2015 (% of total gross weight of goods) [12]

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SSS volumes have reached significant figures during the last decades. Figure 2 presents the share of SSS of total maritime transport of goods in EU in 2015. The share of SSS services in the EU represents 60% on the average of all maritime transport of goods. However, the share of SSS in total maritime transport varies widely between countries. For instance, SSS is predominant (over 80%) in Cyprus, Latvia, Ireland, Bulgaria, Denmark, Croatia, because of countries' geographical positions. Same refers to countries where transshipment points of large volume of feeder services are present, for example Malta. The share of SSS is less than 60% in Belgium, Germany, Portugal, Slovenia, Spain and the Netherlands where major ports are situated and are centers of intercontinental trade.

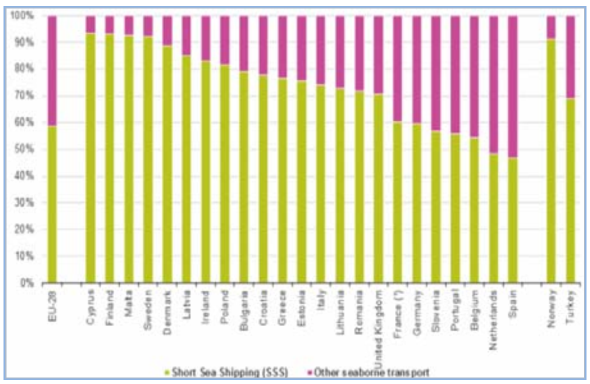

Figure 2 Share of Short Sea Shipping (SSS) of goods in total sea transport in 2015 (in % of total gross weight of goods transported) [12]

Despite the positive development of SSS, the modal split trends have remained stable [12]. The share of SSS is still lower than that of road transport by about 18% of total ton/km of freight transportation within EU (Figure 3).

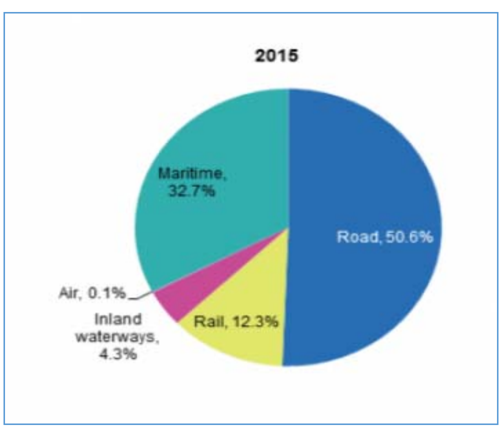

Figure 3 Freight transport in the EU-28 modal split based on five transport modes (% of total t/km) [12]

New infrastructure and technological development of existing infrastructure elements are to be implemented to cope with the expected increase of intra-European SSS and make SSS more attractive. Following this point of view, SSS shall be an important factor in order to meet the objectives set forth in 2011 by the EU White Paper on transport policy – to decrease the importance of road transport and achieve balance between different modes of transport. In 1995 the European Commission announced its Communication on SSS [12]. The EU White Paper of 2001 defined SSS as an important alternative to road transport [3]. The EU White Paper on transport policy aims to achieve increased sustainability of the European transport system via modal shifts to more environmentally friendly modes of transport. The focus is on the development of maritime and railway transport and reduction of air pollution from transportation. Short sea shipping is considered as vital for the implementation of multimodal logistics chains being an alternative to single-mode transport. EU Council Regulations 4055/96 allowed for the liberalization of cabotage within the EU as from the beginning of year 1990 which ensured for higher competitiveness of SSS. The promotion of SSS is of strategic value for achieving a clean and efficient European transport system. Compared with air freight transport and rail transport, SSS is a logical option to decrease the detrimental environmental effects of transport in the EU. The enlargement of the EU allowed for increased number of ports that can potentially be used for SSS. As a result, SSS is presently considered as one of the integration factors for the European transport system. In 1999, the European commission outlined several main objectives to promote the SSS:

- promotion of transport sustainability via SSS as safe and environmentally friendly alternative;
- facilitation of maritime links within EU and enhancing the economic development of EU border regions;
- increasing transport efficiency.

The European Commission introduced the Motorways of Sea (MoS) concept in 2003 [4], that was later approved (in 2004) as a TEN-T network. MoS is presently considered as "the floating infrastructures that move goods by sea from one EU Member State to another which aim to substitute motorways of land to avoid congested land corridors, give access to countries separated from the EU mainland and enable a better integration of waterborne transport with surface modes" [14]. Generally, MoS represents maritime services between minimum two European ports with road carriers and served by RoRo vessels. The European SSS policy is now predominantly concentrated on the concept of MoS. The Communication on SSS [5] declared that there exist main hindrances to be coped with:

- increase of port efficiency and security;
- development of door-to-door services and elimination of bottlenecks;

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- simplification and digitalization of customs/Administrative procedures.

The most important prerequisites for SSS improvement concern the following [16]:

- decreased port turnaround of ships, efficient administrative and customs operations, competitive port pricing;
- integration of SSS in intermodal supply chains, improvement of information exchange between stakeholders;
- introduction of policies for external costs incorporation as concerns other transport modes, equal treatment by customs, harmonization of rules for carriage of dangerous goods.

3. SULFUR EMISSIONS FROM SHIPS: LEGAL FRAMEWORK AND REGULATIONS

As per MARPOL, Annex VI, limits on sulfur oxides (SOx) and nitrogen oxides (NOx) emissions from ship exhausts are imposed. Same refers to particulate matter (PM) and any non-accidental emissions of ozone depleting materials (for example, chlorofluorocarbons). In 1997, as pursuant to Annex VI, a maximum limit of 4.5 % m/m of the bunker sulfur content was implemented and specific rules were imposed in several areas called Sulfur Emission Control Areas (SECAs). The next important revision came into force as from 1 January 2012 - sulfur cap of bunker fuels was reduced to 3.5 % on m/m effective and to be further reduced to 0.50 % on m/m by 1 January 2020. As concerns SECAs, the sulfur contents limits are lower: 1.00% m/m as from 1 July 2010 and 0.10% as from 1 January 2015 (Figure 4). In 2018, IMO will review the availability of 0.50 % sulfur fuel and a decision will be taken for the feasibility of the implementation of global cap by 2020 (or same to be postponed till 1 January 2025).

Generally, shipping is considered having lesser extent of detrimental environmental impact as compared with other transport modes other than higher sulfur (SO_x) and nitrogen oxides (NO_x) emissions [13].

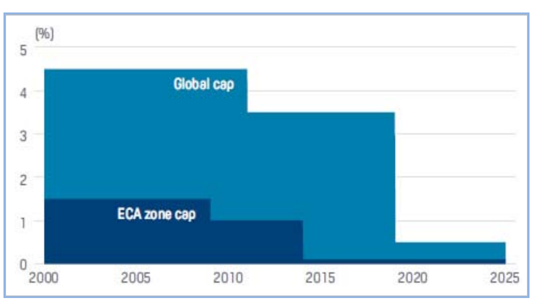

Figure 4 MARPOL Annex VI sulfur limits [18]

EU Directive 2005/33/EC [8] sets forth special regulations limiting the maximum sulfur content of bunker fuels at 1.5 % in the Baltic Sea (starting from August 2006), and, starting from year 2007 – in the North Sea and the English Channel. Following these regulations, shipowners are to arrange for installations in order meet these requirements. The most straightforward method is to use low sulfur bunker fuels (without technical modifications on ships' engine) but at considerably higher costs due to price differential.

The solutions available for the enforcement of the regulations of the EU Directive 2012/33/EU [9] include: transition to low-sulfur distillates (LSMGO used as fuel), installation of an on-board exhaust gas cleaning system (scrubbers and HFO used as fuel), replacement of the ships' main engines so that alternative fuels, such as LNG or biofuels, can be used [1].

According to [10] the main barriers to making environmental investments are (arranged by order of importance):

- high investment costs;
- additional costs for vessel operation;
- technical reliability and experience;
- absence of competitive incentives;
- crew and vessel safety;
- technical complexity of installations;
- crew know-how for operation;
- acceptance by class society.

Each of these measures' application will lead to increase in transportation costs due to considerably higher operating costs. Thus the application of EU sulfur emissions control regulations is considered as one of the obstacles for European SSS competitiveness. According to operators and shipowners, acting in the North and Baltic sea basins that are characterized by stale demand, a modal shift is highly probable in the long-run amounting to over 10% in volume. In a recent study by [10] over 60 % of shipowners and operators state the preference to use LSMGO in order to abide by the existing regulations.

A long-term use of LSMGO will require the use of special coolers that is a relatively low-cost technical solution. The operating costs increase is due to the price difference between LSMGO and HFO. It is expected that only minor savings (below 5%) are expected to be achieved owing to the considerably longer interval for maintenance, higher heating value of LSMGO and the absence of necessity for fuel tanks heating. As mentioned, these are all technically possible options for all vessel engine types. For maritime operators there are several options to accumulate operating costs savings: [15] extension of hauling and maintenance interval by 40% and pertaining savings;

- decreased necessity for heating of fuel tanks (depending on the available technical options for heating provision;
- better fuel quality (about 5% savings if LSMGO is used).

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- From a commercial point of view the above option has lower risk as it is presently already in use [10]. It is technically feasible for HFO burning ships to use LSMGO without major engine modifications other than changes of the fuel system so as to be adapted to the use of fuel of lower viscosity. (fuel chillers, switching procedures). Also, the use of LSMGO will lead to lower maintenance costs for diesel engines. Until 2020 the ships sailing outside ECAs can still use conventional HFO and in such a way will still be benefitting from the lower prices of HFO.

As concerns the primary disadvantage of this option same refers to the cost of burning LSMGO – usually about 60% more than HFO. Many shipowners have invested in systems for MGO cooling in order to increase the viscosity in accordance with engines' technical characteristics. In general, such systems are not complicated and they are designed as a closed fresh water cooling system with a heat exchanger. Recently, some technical difficulties are observed in existing ships when switching from HFO to MGO while entering or leaving ECAs and such procedures have to be performed in accordance with the engines' manufacturer instructions and the recommendations of the classification society. As planned by IMO, after 2020, shipowners that have chosen to use this option during the entire time of the voyages will not be exposed to such problems. It is considered that small modifications in the engines will be needed in order ensure for smooth operations when only LSMGO is used. Thus SOx reduction due to the composition of LSMGO (distillate fuels with few impurities) is naturally achieved - the reduction for SOx is about 96%.as compared with HFO emissions.

According to [17] presently the price spread between HFO and LSMGO is currently US$ 150-160 per metric ton (Table 1). The most important issue is how this price differentiation will develop. The latter will depend on several factors: world economic growth and development, oil price level, profits of oil refineries, availability of low-sulfur fuel oil. As long as, in the long run, the oil prices will be with minor changes, the present price difference will not be affected by significant changes. In case of economic growth downturn and lower prices of oil the spread will decrease and vice versa.

Table 1. Daily prices (USD/mt) for the port of Rotterdam, Jul 2017 [17]

Type of fuel	Price	Difference vs. LSMGO price
IFO 380	290 $/mt	+54%
IFO 180	325 $/mt	+37%
MGO	445 $/mt	-

According to [15] as a maximum assumption, the shipping industry will pay about USD 50 bln annually to switch entirely on LSMGO to meet requirements of the sulfur limits. As per OECD for 2015 the overall costs of the ECAs requirements were about USD 500 million and it is expected that the costs for the 2020 requirements will be in the range of USD 5 bln - USD 30 bln for the container industry only.

4. EMPIRICAL STUDY OF THE DIRECT COSTS OF SULFUR EMISSIONS CONTROL REGULATIONS ON EU SHORT SEA SHIPPING

Annex VI agreement of the MARPOL Convention, which aims for a reduction in sulfur oxide emissions from ships, is very likely to have a negative impact on costs of the European short sea shipping industry and higher freight rates in ECAs in North Europe (Baltic, North Sea and English Channel) and, consequently, on the competitiveness of SSS compared to trucking. [7].

However, this effect will not be similar for all vessels and it depends on the proportion of bunker costs in vessel's voyage (operating) costs, on the specific route and service speed. As per [6] and bunker prices as of year 2005, bunker costs correspond to the following average ratios in vessel's operating: costs: about 45% for container vessel, about 30% for RoRo vessels, about 20% for large (12,000 DWAT) RoPax vessels and about 10% for small (3,000 DWAT) RoPax vessels.

Fuel consumption is very sensitive to vessels' speed (following a logarithmic function). RoRo vessels running costs are considerably higher in comparison with other types of cargo vessels when unit transportation costs are studied. Therefore, the bunker costs per travel day for various types of cargo vessels are: 75% for container vessels, 65% for general cargo vessels and dry bulk vessels resp., 60 % for tankers, 50% for RoRo vessels and 55% for ferries. Table 1 presents the ranges span in accordance with LSMGO and HFO price ranges from 1.2 to 2.0 (LSMGO price as compared with HFO price).

Table 2. Increase of rates on daily operating costs per type of vessel [7]

Type of vessel	Increasing range (%) [1.2 P_{hfo} – 2.0 P_{hfo})
Container vessel	15-75%
General cargo vessel	13-65%
Dry bulk vessels	13-65%
Tankers	15-60%
Ro-Ro vessels	10-50%
Car and passenger ferries	11-55%

In the study of [6] the increase on operating costs due to MARPOL regulations is to rise by 29 % in 2025. As dry bulk vessels as well as general cargo vessels have lower service speed it is technically not feasible to lower speed substantially in order benefit from slow-steaming and offset the higher bunker costs. As per [6], an average service speed of 12 knots for a LoLo vessel will allow for bunker costs reduction by about 12% (Figure 5).

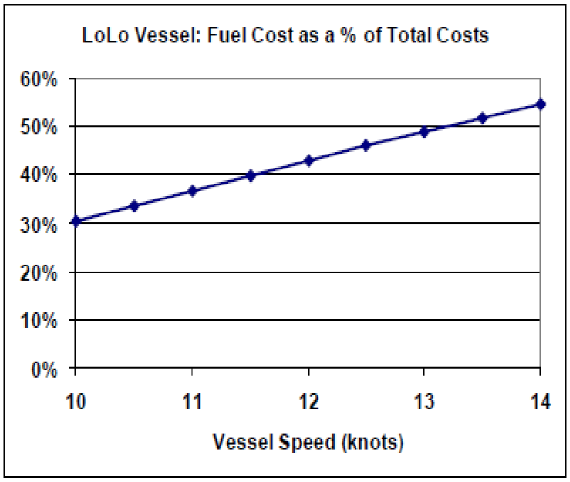

Figure 5 Fuel cost of LoLo vessel as function of speed [6]

The service speed reduction will result in increased transportation duration. The effect of the latter is not linear as vessels' rotations/schedules depend on operating times at terminals, periods of freight traffic peaks, truck operators labor schedules, roads transiting restrictions over the weekends, etc. Consequently, the lowered service speed and restrictions are leading to prolonged port stay of ships and longer sailing times. For SSS liner services this will result in reduction of frequency and considerable increase of transport times and eventually, to overall alterations of services. In the medium perspective companies will start losing customers and the competition will intensify. The latter means that the planned savings due to slow steaming will be less than planned (below 10%) depending on the route and type of cargo. The remaining portion of bunker costs increase must be offset by profit margin reductions and transferred to customers. According to [6] study about 25% of the costs increase will be transferred to the customers.

In order analyze the effect of the option of using LSMGO only, a study was conducted regarding vessels operation of an Eastern European tramp shipping company. The company operates five general cargo vessels with DWAT below 10000 mts, transporting mainly bulk grain cargoes within the Black Sea and the Mediterranean regions. The voyages data are based on a rotation Constanta – Ravenna – Constanta for a 5300 mts DWAT vessel, performing consecutive voyages in 2016. The data used for the calculation of the additional costs per round voyage within a contract employment are presented in Table 3.

Table 3. Details of the voyages performed by a 5300 mts DWAT vessel

Vessel type	**general cargo vessels**
DWCC (bulk grain cargo)	5000 mts
Freight rate **[me-expert]**	21 $ per mt (net)
Service speed (average)	10 knots
Voyage rotation	Constanta – Ravenna
Distance (nm)	1312 nm
Total sailing time (incl. ballast)	10,93 days
Total time in port	5 days
Time waiting for Bosporus passage (one way)	1 day
Total voyage duration	16,93 days
IFO 180 cst price [s&b]	331 $/mt
LSMGO price [s&b]	485.50 $/mt
Total D/As and canal fees	26000$
Daily running costs	3500$/day

The analysis and estimations show that bunker costs represent 30% of total costs, and switch to burning LSMGO only leads to increase of bunker costs with 10% and increase of total costs with 11% (Figure 6).

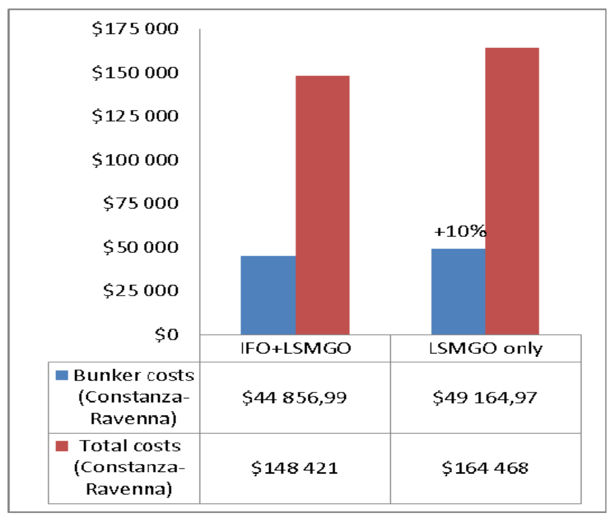

Figure 6 Bunker costs and total costs increase basis LSMGO only option for a round voyage

The mentioned costs increases invoke a further spread of capital and operating costs on the remaining customers that will bear further prices increase. As concerns tramp shipping, the increased costs could not be offset by passing on to charterers as the market freight levels are formed by a completely different mechanism (supply and demand equilibrium). In the long run, however, freight rates will increase, namely due to the increased bunker costs. Fluctuations from the results are possible, as owners both in tramp and liner SSS will be able to absorb part of these costs increases. It has also

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been proved, that slow steaming is not a viable option as it will lead to loss of cargo volumes (owing to longer transport times), decreased service frequencies and finally, amended service schedules.

5. CONCLUSIONS

The MARPOL convention is without doubt the most important international regulation comprising rules for prevention of marine pollution by ships due to accidents and operational reasons. The purpose of Annex VI is to limit atmospheric pollution from ships. In so far as shipping is a global industry, the solution to environmental footprint of maritime transportation must obviously be global [11].

The adoption of the sulfur regulations in ECAs in Europe can be regarded as an impediment to the competitiveness of the European SSS. Even in areas where demand is stable, the application of sulfur regulations, according to EU shipowners and operators, represents a modal shift of about 10% by volume. [7]

In general, vessels currently using HFO will experience a favorable impact to the exhaust emissions profile by switching to MGO only operation. [15]. The results of this study have shown that the option for using LSMGO in ECAs is a technically feasible solution. However, in the long run and in order to compensate for the higher costs, ship owners and operators in EU short sea shipping will resort to transport prices increases and eventually lose market shares.

6. REFERENCES

[1] Bacher, H., P. Albrecht, 2013, *Evaluating the costs arising from new maritime environmental regulations*, Elomatic Marine Engineering Ltd, Liikenteen turvallisuusvirasto Trafi, Helsinki, Helsingfors

[2] European Commission, 1995, The development of short sea shipping in Europe: prospects and challenges, COM (95) 317, Brussels

[3] European Commission, 2001, White Paper – European policy for 2010: time to decide, COM (2001) 370 final, Brussels

[4] European Commission, 2003, Program for the promotion of short sea shipping: proposal for a directive of the European Parliament and of the Council on intermodal loading units, COM (2003) 155 final, Brussels

[5] European Commission, 2004, Communication from the Commission on short sea shipping, COM (2004) 453 final, Brussels

[6] European Commission, Directorate General Environment, 2010, The competitiveness of European short sea freight shipping compared with road and rail transport (COMPASS), Final Report

[7] European Commission, DG Mobility and Transport, 2015, Analysis of recent trends in EU shipping and analysis and policy support to improve the competitiveness of short sea shipping in the EU

[8] EU Council Directive 2005/33/EC of 6 July 2005 amending Directive 1999/32/EC

[9] EU Council Directive 2012/33/EU of 21 November 2012, amending Council Directive 1999/32/EC as regards the sulfur content of marine fuels

[10] European Short Sea Network, 2013, Way forward - SECA report

[11] Fedi, Laurent, 2012, Air pollution from ships: a legal perspective for short sea shipping in European countries, Short Sea Shipping Conference, Lisabon

[12] Maritime transport statistics - short sea shipping of goods, http://ec.europa.eu/eurostat/, accessed Aug, 2017

[13] Ng, A.K.Y., 2009, *Competitiveness of short sea shipping and the role of port: the case of North Europe*, Maritime Policy & Management, Vol. 36, no. 4, 337-352

[14] Ng, A.K.Y., Sauri, S., Turro, M., 2013. *Short sea shipping in Europe: issues, policies and challenges*, Regulating Transport in Europe, Edward Elgar, Cheltenham, pp. 196-217, ISBN: 9781781004821

[15] The IMO'S 2020 Global Sulfur Cap – what a 2020 sulfur-constrained world means for shipping lines, refineries and bunker suppliers, Shipping Special Report, October 2016, Ned Molloy, www.platts.com/shipping/

[16] Rodrigue, J-P., Comtois, C., Slack, B., The Geography of Transport Systems, 4th Edition, 2017, Routledge

[17] https://shipandbunker.com/prices/emea

[18] http://www.imo.org

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