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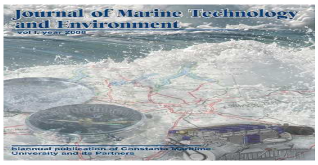

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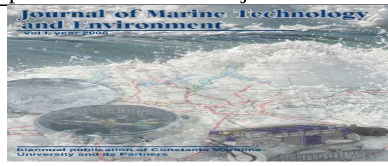

APPLICATION OF PROTECTIVE TIN COATINGS ON COPPER AND ALUMINUM LOW VOLTAGE BUSBARS OF ELECTRICAL DISTRIBUTION BOARDS OF SHIPS

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Abstract: In this study an opportunity for investigation and application of protective monolayers of TiN obtained in reactive arc method in N_2 atmosphere is examined. The coatings are deposited on copper and aluminium low voltage busbars of electrical distribution boards. The aim is to reduce the contact-potential difference between the busbars, made of different metals, i.e. copper and aluminium and, thereby, to reduce the power losses. The article also presents the results of studies of corrosion resistance, in particular the resistance to salt sea mist of the coated busbars. The possibility of using these busbars at sea has been experimentally proven.

Key words): monolayer coatings, TiN, adhesion, microstructure, corrosion, salt mist.

1. INTRODUCTION

The busbars in electrical distribution boards may be connected to each other and to electrical apparatus by bolted, clamped, or welded connections. Often, joints between high-current bus sections have surfaces that are silver-plated to reduce the contact resistance and power losses. In this study we propose an alternative of the expensive galvanic silver deposition [1].

The deposition of protective coatings of different structural materials leads not only to surface modification for improving the operational characteristic of the material, but in some cases to formation of fundamentally new composite materials sometimes even nano in size. Such coatings satisfy practically a set of requirements for technological and long life span advances.

The hard, wear-resistant monolayers with nanoscaled grains of TiN deposited on surface on the material reduce the electrical resistance, wear and friction, increase the hardness and not at least enhance the resistance to high temperature oxidation. The scope of application range of Physical Vapour Deposited (PVD) coatings of TiN on different substrates is not examined and tested in details especially for non-conventional purposes [2], [3].

The processes in the atmosphere or in a gaseous medium at ambient temperature, and sometimes at elevated temperature when the formation of even the thinnest layers of electrolyte (greater than 10 μm) onto the surface of metal is possible, refer to the electrochemical corrosion. Electrochemical corrosion is the most common form of corrosion of ships at sea.

Corrosion damage may be complete or local, uniform or non-uniform. The rate of corrosion in the equipment is measured in grams of damaged metal for 1 h on 1 m^2 metal surface. If its value does not exceed 0,1 g/m^2, the metal is considered to be corrosion-resistant; if the value reaches and exceeds 3 g/m^2 – the metal is somewhat resistant. Metals that lose more than 10 g/h on an area of 1 m^2 are considered not resistant to corrosion [5].

Tests should be conducted according to standard IEC 60068-2-11 [6] and its national equivalents. The standard is used to test the relative resistance to corrosion of protective coatings, when exposed to a salt mist (spray) climate at an elevated temperature. Test specimens are placed in an enclosed chamber and exposed to a continuous indirect spray of neutral (pH 6.5 to 7.2) salt water solution, which falls-out on to the specimens at a rate of 1.0 to 2.0 ml/80 cm^2/hour, in a chamber temperature of +35°C. This climate is maintained under constant steady state conditions. The test duration is variable.

The purpose of this paper is to present the adoption of the technology and the application of monolayer coatings of titanium nitride with electric arc evaporator on low voltage busbars of electrical distribution boards of ships.

2. HELD EXPERIMENTS

On copper and aluminium bus bars with dimensions 60x6 mm were deposited monolayered coatings of TiN by arc method.

The experiments were held in a vacuum system facility type TITAN 1-4 at the University of Rousse "A. Kanchev”. The facility provides vacuum to approximately 2.10^{-3} Pa. General view of the arc evaporation engine, which were performed the experiments is shown in Figure 1.

Figure 1 General view of the engine, used for the deposition of TiN coatings on low voltage busbars

The scheme of the working chamber is shown in Figure 2. The engine for coating is composed of magnetron source of vapour 1, arc evaporator 2, stand 4, which have different configurations depending on the experiment. Samples 3 are hung on the stand.

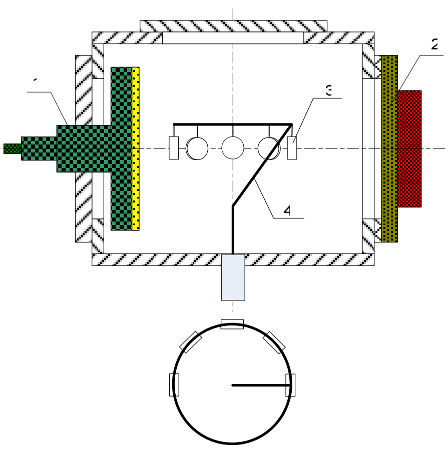

Figure 2 Scheme of the working chamber of the engine for coating. 1 - magnetron source of vapour, 2 - arc evaporator, 3 - experimental samples, 4 - stand

Table 1. The PVD process parameters

Type of the coating	**P [Pa]**	**U [V]**	**I [A]**	**Duration of the deposition, [min]**	**Temperature of deposition, [˚C]**	**Thickness of the coating, [μm]**
TiN	*$2,5.10^{-3}$*	*-150*	*120*	*30*	*~100*	*~ 1*

For reaction gas nitrogen N_2 was used and its quantity was adjusted by the pressure indicated in the table.

The topography and the microstructure of the coatings were examined by an optical microscope and captured by digital camera Zuzi Scope at magnification of x2000. The X-ray qualitative analysis of the coatings was made using X-ray diffractometer URD-6 with Fe-Kα radiation. The working parameters during the exposure were gentle, due to the specifics of the deposition regime and the small thickness of the coating. In order to study the microstructure and abrasive wear resistance, a Ball - wear test method was carried out with apparatus CSEM - Calotest - Switzerland. The scratch tests were performed on the top surface of the sample with a Revetest Macro Scratch Tester - Switzerland with normal force range of 1 N to 100 N equipped with a Rockwell C diamond indenter of 200 μm radius. The system is equipped with optical microscope with possibility to obtain photography. The coefficient of friction was measured under constant (10 N) and progressive loading for each two sets of coated samples and bare substrates. Two or more scratches on each sample were made and verified the obtained results.

The small thickness of the coatings does not allow their microstructure and the coating thickness to be determined in details. The cross-section images show that on the aluminium busbar due to the lower melting temperature and density of the substrate, a part of the coating is re-sputtered and therefore it seems thinner than 1 μm. Because of small thickness of both films, the transitional contact resistance of the busbars should not be affected by the higher resistivity of the thin TiN compound on the surface.

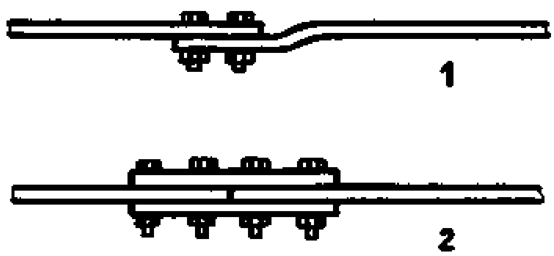

Figure 3 Different types of connections between bus bars: 1- unilaterally offset overlap, 2- strap connection [4]

Different types of connections between bus bars, made of copper and aluminium – Figure 3, will be investigated to prove the minor change of the transitional contact resistance. The both presented connections are appropriate for use in connections subjected to very severe vibrations on ships. For bolting bus the busbars standard galvanized or cadmium plated steel bolts can be used, as well bolts with TiN monolayer coatings [4].

3. METHODS AND APPARATUS FOR CONDUCTING THE CORROSION TESTS

The tests were conducted in the Laboratory for material analysis and testing and calibration of measuring facilities of the "Acad. A. Balevski" Institute of Metal Science of the Bulgarian Academy of Sciences.
Testing of test pieces was made in an aerosol chamber Aerozol-Korrosionsprufkammera Type 1000 – Switzerland - Figure 4, in accordance with standards BS EN ISO 7384:1996 and BS EN ISO 9227:2007, in a medium of neutral salt mist - 5% NaCl, temperature T = 35.0°C, pH of the collected solution in the range from 6,5 to 7,2 at 25°C for the duration of 100 hours.

Test specimens are placed at an angle of 15° to 30° to the vertical and they not shield one another from environmental influences in this arrangement.
The difference with the standard test is that a constant elevated temperature of T = 35.0°C must be maintained in the chamber.

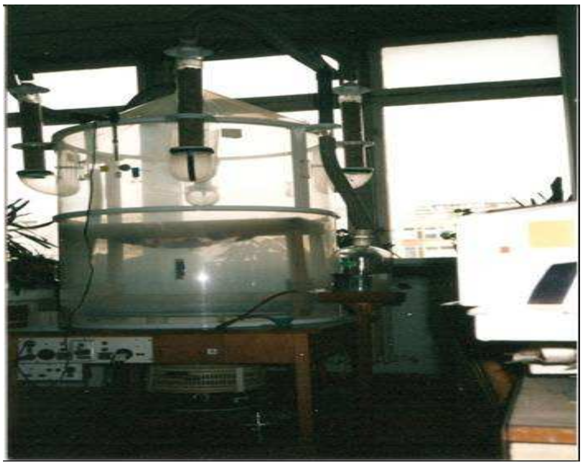

Figure 4 General view of aerosol chamber Aerozol-Korrosionsprufkammera, Type 1000

In general, the coatings are unaltered. They only have different degrees of darkening with no apparent corrosion of the coating. As far as the behaviour of the coatings on different substrates is concerned, no significant differences are noted. Differences in the degree of darkening do not give sufficient information which substrate and its corresponding thickness, is most appropriate.

4. CONCLUSIONS

Successfully are applied monolayer TiN coatings on copper and aluminium busbars for low voltage. The resulting coatings have a high roughness and relatively low thickness, which is apparent from the microstructure analysis. The wear after the applied Calotest is different for the both busbars and depend on the used substrate.
All tested samples were resistant to salt mist for the duration of 100 hours and fulfil the requirements of Standard EN ISO 10289:2006 - Methods for corrosion testing of metallic and other inorganic coatings on metallic substrates - Rating of test specimens and manufactured articles subjected to corrosion tests (ISO 10289:1999). This conclusion is consistent with the high corrosion resistance of coatings of the Ti/TiN type, known in the reference literature.

The study demonstrated that the developed low voltage busbars with TiN monolayer coatings are fully applicable to ships at sea.

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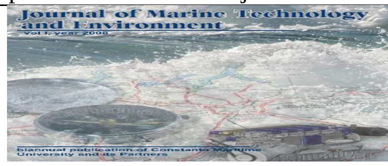

ELABORATION AND TESTING OF LABORATORY STAND FOR INVESTIGATION OF AN ARC FAULT DETECTION DEVICE

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Abstract: The arcing faults may have a severe impact on the ship or on the crew. The paper presents the elaboration and testing of a laboratory stand for investigation of an arc fault detection device in the Technical University of Varna, Bulgaria. The presented laboratory stand will train future electrical engineers to work with this new protection device.

Key words: arc fault detection device, residual current breaker with additional overcurrent protection (RCBO), protective electrical apparatus

1. INTRODUCTION

Arcing faults are the main cause of damage in electrical installations, even in ships. They result in particular from insulation faults or from unstuck contacts in the electrical installation itself and in the equipment connected to it. Caused by unstuck contacts or insulation faults, the arcing faults don't have necessarily serious consequences, but it can ignite a fire and thus have a severe impact on the ship or on the crew.

Most of the electricity distribution panels and the cable network on the ships are usually protected by means of miniature circuit breakers (MCB) and residual current circuit breakers (RCCB). Therefore the large current of an electric arc does not actuate the interrupters of the automatic breakers. The electric arc is not a short circuit connection but is an active load releasing a big amount of heat. The electric arcs are caused by corrosive damages decreasing the distance between the electric rims and damages of the mounting and in the insulation caused by the vibrations. These devices are not designed to detect arcing faults and do not provide adequate protection from them. This is where the arc fault detection devices (AFDD) come into their own, closing the previous safety gap. The AFDDs are recommended for new installations as well as for existing and older equipments. There is a high risk of hazardous arcing faults particularly in older electrical installations.

The residual current protective devices already in use ensure protection against fire and protection in case of direct and against indirect contact. Miniature circuit breakers offer protection against short circuits and overload. The advanced preventative protection against fire provides protection against serial and parallel arcing faults. It is achieved by the arc fault detection unit in combination with a MCB or a Residual current breaker with additional overcurrent protection (RCBO). The combination with the MCB is used together with RCBO. As a result, all poles of the fused circuit are disconnected from the network in the event of a fault. Its integrated overvoltage protection release, which switches off safely at a voltage of more than 275 V between phase and neutral conductor, completes the range of protection of the AFDDs. Thanks to the combination of the AFDDs with an MCB or an RCBO, people and equipment are reliably protected against possible damage from fire caused by overload, short circuits or arcing faults [2], [3], [4].

2. DESCRIPTION OF THE LABORATORY STAND

Figure 1 shows the basic design of the 5SM6 AFD unit. For detection the both active conductors the line conductor L and the neutral conductor N are passed through the unit and switched. The line conductor L is passed through two separate sensors: a current sensor for detecting the line frequency signals and a high frequency sensor for detecting the high frequency signals. Analogue electronic device prepares the signals for processing in the microcontroller. The high frequency signal of the current is scanned in the range from 22 to 24 MHz. It is referred as Received Signal Strength Indication (RSSI) and represents the power of the arc at a defined frequency and bandwidth. When the microcontroller records the criteria for an arcing fault as fulfilled, a tripping signal is created and directed via a shunt trip to the switching mechanism. In the case of the 5SM6 AFD unit, a mechanical coupling link is operated to work the mechanism of the mounted MCB or RCBO. The mounted protective device is tripped along with its contacts and the network is disconnected from the faulty part [1].

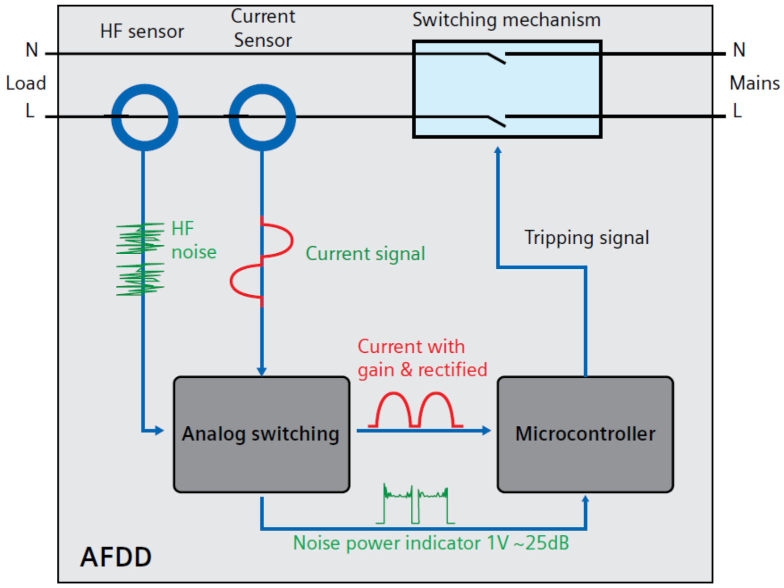

Figure 1 Basic design of Siemens 5SM6 AFD unit [1]

In Europe only Siemens supplies AFD units. The Siemens 5SM6 AFD unit is designed for mounting with RCBO, each with rated currents up to 16 A. The advantage of such solution is the realized complete protection against overloads, short circuits, residual currents and fire. Figure 2 shows the Siemens 5SM6 AFD unit, mounted with Siemens 5SU1 RCBO.

Figure 2 General view of 5SM6 AFD unit with mounted 5SU1 RCBO [1]

Our laboratory stand contains the Siemens 5SM6 AFD unit with mounted 5SU1 RCBO with rated current 16 A and rated voltage 230 V, 50 Hz.

The laboratory study aims to be recreated arcing through regulation (increase) in current shunt Rsh, connected to the phase conductor at the entry of the protection device and the other end is connected to the output neutral conductor. The electric scheme of the elaborated laboratory stand is shown in Figure 3.

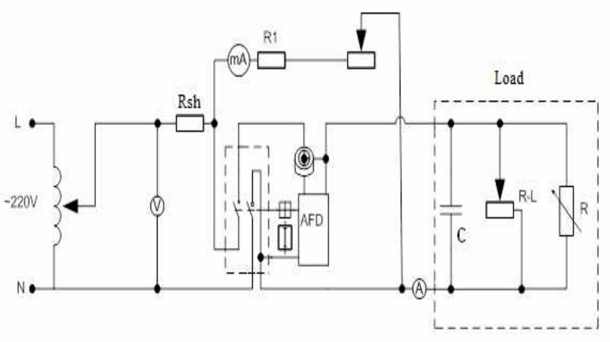

Figure 3 Electric scheme of the elaborated laboratory stand

The load consists of a rheostat with active resistance R up to 13 Ω, coil with inductance L≈10 mH and capacitors with capacity 2x5 μF. The image - Figure 4 shows the used in the staging components, measuring instruments and the load.

Figure 4 General view of the elaborated laboratory stand with the measuring instruments and the load

3. EXPERIMENTS

An experiments were conducted with the participation of the Siemens 5SM6 AFD unit with mounted 5SU1 RCBO in a circuit with R, R-L and R-C character of the load.

The objective is to determine the efficiency of the protective apparatus and to characterize the specific features of the developing process. With oscilloscope are recorded the timing diagrams of the supply voltage at R, R-L and R-C character of the load and voltage 25 V. similar to the previous charts are recorded, but at a voltage 35 V. Also are recorded cases of formation of impulse current during the extinguishing process of the electric arc in different character of the load.
Three types of experiments were performed with the laboratory stand.

- Experiment with active load R, with increasing the input voltage.

At the time of interruption of the circuit a peak of the voltage is observed due of the occurrence of an arc. In smaller resistance values, this peak is noticeable better. At 25 V input voltage, there is also a current peak at the time of circuit interruption – Figure 5.

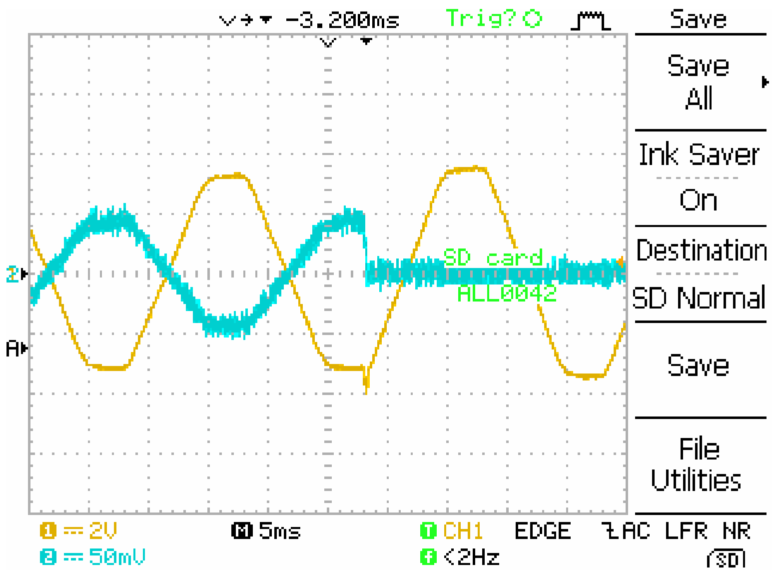

Figure 5 Oscillograms of the input voltage (yellow) and current (blue) curves with active R load

• Experiment with active-capacitive load R-C with increasing the input voltage wherein the capacitance C = 10 µF

In this experiment, in all characteristics an expressed voltage peak is observed at the time of circuit interruption.

A current peak is observed only at 25 V input voltage – Figure 6.

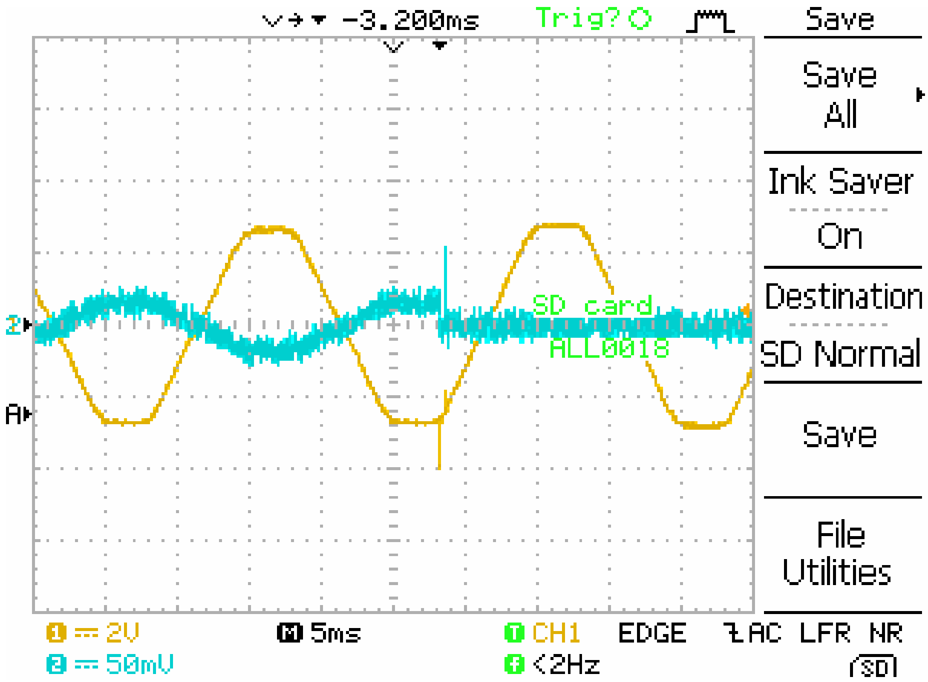

Figure 6 Oscillograms of the input voltage (yellow) and current (blue) curves with active-capacitive R-C load

• Experiment with active-inductive load R-L, with increasing the input voltage, wherein the inductance L ≈ 10 mH.

In active-inductive load clearly demonstrated voltage peaks are observed at the time of circuit interruption only at higher values of the input voltage – Figure 7.

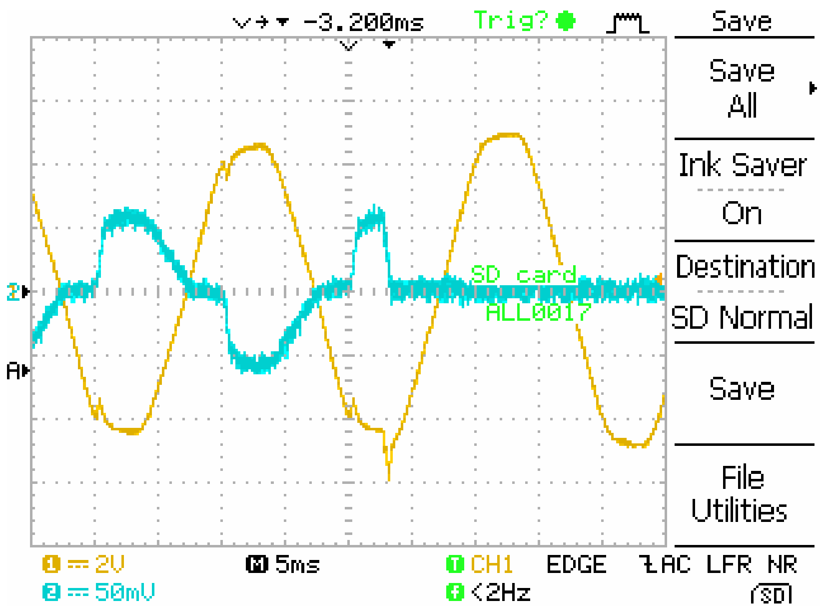

Figure 7 Oscillograms of the input voltage (yellow) and current (blue) curves with active-inductive R-L load

4. CONCLUSIONS

The AFDD serves a dual purpose – not only will it shut off electricity in the event of an arc fault, but it will also trip when a short circuit or an overload occurs. The AFD unit provides protection for the branch circuit wiring and limited protection for power cords. With its fast response and the manner of recognizing of emerging arcs, this protection is becoming a necessity for ships. Also, it is proven its effectiveness in preventing fires in ships, caused by occurred short circuit connections.

The realized experiments demonstrate the operability of the protective apparatus. The extinguishing of the arc is in interval of time much smaller than the half-cycle of the supply voltage, which achieves limiting of the arc current. The rapid current breaking rise characteristic pulses occurring as an over voltage surge.

The developed laboratory stand will train future electrical engineers to work with this new protection device.

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ADOPTING OF SENSORS WITH AMORPHOUS RESISTIVE LAYERS IN ELECTRICAL MEASURING OF SPEED OF FLUIDS IN SHIPS

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Abstract: New resistive elements, formed upon electro insulated plate of vacuum thick ceramics by magnetron sputtering or screenprinting of amorphous resistive layers are studied. The elements possess a relay-type strong negative temperature dependence of resistivity. The new elements are adopted as sensors in standard bridge circuits for measuring of speed of fluids. Prototypes of sensors with various compositions of amorphous metal layers are analyzed and compared. The new elements show better sensitivity compared to a standard sensors.

Key words: amorphous resistive layer, anemometer, sensor, speed of fluids, Winston bridge circuit.

1. INTRODUCTION

The procedure of measuring the fluid flow velocity by hot-wire anemometers is based on the fact that an electrically heated thin metal wire being placed in a fluid flow, its temperature decreases and hence its resistance changes with the flow velocity increasing.

Relations between current intensity I, resistance of the wire Rs, temperature T, initial temperature T_0 and fluid velocity v are well known [1] and are described by the equation:

$$I^2.Rs = (T - T_0)(c + b\sqrt{v}),$$

where in:

b – constant value, depending of the physical properties of the wire;
c – constant for the intensity of the current along the wire at temperature difference of 1°C and zero flow velocity (v = 0).

Thus, with Rs = const. we have I = f(v), while with I = const. – Rs = f(v), i.e. there exists two modes of hot-wire anemometer operation: with constant resistance and with constant current intensity. The principal part of the anemometer circuit is a Winston bridge with constant current supply. A thin metal wire, mostly silver or sometimes platinum, nickel or tungsten, with a diameter of 0,05 – 0,15 mm and length of 30 – 100 mm is connected to the bridge.

2. ELABORATION OF THE NEW RESISTIVE ELEMENTS

Having analyzed the existing types of hot-wire anemometers, we came to a conclusion that it is possible to improve their sensitivity by replacing the silver wire sensor with a flat sensor consisting of a ceramic plate with an amorphous metal layer, reminiscent of a printed circuit board.

In the process of developing of the sensor prototypes aluminium oxide ceramics produced by Rosenthal and Rubalit (Germany) were used.

All specimens were prepared on square ceramic substrates with a side of 2 inches (50,8 mm) and 0,9 mm thick. Having analyzed more than 10 possible procedures for forming a conducting layer upon a ceramic substrate, we preferred the following two of them: magnetron sputtering [2] and screenprinting [2] of the resistive layer, both procedures being applied in integrated circuits production.

In forming the sensor prototypes by magnetron sputtering – Figure 1, Russian stainless steel of 12X18H9T grade (German grade X10CrNiTi18-9), containing C – 0,12%, Cr – 18% and Ni – 9% is used as well as amorphous alloys of the same steel. Two compositions of the amorphous alloy with mass content of Titanium of 13,9% and 15,5% respectively were tested. Coating was performed in a vacuum-pumping plant of B-90 type of Hochvakuum – Germany, with the following process parameters: substrates cleaning voltage – 2 kV DC, cleaning time – 10 min., operating voltage – 390 V DC, operating gas – Argon, operating pressure – 0,267 Pa.

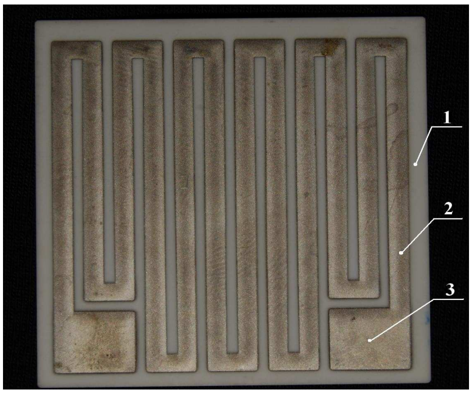


Figure 1 General view (photo) of a prototype with magnetron sputtered resistive layer, wherein: 1 – ceramic substrate, 2 – resistive layer, 3 – contact terminal sites

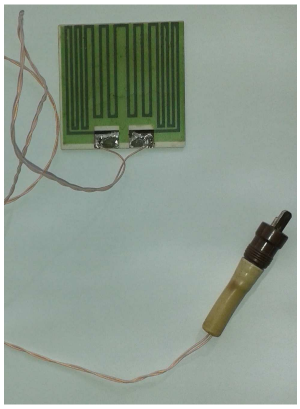


Figure 2 General view (photo) of a prototype of sensor for hot-wire anemometer with screenprinted resistive layer

In forming the sensor prototypes by screenprinting – Figure 2, special amorphous pastes were used for resistive layer material, including pastes produced by Heraeus – Germany and DuPont – USA. Commercial DuPont Model 8010 printer was used, the main parameters of the technological process being as follows: speed of the printing panel – 35 mm/sec, thickness of the emulsion layer of the screen – 11 µm, average baking temperature – 850 °C, time of maintaining of the baking temperature – 10 min, paste viscosity – 105 Pa.sec.

In experimentation of the procedures the mentioned parameters were changed many times and their effects upon the quality of the layer were watched attentively.

3. EXPERIMENTAL RESEARCH

Changes in resistivity of the sensor placed vertically in an air flow caused by the flow velocity were analyzed. Two types of sensors were tested:

- A silver wire (90% Ag) with a diameter of 0,1 mm and a length of 60 mm;
- A sensor on ceramic plate with magnetron sputtered amorphous layer of 12X18H9T grade steel with 13,9% Titanium and a thickness of 6 µm.

The changes of the resistivity of these sensors caused by the increase of the flowing fluid velocity are shown in Figure 3. The sensor with amorphous structure has about three times higher sensitivity compared to the silver wire sensor.

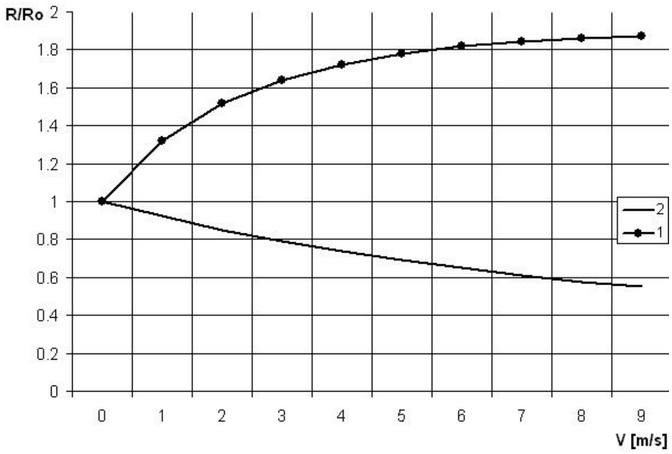
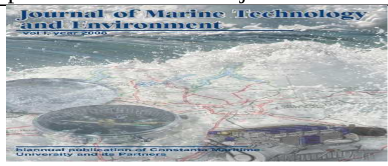


Figure 3 Relative change of the resistivity of two types of sensors, caused by the increasing velocity of the fluid flow: 1- a sensor on ceramic plate with an amorphous metal layer of stainless steel 12X18H9T grade with 13,9% Titanium, 2- a sensor with a silver wire (90% Ag) with a diameter of 0,1 mm and a length of 60 mm, R_0 – initial resistivity



The sensors corrosion resistance is very high. Being subjected to standard (in Bulgaria) corrosion resistance tests, the sensors retain parameters and quality of the layer practically unchanged.

4. APPLICATION AND CONCLUSIONS

The new sensors are adopted as sensors in standard bridge circuits [3] for measuring of speed of fluids – Figure 4.

As seen from the figure the sensor RH takes part in a Winston bridge circuit, with the resistors R1, R2, R3 and the potentiometer RP1. The voltage of the bridge diagonal is feeding across the resistors R4 and R5 the both lead-ins of the booster DA1. The bridge is supplied from the exit of the booster and the signal is increased by the transistors VT1 and VT2. When changing the speed of the fluid, the resistance of the sensor RH changes too. That leads to variance of the potential passed to the non-inverting lead-in of the booster DA1 across the resistor R4. The sensor's heating changes with the change of the booster's exit voltage. The bridge is in equilibrium, but the exit voltage of the transistor VT2 changes and the voltage variations are measured by the voltmeter V.

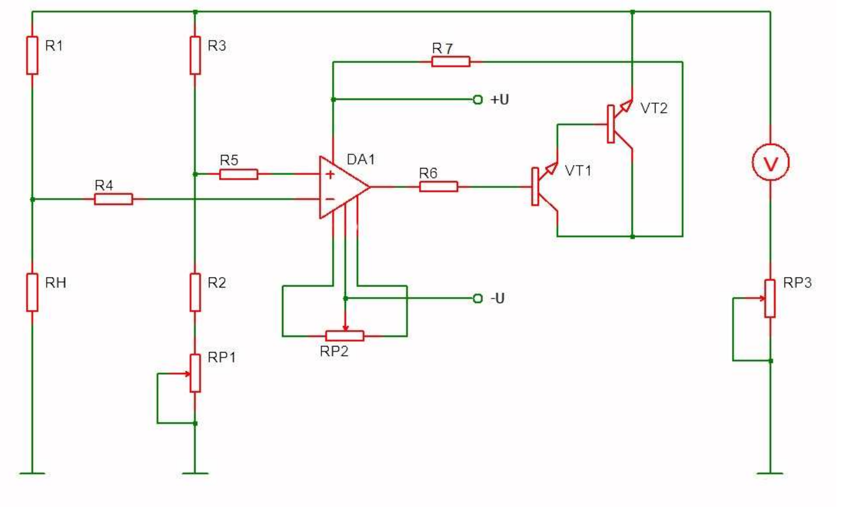


Figure 4 The bridge circuit, used in the prototype of the hot-wire anemometer. DA1 – integrated circuit (booster), VT1, VT2 – transistors, RP1, RP2, RP3 – potentiometers, R1,…,R7 – resistors, RH – sensor with amorphous resistive layer, V – voltmeter

The new sensors are multi-purpose devices and are suitable for use in ships.

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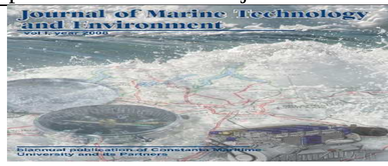

MANAGERIAL ANALYSIS OF ENERGY EFFICIENCY STANDARDS' IMPLEMENTATION ON BOARD TO OPERATING SHIPS

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Abstract: Since 2013, together with the Resolution MEPC.203 (62)/2011 IMO enforcement, the vessels in service top and operational management must adopt the necessary measures to increase energy efficiency on board the ships in order to comply with the standards imposed. In this order, subscribed to a wide study in this mater, the present paperwork is focused punctually on the holistic analysis of the optimum energy efficiency measures that can be implemented at managerial level, on board the commercial vessels in service, operating more than 20 years.

Through the proposed measures, the overtaken analysis provides the prerequisites for an efficient tool in shipping business management, providing a useful working framework, grounded in theory and practice, for adopting the optimum decisions to assure the energy efficiency on board the operating ships, targeting the ratio between lowest costs and best economic performance.

Key words: energy efficiency, ship management, sustainable development.

1. INTRODUCTION

In order to acquire the shipping industry requirements of reducing the greenhouse gas emissions, the International Maritime Organization (IMO) has introduced in 2011, efficiency standards for energy efficiency for the commercial vessels, both at the design stage and building phases and further, for ships in operation (resolution MEPC.203 (62), [8, 9]. Among other things, energy efficiency standards are highlighted through the Energy Efficiency Design Index (EEDI) based, depending on the type and vessel displacement. [8,9]

The scientific work in this area of knowledge asserts that the EEDI is directly proportional to the mass of CO_2 emissions in the exhaust gas energy systems on ships [14, 15]. Consequently, increasing the energy efficiency mainly depends on the fuel consumption, related to the ships' economic performance and on the concentration of carbon in the fuel, as related to the sustainable development principles. Following the technological track of this issue, the energy efficiency should measure which particular alternatives must be implemented on board the operating ships, being specifically focused on technical solutions or operational technologies designed either to diminish competitively, the fuel consumption or to find alternatives to conventional fuel categories with a lower carbon emission footprint (e.g. LNG, biofuels, solar energy).

Thus, the modern ships as improved in energy efficiency standards should first adopt the adequate technical solutions even since the design phase, considering different innovative solutions, as marine propelling systems with low fuel consumption or using alternative clean fuels, or improved hull design solutions for reducing the drag effect and so on. But the real challenge is not for the modern ships, already in use but for the older ships, that didn't comply in the beginning with none of the actual requirements. Considering the real structure of the world fleet the challenge for changing and higher costs will be burden by those vessels in service, sometimes older than 20 years, called for the implementation of these measures, due to obsolete technical on board endowment, that hasn't been designed for this purpose in the beginning. As the procedure is stating, the energy efficiency policies and how will be implemented on board the vessel, should be clearly mentioned, in detail, in the Ship Energy Efficiency Management Plan (SEEMP), developed and implemented, in particular, for each type of vessel. [8, 9]

Fortunately, the age trend in the world fleet structure is a positive one, the modern ships replacing, as percentage share, the classical conventional ships, the world fleet growing younger in spite of sluggish economic recovering worldwide. Thus, more than 67% of the ships nowadays are younger than 10 years, out of which, 42% being brand new vessels, built in compliance with the international standards, and significantly improved in energy efficiency policies, not only in steaming techniques but also in operation and ship manoeuvre efficiency.

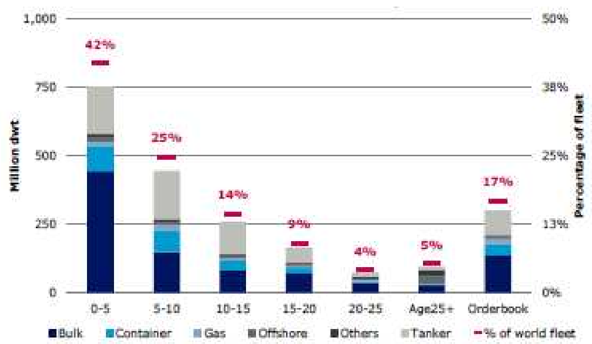

Figure 1 World fleet structure after vessels types and age
(Source: Clarkson Institute, Danish Ship Finance, Shipping Market Review, Nov. 2015, pp. 21)

The order book is on ascending trend, the new shipbuilding units increasing with almost 4% yearly, covering 17% of the fleet structure in the end of 2015 [20]. That means already the new policies of IMO energy efficiency is on the track, becoming more important to study and to seek for new "green" technical solutions from the design and building stages, in order to promote cleaner ships' propelling system. Regarding the operational measures to support the energy efficiency, the challenge is to develop new operational capacities in port area but also on board the commercial ships, based on optimum resource allocation or on new technical insertion, as punctual alternative energy resources employed not only for the propelling systems but also for: loading/unloading equipment, port structure outlays, operation lines etc.

Following the *economic track*, as of the sustainable development standing point, the energy efficiency concept is attached to the contemporary vessels' efficient commercial operational strategies and is targeting the shipping companies' management decisions in this respect. The managerial staff has a wide range of technical and operational solutions for increasing energy efficiency together with the voyage performance increment, in order to optimize first the consumption and secondly the harmful effects of gas exhausting produced by fossil fuels steaming. On social level, the cumulative effects of shipping companies will be further able to contribute to the sustainable development desiderata, guarding for a cleaner area of the international seaborne and port areas.

Ship management's decisions to adopt the energy efficiency measures will be determined mainly by fuel cost/ voyage earnings ratio. The main costs that influence the decision to implement measures to increase energy efficiency on board are: the bunker cost energy efficiency measures, market freight evolutions, and the financial restrictive measures imposed by national and international authorities regarding compliance with classification within emission reduction CO2. [18]

2. ENERGY EFFICIENCY ACCOUNTING

When we speak about onboard solutions, the acting typology and technical instruments dimensioning adopted in order both to reduce the energy efficiency and to reduce CO2 emissions, as a matter of externalities' accounting, depend on propelling system type, the equipment parameters on the yield reduction of CO2 emissions and not least, on the cost of implementing these measures on board the commercial vessels. IMO by Resolution MEPC.213 (63) has drawn specific recommendations on operational measures that can be taken on board to reduce emissions of carbon dioxide, the decision to implement them depending on the operational management of the vessel [8, 9]. In the picture below has been depicted the potential usage of different measures claimed to reduce CO2 emissions, according to ICCT (International Council on Clean Transportation). [7]

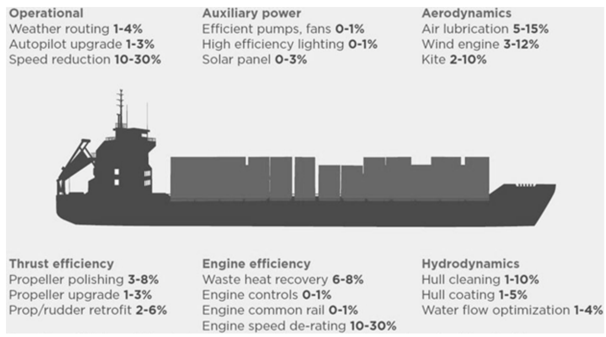

Figure 2 The synthetically frame of increasing energy efficiency solutions on board the ships in operation (source: International Council on Clean Transportation)

Sometimes, as studies have shown, the operational measures are more accessible to be adopted instead of direct technological insertion, for the case of operating ships, due to the lower costs of the subsequent implementation on board of these specific tools [7]. In this respect, Lloyds' Register recommends as more suitable the operational managerial tools, for improving energy efficiency and for reducing the CO2 emissions as following:

- vessel speed reduction down warding to the steaming efficiency threshold;

- transport route optimization by adjusting the trim of the ship loading, by choosing routes with the shortest distances and avoiding areas with improper weather conditions, that may affect engine efficiency propelling systems;
- the decreasing of electricity consumption on board, due to strictly ship operation necessities. [13]

These simple operational measures provide the greatest yield in terms of CO2 reduction conducting toward more extensive and deeper strategies as the use of alternative fuels or insertion of more efficient technologies, clean and productive, onboard of commercial vessels. In technical terms, besides the economic leverage of losing money in the dead freight, lowering the speed of the ship is very effective in terms of reducing fuel consumption and, further, the CO2 emissions, but this may involve to operate the propulsion systems outside of the designed technical parameters, which will determine the distortion of proper operating temperature and pressure within combustion steaming, with consequent cost hiking effects coming from additional maintenance operations and from the increasing particulate emissions [13]. Practically, as of future trend, the most used technical measure considered nowadays is the replacement of existing marine fuels steamed in classical propelling systems, with clean fuel sources, such as LNG and biofuels, with a sustainable potential for reducing CO2 emissions, almost by 50% compared with the projected CO2 emissions desirable for 2050. [6]

3. ENERGY EFFICIENCY AND THE BUNKER COSTS MANAGEMENT

The analysis performed by the authors has started from the observation that, in most situations, bunker costs represent 60% of voyage costs and almost 30% from total costs of a shipping company (including here the operational costs, voyage costs, periodical maintenance costs, capital costs and cargo handling costs), consisting as variables mainly in fuel and lubricants consumption values [11, 19]. Therefore, the bunker price is an important decision factor in the holistic approach of the energy efficiency of ships' operation. From this perspective could be considered that, in decision making process about the type of bunker that will be used the management should take into account the price trend over the remainder of decommissioning the ship. But, as it can be seen in the latest statistics (Figure no. 3) the bunker prices use to be volatile and only in 2015 have decrease sharply with 43%, due to the dip of fuel prices on international markets on the historical minimum of the latest 15 years. Once such a significant variance has been recorded there is no much influence left against voyage efficiencies as coming from fuel prices, the slow steaming concept becoming obsolete in terms of costs. But if this tendency will last then will negatively contribute to a strong neglecting attitude against the energy efficiency principles, the low costs for classical fuels becoming quite an incentive toward an irrational behaviour regarding the perennial resource scarcity, as a unrealistic bet for a massive renewal in shipping power supplying technology on a short and medium term.

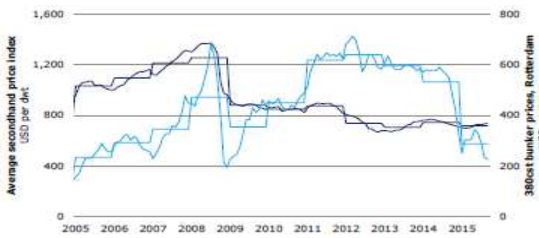

Figure 3 The bunker prices evolution in 2005-2015 (Source: Clarkson Institute, Danish Ship Finance, Shipping Market Review, Nov. 2015, pp. 20)

The contribution of maritime shipping to the air pollution shows that, in making decision process regarding the type of fuel that can be implemented on board, should always be considered the restrictions enforced by the IMO on emissions of other pollutants (SOx, NOx, etc.) in exhausting gas composition, resulting from systems and equipment functioning on board [15, 16]. Currently, most of the world fleet of vessels with an average age higher than 10 years still use as fuels HFO and MGO/MDO. So the tendency of judging just the price, but neglecting the negative polluting effects can be a wrong attitude against the international efforts of putting the sustainable development in place of market economic rationales.

There is a cautious attitude of worldwide authorities at the moment to issue forecasts or predictions regarding the trend of bunker cost in the coming years, due to the latest massive decrease in oil prices just during couple of months. The oil prices fall by over 50% compared to 2010 and more than 70% compared with the late years maximum. As recent studies have shown, in the near future the oil price will return to the 2010 average and is forecasted it to grow more than double in 2050 compared to 2005 level [12]. This forecast is based on oil reserve scarcity, based on oil reserves progressive decreasing in the coming decades, and on the sensitivity of this resource, as much of the oil comes from unstable politically areas. Several political and economic events recorded in the past years shown that are able to produce a high volatility of the oil market [5]. Therefore, to avoid this kind a miss judgements in analysis, the study on the implementation of measures to reduce CO2 emissions from ships in operation, should consider as reference value for fuel costs a ten years moving average, accordingly with the completion service duration for a vessel.

A forecast that includes the price of various fuels has been conducted by the Centre for Maritime Studies (CMS) at the University of Turku in Finland within “2025 LAIV” project (Figure no. 4), [2]. This forecast includes both conventional fuel cost developments that are currently used on board the ships but also for alternative fuels that have the potential to be used in the near future in the maritime transport. In Figure no. 4 can be seen that in 2025 is predicted to record the lowest operating costs based on ethanol and biodiesel LPG (LNG) utilization onboard the commercial vessels, implementing alternative propelling power systems on optimized procurement costs. But nowadays, the implementation of LPG ships (LNG) infrastructure involves an estimated cost of 1600 USD/kW, not being recommended yet to choose this type of fuel, not even earlier than 20 years considering the economic standpoint [6].

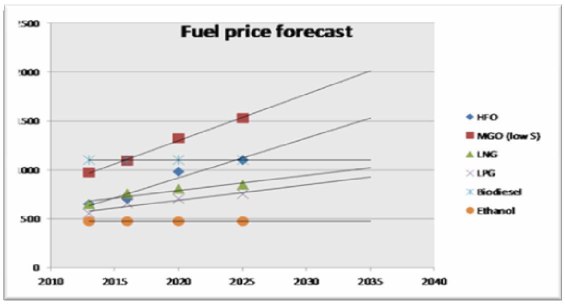

Figure 4 Market prices trend for naval fuel alternatives in 2010-2040
(source: Center for Maritime Studies, LAIV project)

The research previously conducted by the authors, regarding the biodiesel and ethanol usage shows that this forecast may undergo substantial changes in favour for non-polluting fuels, not considering the investment costs, but the lowest raw materials costs. From this perspective it is expected a decrease in the purchase price of the raw material by using seaweed (project Maersk and the US Navy for testing biofuel-based oils, algae) [16] and lower production costs as a result of the new technologies usage (eg. hydrogenise pyrolysis), [18]. The biodiesel can be used in combination with marine fuels classics because of owner chemical and physical related with them. We recommend using a mixture 20% biodiesel in marine fuels MDO / MGO and 100% replacement fuel to marine HFO biodiesel [1]

4. MARKET FREIGHT RATES AND ENERGY POLICIES

The trend of increasing volume of goods transported by sea worldwide as recorded in the last decades imposes on the one hand, the growth of transport capacities and, on the other hand, the increasing the speed enhancement for the vessels in service. From another point of view, the global economic crisis of 2008 negatively affected the price paid per ton of goods transported, as can be seen in the example below, provided for a Panamax bulk carrier (Figure no. 5). Moreover, the earnings have decreased sharply almost of the half of the values recorded before the crisis and is still stalling due to the slaking recovery in the world economy and trade. The worries are more significant due to the fact that the fuel costs are on the historical lowest prices in the last decade, but not enough to reverse the trend.

The energy policies cannot be limited to the slow steaming strategies, because the delays are now more expensive than the savings brought in the business. Following the principles stated in the economics of maritime transportation the recent studies have shown that the speed reduction nowadays brings lower saving than the loss recorded as delaying in excessive manner the voyage contracts [19]. The slow steaming as reducing the speed on half is bringing demurrage and other penalties that will not be further covered by the economies recorded in bunkers [3]. On half of the speed the distance will be covered in double time spent on the route, with an economy of not more than 10000USD/day, since the demurrage will be at least 16000USD/day. So the leverage threshold has been touched in respect of fuel savings and slow steaming incentive.

Figure 5 Freight market evolutions in period of 2000-2016
(Source: Clarkson Institute, Danish Ship Finance, Shipping Market Review, Nov. 2015, pp. 20)

In this framework, the ship owners and the freighters seek for managerial solutions to reduce the costs and to make the business more efficient and resilient to the freight market shocks. Due to the limits in fuel costs limits as presented, the implementation of new technical solutions in order to increase the energy efficiency onboard the operating ships becomes one of the most relevant solutions to minimize costs and to maximize revenues from shipping activities. Speaking about the cargo shipping, the operational speed reduction would increase the time period elapsing for undergoing the maritime voyage. This time increment will further negatively affect the freight rates, decreasing the operating incomes for ship owners. Also, reducing the speed of the fleet could cause charterers' shifting toward other modes of transportation, such as land and air, in order to maintain the time restriction and the good ability to be transported within the delivery time [3, 19]. The only way to value the speed reduction as a proper managerial tool is to practice a time trade off developing a good communication between the parties involved in freight transport logistics network (port authorities, port operators, ship service providers etc.) in order to compensate the transportation delays with a faster operation and lower congestion in the port area [16].

5. VOYAGE COSTS AND THE ENERGY POLICIES

Once the time for voyage speed reduced and the time for operation boosted the decision factors should seek for other managerial instruments to trade off the extra time recorded, optimizing the voyage consequently. Assuring the seaworthiness of the vessel by adjusting the trim of the ship loading in that manner the drag will be minimized, planning the voyage by reducing stationary periods of the ship waiting in the ports' area to onset the loading/unloading operations, are just some of the measures that can determine an additional optimization of the shipping activities [19].

The research conducted in this area had asserted the fact that the waiting time in harbour basin of a commercial vessel is due to several factors as following: 65% of delays are due to port congestion or terminals' clinkering, 20.6% of the wasted time is due to the terminal limits or restrictions in loading/unloading capacities or equipments and almost 4.7% of delays are coming from different port services for ships non-conformities as for pilotage or towage [11]. Moreover, surpassing the time enhancement desiderata as treated above, another managerial tool for energy efficiency should consist in optimizing the voyage planning, considering in the adopted operational strategies not just the speed, but also taking into account the cost effects of route itself, starting from the destination port facilities and amenities as mooring procedures and operating capacity of goods. Voyage planning means shortly: a) the operation points and voyage legs analysis, and b) the most efficient route in terms of natural hurdles in ratio with ship design variables.

In practice, in maritime transportation the most important managerial tool regarding the budgetary headlines is to look after variable costs, as the most relevant element in planning the voyage, considering here the next classical element as treated in the literature [19]:

$$VC_{tm} = FC_{tm} + P_{tm} + D_{tm} + TP_{tm} + CD_{tm},$$

where, *VC* represents voyage costs, *FC* is the fuel costs for main engines and auxiliaries, *PD* port and light dues, *TP* tugs and pilotage, and *CD* is canal dues.

Therefore, just if the manager is considering the above simple formula some particular visible measures related to the energy efficiency optimization, other than fuels costs arbitrage, will be easy deducted. First, is important to choose the right trip legs for bunker supply and for operation, diminishing by proper analysis, the port and light dues. Thus, to get the energy efficiency target it should be chosen the cheapest port in terms of pier dues, but also properly equipped for a faster operation and short noticing time in operation procedures, mostly using the wharf endowment and on-shore power supply. Secondly, the logistics network should provide the proper hauls in ratio with the ships payloads, thus supporting the threshold turnover and to offer a proper image, in advance, regarding the speed of operation. The harbour services, starting with towage and pilotage, custom clearing and finishing with the departure corresponsive formalities should be improved, using the EDI systems or other forms of networking cooperation in order to reduce the stalling time, spend in the harbour basin. The manager should act dynamically, studying the port congestion variables and using their cancelling rights in order to onset the most reliable port for charging/discharging. Less energy will be used if the harbour stalling time and operation time will be reduced. The ship agencies should also take care about decreasing the operation time, asking for stronger relations between those actors implied in management of information systems and providing both headhaul and backhaul trips. [3]

On the other hand, the proper choice decision regarding the navigational routes, reducing distances between two ports and avoiding areas with unfavourable sailing conditions, can influence efficiency of the propulsion machinery, constituting another course of action subject to the objective of optimizing transport. Complying with a reliable MRO policy (maintenance and repairing operations) is important also to provide a better technical framework for the voyage execution. Furthermore, considering the energy diagram drawn below other measures can be drawn by managers, in order to reduce the voyage costs, accounting the waterborne trip variables. As shown in literature the ship energy is wasted not just for a useful effect, but also for the environmental variables or for technical reasons on subsidiary loops (Figure no. 6).

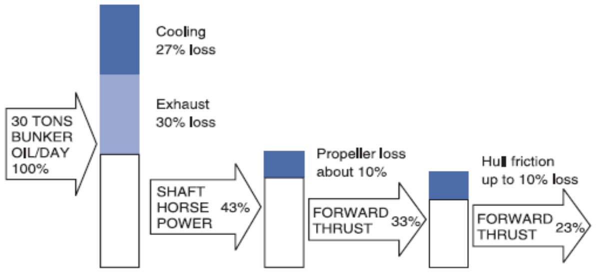

Figure 6 Ship energy losses diagram for a Panamax bulk carrier, on 14 knots design speed
(Source: Stopford et al, 2009, pp. 233)

More than 27% of the oil bunker is wasted for engine cooling that means navigation in cooler season on sailing route will bring important saving in energy consumption. Also, an alternative energetic system can be implemented in order to provide engine cooling service on board, as based on solar panel or else. Exhausting is taking a share of 30% of total losses, so is important to look for alternative in using burnt gases in other propelling components, to help cooling, or the propelling power by heating transfer pumps or else. The hull friction is bringing an additional loss of 10% in consumption. The ship should be prepared for the optimum sailing conditions, based on a rigorous technical condition and following the recommended maintenance operations at the time, accordingly to the technical requirement, especially in the matter of ship fouling and hull polishing to assure the best propelling forwarding and the lower ship drag effect. Hence, the hull maintenance is very important for energy efficiency since the fuel consumption of two maritime carriers operating at the same speed could differ by 20–30% depending on age, machinery and hull condition [19].

All these measures can be implemented only through responsible manner of action on board and onshore. The management should consider both the profit principles together with the technical requirements. The training sessions provided onboard, along with the other managerial energy efficiency policies, are important constituents of the Ship Energy Efficiency Management Plan (SEEMP), contributing to assure the sustainable principles insertion throughout the whole process of merchant ship operation.

5. CONCLUSION AND FINAL REMARKS

The need to reduce CO2 emissions from ships exhausting is a current global problem, and any shipping company is facing both the challenges and the restrictions of the international policies in this mater. Synthesizing the major aspects involved by energy efficiency principles consideration in the managerial decision making process, the present paperwork sought to reflect both economic and technical issues involved in this analysis, collecting data from all variables involved in a voyage contract execution, that further impacts the major costs of the maritime transportation, such as: freight market evolution, fuel steaming policy, voyage costs management or loading/unloading operations management in harbour area.

The study conclusions assert that each managerial policy to reduce CO2 emissions has its advantages and disadvantages and their implementation onboard the ships depends on several factors, among which the most important are: type and capacity of the ship, ships' technological age, the forecast evolution of the freight market and the bunker prices and also the speed of the port operation processes. The research carried out can be extended to all types of vessels serving the seaborne trade, referring to the decision making chain objectives**.** In conclusion, the next ideas were drawn as essential recommendations for the managerial factors in planning and implementing energy efficiency policies:

- increasing energy efficiency on board the ships involves a holistic approach on managerial level, involving the entire chain of planning, coordination and execution of the maritime voyage, including ship management, operation management or subjects connection on a common logistic network;
- the public content of energy efficiency becomes relevant to the sustainable development strategies on global level, impacting the international shipping future evolutions, in terms of new restrictions, limitations or recommendations in respect of energy efficient allocation and environment protection;
- future innovative results will consider reliable the clean technologies usage in a wide spectrum and the international shipping should seek for such technological insertion in all future developments, no matter the present costs are.

A common approach for international negotiations has been opened; a common view in operational policies should be adapted accordingly. If the maritime transportation systems as a whole and seamless "hub and spoke" logistic system will act toward energy efficiency desiderata, then a reasonable demand will still be preserved on a sustainable basis in the future for this type of transportation route, proving as competitive in the new era of a "clean and green" economy.

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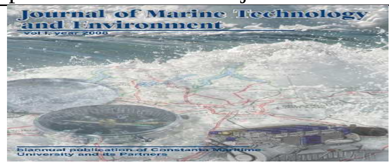

A CFD STUDY ON THE EFFECT OF INJECTION PARAMETERS ON THE FORMATION OF NOX EMISSIONS IN DIESEL ENGINES

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Abstract:The objective of this study is to predict the effects of two main injection parameters on the formation of NOx emissions. The first parameter is the injection timing, the effects of injection timing on the formation of NOx emission will be illustrated and explained at four different injection timings. The second parameters is the cone angle, the effect of changing the cone angle on the formation of NOx emissions will be illustrated and discussed at different three cone angles as well. Computational fluid dynamics (CFD) and ANSYS ICE program were used for simulating the injection process, combustion, and the formation of NO. The Volume-average mole fraction of NO, the Mass-Average mass fraction of NO and the NO density will be discussed at all cases of injection parameters..

Key words: Diesel engines, injection timing, cone angle, NO, NOx, CFD.

1. INTRODUCTION

The Injection timing plays an important role in terms of engine power and the formation of emission gases especially NOx emissions. The temperature and the pressure of cylinder gases at the start of injection affect the atomization and evaporation of injected diesel, which will affect the combustion process, and the formation of NOx emission gases [3,6].

In case of early injection, the temperature and the pressure of cylinder gases will be smaller than the temperature and pressure if the injection process starts closer to top dead centre. Hence, smaller temperature and pressure will lead to increase the delay period; increasing the delay period allows to evaporate more diesel fuel before the ignition occurs, which will cause in increasing the rate of heat release during the first phase of combustion. Increasing the rate of heat release during the first phase of combustion will lead to higher NOx formation rate [6,7,8]. On the other hand if the injection process starts at high temperature and pressure at angles close to top dead centre, the ignition delay period will reduced and the NOx emissions as well. Hence, from the previous discussion we can say that the use of “retarded injection” strategy can be a good way for reducing the NOx emissions in diesel engine [6]. Cone angle is considered an important factor which affects the combustion process and the formation of emissions inside the combustion chamber of diesel engines due to its effect on the formation of diesel-air mixture.

2. THE SIMULATION OF INJECTION PROCESS

The simulation was carried out on direct injection naturally aspirated diesel engine. The engine bore is 107mm, stroke 118 mm, compression ratio 17.5. The number of injector holes are 4, and the diameter of injector hole is 0.024 mm. The engine operation regime is 1440 rpm, 150 N.m.

Figures 1 and 2 show the temperature and the velocity magnitude of the diesel spray at 356 CAD respectively. It is obvious the diesel spray breakup and the impingement of diesel spray on the walls of cylinder chamber.

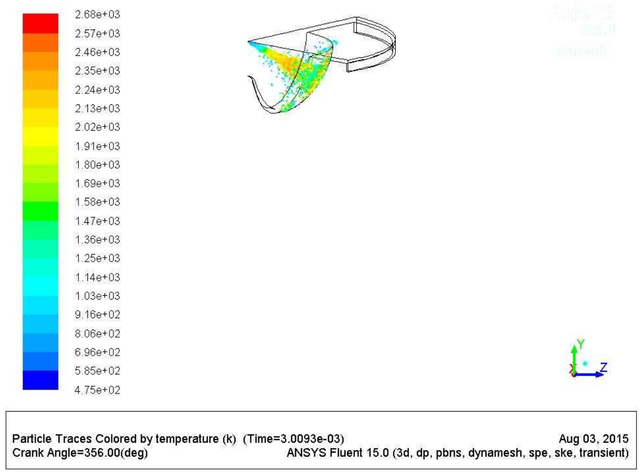

Figure 1 The temperature of particle traces at 356 CAD [K]

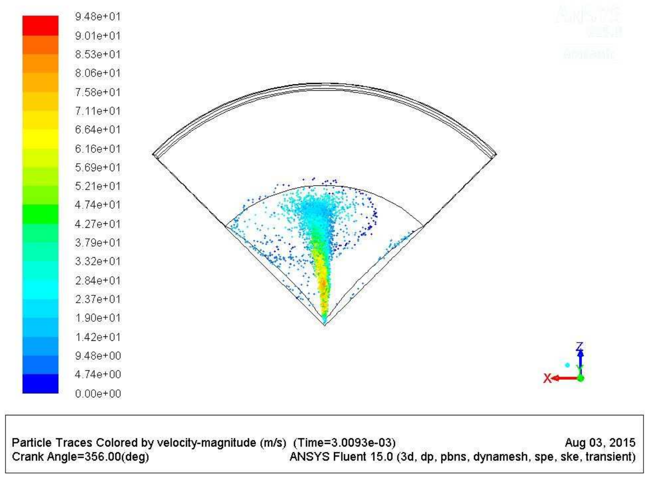

Figure 2 Velocity magnitude of particle traces at 356 CAD [m/s]

3. THE RESULTS OF SIMULATION

Figure 3 shows the cylinder pressure at four different injection timing, the first case the injection timing occurs at 341 CAD, the other cases are at 344, 347, and 350 CAD. It is obvious that earlier injection timing leads to higher cylinder pressure due to the increase of evaporated diesel during the delay period. It can be noticed that the peak of cylinder gases temperature occurs closer to top dead centre for earlier injection timing.

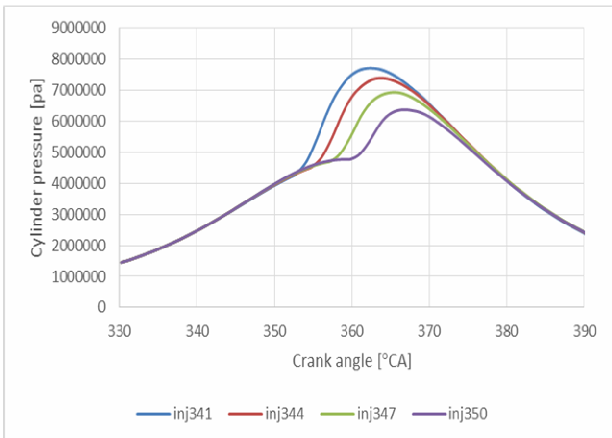

Figure 3 Cylinder pressure as a function of crank angle [pa]

Figure 4 shows the volume-average mole fraction of NO for different injection timing, it is obvious how the volume-average mole fraction of NO increases rapidly at 10-15 degrees after the ignition occurs, then the curves of NO mole fraction start to decrease. It can be noticed that the rate of increase of the average mole fraction of NO is higher at earlier injection timing due to the higher rate of heat release during this period of combustion. The NO emissions have reduced by 16.69% by retarding the injection timing 3 degrees. On the other hand retarding the injection timing by 6 degrees will lead to reduce the NO emissions by 37.63%, and the reduction of NO emissions will reach 54.31% by retarding the injection timing 9 degrees.

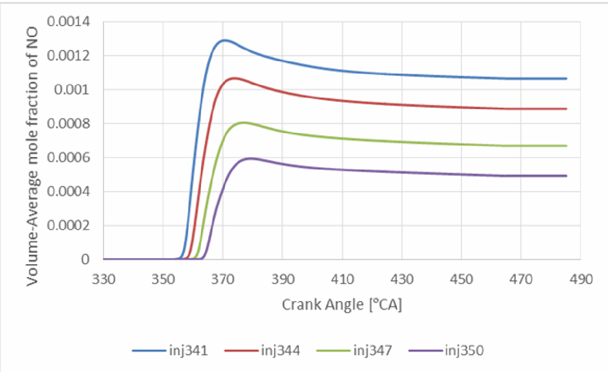

Figure 4 Volume-Average mole fraction of NO as a function of crank angle

Figure 5 illustrates how the mass fraction of NO emissions increase rapidly till reaching the peak value after about 15 degrees from auto-ignition, then the value remain constant till the end of expansion stroke. The rate of increasing of mass fraction of NO emissions is higher at earlier injection timing than retarded injection timing. The reduction in the mass fraction of NO emissions is 18.33%, 48.34%, and 58.56% at 3, 6, and 9 retarding degrees.

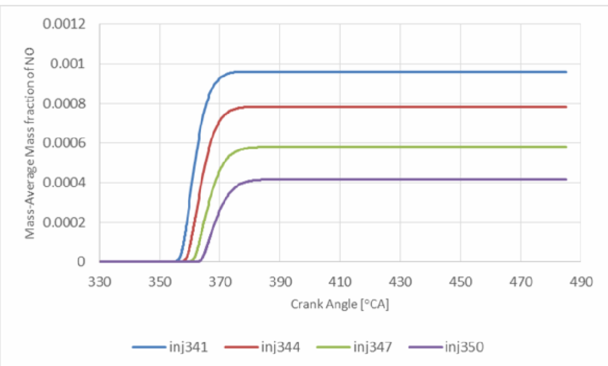

Figure 5 Mass-Average mass fraction of NO as a function of crank angle

The same analysis will be carried out on figure 6 which represents the density of NO emissions. It is obvious that the density value increases rapidly during the first 15 degrees after the auto-ignition. The peak of NO density occurs after the top dead centre by 10 degrees for injection timing 341, and 344CAD. And after the top dead centre by approximately 15 degrees for injection timing 347, and 350 CAD.

After the NO density reaches its peak, it starts to drop down gradually because of the increasing of the cylinder volume during the expansion process. It can be noticed that the difference between the NO densities at different injection timing gets smaller with further increase in cylinder volume.

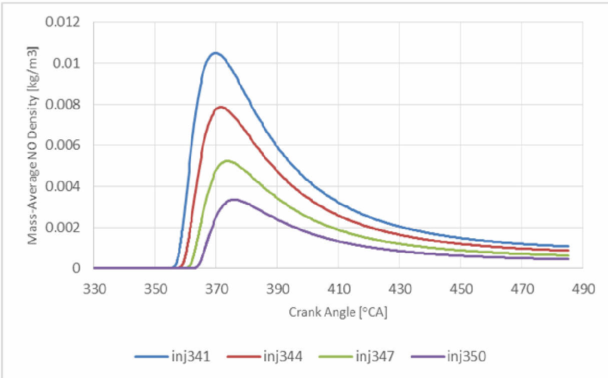

Figure 6 Mass-Average NO density as a function of crank angle [kg/m3]

Figure 7 shows how volume-average mole fraction of NO varies at three different cone angles, it is obvious that increasing the cone angle leads to increase mole fraction of NO. Whereas the mole fraction of NO increases 9.76% by increasing the cone angle 3 degrees and 23.69% by increasing the cone angle 6 degrees. It can be noticed that changing the cone angle leads to a slight change in the rate of increase of NO mole fraction. The peak of NO mole fraction occurs at 10 degrees after to the top dead centre, then the curves start to drop down gradually till 430CAD where the rate of reduction in NO mole fraction becomes too small.

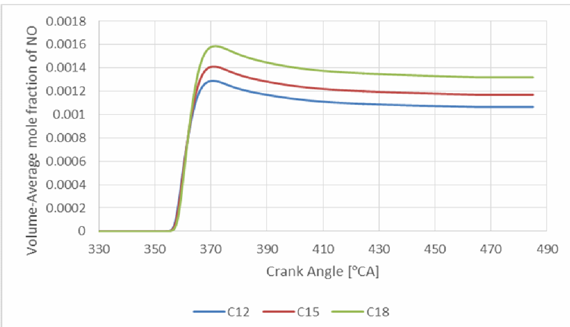

Figure 7 Volume-Average mole fraction of NO as a function of crank angle

Figure 8 shows the difference in mass-average mass fraction of NO when changing the cone angle, it can be seen that the curves increase rapidly at the first phase of combustion till reaching the peak value near to the top dead centre, then the curves become straight till the end of expansion stroke. Mass fraction of NO increases by increasing the cone angle, while increasing the cone angle 3 degrees leads to increase NO mass fraction 10.10% and increasing the cone angle 6 degrees leads to increase NO mass fraction 24.58 %.

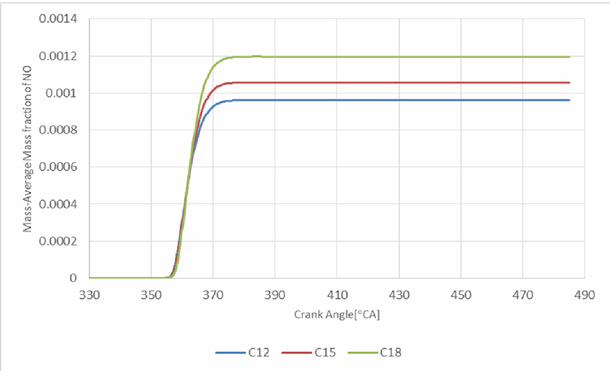

Figure 8 Mass-Average mass fraction of NO as a function of crank angle

The effects of increasing the cone angle on the NO density are shown in figure 9. The NO density increases rapidly from the beginning of combustion till 10 degrees after top dead centre where the peak value of NO exists. After that the NO density drops down till exhaust valve opens. NO density is linked with two factors the first one is the formation of NO emission and the second one is the cylinder volume. Hence increasing the cylinder volume during expansion stroke results in decreasing the NO density in spite of the mass of NO is constant during the expansion stroke. NO density increases 9.74% at top dead centre by increasing cone angle 3 degrees, and 23.51% by increasing cone angle 6 degrees.

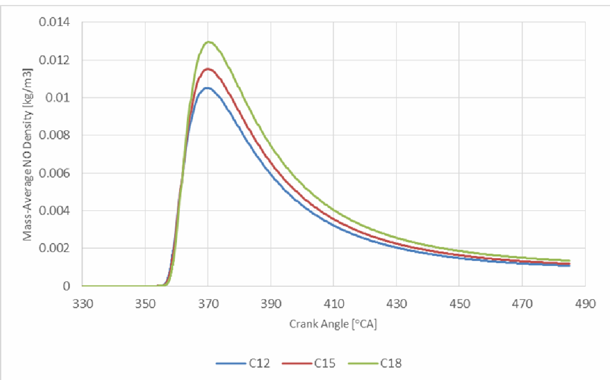

Figure 9 Mass-Average NO density as a function of crank angle [kg/m3]

5. CONCLUSIONS

At the end of this simulation study we can conclude that the simulation process was carried out successfully at different injection timings and different spray cone angles, the results of simulation were in a good agreement with the available data in the literature regarding the effects of injection timing on the formation of NOx emissions. The results show a significant reduction in NO emissions when the injection timing was retarded, and higher retarding periods leads to less NO formation which means less NOx emissions. Regarding the effects of cone angle on the formation of NOx emissions, the study showed that increasing the cone angle leads to increase the formed NO which means increasing the formed NOx emissions.

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THE PREDICTION OF NOX EMISSIONS FROM DIESEL ENGINES BASED ON TWO-ZONE THERMODYNAMIC MODEL

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Abstract: In this study a two-zone thermodynamic model is used for the prediction of NOx emissions from marine diesel engines, the calculation of two-zone model will be based on one-zone thermodynamic model and on the use of Zeldovich mechanism. The calculated NOx emissions validated by comparing them with measured values at different engine operating regimes. The effect of cylinder wall temperature, air temperature coefficient, and residual gases coefficient on the model sensitivity will be illustrated and explained as well.

Keywords: NOx, NO, diesel engines, Two-Zone, thermodynamic models.

1. INTRODUCTION

Diesel engine emissions are a complex mixture of substances, these substances are found in a gas form or in a solid form. They are formed inside the combustion chamber as a result of combustion process of diesel fuel. The main gaseous substances include water vapour, oxygen, nitrogen, carbon dioxide, carbon monoxide, oxides of nitrogen, oxides of sulphur, and gaseous hydrocarbons compounds [2,9].

Due to the increased concerns about the environmental issues, the impact of emissions on the quality of air in populated areas, and the other environmental phenomenon like acid rains, hurricanes, and typhoons many legislation have been issued in order to reduce the level of diesel engine emissions, and these legislations and regulations are getting stricter by the time. Hence, diesel engines companies and researchers started to develop methods to predict the amount of the pollutants that emitted from diesel engines. One of these methods is two-zone thermodynamic model for the prediction of NOx emissions.

2. TWO-ZONE THERMODYNAMIC MODEL

Two-zone thermodynamic model is used for its satisfied and accurate results in calculating NOx emissions when it compared with one-Zone thermodynamic model. The combustion chamber is divided into two separate zones, the first zone is burned gases zone and the second zone is unburned gases zone. The two-zone thermodynamic NO model is based on the calculations of one-zone thermodynamic model and on the Zeldovich mechanism as mentioned before. Figure 1 illustrates the two-zone thermodynamic model, more data about this model [7,8,9].

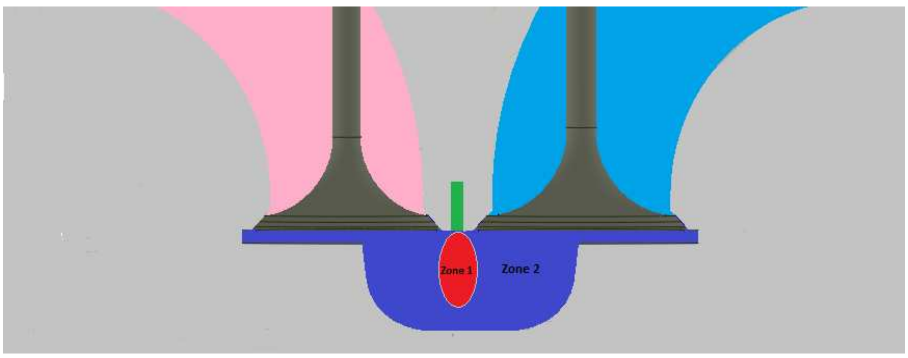

Figure 1 Two-Zone thermodynamic model

3. THERMAL NO EQUATIONS

There are many equations which developed to calculate the initial NO formation rate, one of the earliest equations which used for this purpose is Heywood (1988) [2,7,8].

$$\frac{d[NO]}{dt}=\frac{6\cdot 10^{16}}{T^{1/2}}\exp\left(\frac{-69090}{T}\right)[O_2]_e^{1/2}[N_2]_e . \quad (1)$$

The other equations which can be used are Baulch et al (1991) and CRT-MECH 3.0 (2000) equations. The difference between these equations is the speed constant. For Baulch et al speed constant is written as [7,8]:

$$k_{1,r}=1.8\cdot 10^{4}\exp\left[-\frac{38400}{T}\right]. \quad (2)$$

For CRI-MECH 3.0 speed constant is given as:

$$k_{1,r}=0.544\cdot 10^{14}T^{0.1}\exp\left[-\frac{38020}{T}\right]. \quad (3)$$

4. RESULTS DISCUSSION

The calculations were performed on HINO W04D high speed marine diesel engines, the experimental data is available with the author. The model was used for calculating the results of NO at three different operation regimes.

As it can be seen in figure 2 the rate of NO formation increases very rapidly at the beginning of combustion, this period represents premixed phase, then about 21 degree after the start of combustion the rate of NO formation freezes, and it can be said that no additional NO forms due to the drop of in-cylinder gases temperature. Figure 2 illustrates the results of three NO formation models, Heywood, Baulch, and CRI-MECH. It can be noticed that the Heywood model is the less accurate model by error reaching 69.1%, The error decreases by the use of Baulch et al, but still large because it reaches 29.3%, the last model is CRI-MECH the error by using this model does not exceed 1.6%.

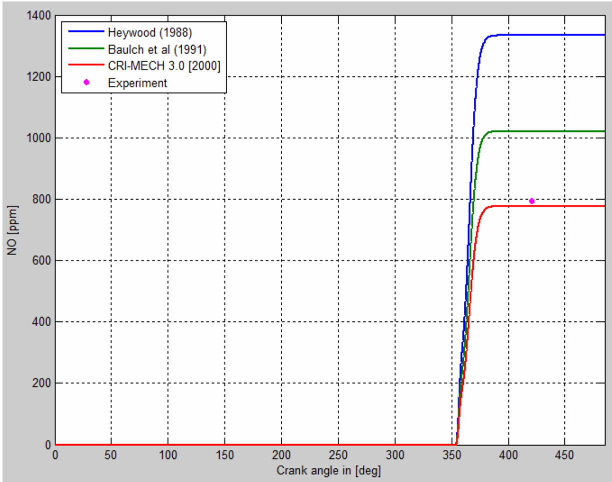

Figure 2 Calculated VS measured NO concentration in ppm at 1600rpm and 150 N.m

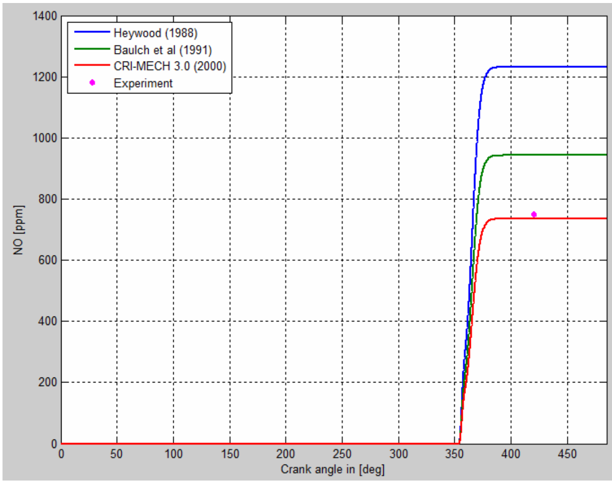

Figure 3 Calculated VS measured NO concentration in ppm at 1800 rpm and 150 N.m

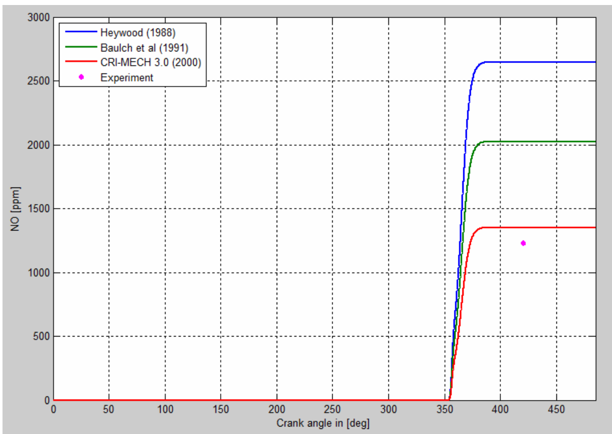

Figure 4 Calculated VS measured NO concentration in ppm at 1800rpm and 200 N.m

It can be seen from figure 3 that the error of Heywood, Baulch, CRI-MECH is 63%, 24.9%, 2.6% respectively. From figure 4 it can be released the error of Heywood, Baulch, and CHI-MECH methods is 101%, 53%, and 7.6% respectively. Hence, from the previous three figures we can say that CRI-MECH method is the most accurate method, and the results which obtained by using this method is so satisfied in terms of accuracy.

5. TWO-ZONE THERMODYNAMIC MODEL SENSITIVITY

5.1 The effect of cylinder wall temperature

The relationship between the cylinder wall temperature and the predicted NO will be explained as follows.

Table 1 Variation of wall temperature and NO prediction

Wall temperature	Predicted NO	NO changed %
440 K	922	-0.32
450 K initial	925	-
460 K	928	+0.32
470 K	930	+0.54
480 K	932	+0.75
490 K	935	+1.08
500 K	938	+1.29

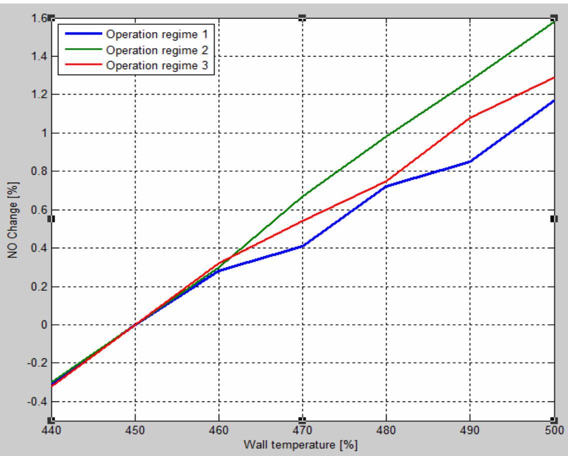

Figure 5 Variation of cylinder wall temperature and NO prediction

Figure 5 shows the effect of wall temperature on NO prediction at different engine operating regimes, where operation regime 1 when the engine works at 1600 rpm and 150 N.m, engine operation regime 2 when the engine works at 1800 rpm and 200 N.m, engine regime 3 when the engine works at 1800 rpm and 150 N.m. It can be released that the NO prediction changes 0.2% to 0.32 % for every 10 degrees K in wall temperature. Or in other words increasing the assumed wall temperature by 10 K will increase the predicted NO by 0.2% to 0.32% and vice versa.

5.2 The effect of air temperature coefficient

Cylinder charge is heated up due to difference in temperature between cylinder charge and cylinder wall, from the literature the increase in charge temperature due to wall temperature given between10-15 $^{\circ}$C [6]. In this model the base value was taken as 10 $^{\circ}$C, anyhow the effect of this parameter on the amount of predicted NO will be discussed and illustrated.

Table 2 Variation of the cylinder charge temperature coefficient and NO prediction

Cylinder charge temperature coefficient	Predicted NO	NO changed
10 $^{\circ}$C initial	925	-
11 $^{\circ}$C	953	3.02%
12 $^{\circ}$C	979	5.08%
13 $^{\circ}$C	1007	8.86%
14 $^{\circ}$C	1036	12%
15 $^{\circ}$C	1065	15.13%

Figure 6 shows the change in NO prediction at different engine operation regimes. It can be concluded that the NO prediction is increased by 3% by increasing the cylinder charge one Celsius degree.

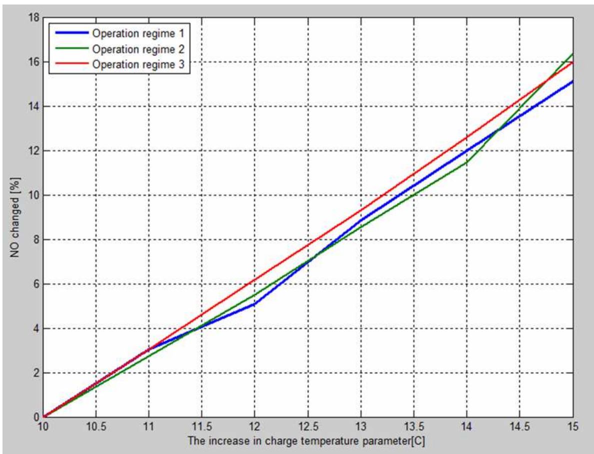

Figure 6 Variation of the coefficient of cylinder charge temperature and NO prediction

5.3 The effect of residual gases coefficient

The residual gases coefficient range is between 0.04-0.06 [6]. The effect of changing the value of residual gasses coefficient on NO prediction is illustrated in Figure 7

Table 3 Variation of the residual gases coefficient and NO prediction

Residual gasses coefficient	Predicted NO	NO changed
$R_{g,c} = 0.046$	867	-6.27
$R_{g,c} = 0.047$	881	-4.75
$R_{g,c} = 0.048$	896	-3.13
$R_{g,c} = 0.049$	910	-1.62
$R_{g,c} = 0.050$ initial	925	-
$R_{g,c} = 0.051$	940	1.62
$R_{g,c} = 0.052$	955	3.24
$R_{g,c} = 0.053$	970	4.86
$R_{g,c} = 0.054$	986	6.59

It can be released that for each 10% increase in residual gases coefficient, the NO prediction increases in average 2% and vice versa.

6. CONCLUSIONS

Two-zone thermodynamic model was used successfully for the prediction of thermal NOx emissions from marine diesel engines. The results of modelling the NOx emissions are satisfied in comparison with the experimental results by using CRI-MECH (2000) equation. The results of using the other two methods Heywood (1988) and Baulch et al (1991) are not satisfied and the speed constant of equations should be modified. The sensitivity of the model was illustrated by changing the value of three main parameters which were implemented for performing the calculations.

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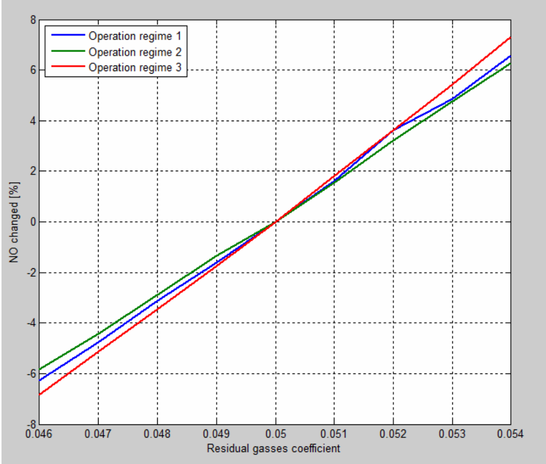

Figure 7 Variation of residual gases coefficient and NO prediction

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SYSTEMS FOR COLLECTING AND TRANSFERRING OF METEOROLOGICAL INFORMATION USED FOR WEATHER PREDICTION

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Abstract: During the ship's voyage the mariners are facing many hazards like strong winds, rough sea, icebergs, etc. That is why the accuracy of meteorological information received on board is vital. Although the WMO is aiming for automation of the processes for collection and transmission of meteorological information the watchkeeping officers role in manual input of meteorological information is still very important. Meteorological data obtained from satellites, shore stations, aircrafts, research and merchant vessels performing the voyages in different areas of the Worlds Ocean, and systems of floating, drifting and moored buoys are used for weather forecasting. Reliable database for every region requires constant measurements of meteorological parameters for a long period of time. Real time wave and wind measurements are important for forecasting and sending of warning messages to the ships, creation of numerical models and proper work of the companies, providing ship's routing services. This paper discusses the systems used for collecting, storage and processing of meteorological data, the automated weather systems used for observation of meteorological parameters on board of the ships and the systems used for transferring of all these data.

Key words: meteorological data, weather system, measurement.

1. INTRODUCTION

The data obtained from on-board meteorological systems includes three types of information: navigational, meteorological and oceanographic (Fig.1). Navigational information from ships contains geographical coordinates, ship's speed and course, while meteorological buoys send only geographical coordinates. The new data is added to the database. This data is stored and after several hours, it is sent via satellite system to shore stations for further analysis, verification and distribution through communication system (dial - dial-up and / or Ethernet) to the regional databases.

The systems of moored buoys provide data for basic parameters, such as sea surface temperature, air temperature, wind's direction and speed, atmospheric pressure, air humidity and precipitation [4]. Further this data are used for prediction of air masses movement at different layers above the sea surface. The information obtained from floating sensors and drifting buoys additionally increase the accuracy of measured parameters from ships weather stations and moored buoys.

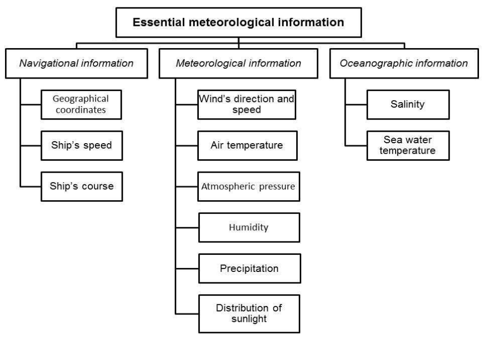


Figure 1 Essential information from ships weather stations

2. SYSTEMS USED FOR TRANSFERING OF METEOROLOGICAL DATA

Global Ocean Surface Underway Data (GOSUD) and Shipboard Automated Meteorological and

Oceanographic System (SAMOS) are working together to provide high-quality oceanographic and meteorological observations from ships. GOSUD (Fig. 2) collects and evaluates meteorological data for temperature and salinity of the World's Ocean received from different types of ships. SAMOS improves the access to measured and validated meteorological data collected on spot by automated equipment mounted on merchant and research vessels [1].

Data transfer in SAMOS system (Fig. 3) is carried out in near-real time by e-mail (not GTS) protocol. The data transfer in GTS format is very limited for accurate decision-making, when performing SAMOS data analyzes. The shipping center for collection of meteorological information has developed a series of web-based forms for automated ship to shore transfer of meteorological data. The authentication assessment of the collected data is carried out by specialists and computer programs [10].

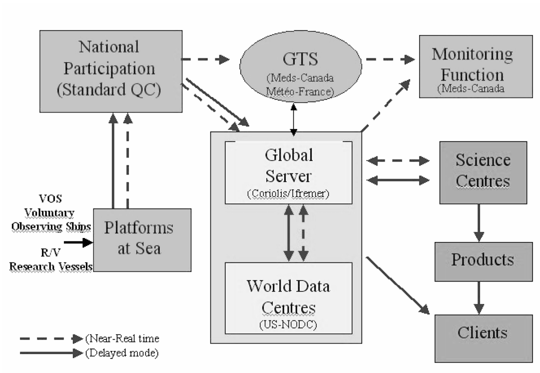


Figure 2 GOSUD data flow

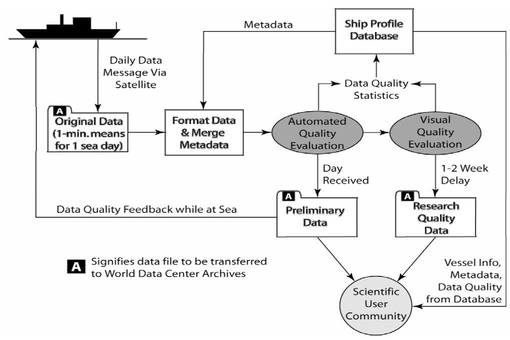


Figure 3 SAMOS data flow

The information received from ships is sent to the nearest meteorological center, usually by the Global telecommunications system (GTS) or through Inmarsat-C using special access code - SAC 41. From 2012 the universal format FM96 BUFR has been used in Met Offices for the presentation of weather data instead of so-called ship format FM-13.

Under the guidance of IMO there have been used 12 telecommunication satellite systems for transmission of meteorological information. The meteorological data from most of the research vessels has been sent "in real time". This allows quick detection of the problems in measuring instruments and reduces the loss of information.

In order to achieve lower price of data transfer instead of well-known Inmarsat-C communication system World Meteorological Organization is using alternative communication systems for transmission of meteorological information received from buoys and Voluntary Observing Ships (VOS).

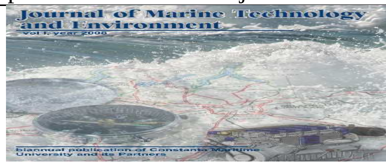
Therefore Argos satellite system has been used from 1987 for collection, processing and transmission of meteorological data. Argos is the main communication system used by moored and drifting buoys and sensors and Automatic Weather Stations (AWS). All ships and buoys have their own identification number. They regularly transmit reports in format FM-13 on frequency 401.650 MHz ± 30 kHz at intervals from 90 to 200 seconds, depending on the data size. Their location is determined by measurements based on the Doppler Effect. The data obtained by the ships are verified by the software on board and thereafter are sent encrypted to the satellite systems, where the information is processed and quality controlled by the GTS subsystem. Further the information is transmitted to land processing centers and to Meteo France for GTS transmission.

The users of the system receive data directly in the office or on site, depending on their personal choice (Internet, e-mail, fax or CD-ROM). Once the information is received, it can be used for weather forecasting or research purposes [9].

The system can operate in "one-way" communication and "two-way" communication modes. Solar batteries mounted on buoys and ships can be used for power supply of the transmission antennas, because they transmit short messages at duration of 1 second and they use satellites at an altitude of 850 km.

After unification of CNES and NOAA the Argos system added two new major partners: Japan, represented by National Space Development Agency NASDA and Europe, represented by EUMETSAT. Next step is signing of a partnership agreement with the Brazilian National Institute for Space Research (INPE). Four Argos-2 satellites and four Argos-3 satellites were launched in 2012. One Argos-3 satellite was additionally launched in 2014. The satellite system Argos-4 is currently under development.

Argos-2 satellites support fast data transfer and increased memory for data storage. Users may establish connection with Argos system server by Internet and they can choose desired information to be received. They send commands to their platforms through web interface and satellite link. Argos-2 system can receive three times more messages simultaneously than previous series



satellites. The Argos system is using repetitive messages in order to reduce the random errors when receiving data from satellites.

Argos-3 satellites have data transfer speed of 4800 bits per second, which is 10 times faster than "one-way" transmission. This speed helps for easy harmonization of the transmitted data from moored buoys and ARGO buoys [11]. Argos-3 "two-way" communication systems used in last few years reduces significantly the time for message transmissions.

The major advantages of the Argos system are low price of the transmitters and low power consumption. However, transmission costs are relatively high (approximately € 0.33 per message) and significant transmission delays can be expected according to the location of the satellite, due to the fact that the system uses polar orbiting satellites.

The communication systems Globalstar, Meteosat and Iridium can also be used for data transmission. On Table 1 is shown the comparison of the communication systems used for data transfer to shore. The Globalstar system does not provide global coverage. The system is used by ships having on board automated acoustic systems E-ASAP [6].

The Iridium communications system works in dual-channel mode. It is used for transmission of information from onboard automated weather systems BAROS and BATOS and moored and floating buoys ARGO as a substitute for Argos and Meteosat systems [2]. The system supports text and voice messages and fast data transfer. The cost of a "Short Burst Data" message is about 0.08 euros. Another advantage of the system is that there are no delays in the transmission of messages. Only 3 minutes are required to send a message, and this allows observing the currents surface by making records of the times when there is no information received from drifting sensors [8].

Table 1. Comparison of communication systems used for transfer of data to shore

System	Service	Format	Tranmitter + Anten. cost	Op. cost per report	Total cost per report	Coverage	Remark
Inmarsat-C	Text	ASCII	0 € (GMDSS)	1.00 €	1.00 €	Quasi-global	Turbowin Code 41 or not
Inmarsat-C	Text	ASCII	0 € (GMDSS)	0.40 €	0.40 €	Quasi-global	Half compressed reports
Argos		Binary	150 €	0.33 €	0.33 €	Global	Transmission delays Minos station
Globalstar		Binary	1500 €	0.20 €	0.22 €	Regional	Under evaluation at Met.no
Inmarsat-C	Data R.	Binary	1600 €	0.15 €	0.17 €	Quasi-global	New Batos systems
Iridium	SBD	Binary	1000 €	0.08 €	0.09 €	Global	Planned for Batos
Meteosat	DCP	ASCII or binary	5600 €	0.00 €	0.07 €	Regional	German Milos AWS

Manned VOS AWS systems

Binary compressed messages with special access codes can be used for data exchange, in order to reduce the costs of the messages. E-SURFMAR system has Inmarsat-C developed program for compression of manually entered data in alphanumeric format. An uncompressed message has five blocks of 32 characters and the price of one message is 0.8-1.0 euro, subject to the terrestrial coast station used. Each compressed message consists from two blocks of 32 characters and the price of one message is 0.32 euro.

3. SYSTEMS USED FOR COLLECTING, STORAGE AND PROCESSING OF METEOROLOGICAL DATA

The systems collecting information for meteorological parameters can be generally divided to:

- systems, which use data for monitoring of climate and oceanographic changes from one network only;

- combined systems, containing a large database from measurements obtained by drifting sensors, moored buoys, research vessels, commercial vessels and regional coastal meteorological stations.

Some of the most important systems for collecting and processing of meteorological information are Argo floating sensors system and EUMETNET's combined system E-SURFMAR. The systems like OceanSITES, database of the buoys (DBCP) and observations from ships (SOT, GO-SHIP) are used for evaluation of weather conditions and climate change in the oceans in addition to Argo system, which is coordinated by GOOS. The Argo system receives real-time observation data for temperature and salinity of sea water from floating sensors. The system is operated by two Global Data Assembly Centers (GDAC), located in France and United States, 11 National Data Assembly Centers (DAC) and several Argo Regional Centers (ARC). GDAC centers are collecting data processed by DAC centers. They synchronize information and distribute it to the consumers in standard NetCDF format both on FTP and WWW. DAC centers receive data from satellite operators. They decode this data and make real-time check for their accuracy. After correction the information has been sent to both international center and to GTS. Argo Regional centers possess a wide variety of meteorological and oceanographic information (Figure 4) [7].

The information from floating sensors has been used by qualified specialist for further analyzes. The information can be received by users with 24 hours delay.

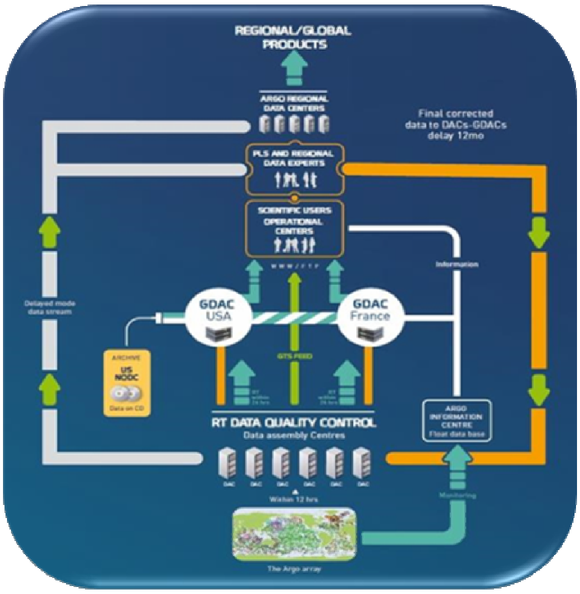


Figure 4 Scheme of the ARGO system

In June 2015 the Argo system comprises 3800 floats (Fig. 5), 55% of which are provided by USA. The network provides 140 000 measurements of temperature, salinity and velocity per year. The sensors are placed on average spacing of three degrees from each other. The floats perform cycles every ten days at a depth of 2000 meters, and the lifetime of each sensor is about 4-5 years. All data from Argo floats are publically available in near real time after automated controls for verification the reliability of data by qualified personnel via GDACS in Brest (France) and Monterey (California, USA) [16].

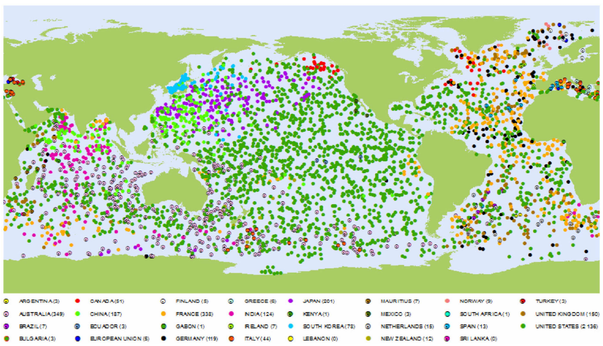


Figure5 Argo network in June 2015

All Argo floats, which have bio-optical sensors for measuring the oxygen, pH, nitrates, coloration of the ocean, and back scatter, are used in development of different methods for evaluation from many programs. At the end of June 2015 there were 262 floats for measuring the oxygen concentration. The development trends are aimed in equipping the areas where many sensors soon will be out of operation, better coverage of the equatorial regions and borderline areas, as well as carrying out detailed biochemical measurements.

The Global Ocean Ship-Based Hydrographic Investigations Program (GO-SHIP) was established as a part of GOOS and serves in a number of scientific researches related to the study of the oceans. The program stores data from hydrographic observations on shore and at open sea, which are used for prediction of changes, concerning global heating, fresh water, carbon, oxygen, nutrients and others.

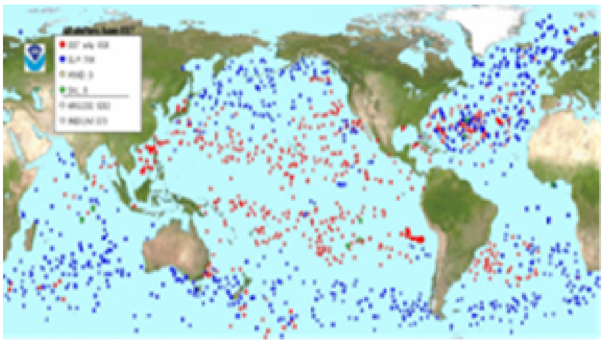


Figure 6 Drifting buoys network in July 2015.

The drifting buoys network consists of 1 250 buoys. They sent constantly information about currents, sea surface temperature (SST) and surface pressure through GTS communication system. The major part of the total number of 1401 buoys is standard Surface Velocity Program (SVP) drifting buoys. About 50 % of them can measure surface pressure and only a small part of the buoys can measure wind and salinity. Figure 6 shows the network status in July 2015. In the period from 2011 to 2012 many of the buoys went out of operation before reaching the maximum lifetime of 450 days. The main reasons for this were: - batteries defects;

- some of the modems were not energy efficient and this has led to significant reduce of their operational life;
- increase in power consumption of electronic equipment of the buoys.

Nowadays about 80% of the drifting buoys are provided by Global Drifter Program of NOAA. The rest of the buoys are provided by European countries, mainly under the program of EUMETNET. The development of the system is aimed in increasing the number of atmospheric pressure measuring sensors and increasing the measurements in the Pacific Ocean region.

The moored buoys network has been built for 20 years. About 90% of the buoys are using GTS for data transfer. Most of them are measuring meteorological parameters and only some networks have the ability to measure oceanographic parameters. The moored buoys network is used for long-term and short-term forecasting of the climate changes in the oceans.

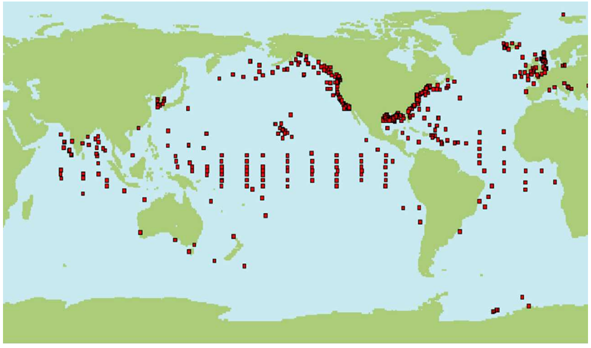


Figure 7 Moored buoys network in April 2015

There are approximately 400 moored systems in operation, with networks operated by different countries from North America, South America, Western Europe and North Indian Ocean (Fig.7) [15]. More than 50% of the buoys are provided by USA. The system consist of tsunami buoys, Tropical Atmosphere Ocean (TAO) array and national moored buoys networks. The Data Buoy Cooperation Panel (DBCP) maintain link with OceanSITES. The network for monitoring of the tropical area TAO array contains data from The Tropical Atmosphere Ocean/Triangle Trans - Ocean Buoy Network - TAO/TRITON, The Prediction and Research Moored Array in the Tropical Atlantic – PIRATA and The Research Moored Array for African - Asian - Australian Monsoon Analysis and Prediction - RAMA.

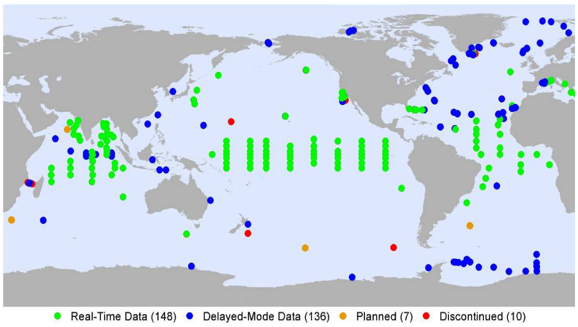


Figure 8 OceanSites network in September 2014

OceanSITES is a global research system which performs long-term deep-water measurements of various oceanographic parameters (Fig. 8). The program focuses to build and maintain a network, which performs a wide range of scientific research (physical, biochemical and atmospheric) for monitoring of the changes in ecosystems and ocean forecasting. Deep Observing Network (DON) which is aimed to make deep-ocean measurement of the temperature and salinity is functioning since 2011. Another similar system MOIN (Minimalist OceanSITES Interdisciplinary Network) provides information about the marine ecosystems. All information in OceanSITES database is publically available.

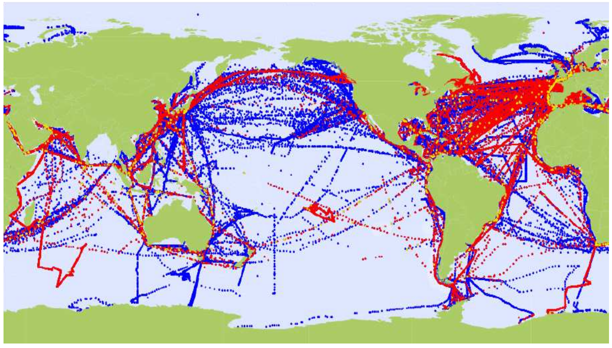


Figure 9 Distribution of VOS and VOSClim ships in January 2015

The Voluntary Observing Ship (VOS) program is part of Ship Observations Team (SOT). The program is coordinated by the joint WMO and the International Oceanographic Commission of UNESCO – IOC (WMO/IOC) Technical Commission for Oceanography and Marine Meteorology (JCOMM) [14]. In July 2015 VOS ships were more than 3100. They send meteorological data to the national meteorological centers mainly through satellite communication systems (Inmarsat, Iridium, Argos). The VOS observations provide information for pressure, humidity, temperature, and visually observed parameters such as visibility, type of clouds and swell. The weather parameters are monitored manually or automatically.

Additional sensors for wind's direction and speed and sea temperature can be included. All data is collected in electronic logs by watchkeeping officers and transmitted in real time every three hours through Inmarsat-C to meteorological centers for preparation of numerical models for weather prediction. Meteorological information together with ship's coordinates at the time of the measurement is saved on-line in the database by E-SURFMAR system.

The software on-board has possibility for averaging the results at one minute. In most models, meteorological sensors are mounted on a single mast and they include sensors for measurement of the wind's direction and speed, electromagnetic compass, atmospheric pressure, air temperature and relative humidity. A combined sensor which measures the temperature, conductivity, oxygen content, pH, and is used for oceanographic measurements. Platinum thermometer can be mounted additionally outside the hull in the water for sea surface temperature (SST) measurement. Solid optical sensor can be mounted for measuring the amount of chlorophyll, dissolved organic material (DOM) and turbidity of the water.

VOS ships can be of various types and sizes and they can be engaged in linear or tramp voyages in different regions of the World Ocean. The system can be implemented on yachts, passenger ships, tankers, container ships, bulk carriers, specialized research vessels and in ports. One of the advantages when using a yacht as a component is the ability to perform measurements in not very common ocean regions. The system aims to hire more vessels performing a wide range of meteorological and oceanographic measurements suitable for climate research and scientific studies. The number of vessels that have been upgraded in VOSClim class is gradually increasing, and in the middle of 2015 their number was 500, or over 1/3 of the VOS-ships. The number of reports received by VOS-ships over past two decades is 2 million observations per year. The system consist of ships from 30 member states of the WMO and most of the observations comes from fleets maintained by the USA, Netherlands, Great Britain, Germany, Canada and France. The distribution of VOS and VOSClim ships is shown on Fig. 9.

VOS-ships network must contain not less than 25% VOSClim ships. In January 2015, VOSClim ships were 28%. The number of sea surface temperature measurements provided by VOS-ships have increased in 2012, due to additional manual input of data after the measurement. The total number of VOS observations and the number of SST observations increased up to 2012 (Fig. 10), which is based on delayed-mode data collection. The number of received near-real-time atmospheric data increases in 2014 compared to 2012, while the percent of SST observations remained the same over the years.

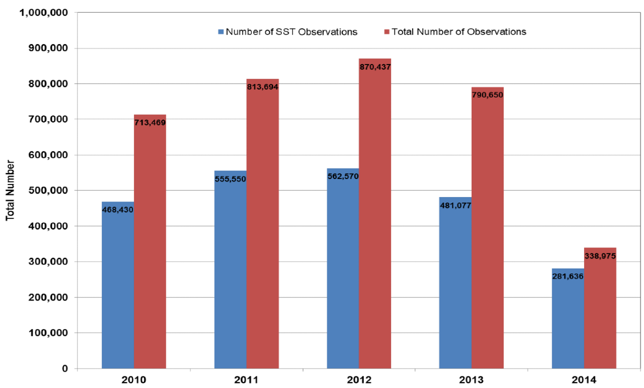


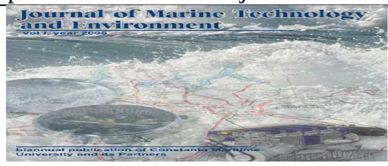
Figure 10 The distribution of VOS ships (including SST measurements) from delayed-mode data collection for the period 2010 – 2014

The Voluntary Observing Ship Climate project (VOSClim) was created to provide high quality meteorological and oceanographic data available in real-time and database to support the climate change researches. VOSClim project followed the successful VOS Special Observing Project North Atlantic (VSOP-NA) that was conducted on behalf of the World Climate Research Project (WCRP) between May 1988 and September 1990. The aim of VSOP-NA was to establish the effects on the quality of VOS data of different ship instrumentation and observing practices. In future studies, the observed real-time data model, meteorological data and additional data from VOSClim ships will be collected together to display a complete picture of how, where and when the measurements were made. The data from the project VOSClim are used for studies and climate change research by calculation of the movement of air masses over the sea. These data can be used for calibration of data obtained from satellite observations. This will lead to the development of more accurate marine meteorological forecasts and will provide more comprehensive weather information in real time. Data from VOSClim ships are collected in the national centers of NOAA, where the information is processed and stored [3].

SOOP program of JCOMM is also part of SOT. It collects and stores oceanographic data, where the samples are taken from different ships, like research and cruise vessels using bathythermographs (XBT). This network can also use measurements made by: eXpendable Conductivity Temperature Depth (XCTD), Acoustic Doppler Current Profiler (ADCP), thermosalinograph (TSG) and Continuous Plankton Recorder (CPR). The measurements are made at regular intervals. This network is using ships that regularly operate on specific routes. These measurements complement the data obtained from Argo network and satellite measurements. Heaving in mind the advantages of Argo floating sensors network, XBT network now focuses on:

- evaluation of seasonal currents and directions for changes of the open sea currents;
- assessment of the currents leading to temperature changes and transfer of biomass from one water basin to another;
- observing the seasonal changes and preparing the long-term assessments for the change of SST;
- the creation and verification of numerical models.

They are deployed on ships around 20 000 XBT per year, while measurements from only 17 000 correspond to XBT network (Fig. 11). The remaining 3000 XBTs are deployed on research ships. The network is divided into 40 sectors and the data is sent to the database in real time through GTS. The data is stored for further processing and analysis in the National Oceanographic Data center and Coriolis Centre, after automatic control for reliability of measurements. 60 vessels are maintaining the XBT network and 70 vessels are participating in data transfer. Annual analysis of the data from XBT network is prepared by Atlantic Oceanographic and Meteorological Laboratory (AOML) of NOAA. AOML database was not complete because some XBT stations send their data only to AOML, while



the others only to JCOMMOPS. That is why after April 2015, AOML sends all received data to JCOMMOPS.

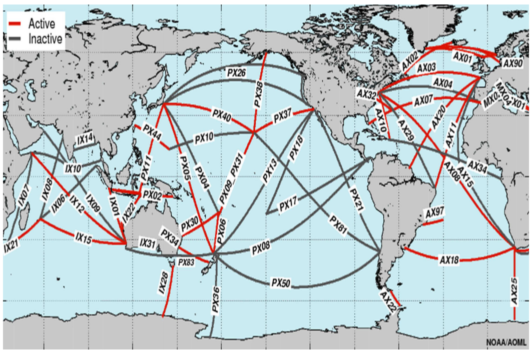


Figure11 XBT network: currently occupied lines (red) and unoccupied lines (black)

International Comprehensive Ocean–Atmosphere Data Set (ICOADS) is a database that stores data obtained over a long period of time for the sea surface wind. These data are subsequently used for analysis of the climate change. The buoys have limited spatial and temporal coverage. However, the measurements of wind's direction and speed from moored buoys contain less random error than measurements made on ships. The buoys are sending information every hour, and they are considered more reliable in the development of numerical models and means for remote data collection of meteorological parameters.

The E-SURFMAR meteorological data system was developed by the European program EUMETNET. The system receives data from drifting buoys and VOS-ships from 31 meteorological centers from 19 European countries. The reports cover the special areas in the North Atlantic (north of 35°N) and the Mediterranean Sea. The average number of drifting buoys used in July 2012 was 75. In addition to them the system receives data from about 45 drifting buoys and sensors operating in the aforementioned areas from NOAA, Meteo-France, LOCEAN and Marlin [12]. The systems of four moored buoys are used for calibration of the data obtained from satellites. In 2013, about 370 VOS-ships sent average of about 270 manually and 1600 automatically entered observations per day. The buoys, which are used to collect meteorological information, are equipped with computer module for sending of automatic messages to satellite systems, internal memory and a solar power supply panel.

By the end of year 2013, 28 E-SURFMAR AWS were in operation: 10 BaTos (measuring 5 parameters) and 18 BaRos (measuring 2 parameters). The total number of AWS used in July 2015 was about 400. Automatic weather system can measure several parameters automatically: pressure, air temperature, humidity, sea water temperature, wind's direction and speed.

The data from visual observations like cloud coverage, height and type of clouds, sea surface state (swell, ice) can be entered manually. 90% of the data has been receiver from the users via GTS, with maximum 50 minutes delay after the measurements.

The accurate data for the measured wind's direction and speed at sea are important because the wave height is related to wind's speed. The main problem is to reduce the errors and deviations in measured and reported parameters of the wind from research ships, VOS-ships and weather buoys. The main reasons for the inhomogeneity between the measured data obtained from different sources are shown on Figure 12.

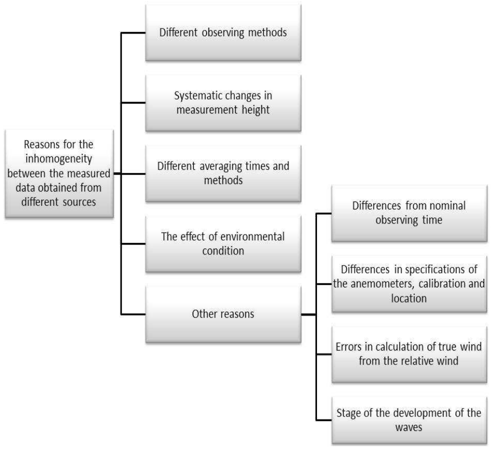


Figure12 Reasons for the inhomogeneity between the measured data obtained from different sources

4. AUTOMATED WEATHER SYSTEMS USED FOR METEOROLOGICAL OBSERVATION ON BOARD OF THE SHIPS.

In the last decade there has been a constant increase in the use of Automated Weather Stations (AWS) on board of the ships. AWS significantly differ concerning their construction and measurement capabilities. The most common AWS have the same equipment like moored buoys: barometer and satellite communication module.

The system is adapted for use on board of the ships in connection with GPS device which allows automatic calculation of position, course and speed, and determination of the direction and speed of the true wind. Furthermore, AWS measures the air temperature, relative humidity and atmospheric pressure. Some of these systems have an autonomous power supply, while others require connection to ships power supply. This system can be connected to navigational devices. VOS-vessels are using several different types of AWS: BATOS and MINOS, developed by Meteo-France, the Canadian system AVOS, developed by Axys Technologies and the AUTOMET system, developed by Christian Michels.

BATOS and MINOS are the most commonly used automated weather systems. Meteo-France has BATOS system installed on 45 VOS-ships. MINOS system is using barometer Vaisala PTB 210, GPS module and antenna for transmission of messages via Argos system. The operation of the Canadian system AVOS is similar to BATOS, but the difference is that all sensors are located on a single mast. AUTOMET system is similar to the system MINOS and she is measuring only temperature and barometric pressure.

The electronic logbooks TurboWin, SEAS and OBSJMA are used for manual input of the measured data. These logbooks have integrated system for accuracy control of the monitored data. The software creates automatically encrypted messages in required format, which can be sent directly or transferred to an external storage device for sending via Inmarsat. TurboWin software was developed by the Royal Netherlands Meteorological Institute (KNMI). It is used worldwide. SEAS software is developed by NOAA. It is used by US VOS-ships. OBSJMA software is developed by the Japan Meteorological Agency (JMA). It is used by Japanese VOS-ships [5].

4.1 Automated onboard system BATOS

BATOS system collects data from digital weather sensors for pressure, air temperature, sea surface temperature, wind's direction and speed. It allows manual data input from visual observations (visibility, sea state, type and height of clouds, ice, etc.). The satellite communications has been used by BATOS for sending data to shore services.

In 2004, the first version of BATOS was installed on board of thirty French VOS-ships. The system verifies the accuracy and consistency of the measured data. After that she creates and sends messages at every one, three or six hours. The second version of the system receives information directly from the different sensors. The automatic weather station BATOS II includes ultrasonic anemometer, temperature and humidity sensors, pressure sensor, sea surface temperature sensor, gyrocompass, NMEA output (Figure13) [13].

Pressure, humidity, air sea surface temperature, wind's speed and direction are measured every hour and automatically transmitted by GTS. NMEA meteorological data are collected together with navigational data every 5-10 minutes and uploaded onshore using the ISMAR software Daphne. The integration of oceanographic and meteorological measurements is possible if adding a thermosalinometer to the system and sending data messages in TRACKOB format at every one, three or six hours.

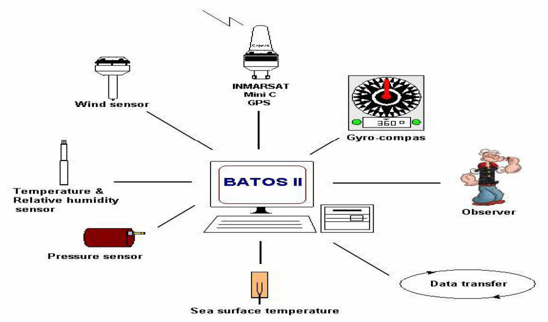


Figure13 Scheme of ship automated system BATOS II

4.2 Automated onboard system MILOS

Automated weather stations MILOS makes continuous observation. They use satellite communication system to send meteorological data encrypted in a certain format in real time. This means that the information can be used directly for weather prediction.

Vaisala's MILOS 520 weather stations is used mostly on German and Irish research vessel. It has sensors for: wind's speed and direction (anemometer WAA151) and the wind's vane WAV151 is installed on the mast or ultrasonic wind sensor WS425S can also be used, humidity and air temperature (HMP45D), pressure (DPA501), and sea water temperature (DTS12W). In addition in the system can be added sensors for measurement in real time of precipitations, solar radiation and optical sensors for clouds and visibility. The data obtained from these sensors can also be included to the messages. Scheme of ship automated system MILOS is shown on Fig. 14.

GPS receiver or Inmarsat-C and gyrocompass can be used in calculation of true wind's direction and speed. The information about the ship's heading from gyrocompass is converted in NMEA 183 format. AWS are using computer processing system and database for storage in meteorological FM-13 format and in oceanographic IMMT-2 data format. The software Vaisala Yourlink PC is used for manual input of information. The generated binary messages are stored every 1 to 3 hours on the system's hard drive for transmission via Inmarsat-C to land coastal station where it is processed and send by GTS.

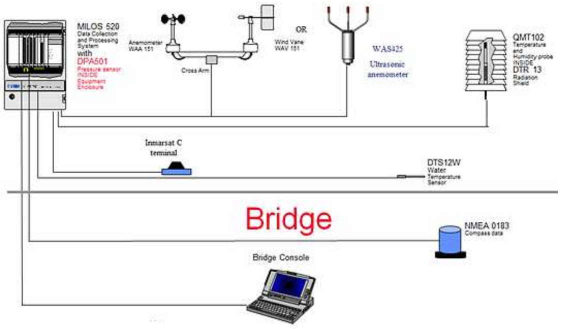


Figure14 Scheme of ship automated system MILOS

An algorithm for mathematical calculations of the minimum and maximum deviation values for each parameter is built in MILOS system in order to guarantee the quality of the measured data. The system also calculates the relationship between various parameters. Manually entered values are checked for proper input. Each AWS has built-in testing system which runs continuously to check the hardware and report if a problem or malfunction occurs. Meteosat GOES, GTS and Argos networks can also be used for communication by these stations.

5. CONCLUSIONS

The ability to collect high-quality meteorological data at sea has become very important. Although the satellites can be used for collection of basic meteorological data, measurements on spot made by ships and weather buoys are essential for preparation of correct and complete weather forecast for the open sea.

The alternative communication systems offer lower communication costs than Inmarsat-C. This is important when using AWS which sends an average of 1 600 messages per day. The development of cost-effective telecommunication systems like Iridium and Argos 2, 3 and 4, allows “two-way” transmission of messages and performing a direct control of the systems, instruments and sensors. In 2013, 60% of the drifting sensors were fitted with Iridium antennas and 40% of them were fitted with Argos antennas. The new systems of moored buoys and drifting sensors are using Iridium as a communication system.

Moored buoys are generally located in areas with limited navigation, where the availability to obtain meteorological and oceanographic information is of great importance. Some of the buoys can send messages through mobile networks.

Great amount of marine meteorological data is still being collected mainly from analog devices and are entered manually in ship's format. The reliability and frequency of the manually measured data depends on the operator, while AWS provide continuous and periodic measurement of the parameters. AWS and systems of drifting buoys and sensors provide meteorological and oceanographic information at regular intervals.

Improved real-time wave measurements from VOS-ships will be of great benefit in wave analysis, verification of data, weather forecasting and preparation of numerical models.

Despite the progress in technologies for monitoring and forecasting, the data obtained on spot by ships measurements is the base for accurate assessment of the meteorological situation in the navigating area.

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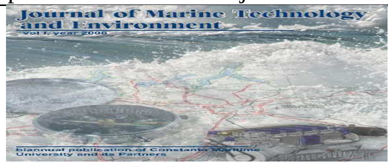

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METHODOLOGY FOR MANAGEMENT AND IMPROVEMENT OF ENERGY EFFICIENCY OF SHIPS

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Abstract: ***Ship owners and the management team of shipping companies have a crucial role in the optimization process. They have to establish and implement a specific energy policy focused on the use of innovative solutions for energy saving, emission control and performance optimization. The purpose of this paper is to present a methodology for energy management and energy efficiency improvement of ships. It is necessary to assist shipping companies in the selection of appropriate measures to achieve balance between economic, technological and environmental challenges.***

Key words: energy efficiency, ships, energy management.

1. INTRODUCTION

The proposed methodology for management and improvement of energy efficiency (EE) comprises systematic analysis and study of the energy consumption of ships (by implementing energy audit, energy calculators, energy balance, "Sankey" diagrams, etc.), as well as identifying opportunities for application of innovative optimization measures.

The process of energy efficiency management of ships refers to rational use of resources for achievement of effective shipping. It is necessary for shipping companies to improve the efficiency of data and methodological provision in order to achieve power management and energy efficiency optimization of the ship.

The process of managing the EE of ships consists of stages and procedures that will ensure:

- development of unified database for examination of ship systems;
- study of various opportunities for energy efficiency improvement;
- development of a plan for the implementation of the selected optimization methods;

rational energy efficiency management problems solving.

In the existing methods for analysis and improvement of energy efficiency some issues are insufficiently developed.

The main areas for improvement of the methodological provision are as follows:

- Development of instructions for conducting energy audit of the ship - methods for study and measurements;
- Development of a methodology for analysis of the results of the energy audit of ship and the most effective method for EE improvement;

This methodology follows the principles of the system approach, taking into account the interaction between economy and technology.

2. MAIN STAGES OF THE METHODOLOGY

The proposed methodological approach for study and optimization of energy efficiency of ships consists of three main stages and a final stage.

Diagram represents the proposed algorithm (Figure 1.)

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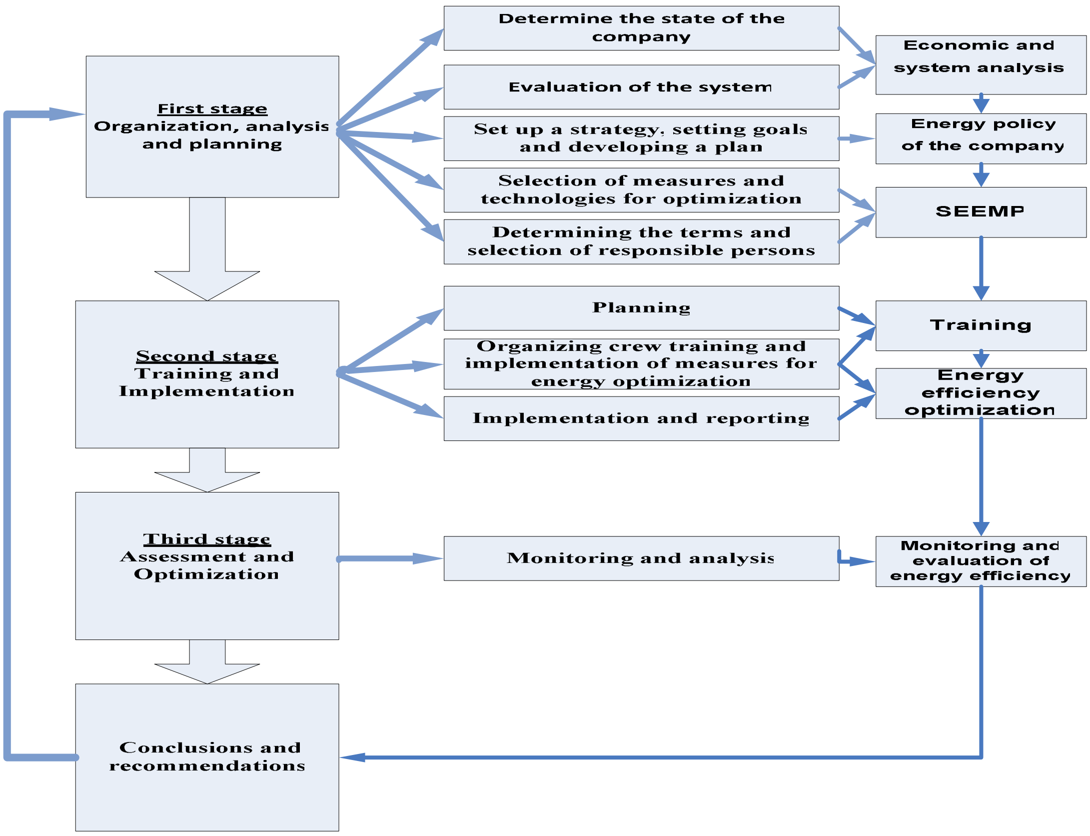

Figure 1

FIRST STAGE - Organization, analysis, planning

At this stage must implement a comprehensive analysis of system performance. First stage is a preparatory (organizational) and aims to create favorable conditions for performing the activities of EE improvement. It requires support from the company management for selection of a team to carry out research and development of working program.

This stage of the procedure consists of the following sequence:

- **establishment of a research team;**

determining the team leader responsible for organizing, planning and monitoring the implementation of the various stages of the study;

- **obtain baseline data** - collect information on the effectiveness of the system, applied technologies and economic resources;
- **determining the basic parameters and energy consumption** - study the current state, which enables the assessment of the efficiency of energy consumption;
- **identify opportunities for energy efficiency improvement** of the system and evaluate their importance for the development and validation of working program for the study;
- **amendment of the technical - economic indicators.**

The effective energy management requires improvement of the organizational structure.
Important role in this process is performing an energy audit. This process represents an energy audit system to assess the effectiveness of the energy resources, development and implementation of measures to increase energy efficiency. Identify activities, equipment and systems with the highest energy consumption (fuel, electricity) in operation. Determine the activities and measures for reducing energy consumption and conducting economic analysis of these options.

This process includes the following phases:

A. Determining the state of the company - efficiency analysis and assessment of opportunities for development.

Conducting economic analysis of the effectiveness of the companies, assessment of positions and opportunities as well as the status of their ships in the fleet. Coordinated actions and cooperation between stakeholders in the transport business will provide increased efficiency. Establishing cooperation between stakeholders - companies developing marine technology, ship owners, operators, charterers, cargo owners, ports, traffic management, repair workshops and more.

B. Evaluation of the system

Shipowners are required to submit information on current practices and the energy used on board, as well as guidance on possible areas for optimization of energy efficiency. This is an extremely important step for the development of an effective management plan. Consists indication of the specific measures for each vessel as well as those for the company. This step comprises organizing and conducting energy audit and evaluation of the system.

It consists of the following steps:

STEP 1. DATA COLLECTION - INFORMATION

Gathering data for all sub-systems and the links between them. Determination of installed power, type and amount of energy consumtion and the main consumers. Identifying the most energy-intensive subsystems and areas with the highest energy losses.

To determine the appropriate opportunities for energy efficiency improvement, the most - effective approach is to carry out comprehensive audits of all elements of the system.

Data sources include:

1/ Interviews with the management and technical team;

2/ Technical documentation of the equipment;

3/ load profiles of ship power plant; MIP calculators;

4/ Data on the amount of goods transported and fees;

5/Regular documentation of diagnostics, repairs and energy-saving activities;

6/Design documentation, management, technological and operational activities for improvement of the EE of the ship. Plan for optimization of energy efficiency (SEEMP).

STEP 2. DATA COLLECTION BY MEASURING APPLIANCES

Operational data is needed to supplement the information obtained from the documents and verification of obtained information.

Studies could be conducted with fixed or portable devices, software and tools for power measuring taking into account fuel consumption and load profile.

The information obtained is processed and systematized, checked for accuracy and completeness. If necessary, carry out further inspection of the equipment. Conducting measuring of the energy flows, operation time, technical parameters of the equipment and productivity.

The methodology for conducting an energy audit comprises several phases [3].

1/ First phase - preliminary audit - it includes evaluation of the necessity for energy savings. A database - records, activities, equipment, interviews with the crew. Application of modern systems for monitoring and control of ship performance - IAMCS (Integrated Alarm, Monitoring and Control System). They enable remote data collection on the quantities of generated and consumed energy.

2/ Second phase - evaluation of energy consumption and losses. Implement identification of activities that ensure immediate energy savings and do not require additional investments. Identification of the areas with highest consumption and set priorities for future work. Determining the opportunities to obtain the greatest savings and fastest payback.

3/Third phase - comprehensive inspection of energy subsystems, development of a strategy for EE improvement.

The energy audit comprises analysis of the following data:

- Fuel consumption, energy losses and expenses – for main, auxiliary engines and auxiliary boilers.
- Power, current, voltage - study of the load of the ship's power system, determination of the power losses.
- Temperature, pressure, flow, time - study the systems and equipment operation.

STEP 3. PROCESSING AND ANALYSIS OF THE INFORMATION RECEIVED –

determination of appropriate measures and recommendations for EE optimization of ships.

At this step is processed information obtained from the technical documentation and measurement equipment sets. Carry out assessment opportunities for energy savings. At this stage are specified the objectives and tasks of complex technical and economic analysis. Carry out complex analysis and assessment of the:

- current state of the system;
- factors affecting EE;
- energy saving opportunities.

This stage comprises selection of the most promising options and assessment of their effectiveness. For this purpose need to developed a model of the system with all subsystems and components.

The next step is development of a plan for implementation of the most appropriate method for EE improvement.

C. Set up a strategy, setting goals and developing a plan

At this stage, the chosen method become a system of measures to achieve the objectives. This step includes development of an optimal program for EE improvement of the ship. The owners of shipping companies are encouraged to take action to improve energy efficiency. They must develop an energy strategy and SEEMP for ships in its fleet.

The Resolution MEPC.1 /Circ.683 of IMO contains guidelines for the development of a SEEMP.

SEEMP include [1]: planning; application; monitoring; self-evaluation and improvement. It provides instructions for improvement of EE of all ship systems and operational processes. SEEMP identifies methods of carrying out the analysis of the system, specific objectives and measures for the company and for each vessel in its fleet.

The plan defines the responsible persons and establishes a system for application of chosen measures. SEEMP specifying quantitative assessment and monitoring tools for the optimization.

During this phase, an overall assessment is made of the resources needed for the implementation of selected activities and the results of their application. Classification of the measures is carried out according to: achieved EE; sequence and timing of application; required investments. Each individual measure should be considered in a systematic aspect for achievement of an overall improvement in energy efficiency.

D. Selection of measures and technologies for optimization

This stage comprises analysis of the process and assess the effectiveness of implemented organizational and technical opportunities, and selection of guidelines for effective energy use. SEEMP contain all measures and opportunities for the application of innovative technologies and practices for EE improvement, terms, investments, monitoring, recordings and responsible personnel.

Measures and activities for energy efficiency optimisation consists: activities for achieving fuel efficiency; optimized operation of the ship; optimization of the structure and propulsion machinery and equipment; optimized handling and energy saving methods.

E. Determining the terms and selection of responsible persons

The owners of shipping companies must provide appropriate conditions for application of SEEMP. Management team must develop a plan to implement energy audit on board the ship, and for the implementation of energy efficient practices and measures. The company's management, captain and chief engineer carry out control for the implementation, monitoring and recording of the implemented measures.

SECOND STAGE - training and implementation

This stage includes three basic steps:

Step 1. Planning - set targets, estimation of the resources - detail the sequence of the project.

Step 2. Organizing, crew training and implementation of measures for energy optimization - structure development and establishing links between project participants - to coordinate actions, set of procedures and state contractors. To stimulate implementation of the plan for the project.

Step 3. Implementation and reporting - Includes implementation of optimization measures, reporting, control and regulation of processes of the project. Performs analysis and evaluation of the cost of resources and deadlines for implementation of all measures.

THIRD STAGE - Assessment and Optimization

This stage comprises monitoring and analysis.
For verification of the appropriate measures for EE improvement, it is necessary to make a quantitative assessment of all measures. Monitoring and analysis of system performance before and after the application of optimization measures assists to assess the effectiveness and provides guidance for further activities.

This stage include the following activities:

• Use of modern systems for monitoring indicators IAMCS (Integrated Alarm, Monitoring and Control System) (continuous reporting and analysis of the parameters of the engine);
• Examination of all subsystems and analysis of energy efficiency - energy calculators and software tools.
• Economic analysis of measures for energy efficiency optimization
- Calculation of energy savings (fuel, kWh)
- Calculation of the savings ($, €)
• Data recording and result analysis.

Performs analysis, assessment and generalization of data obtained on all the measures implemented.

THE FINAL STAGE of the optimization cycle represents a summary of the results, conclusions and recommendations. It includes control of the fulfilment of the project, evaluation of inputs and time to implement, indicating the effectiveness of each measure. It describes the tools and processes for self-evaluation and improvement.

3. CONCLUSIONS

The proposed generalized methodology for management and improvement of EE of the ship unites all steps and actions for energy assessment and overall optimization of energy efficiency.

Shipping companies (shipbuilding, ship repair, operators, trade, etc.) could use presented database for development of energy management and saving strategy.

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METHODS AND INSTRUMENTS FOR ENERGY EFFICIENCY ASSESSMENT AND IMPROVEMENT OF SHIP SYSTEMS

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Abstract: The purpose of this paper is to present instruments for complex assessment and energy efficiency improvement of ship systems. This article presents energy efficiency analysis through the study of energy flows in the system and tools developed by IMO for monitoring of greenhouse gas emissions from ships. The combination proposed, of various energy-saving technologies and measures can provide achievement of fuel efficiency and reduction of greenhouse gas emissions.

Key words: energy efficiency, ship, optimization, waste heat recovery.

1. INTRODUCTION

The ship is a complex energy system therefore, it is necessary to implement an integrated approach to increase overall system efficiency.

The ship's energy system is one of the most important systems, which provides proper and safe operation. It includes two very important subsystems - Ship Propulsion System and Ship Power System. The greatest amount of consumed fuel is for electricity generation and for ship propulsion. These are the main areas that need to implement optimization measures to increase the efficiency of the system.

The power system provides the required electricity for all other systems on the ship. It represents a complex system, consists three main subsystems: 1) energy sources, 2) transmission and distribution of energy and 3) consumers.

For evaluation of energy efficiency (EE) of the ship, it is necessary to undertake a study of distribution and sizes of the energy flows in the system. Shall also apply Sankey diagrams for graphical representation and analysis of these flows. Determine the areas with the greatest losses and identifying the most appropriate optimization measures for each subsystem individually. Assessment of EE apply tools developed by IMO for monitoring of greenhouse gas emissions from ships and fuel consumption calculations.

Through an integrated approach - optimizing individual subsystems as part of the whole system could achieve overall improvement of energy efficiency (EE) of the system.

2. FUEL CONSUMPTION AND COSTS

The article presents an analysis of EE of a container ship. This type of ships have four main types of costs - capital, fuel, for crew and fees. The largest share is fuel costs.

The incoming energy flow (fuel) of the ship is divided into three parts (Figure 1.) - energy consumed by the main engine (ME), auxiliary engines (AE) and boiler (B). Using data from the literature assume that the days of sailing for the year - 292, and the days spent on the berth in port - 73. [44]

In presented example for the assessment of energy efficiency, a container ship is considered - „Jaguar Max“ 2,200 TEU (2,262 TEU) class BV.

Table 1

Rated power (MCR)	30560 PS (22477 kW) 91 RPM
length	185,50 m
width	30,20 m
depth	16,60 m
capacity (d=11,016m)	30554 t
speed (design draft MCO)	22,10 Knots
speed (design draft SERV.)	21,90 Knots
Diesel generator	1470 kW, 720 RPM
Emergency diesel generator	120 kW, 1800 RPM
auxiliary boiler	7 kg/cm^2 x 3000 kg/h
exhaust gas economizer	7 kg/cm^2 x 2500 kg/h
fuel consumption	97,6 T/Day

MAIN ENGINE (ME)

For this example, daily consumption of fuel (FOC) of ME is:

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

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

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

AUXILIARY ENGINE (AE)

Daily fuel consumption of AE - for two main modes:

- **Sailing with working refrigeration equipment** (WITH REEF)

In this mode, it is necessary to use three diesel generators.

Daily consumption of fuel from AE:

$$FOC_{AE/S} = \frac{P_{AE} \times SFC \times h}{g/t} = \frac{3982 \times 200 \times 24}{1000000} = 19,1[t/day].$$

- **Stay in port**

In this mode, it is necessary to operate only one diesel generator 1470kW. LF of the auxiliary engines for stays in port was 37% and power consumption is: P_{AE} = 544kW.

Daily fuel consumption for this mode is:

$$FOC_{AE/B} = \frac{P_{AE} \times SFC \times h}{g/t} = \frac{544 \times 200 \times 24}{1000000} = 2,61[t/day].$$

AUXILIARY BOILER (B)

Daily fuel consumption of the boiler at port is:

$$FOC_B = \frac{P_B \times SFC \times h}{g/t}, [\text{t/day}].$$

P_B is the power of the boiler at port.

Fuel consumption calculated by the fuel used per hour = 232 [kg/h]:

FOC_B = 0,232 x 24 = 5,57 [t /day].

Full fuel consumption of ME and AE for sailing mode with working refrigeration equipment:

$$FOC = FOC_{ME} + FOC_{AE} = 72,94 + 19,1 = 92,04[t/day].$$

Fuel consumed per year in this mode is:

$$FOC_{year/S} = 292 \times 92,04 = 26875,68[t].$$

The cost of fuel per year in sailing mode is (cost of fuel = \$ 600):

$$C_S = FOC \times 292 \times \$600 = \$16\,125\,408.$$

Full fuel consumption per day for stays in port:

$$FOC = FOC_{AE/B} + FOC_B = 2,61 + 5,57 = 8,18[t/day].$$

Fuel consumed per year in this mode is:

$$FOC_{year/B} = 73 \times 8,18 = 597,14[t].$$

Cost of fuel in this mode for a year:

$$C_B = FC \times 73 \times \$600 = \$358\,284.$$

Full amount of fuel consumed per year:

$$FOC_{year} = 26875,68 + 597,14 = 27472,82[t].$$

Full fuel costs per year:

$$C = C_S + C_B = 16125408 + \$358284 = \$16\,483\,692.$$

The sequence of actions for power management and EE optimisation of the elements of the energy system includes three main stages: determining effectiveness (analysis of energy flows); determination of the energy losses and improvement of EE.

ANALYSIS OF ENERGY FLOW - **Main engine**

Efficiency (fuel efficiency) of ME determines fuel amount converted into output power PB:

$$\eta_{BTh} = \frac{P_B}{Q_f} = \frac{17981,6}{36043,36} = 0,499.$$

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

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

mf - amount of fuel burned per second [kg /s];

C.V. (calorific value) - the thermal energy released during combustion of 1kg of fuel [kJ / kg].

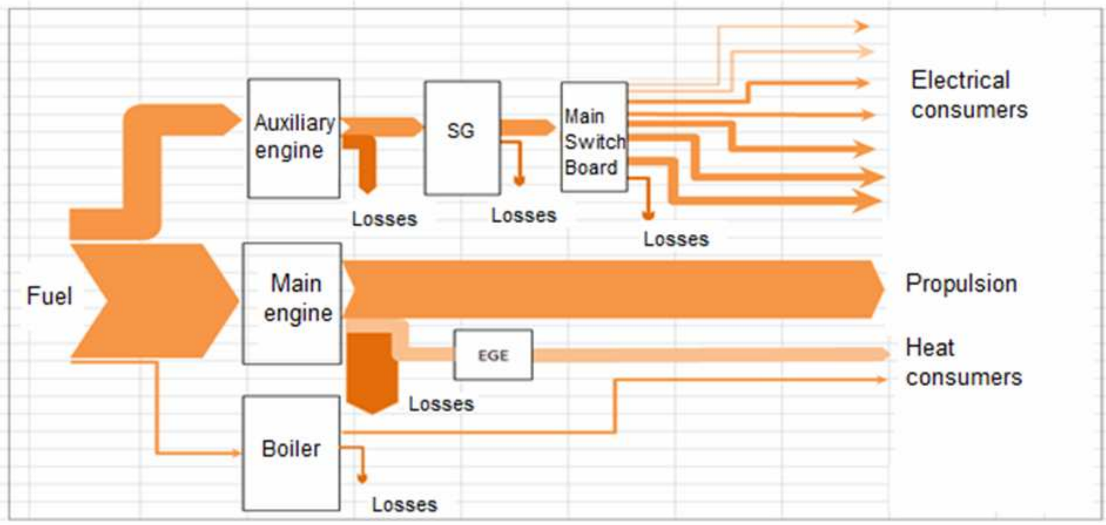

Figure 1 Energy flow (fuel) of the ship

IMO developed instruments for monitoring greenhouse gas emissions and EE of the ships [92], [89]:

1/ Energy Efficiency Design Index (EEDI) - stimulates optimization of energy efficiency in new ships and the reduction of CO2 emissions emitted per tonne of freight transported per kilometre, [g/tnm]. It represents the total amount of emissions from combustion of fuel compared to useful transport work [89]:

$$EEDI = \frac{CO_2 emission\left[g_{CO2}\right]}{transport\ work\left[tnm\right]}.$$

2/ Energy Efficiency Operational Indicator (EEOI) - it measures the energy efficiency of each voyage using actual values for the fuel consumed, the amount of cargo and sailed distance [92]:

$$\text{EEOI}=\frac{\text{Fuel}\times\text{CO}_2\ \text{Convertion factor}}{\text{Cargo quantity}\times\text{Distance}}.$$

Calculation of the EEDI

MCR_{ME} = 22477,53 kW
Capacity:
Container ship70% DWT = 30554.70% = 21388t
$CF,_{ME}$ = $CF,_{AE}$ = 3,1144 (t-CO2/t-Fuel) for HFO
Specific fuel consumption:
SFC = 169 g / kWh; SFC = 200 g / kWh
Ship speed: Vref = 21,90 kn

$$P_{ME} = 0,75 \times MCR_{ME} = 0,75 \times 22477,53 = 16858,15kW$$

$$P_{AE} = \left(0,025 \times MCR_{ME}\right) + 250 = 811,94kW.$$

The resulting index has a value lower than the reference for new ships built after 01.01.2013g. (fig.2) But to fit the design of the ship EEDI requirements after 2015. It is necessary to take actions for optimization - application of innovative technologies and operational measures.

$$EEDI = \frac{\left(\left(P_{ME} \cdot C_{F \cdot ME} \cdot SCF_{ME}\right) + \left(P_{AE} \cdot C_{F\ AE} \cdot SCF_{AZ}\right)\right)}{C_{capacity} \cdot V_{ref}} =$$

$$= \frac{\left(\left(16858,15 \times 3,1144 \times 169\right) + \left(811,94 \times 3,1144 \times 200\right)\right)}{21388 \times 21,90} = 20,023\left[gCO_2/t.nm\right].$$

In phase 0 (from 01.01.2013 to 31.12.2014) for over 20,000 DWT, x = 0

$EEDI_{Required}$ = (1-0/100)x 23,48 = =23,48[gCO_2/t.nm].

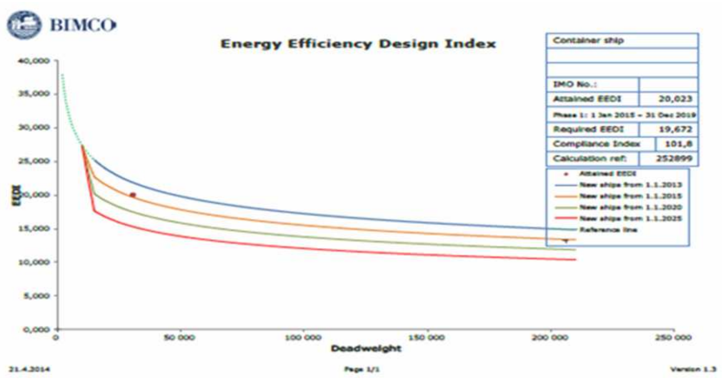

Figure 2

The resulting index has a value lower than the reference for new ships built after 01.01.2013g. (figure 2) But to fit the design of the ship EEDI requirements after 2015 it is necessary to take actions for optimization - application of innovative technologies and operational measures.

3. ENERGY-SAVING TECHNOLOGIES AND MEASURES

The incoming flow of energy (fuel) of the ship is divided into three parts - the energy consumed by the main engine (ME), auxiliary engines (AE) and boiler (B).

The losses of thermal energy from the exhaust gases and cooling systems represent a significant part of the energy flow through the main
diesel engine, usually about 20-30%. Part of this energy can be recovered to ensure savings and reduction in emissions, which will increase the efficiency of the system.

Energy flows of the engine have the following values:

Table 2.

Energy flow	**%**
Fuel (inlet energy flow)	100
Shaft power	49,90
Exhaust gas	19,70
Air cooler	18,18
Lubricating oil	3,53
Jacket water	7,52
Heat radiation	1,17

The exhaust thermal energy is:

$$Q_{us,g} = m_g . c_p . \left(T_{in} - T_{out}\right),$$

m_g = 149000 kg/h - exhaust gas flow (80% engine load);

Heat obtained from the exhaust gases:

$$Q_{us,g} = \frac{149000}{3600} \times 1,009 \times \left(490^0 - 320^0\right) = 7099,4kW.$$

Improved system efficiency by utilizing the energy of the exhaust gas is determined by the formula:

$$\eta_{tot} = \frac{P_B + Q_{us,g}}{Q_f} = \frac{17981,6 + 7099,4}{36043,36} = 0,7.$$

Cp =1,009 kJ/kg^{0}K (www. dieselnet.com) - specific heat capacity of the exhaust gases;

$\boldsymbol{T_{out}}$ - the temperature of the exhaust gases (turbocharger) = 320 0C;

$\boldsymbol{T_{in}}$ - inlet temperature of the gas turbine 490 0C

This combined generation of heat and mechanical energy from the main diesel engine provides savings and increase the overall efficiency of the system.

Recovery system of exhaust gases from the engine (WHR) can be applied. To receive electricity by recovering the energy of exhaust gases installing boiler for exhaust gases, power and steam turbine and generator. This provides reduction of the amount of incoming and outgoing air emissions and increase the temperature of the exhaust gas after turbocharger and bypass. It should increase the steam produced by the exhaust gas boiler.

Power turbine used to generate additional electrical power can replace the energy production from the AE.

There are complex systems for energy recovery of the waste gases (WHR) with shaft motor / generator, but they are more expensive.

Electrical energy obtained from the thermo-electric system (TES) allows increasing the temperature of the waste gases in order to use their energy for heat generation of steam. (Table 3):

Table 3

Ship type	**Container ship 2,200 TEU**
Main engine type	**8S70MC**
Specified MCR of ME	**22477 kW**
Main engine load	**85%**
Main engine power output	**19105,5 kW**
EGT electric power production (EGT = Exh. gas turbine)	**600 kW (3,1% of ME output)**
ST_1 electric power production (ST_1 = Steam turbine Single steam pressure)	**1200 kW(6,3% of ME output)**
ST_2 electric power production (Dual steam pressure)	**1400 kW(7,3% of ME output)**
TES_1= EGT+ST_1	**1800 kW (9,4% of ME output)**
Annual fuel savings of TES_1	1 230 990 $/year
TES_2= EGT+ST_2	**2000 kW (10,4% of ME output)**
Annual fuel savings of TES_2	1 361 946,5 $/year
Payback time (Fuel price : 600 $/t)	**5 years**

To determine the amount of savings, must calculate fuel costs FC (Fuel Cost) at engine load 85% (P_{ME} = 22477kW), specific fuel consumption 0,00017 t / kWh for operational period 280 days, 24 hours / day and fuel cost $ 600.

$$FC = 280 \times 24 \times 0,00017 \times 22477 \times 0,85 \times 600 = 13\,095\,639,7$$

Systems for energy recovery provide a reduction in fuel consumption and cost savings:

TES_1= 0,094 x 13 095 639, 7 = 1 230 990 $/year
TES_2= 0,104 x 13 095 639, 7 = 1 361 946,5 $/year

ANALYSIS OF ENERGY FLOW - **Auxiliary boiler**

The auxiliary boiler on the ship provides thermal energy and steam for households and heating fuel. The useful heat from the boiler is:

Q_{Out} = 2301,65 kW,

This energy added to the energy of the exhaust gases, which represent 7.64% of the total energy produced by the fuel is: Q_g = 209 kW.

Full boiler efficiency with recovery of waste energy is:

$$\boldsymbol{\eta}_{tot}, \% = \frac{Q_{Out} + Q_g}{Q_f} = \frac{2510,65}{2732,8}.100 = 91,9\%$$

The highest power losses in the boiler are heat losses from the surface of the boiler because of the incomplete combustion of fuel. They can be reduced by decreasing air excess and flue gas temperature.

ANALYSIS OF ENERGY FLOW - **Auxiliary engine**

It is appropriate diesel generators to operate in parallel with load 80% of rated power in order to achieve lower fuel consumption and higher efficiency

A comparison is presented and calculation of savings obtained in the optimal load of the engine.

For example - voyage of six months, 24 hours a day, consumed power 983kW, **at 50% load**, the fuel consumption is:

$$FOC = 180 \times 24 \times 221 \times 983 = 938,5t,$$

-**at load 75%,** fuel consumption has value:

$$FOC = 180 \times 24 \times 217 \times 983 = 921,5t$$

Fuel saved for voyage is 17t.

($FOC = 180 \times 24 \times 4 \times 983 = 17t$).

At fuel cost $ 600 the value of estimated savings (for 6 months) is: 17t x $ 600 = $ 10,200

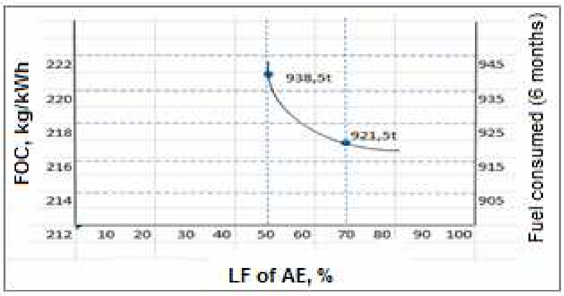

Figure 3

• AE waste heat recovery system (WHR)

The main advantages of the installation of economizers for flue gases from the auxiliary engines are the following:

- Reduction in greenhouse gas emissions
- Providing the necessary steam at a port - energy is obtained at a lower price
- short payback time (1-1 ½ years)

The thermal energy of the exhaust gases is:

$$Q_{us,g} = m_g . c_p . (T_{in} - T_{out}) = \frac{12508,22}{3600} .1,014.(500-400) = 352,3kW.$$

Distribution of energy flows for optimized system with recovery of waste heat energy (Figure 4).

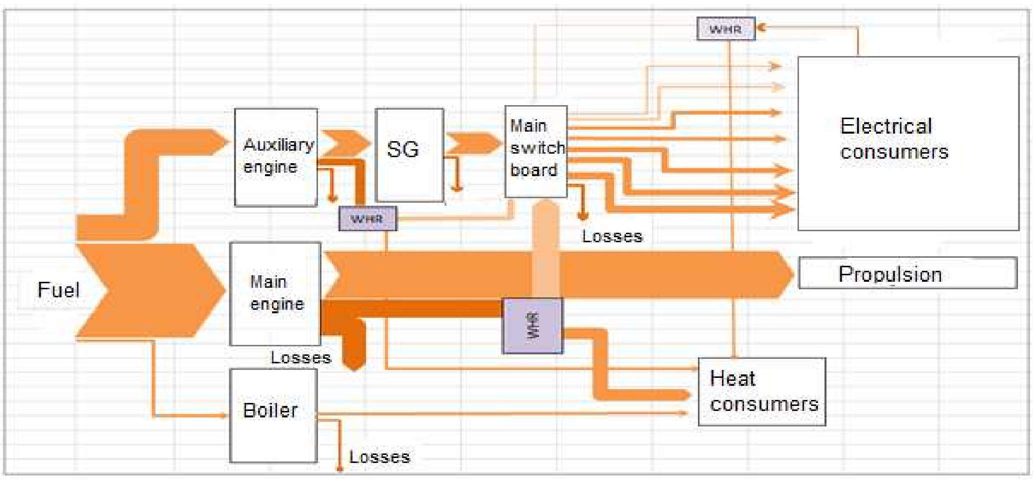

Figure 4 Distribution of energy flows for optimized system

ANALYSIS OF ENERGY FLOW - **Consumers**

Propulsion system

The largest share of the consumed fuel energy is for ship propulsion. The vessel, which has been studied is powered by two-stroke, eight-cylinder, low-speed diesel engine and propeller with fixed pitch (FPP).

The power is proportional to the cube of speed: P □ n3, therefore, the same ratio is for fuel consumption.

To determine the amount of savings at the optimized speed, calculate fuel consumption:

$$FOC = (P_{ME} \times SFC_{ME} + P_{AE} \times SFC_{AE}) \times h \times \left(\frac{\upsilon_2}{\upsilon_1}\right)^3.$$

Installed power of ME is:

$$P_{ME} = MCR_{ME} \times LF = 22477 \times 0,75 = 16857,75$$

(MCR_{ME} = 22477kW; LF = 75% - load factor)

The power of AE is:

$$P_{AE} = 1470kW.$$

SFC is the specific fuel consumption of the engine (SFC = 169 g / kWh; SFC_{AE} = 200 g/kWh); h - hours (280 days x 24 hours);

υ1 - nominal (design) speed; υ2 - reduced speed;

- at 100% speed - fuel consumption FOC_1 is:

$$FOC_1 = (16857,75 \times 0,000169 + 1470 \times 0,0002) \times 280 \times 24 \times (1,0)^3$$

$$FOC_1 = 21127,68t$$

At fuel price $ 600, the fuel costs per year is:

$$FOC = (P_{ME} \times SFC_{ME} + P_{AE} \times SFC_{AE}) \times h \times \$ \times \left(\frac{\upsilon_2}{\upsilon_1}\right)^3$$

$$FOC = \$12\ 676\ 608$$

- at 80% of the nominal speed - fuel consumption FOC_1 is:

$$FOC_2 = (16857,75 \times 0,000169 + 1470 \times 0,0002) \times 280 \times 24 \times (0,8)^3$$

$$FOC_2 = 10817,4t.$$

Fuel cost at a reduced speed per year:
$ 6,490 423,3.

Power is cut in half:
$P_2 / P_1 = (\upsilon_2/ \upsilon_1)^3 = (0,8)^3 = 0,512$

Respectively fuel consumption is reduced.

Savings amount to $ 6 186 184,7 per year.

The amount of harmful emissions - reduced:

$$\Delta CO_2 = C_F \times \Delta FOC = 3,1144 \times 10310,28 = 32110,3tCO_2$$

ΔCO_2 is the amount of carbon emissions reductions;

Fuel savings:

$$\Delta FOC = FOC_1 - FOC_2 = 21127,68 - 10817,4 = 10310,28t$$

(Conversion rate of CO_2 emissions: C_F = 3,1144 (t-CO_2/t-Fuel) for HFO).

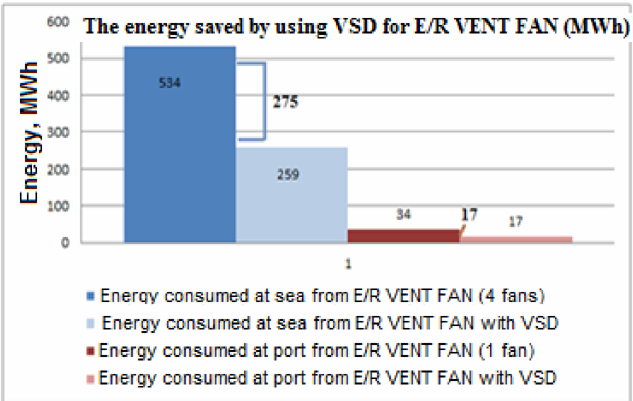

Figure 5 Energy savings when use variable speed drives for speed regulation of the fans in engine room

Consumers of electrical energy

The main part of the electrical energy is consumed by refrigeration equipment, drive systems of pumps, fans and compressors. These consumers are the most common on ship, they provide normal operation and proper working conditions for the systems, and therefore the biggest savings obtained at their optimization.

In the vessel, which has been studied - container ship (2,200 TEU) fans in the engine room (E/R VENT FAN - 4 pcs.) at 80% of the time working with 70% of the nominal speed (power 22 kW, efficiency 89%, Pk = 98,9 kW at 5400 hours).

When use variable speed drives (VSD - efficiency = 98%) for speed regulation, the energy obtained is:

E_1 = 98,9 x $(0,7)^3$ x 5400 x 1/0,98 x 0,8= 150MWh.

For the other 20% of the running time, energy at full load is calculated:
E_2 = 98,9 x$(1,0)^3$ x 5400 x 1/0,98 x 0,2 =109 MWh.

The power consumption is:

$$E_{vsd} = E_1 + E_2 = 259 \text{ MWh}.$$

The energy saved by using variable speed drives:

$$E_s = E - E_{vsd} = 275 \text{ MWh}$$

(Power consumption without the use of variable speed drives: E = 98, 9 x 5400 = 534 MWh)

3. CONCLUSIONS

Presented instruments for assessment and energy efficiency improvement of ship systems can assist in energy management and savings.
Specified methods for energy efficiency analysis through the study of energy flows and various energy-saving technologies could be applied for achievement of fuel efficiency and reduction of greenhouse gas emissions.

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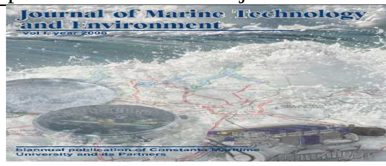

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MANAGEMENT OF INVESTMENT RISK OF ECONOMIC OPERATORS IN THE BLACK SEA REGION

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Abstract:The economic interest in the Black Sea region is determined by its dynamic development, complex reality, opposing outside interests and relations of the Black Sea countries to the rest of the world. One aspect of this interest is related to the investment process. Successful implementation of investment decisions requires consideration of various factors determining the degree of risk for the investor. In this context, the current report presents some strategies to manage an investment risk.

Key words**: **Black Sea region; investments; investment risk; strategy.

1. INTRODUCTION

Investment risk in the Black Sea region arises from the peculiarities of the functioning of the economy in the region. Traditionally Black Sea region includes Greece, Bulgaria, Romania and Moldova in the west, Ukraine and Russia to the north, Georgia, Armenia and Azerbaijan in the east and Turkey to the south. Although Armenia, Azerbaijan, Moldova and Greece are not littoral states, history, proximity and close ties make them natural regional actors. After the admission of Bulgaria and Romania to the EU, the Black Sea region no longer was accepted as European periphery but as integrator of the axis Caspian - Black Sea - Europe. Moreover, active participation of Bulgaria and Romania in the implementation and development of the objectives of the European Commission towards the Black Sea region contributes to its transformation into a European area of development.

2. ECONOMIC PREREQUISITES

Economic interest in the Black Sea region is determined by its dynamic development, complex reality, opposing outside interests and relations of the Black Sea countries to the rest of the world. Largest market, oil, gas, transport and trade routes characterize their importance regionally and globally. The strategic location of the Black Sea region - between the hydrocarbon resources of the Caspian basin and the energy need of Europe, is a prerequisite for the transfer of Caspian oil and gas to European markets and regional economic development. This creates competition for control of pipelines, sea lanes and transport routes, as well as strengthens the quest for political and economic influence in the region. What is the place and role of Bulgaria in the Black Sea region? Bulgaria is a part of the Balkans, located on the Black Sea and Danube river, but in the context of new geopolitical and geo-economic realities it is a part of Eurasia. This aspect should not be overlooked because in a geopolitical plan it gives serious chances of Bulgaria to become an energy center of Europe through which pass the transport corridors from the Caspian region. This will allow Bulgaria to turn into economic, political and strategic mediator between the different partners of the European Union, variously interested in its presence in the Black Sea region and Eurasia. In the Black Sea area, there are significant opportunities and challenges for business in key sectors such as energy, transport, environment, transportation and security. Investment decisions, however, are inherently risky, so the emphasis in the present report is on strategies for risk management for companies - investors in the Black Sea region.

Investments are ~~a~~ very important part of the capital flows and one of the main channels of the impact of financial globalization on the economy. Any investment requires investing of a certain amount of cash in order to receive revenues and capital for the company. The income is not an end in itself, but it is necessary the magnitude of this income to be substantially higher than the magnitude of the costs incurred. Regarding the income from investments and the investment costs it should be bare in mind that the costs are made in real present time until the benefits are linked to the future. It is this feature of the income which determines the relationship between earnings and risk. By presumption, the future carries uncertainty and insecurity, which means that it carrier a particular risk. In this sense, the implementation of a specific investment project is always accompanied by risk uncertainty and insecurity of income connected to the invested funds.

Generally, participants in the implementation of an investment project are interested in avoiding a project failure as well as avoiding occurrence of operating losses. Each investor himself determines the level of risk which can afford to take, which means that the level of risk is a subjective value. The assessment of investment risk is fundamentally important in two cases:

• When you have to make a choice of an investment project on the analysis of alternative one - then we talk about assessment of the overall risk of investments;

• When you need to take the specific factors that will affect individual projects - then we talk about risk assessment of the project.

The assessment of the overall risk is a major part of the investment planning and a restrictive condition for making a decision whether or not an investment to be made. In practice, the assessment is made on the basis of estimatation of various indicators corresponding to the attitude of the investors to risk in general. The lack of an absolute indicator of risk leads to the need of evaluation of various alternatives for input of cash, each of which is characterized by a lesser or greater extent to the risk. Ceteris paribus investor chooses a project whose overall risk is relatively smaller than those of the alternatives for investment.

In assessment of the risk of the project, the presumption is that in the process of realization of the investment decision making process is influenced by the external environment, sometimes random and uncontrollable nature. This is a prerequisite for different versions of the future outputs (results) of the investment project. In the futire the investor may assume different combinations of these factors. For each combination may be allowed different variations of a numerical value of the useful result of the investment. As a formal expression of the useful result can be used different indicators. Traditionally in regard to the financial investment, a key indicator of their effectiveness is the profitability of the investment. In investments in real assets can be used indicators such as net present value of the investment, ratio of profitability, payback period of the investment, etc. Important in the selection of indicators for assessment the risk is the selection of those indicators that are used as a basis for planning the investment.

3. ASSESSMENT OF INVESTMENT PROJECTS. *STRATEGIES TO MANAGE INVESTMENT RISK.*

The first step in the evaluation of investment projects is to be determine the extent of loss, respectively risk (permissible, critical, catastrophic) for each of them. For this purpose is calculated the loss ratio which is the ratio between the maximum possible amount of losses and own funds in the light of all proceeds from the investment project [4, p.162]. To be considered as an acceptable, is the risk which do not lead to more loss and damage than benefits. Usually this is within 30% of the own funds. In cases when the possible losses exceed the amount of the expected profit, but it is possible to be covered by the expected revenues, we talk about *critical risk*. Where the amount of the losses exceed the amount of the alleged proceeds and reaches the value corresponding to the value of the assets of the company, we talk about *catastrophic risk*. Usually catastrophic is the risk where the possible losses are 70% of the volume of their financial resources in the reporting of all revenues. All projects, which are in the area of intolerable for the company, drop.

The next step in the evaluation of investment projects related to the determination of the expected profitability, taking into account different future states of the environment in which the company operates. Profitability, however, is the most universal and practicable assessment of each type of investment indicator. It is obvious that the most preferred will be a project that has the greatest expected profitability in cases of different conditions of the factors from the external environment. It should be noted that in the process of realization of the investment project modification of some of the factors determining the state of the external environment may occur. This may lead to an alteration in the expected profitability of the investment project. Such factors can be the market situation, the interest rate level, the taxation, etc.

As a numerical measures of assessment of investment risk can be used the statistical indicators such as:

• Standard deviation (dispersion), measuring the deviation of returns from its expected value. The less the deflection in different states of external factors, the lower the degree of risk of the project. It shall be noted that the use of standard deviation as a measure of risk assumes a normal distribution of returns. In other words the values of the profitability of the investment project with a combination of different factors from the external environment must be symmetrical to the expected return. Otherwise, the use of this indicator is impractical because it would give a false result.

• In calculation of the standard deviation all the deviations are taken into account despite the fact the profitability is greater or less than the what is expected.

In risky situations, it is possible to take into account only the income values that are lower than expected. And as a measure of risk can be used indicator semi-dispertion. This indicator can be successfully used when the profitability is located asymmetrically compared to the expected value.

• It is known that the level of risk and profitability in most cases are in direct proportion, i.e profitable enhancement is possible with a corresponding increase in the risk of the project and vice versa. But the measurement of risk is conditional and relative value. So it may be that some projects have the same risk as measured in one of the two specified indicators. In this case, for risk assessment is used the coefficient of variation, which is calculated as t*he ratio of standard deviation* to the expected value of the income from the investment project. The lower the value of the coefficient of variation, the smaller the level of risk of the investment project.

All of the three indicators used to experts, the likelihood to show different combinations of factors from the external environment. Given the complexity of the environment in the Black Sea region these indicators can be extremely useful in making an investment decision.

On the basis of the assessment of investment risks are identified the appropriate actions and measures to reduce the vulnerability of the company and overcome the adverse consequences. These measures are divided into internal and external. Internal measures incorporate the creation of insurance and reserve funds, as well as development of events designed to avoid the possibility of incurring these risks. External neutralization measures are mostly related to insurance of various types of project risks or the use of guarantees from third parties.

The application of different measures depends on the willingness of the leadership of the company to assume a certain degree of risk when making an investment decision.

Popular strategies for risk management according to the general theory of risk are: [26, p.186]:

- *Ignore Risk*

In this case, it is assumed the absence of any specific actions aimed at reducing the negative effects of risk. Management of the company may deliberately ignore the risk, such as suggesting that the effects of the project are insignificant or less significant. Of course sometimes ignoring the risk is possible due to ignorance.

- *Avoid Risk*

In this case, the management unit consciously decides not to put the company on a certain kind of risk. In other words, risk aversion implies an inevitable failure of the implementation of certain projects that lack in confidence in the effectiveness. However, this is not typical for the investment decision and may not be taken as inherently such as the management behavior.

- *Acceptance of risk*

The company management has assessed and considered possible potential losses from an investment project at the expense of own resources. In this case it is not consciously attempting to reduce the level of risk. For example, the costs for the project are not reduced consciously because it accepts that in case of occurrence of adverse events costs will be covered by the income from the project itself or from other sources. It should be noted that the acceptance of risk does not mean the absence of negative effects of the project. Possible methods to reduce losses resulting from the implementation of the risk situation are related to the establishment of specific insurance and reserve funds in the company with its own funds. Their purpose is to cover the negative effects of unfavorable development of events due to external environment.

One of the specific forms of acceptance of risk is provoking/induction of risk. This means that some forms of investment to increase the level of risk may lead to additional profit. Therefore, the management of the company consciously seeks opportunities to increase the level of risk. Such situation is possible in venture financing or investing in subprime securities.

- *Exclusion of the Risk*

In this case the management of the company generates a set of special measures to prevent the negative consequences of the investment project. They can be applied when the effects have already occurred, during their manifestation or when they have already occurred. For example, technological problems with the introduction of new technology cannot be excluded if the pre-conditions are created for timely servicing of production equipment, providing a continuous supply of raw materials and others. In most cases, these measures are administrative and organizational decisions requiring certain costs for their realization. When these costs are very high, it can be used other methods to reduce the risk. This is possible when the causes of risk are objective, i.e they cannot be avoided.

- *Risk Transfer*

In this case the responsibility is passed to third parties. To implement this method it can be used special procedures (hedge) or services of special institutes of the financial market (insurance).

- *Risk Reduction*

In this case, the management of the company realizes specific events in the time of the risk in order to reduce negative consequences. One of the main methods to reduce the risk is diversification. The basic idea is to distribute the risk among more assets or to invest in more than one asset. Most commonly ths method is used in forming of the investment portfolio of the company. It can include not only securities but also other financial instruments, as well as investments in real assets. In modern conditions it is good for the business to strive for being maximum diversified business in order to allocate the total investment risk[1]. Diversification increases the reliability of the business sustainability of the company and as a result allows to activate investment activity of the company. Various options of diversification are available:

- Diversification of activities - based on the increasing number of technologies, expanding the range of products manufactured or the spectrum of its products / services, as well as orientation towards different social groups of users, etc .;
- Diversification of the market - action on several stock markets when a failure of one may be offset by the success of another;
- Diversification in the purchase of raw materials - suggests interaction with other suppliers and thus independence from unreliable suppliers is achieved.

Businesses can reduce the risk level also through the involvement of other entities or individuals as partners. For this purpose joint stock companies, financial-industrial groups, associations and others are created. In many cases is possible distribution of total risk into stages of realization when they realize long-term projects or implement strategic issues.

Another popular method of reducing risk is the management of assets and liabilities.

The aim is to be found such a ratio between assets and liabilities of the company which allow avoidance of the reduction of net asset value.

Methods used for making an impact on the risk should be modified in any alteration of the content and specifics of the risk situation which causes a change in the company. In this manner of speaking, the use of any method of risk management implies constant monitoring of its impact on the business results and in case of alteration of the external or internal conditions adjustment of the used method.

Organization management of investment risk involves determining a specific entity of risk management - financial risk manager - manager or other specialized entity in the company. Whatever is this entity, it must fulfill the following functions [5 p.168-175]:

a) to make risky investment holdings in accordance with the current legislation in the country;

b) to develop a program for risk investment activities;

c) determine the extent and magnitude of investment risk;

d) to develop a specific program for risky decisions and to organize their implementation;

e) to conduct insurance activity related to risky operations.

Assuming that these functions form the tactics of risk manager, still remains the question what is the possible strategy of this management entity.

The strategy of the financial risk manager can be seen as a sort of art for risk management in conditions of uncertainty and unpredictability of the situation – art which is aimed at forecasting and foremost to limit the parameters of investment risk.

Risk strategy should be built on the following principles and procedures [5]:

a) maximum revenues and benefits;

b) determination of the maximum likely outcome;

c) determination of the minimum volatility (likelihood) of the outcome;

d) the optimum ratio between income and risk.

The essence of the rule of the maximum income is based on the fact that by all possible variations of risky investments it is necessary to choose the option that gives the most efficient result in minimal or acceptable risk for the investor.

4. CONCLUSIONS

Development of a strategy for investing in the Black Sea region shall comply with the economic development prospects in the country and with the risk assessment of each investment opportunity. The estimates of the level of risk have no singular value, but reflect on the need of decision-making process considering specific conditions.

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[1] The overall risk of the investment portfolio of the company consists of two components - a systematic and non-systematic (unique) risk. A systematic risk due to general economic risks affects the overall market. It can not be eliminated through diversification and it is popular in the literature as market risk. It must be borne even by the investors who hold well-diversified portfolio. Non - systematic risk cannot be explained by general market changes, it is independent of economic, political and other factors that affect all traded securities. This risk is unique to a particular company or industry and through diversification can be reduced and even eliminated. Investors expect to be maked up for taking systematic risk. They should not, however, expect the market to provide compensation for risk that can be eliminated.

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WIND ENERGY AND CONTAINER SHIPS

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Abstract: The main focus of this article is the development and use of clean renewable energy sources – wind energy, on ships. The main goal is the diversity of energy sources and the reduce of environmental pollution, hoping that this will ensure future energy security of supply. I propose to install wind turbines, kite which generates electricity and kite used for propulsion on a port-container. The main reason of this article is to try to show a modality for reducing ship pollution and the quantity of fuel used, that mince, to reduce the price of transportation and a method of saving money. As a result of my research I discovered that is more convenient to use vertical axe wind turbines like French model Statoeolien GSE 4 comparing with a normal wind turbine with orizonthal axe, to use the mixed propulsion motor-kite then only a diesel motor, and a kite with generates electricity than a simple wind turbine.
Wind energy is a very good solution to global energy problems. It is considered the cheapest source of energy. The kites which generate electricity are revolutionizing wind turbines.

Key words: Pollution; Ship; Wind turbine; Energy; Kite.

1. INTRODUCTION

The article below it fits into a larger system of research on air pollution, more accurately, at methods to reduce pollutant emissions from marine engines.
In the conditions that the price of oil continues to rise, the atmosphere is degraded due to exhaust emissions and overall pollution of our planet every day, unconventional solutions for energy began to attract interest from parties involved in maritime transportation.

Unconventional propulsion systems such as wind or electricity, have come to the forefront after a long time of being ignored.

2. USING WIND ENERGY ON CONTAINER SHIPS

I decided to place three vertical axis wind turbines from the company Gual Industry on the monkey island, on the container ship Pelican.
I have chosen the vertical axis wind turbine from the company GSE 4 Gual Industrie- Statoeolie because in comparison with the other models:

- resist at winds of 220 km / h and more, remaining compact;
- it is aesthetic;
- no stability problems;
- can be installed directly on a flat surface;
- it is silent;
- low rotation speed up to 85 km/h, the turbine provides an increased safety level, against emergency stops;
- all the structure generates a few vibrations due to the resonance phenomenon, but which are amortized by using suspensions.

Safety systems of the turbine:

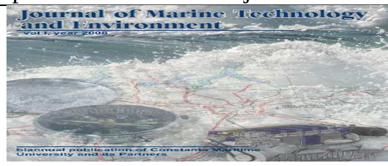
- speed limitation device for winds exceeding 150 km/h;
- disc brakes integrated on the generator- with the role of shutting down the turbine in the event of failure or abnormal vibration;
- the stator constitutes a safety device for limiting the access to the rotor movement for people and foreign articles.

It has a 4-point anchoring system that eliminates the turbine movement, at very strong winds.

Annual test - turbine is limited only by its location, not by its high.

Minimum requirements for maintenance:

- bearings have lifetime warranty;
- simplified verification bearings;



- gearbox requires draining every four years and changed at 10 years;
- electric power generator should be checked once a year, with the entire turbine.

Tablel 1: Technical characteristics of Statoeolien GSE 4 wind turbine

Height and diameter	4m/1,5 m
Runs from a power of the wind of	2 m/s (7 km/h)
It operates at a maximum wind speed of	60 m/s (216 km/h)
Power generated at 15 m/s (54 km/h):	1,3 kW
Power generated at 25 m/s (90 km/h):	4,4 kW
Power generated at 40 m/s (140 km/h):	10 kW
Speed rotation	0 -120 rpm
Generator with	Synchronous Permanent magnet
Weight	800 kg
Mentenance	Yearly
Warranty	3 years

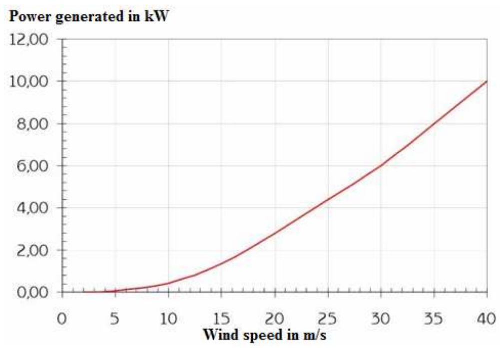


Figure 1 The power generated by the turbine at various speeds

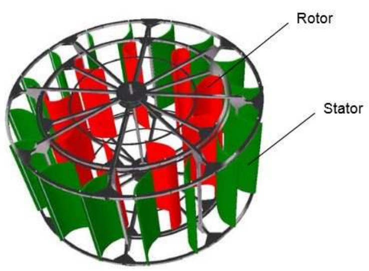


Figure 2 Statoeolien GSE 4 wind turbine

The three wind turbines Statoeolien GSE 4 located on M/V Pelican will generate maximum:
P=3 x 10 kW= 30 kW

3. USE OF KITES FOR PROPULSION AND POWER GENERATING ON CONTAINER SHIPS

The German company Beluga equipped in 2008 the containership M/V Beluga with a kite of 160 m^2 from the company Sky Sails

According to research it proved that this innovation has reduced the amount of fuel used by 15- 20 %, or approximately $ 1,000 per day economy. The ship had the kite high between 5 minutes and 8 hours a day. That reduced significantly the CO_2 emanations.

Figure 3 M/V Beluga powered by a kite from Sky Sails

It is estimated that if it will be increased the size of the kite by 320 m^2, the amount of fuel used will be around 30%, which would reduce both operating costs and CO_2 emanations.

The kite is connected to the ship with a cable which has the length between 100 m - 500 m, and is automatically controlled by a computer.
Sky Sails estimates that if the system will be implemented worldwide, there will be a reduction in CO_2 emissions of approximately 0.6 %.

Figure 4 M/V Beluga powered by a kite from Sky Sails

On M/V Pelican we will install the necessary platform for Ampyx Power Kite with its related generator at the aft of the ship, on level 84.
The kite is connected to the generator with a cable of 450 m length.

When the plane moves it pulls the cable.
The plane goes up and down automatically creating tension in the cable and forming a figure of eight. The process is repeating over and over again.

On the ship we will install a model of kite with a wingspan of 30 meters which will generate approximate 2 MW = 2000 kW. The ship has width of 30 m.

Ampyx Power kite has characteristics:

- High durability;
- Low cost;
- Reduced environmental impact;
- Automation.

On the M/V Pelican we had installed some devices that use wind energy:

- A kite generator of electricity from Ampyx Power – that will generate up to 2000 kW;
- A kite used for propelling the ship, placed at the bow, from the company Sails- Sky, that will help reducing the fuel consumption by 15 % -30 % when the ship is in ocean crossing.

P= 30 Kw+ 2000 Kw=2030 Kw.

With this energy we can power the secondary consumers from M/V Pelican:

- The lights of the accommodation;
- Consumers Service (outlets);
- Lights from engine room;
- The lights on the main deck;
- Fire detection system;
- Fire extinguishing system with water and foam in the engine room;
- Smoke detection system in cargo holds;
- Emergency Generator Console from engine room and the bridge;
- The control panel for charging/discharging batteries.

Schematic for connecting the three wind turbines and the power generator kite to the ship, we must follow the following steps:

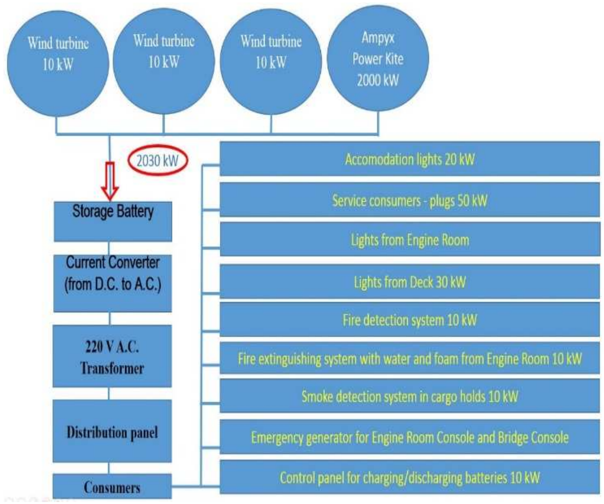


Figure 5 Scheme for the connection the wind turbines and the power generator kite to the ship

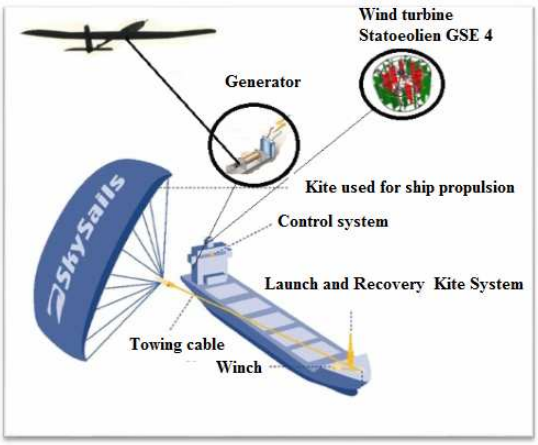
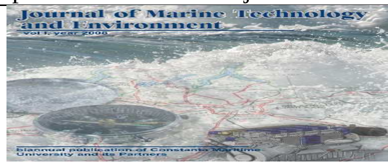


Figure 6 M/V Pelican equipped with wind turbines, power generator kite and Sky Sails kite used for propelling the ship



4. CONCLUSIONS

Wind energy is a very good solution to global energy problems. It is considered the cheapest source of energy. The costs to produce it are zero.

Other advantages of wind energy:

- zero emission of pollutants and greenhouse gases, because they do not burn fuel;
- No waste is produced. Wind power; production does not involve any kind of waste;
- Reduced costs per unit of energy produced.

Using kite electricity generator is the newest method that revolutionizing wind turbines.

Advantages for kite electricity generator comparing with a normal wind turbine system are:

- Durability;
- Reduced Costs;
- Reduced environmental impact;
- Automation;
- Easy - level of implementation
- Improved operational performance

Because of price of fuel which is steadily growing, the world is attempting to reduce pollution, and by default also pollution caused by naval engines.

It was proved that we can use for ship propulsion also unconventional energy, so we can say that in a future ship propulsion will be replaced by mixed propulsion motor-kite.

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