Marine Vessel Structure and Equipment Corrosion Defect Characteristics

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***Abstract* – The analysis of the losses that are caused due to corrosion is an important input in the economy of Latvia and the European Union. The corrosion of the ship's structure and equipment accounts for a considerable proportion of the total corrosion losses, thus it is the impetus for further investigation and developments for protection from corrosion, providing the ship building companies with corrosion preventive materials and tools. This paper gives an insight into ship structure and equipment corrosion, and it aims to develop in-depth study of ship components, assemblies and corrosion damage and its coating options.**

***Keywords*: shipbuilding, metal protection, vessel structure corrosion.**

I. Introduction

Protection of metals from corrosion is a particularly topical issue, which affects all areas of the global economy. Losses due to corrosion of ship structures of new ships (see Tab.1.) and ship annual maintenance and repair (see Tab.2.) total to 10 billion USD in the world. [6]

Corrosion effects are diverse. First of all, it is irreversible loss of metal (about 10-20% of metal production is lost due to corrosion [6, 9]). Main losses are related to indirect losses – increasing the mass of metal structures due to corrosion increment, due to design for manufacturing of the increased workload, due to performance decrease, due to large amount of repair, etc.

Practise shows that correct designing of ship structures and corrosion protection together with qualified technical operation and replacement of damaged structures in time may reduce losses caused by corrosion by 50 – 70% [6,9], also these operations may reduce metal increment by 10 – 30% [6,9] hence increasing deadweight and vessel's life.

Diversity of vessel's structures and operating conditions cause particular difficulties in developing and using methods against corrosion. The effectiveness of the most common corrosion prevention measures is achieved using different protection resources.

TABLE 1

Average expenses associated with corrosion in new ship structures [6]

Ship type	Amount	Structure expenses due to corrosion (%)	Average ship expenses (USD millions)	Average corrosion expenses per year (USD millions)
Oil tankers	6..920	13	50	1,799
Chemical tankers	2..471	30	50	1,483
Bulkers	6..252	10	20	500
RoRo	18..611	10	15	1,117
Fishing vessels	23..711	10	5	474
Tugs	12..954	10	11	570
Refrigerating vessels	1..441	10	6	35
Cruise vessels	337	13	200	350
Passenger vessels	5..386	10	24	517
Others	7..724	10	20	618
World total				**7..463**

TABLE 2

AVERAGE EXPENSES ASSOCIATED WITH CORROSION IN SHIP OPERATION AND REFIT [6]

Ship type	Amount	Refit expenses due corrosion (USD thousands)	Annual refit expenses (USD millions)	Average corrosion expenses per year (USD thousands)	Total annual expenses (USD millions)
Oil tankers	6.920	200	1.384	140	969
Chemical tankers	2.471	300	741	140	346
Bulkers	6.252	50	313	56	350
RoRo	18.611	50	931	73	1.303
Fishing vessels	23.711	25	593	20	474
Tugs	12.954	50	648	50	648
Refrigerating vessels	1.441	50	72	50	72
Cruise vessels	337	200	67	1.000	337
Passenger vessels	5.386	50	269	56	302
Others	7.724	50	386	56	433
World total			**5.404**	**World total**	**5.234**

II. METALLIC MATERIALS IN SHIPBUILDING

Metallic materials used in shipbuilding can be divided into two groups: ferrous metals and non-ferrous metals. The iron alloys – steel and cast iron – belong to ferrous metals. Steel is the most widely used shipbuilding material, but cast iron is also used in small amounts. Non-ferrous metals that are used in shipbuilding are aluminium, titanium, copper and their alloys.

Metallic materials used in shipbuilding are divided into two classes: constructive, which meet mechanical and technical performance requirements, and non-constructive, which have specialized properties (physical, chemical, etc.). Shipbuilding industry commonly uses alloys, pure metals are used mainly for coatings [3, 9].

Shipbuilding metallic materials are divided into the following categories [9]:

- Shipbuilding materials for structures, structural constructions, engine parts, ship systems, pipe manufacturing, etc.;
- Basic coverage protection – galvanic, gas thermal, diffusion, hot;
- Protector manufacturing;
- Anode manufacturing – die cast and bimetallic;
- Alloying elements – metals imparting special properties of the main group of metals.

This paper discusses details of the ferrous-class element – steel and non-ferrous element – aluminium.

Steel

Shipbuilding steel is the most commonly used material. It has to comply with pretty stringent requirements: strength, flexibility, high productivity, ability to be welded, costs, correctional possibility, etc. Steels used in the shipbuilding industry, are characterized by high frost resistance, good welding properties and higher fracture strength. In ship building the most commonly used is carbon, low-alloy and alloy steel. [15, 17]

Usually soft steel is used for hull structures; it contains 0.15% to 0.23% carbon, and may contain reasonably high manganeseamount. Both the sulphur and phosphorus content in low alloy steel is maintained at a minimum (less than 0.05%). Higher content of both substances impairs steel welding properties and cracks can occur during welding if the sulphur content is high. [1, 14]

Ship steel sheet thickness is from 0.5 mm to 4 mm (thin sheet), and from 4 mm to 140 mm. Sheet length mostly is 6 m to 8 m, but width from 1.5 m to 2 m. Carbon steel profiles are used to make: angle profiles, arc profiles, U-shaped and Z-shaped profiles These profiles except the U-shaped and Z-shaped profiles are also used for mild steel.

Alloy steel is used for hull plating, bulkheads, tweendecks, decks, etc. Profiles are used for beams, frames, stringers and other body elements. Alloy steel is also used for shed parts on board: hawse pipes, anchors, chains, screw brackets, propeller, etc. [15]

Cast iron is used to make a variety of castings: bollards, square bars, stern tubes, propellers and other parts.

Steel for Lloyd's Register class ships is produced only by the recognized manufacturers, and inspection and testing of steelworks are made before shipment. All certified materials are marked with the sign of the classification society and other parts that should be marked as required in rules.

Ship classification society initially gave different specifications for steel, but in 1959 the principal societies agreed to standardize their requirements in order to minimize the required steel grade. Now there are five different steel grades, which are used in the construction of commercial vessels. These classes are A, B, C, D and E. Class A is an ordinary mild steel by classification society requirements, and it is usually used in the construction of ships. Class B is better than mild steel class A, and it is used in places, which require thicker sheets, in dangerous places. Classes C, D and E have increased gap-wave characteristics. [1, 14]

In areas where high corrosion rate is expected or is likely to occur, it is advisable to choose a special solution for steel technical maintenance out of one or more of the following methods:

- Thicker steel material choice, higher grade of steel or extra steel sheets;
- High-quality protective coating;
- Electrical systems and cathodic protection;
- Construction ensuring that high bending moments are concentrated in areas other than the intended corrosion sites.

Construction should be checked at regular intervals in order to identify corrosion activity at an early stage. [5]

High-strength steels with higher strength than mild steel are used for large tankers, container ships and bulk carriers in the presence of large tension. The use of higher strength steel reduces deck, the lower shell and larger ships mid-thickness of the frame, but it increases deflection. Higher-strength steel welding capacity is an important consideration in the application of ship design and therefore there is an issue regarding the reduced endurance strength of these steels. Corrosive effects within the lower steel plates and sections often require ongoing and thorough examination.

Higher-strength steels used in the construction of ships are manufactured and tested in accordance with the requirements set by classification societies. Higher strength steels are available in three strength grades – 32, 36 and 40 kg/mm^2, when shipped rolled or original state. There are also requirements for materials with six degrees of strength – 42, 46, 50, 55, 62 and 69 kg/mm^2 when delivered in tempered or recycled condition. Each strength level is divided into four classes – AH, DH, EH, and FH, which depend on the cut-off rigidity required level. [1, 14] A wide range of higher-strength steels are used for polar-class vessels.

Corrosion-resistant steels – steels with alloying elements that give them good corrosion resistance properties, colloquially referred to as stainless steels, are not widely used in shipbuilding, mainly because of their high production costs. Such materials can only be found in cargo tanks which are designed to carry cargo, which drastically speeds up the corrosion.

Stainless steel products have high surface quality, but it doesn't mean that such materials shouldn't be machined before exploitation. All classes and finishing stainless steels may in fact become stain, pale, sticky with dirt layer in normal service. To achieve maximum corrosion resistance stainless steel surface should be cleaned. It is essential to select carefully stainless steel grade, condition and surface treatment for the required operating environment. Moreover, it is essential to ensure that the manufacturing and installation procedure are correct, and regular cleaning schedules are adhered to. As a result, the structures will demonstrate a very good performance and long life expectancy. Stainless steel cleaning intervals and costs are lower than those of many other materials, and it is often outweighed by larger acquisition costs.

Surface contamination and sediment formation are critical factors that can lead to a drastic reduction in life expectancy. These contaminants may contain small particles of iron or rust from other non-stainless steels, which are applied to adjacent structures. Industrial, commercial and even domestic environment and natural atmospheric conditions can cause sludge, which is quite corrosive. Deposition of marine conditions can be used as an example.

The work environment (warmness, moisture) may lead to more aggressive conditions. Such an environment can increase the rate of corrosion and therefore the structures will require more frequent maintenance work. Modern processes use many cleaners, sterilizers and bleaches for hygienic purposes. All of these fluids, which are used according to the manufacturer's instructions, are safe, but if used improperly, can cause a stainless steel surface corrosion and fading. It is forbidden to clean a stainless steel surface with strong acidic solutions.

New cleaning products should not be a problem, but more attention should be paid if the set-up time is increased. In places where there is a suspicion of surface deterioration, immediate attention to cleaning will not cause problems throughout the lifetime. Metal has to be cleaned when it is dirty to restore its original appearance. This can vary from one to four times a year for external use. [16]

Oil tanker inner surface, particularly the bottom of the deck and the bottom of the vessel, mainly are protected by high-cost coverage that protects against corrosion and requires careful examination and technical maintenance. [1]

<u>Aluminium</u>

Aluminium alloys weigh less than steel (density 2.7 g/cm^3) and are strong enough. The most common are aluminium alloys with magnesium and manganese. The products that are usually made of such alloys include small boats, ships superstructure, bulkheads, pipes, funnel pipes, masts, gangways, and other important components of the ship. [15]

Aluminium alloys with high corrosion resistance, as well as aluminium-based composite materials, have become popular in construction of high-speed marine and river vessels, and vessels with air-foils, hydrofoils and air-static. [17]

Manufacturing of the hull entirely from aluminium alloys is difficult, and it has been done only on smaller ships. Multiple vessels are equipped with aluminium alloy superstructures, as a result, not only the displacement of the ship has decreased, but it also improves vessel's durability. Since the reduced body weight is in the position above the vessel centre of gravity, it provides lower centre of gravity coordinates than those of the steel superstructure. If the vessel's stability is critical, then aluminium alloy could be used to increase the metacentric height and to improve the initial stability. Due to the improved initial stability, passenger ships can increase the number of seats for passenger accommodation. Ship weight can be further reduced to the lower weight and the ship may require less machine power, which results in weight loss at the expense of the ship's machinery.

Only high-speed and high-capacity vessels and ships with a low deadweight/lightweight ratio can be expected to produce tangible savings. These ships are mid-velocity ships and high speed passenger crafts with a low deadweight. A very small number of cargo liners are equipped with aluminium alloy superstructures, mainly to reduce draft in order to carry more cargo. Aluminium alloys are increasingly being used in the structures of multi-hull and high-speed ferries, where the high ratio between strength and weight is used as a good advantage. [1, 14]

Aluminium alloys applied in modern shipbuilding corrode 100 times slower than steel. In the first year of operation steel corrodes at a rate of 120 mm/year, while aluminium – at a rate of 1 mm/year. Therefore, aluminium vessels do not necessary need such careful attention as steel vessels. [13]

Marine grade aluminium alloy corrosion resistance ensures that the protective coverings are not necessary for all body surfaces. [12] Only 5000 and 6000 grade aluminium alloys are used on vessels. These two groups of the above mentioned alloys are resistant to corrosion in the marine environment due to the formation of dense surface layer of aluminium oxide. [10]. A protective aluminium oxide layer ensures that the containers, tanks, void spaces and other interior spaces do not require annual maintenance and painting. [12]

Aluminium alloys are susceptible to corrosion cracks because they are dependent on the presence of oxide to be able to fix them by their selves. This means that if aluminium is in contact with something, even with another piece of aluminium or zinc, it has to be painted with an adhesive waterproof paint. Plastic coating alone is not sufficient as an insulator. It is highly not recommended to allow salt water enter into the cracks, otherwise corrosion will start. Aluminium has to be painted in places where materials have been added to the aluminium surface and below the waterline. In other cases, marine aluminium alloys do not require any painting [10]. If the surface is painted, it requires the same maintenance as steel surfaces [11]. Aluminium surface preparation before painting is very important. Thorough cleaning and sandblasting makes a surface paint-friendly . Despite the application of the basic colour, zinc should be used in order to reduce the corrosion power. Zinc anodes must always be used on aluminium vessels , mainly in the same quantity as on the steel vessels to reduce the corrosion current. Of course, zinc welding on aluminium is the best; it is usually bolted on aluminium. A good connection between aluminium and zinc is highly important [10].

III. Corrosive Environments

Ship hull and ship structures are subject to corrosion of liquid and gaseous environmental influences (continuous and periodical). Different areas of the vessel may be subject to corrosion of various environmental influences (see Fig. 1). [3, 4, 9]:

- Salinity S – The total amount of minerals, g, per 1 kg of water – is expressed as per mille consisting of 2 ‰ to 40 ‰. Average sea and ocean salinity is 35 ‰. For environmental assessment of corrosion aggressiveness ion concentration in the given sea basin is determined by salinity;
- Oxygen, carbon dioxide and hydrogen sulphide affect corrosion activity. Oxygen and carbon dioxide are dissolved in all sea basins. Hydrogen sulphide content in black sea is 87%. There are migratory zones ("clouds") in the sea waters, which have large concentrations of hydrogen sulphide;
- Sea waters are characterized by high electrical conductivity from 0.5 to 6.7 S, a stable and a narrow pH range (7.3 to 8.6). Sea water is a typical weak alkaline electrolyte;
- Water composition that has settled in crude oil during cargo transportation is similar to natural waters. Mineralization ranges from 1 to 300 g/l. Infused water composition and characteristics are determined by many factors. In order to assess the corrosion activity of water and select the most suitable protection materials it is more appropriate to determine the physical and chemical characteristics of each specific type of water;
- Dark and light oil products are not aggressive corrosion environments. Oil protects the metal from corrosion. On the contrary, removing the metal surface gasoline and kerosene facilitate the corrosion process in the atmosphere and sea water;
- Industrial atmosphere affects corrosion of the ship metallic structures during the trip, air does the same during sea passage. Air composition and properties depend on many factors – climatic areas and operation of the ships;
- Gas phase consisting of water, air and evaporative load products forms during transporting of the cargo in free tanks and containers. Ballast and cargo tanks of dry cargo ships contain a blend of water vapour atmosphere and sea atmosphere. Tanker ship tanks have different gas mixtures containing volatile oil and oil vapour, H_2S, SO_2, and various compounds containing hydrogen sulphide. In the conditions of changeable humidity – 40 to 60% – condensing fumes form electrolyte, whose composition is close to strong acid (SO_3 2 -, SO_4 2 -) with pH 3-4, and these fumes have a high corrosive effect;
- Gases, coming from the boiler combustion engine exhaust gases, belongs to the specific corrosive environments;
- Inert gases are gases that are used for tanker ship tank fire and explosion safety. The following inert gases are used for corrosion protection: developed and refined exhaust gases from gas turbines, gasses from special autonomous gas generators.

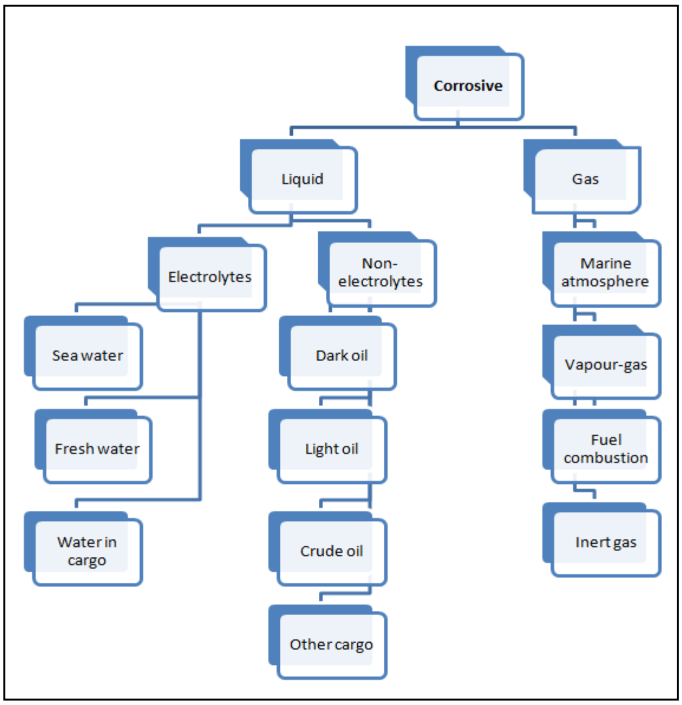

Fig. 1.Corrosive environments on ships

IV. THERMODYNAMICS OF CORROSION PROCESS

Corrosion (see Fig. 2.) is one of the most common naturally occurring processes that have been studied by thermodynamics – including oxidation process, metal disruption, and its chemical and electrochemical effects under environment influence.

Corrosion mechanism is the basic set of processes, which are determined by the reaction of metals with the environment. It determines the stages of the process and corrosion processes, distinguishes elementary processes, thus enabling to look for ways to control this process. There are 2 types of mechanisms – chemical and electrochemical corrosion. [2, 3]

Chemical corrosion is an arbitrary process of metal exposure to corrosive environment, when metal oxidation and environmental oxidation components regeneration take place simultaneously. It occurs in dry gasses, liquid electrolytes and non-electrolytes. Chemical corrosion mechanism in electrolytes is not discussed in this paper, because electrolytes, in which corrosion mechanism is observed, are not used in ship building, operation and maintenance On seagoing vessels, various elements of power plants, fuel combustion products discharged into the system, oil tanks, fuel tanks and other structures are subject to chemical corrosion. In shipbuilding and ships repairing the metal constructions which are processed in high temperatures (e.g., welding, cutting) is the subject of corrosion [9].

Electrochemical corrosion is an arbitrary process of metal exposure to corrosive environment (electrolyte), when metal oxidation and environmental oxidation component regeneration do not take place simultaneously – their regeneration speed depends on electrolyte potential. It is the most common mechanism of metal corrosion in shipbuilding and on board ships. All gas environments containing water vapour (industrial and marine atmosphere, container, tank and tank vapours in the gas phase) and liquid media containing water (sea, rivers and moisture infused from cargo) influencing corrosion of ship structures and equipment have electrochemical nature. [9]

V. KINEMATICS OF CORROSION PROCESS

The kinematics of corrosion process significantly changes the external (composition, temperature, pressure, physical state environmental) and internal (chemical and phase composition, structure, physical and mechanical metal chemical) properties. Corrosion rate (1) – quantity of metal that is ionized in time unit dependable from area unit and is characterized by

$$K = \Delta b \tau \,, \qquad (1)$$

Δb – Depth of corrosion or decrement of structure thickness during unilateral corrosion, mm,
τ – Durability of corrosion process, years.

A. *Chemical corrosion in gas environments*

The corrosion process in gas environment at high temperatures occurs as follows:

Oxidizer and metal absorption → Oxidizer ionization → Formation of chemical compound.

Actions on the parts of the process can change the corrosion rate.

The main structure material in shipbuilding, which is used at high temperatures, is steel. Corrosion products will be oxides which are formed according to the following scheme [7]

$$t°C \xrightarrow{Fe_2O_3} 200 \xrightarrow{Fe_2O_3} 400 \xrightarrow{Fe_3O_4} 575 \xrightarrow{FeO} 730$$

Changes of steel structure and physical and mechanical properties occur at higher temperatures. Fe_2O_3 oxides dissociation occurs at temperature higher than 1,100C.

B. *Chemical corrosion in liquid environments*

Non electrolytes in shipbuilding and marine vessels usually do not cause hazard and environmental corrosion. Corrosion rate is low and it can be ignored. [2, 9]

C. *Electrochemical corrosion*

Electrochemical corrosion in electrolytes is associated with electric double row metal – electrolyte creation and the potential jump to its limits. It includes 3 basic stages [9]:

1. Adsorption of ion or/and molecules on the surface of the metal together with formation of potential;
2. Metal ionization and recovery of the electrolyte component together with formation of potential in the electrode;
3. Formation of corrosion products.

In natural environments such as seawater, two cathodic processes are possible – recovery of molecular oxygen and formation of hydrogen ion. The corrosion process kinetics changes according to the nature of electrolyte – slope angle between oxidant equilibrium potential and the anode polarization curve. This factor is used to reduce the aggressiveness of the electrolyte. [9]

Metal electrochemical corrosion process mechanism and the rate is determined by various internal and external factors that depend on the physical nature of the metal and the electrolyte characteristics of the fixed and dynamic variable system "metal – electrolyte – the environment". Inclusion of ambient systems means that for the evaluation of corrosion kinetics it is necessary to take into account factors other than the nature of the metal and the electrolyte, such as heating, pressure, flow, etc. These factors can significantly affect the system "metal - electrolyte" stability and even principal possibility or impossibility of the corrosion process.

Laws of diffusion kinetics and concentration polarization give overall impression of the impact of the above mentioned factors on the electrochemical corrosion of metals. Diffusion kinetics laws reveal dependence of corrosion rate on the oxidizer supply dynamics to the metal surface and the discharge of reaction products.

Concentration polarization is characterized by the difference between the electrode potential difference in balance and power transmission

Ship construction safety and longevity is largely dependent on the type and nature of corrosion. Corrosion types on ships are summarized in Fig.2. [2, 7, 9]

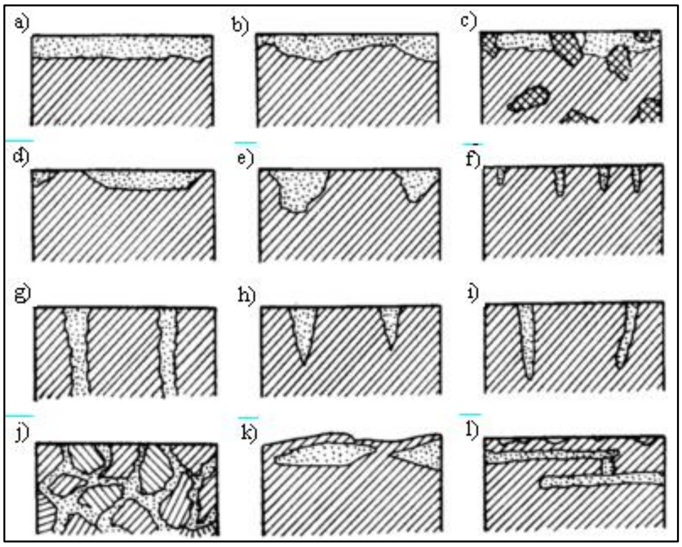

Fig. 2. Types of corrosion: a) constant; b) uneven; c) selective; d) patch type; e) tetter type; f) point type; g) through breaking type; h) knife type; i) crack type; j) inter crystalline type; k) subsurface type, l) layer type. [2, 7, 9]

VI. Corrosion of Ship Hull Structures

Ship basic structures, equipment and systems affected by corrosion effects are presented in Table 3. [2, 3, 9]

A. *Types of corrosion characteristic of ship structure*

Since the operating conditions of ship structures are different, unified whole vessel corrosion cannot be prevented accessed. Contact corrosion, weld corrosion and corrosion as a result of heat treatment is typical for all types of ships and classes.

TABLE 3.
Ship hull structure and equipment in corrosive environments [2, 3]

Name of structure	Sea water	Marine atmosphere	Other
I. Hull			
<u>*Hull underwater part*</u>			
Forepeak and afterpeak under water	x	x	
Keels, shaft brackets	2x		
Outer sheathing	x	x	
Kingston boxes, spaces of logs and echosounders	2x	2x	
<u>*Hull above water part*</u>		2x	
Forepeak and afterpeak above water		2x	
Outer sheathing, upper deck flooring		2x	
Superstructure, spaces of Engine room		2x	
Coamings, bulwark		2x	
II. Equipment			
Hatches		x	
Steering equipment			
Rudder blade, baller, propeller	2x		
Anchor equipment		2x	
Anchors and hawses, chains	x	x	
Shaft	x		
Rudder shaft pipe	x	x	
III. Systems and pipe system			
Ballast	x	x	
Ventilation, compressed air supply		x	
Fuel, luboil, hydraulic		x	x
Water cooling	x	x	
* 2 – both sided			

B. *Corrosion of ship structures*

Hull corrosion determines the overall ship's operational reliability. Ship's bottom nature and corrosion rate depend on many factors. Ship speed and sea water flow affect the nature of the ship's hull corrosion rate.

Shaft, propeller and steering system operate in an intense flow of sea water at high alternating loads of characters. For the above-mentioned structure the most dangerous is corrosion and fatigue damages in transition and seal areas. Each device creates a complex effect on the operation and corrosion.

Welded and cast-welded pipe materials of rudder shaft pipe include carbon and low alloy steels. Rudder shaft pipe corrosion has the nature of the blister. The corrosion rate in different locations is 0.2 to 3.0 mm/year [9].

Ship rudder is made from carbon and low alloyed steels, as well as corrosion-resistant steels. Ship rudders are divided into 3 parts: welded, molded-welded and molded. Notwithstanding the way of manufacturing the rudder, all rudders are exposed to intensive flow of sea water that comes from the propeller blades.

Carbon and low alloy steels have the nature of blister corrosion, corrosion rate 0.25 to 2.5 mm/year. Corrosion-resistant steels are exposed to blistering and pitting corrosion, corrosion rate 0.2 to 2.0 mm/year [9].

Parts of rudder that are subject to enhanced corrosion are shown in Fig. 3.

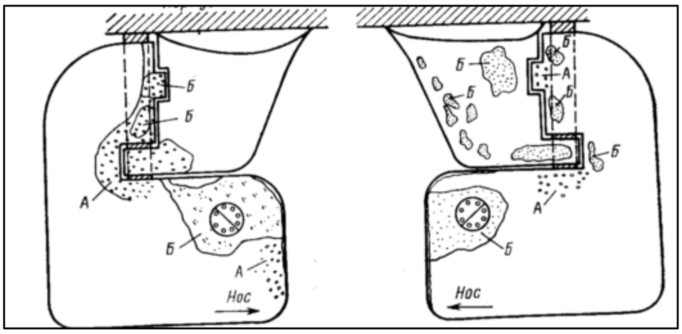

Fig.3. Corrosion damage on rudders. A – point type (0,1 – 0,2 mm/year), B – tetter type (0,3 – 1,0 mm/year) corrosion [9]

Steering shafts are made from carbon, low-alloy and high-alloy steel grades, analogous to those that are applied for shafts. Pads for ballers are made from copper alloys; ballers are subject to contact and blister corrosion. The corrosion rate in different areas is 0.7 to 5.0 mm/year [9].

The upper deck surface is exposed to the marine atmosphere, atmospheric and seawater corrosion. According to the deck constructive performance and mission, ship design and equipment placement on the deck of the individual areas of corrosion and the condition can vary. Enhanced corrosion places are those ones where sea water, precipitations and condensate can accumulate.

Subject to the contact corrosion are structures from heterogeneous metals, such as aluminium structures (superstructure) that are not insulated from the steel structures. Deck elevated temperature near the engine room also leads to an increased surface corrosion.

VII. Conclusions

It is necessary to distribute requirements that would ensure reliability of ships, ship structure operation by reducing the overall corrosion to an acceptable size, the selective nature of corrosion, corrosion erosion and corrosion mechanical damage repair, including:

Ability to link different protection methods of corrosion prevention or reduction;

Accessibility of methods and protective equipment, simplicity of technological operations and implementation during shipbuilding, maintenance and repair time;

Decreased use of metal, amount of work during construction, increased vessel operating period, project speed maintenance on ships, reduction of fuel consumption;

Ability to use new advanced shipbuilding materials and alloys, establishment of fundamentally new ships and the World Ocean cognitive resources;

A high level of technical and economic efficiency of corrosion protection and increment of ship operating profitability.

Ship classification society constantly emphasizes that metallic materials applied on vessels should have high corrosion resistance. [6]

In accordance with the set research priority “Innovative Materials and Technologies” in Latvia, the authors of the paper taking into account the above discussed corrosion analyses of ship structures, equipment and world trends are expanding RTU research into nanostructured multifunctional materials and nano technology, shifting it to corrosion characteristics of sea-going vessel parts and assemblies.

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Her fields of scientific interest: green energy; liquefied natural gas use; polar water navigation; marine environment protection; acoustic emission.

Aleksandrs Urbahs, Gints Rijkuris, Ilze Stelpa. Jūras kuģu konstrukciju un ierīču korozijas bojājumu īpatnības
Korozijas radīto zaudējumu analīze ir nopietns ieguldījums Latvijas un Eiropas tautsaimniecībā. Kuģu konstrukciju un ierīču korozija ieņem svarīgu vietu kopējos korozijas zaudējumos, tāpēc tas ir pamats tālākiem pētījumiem un izstrādājumiem aizsardzībai no korozijas, nodrošinot kuģu būves uzņēmumus ar nepieciešamiem materiāliem un līdzekļiem kuģu aizsardzībai no korozijas. Katrai metodei ir kopējas prasības, kas nodrošina: a)kuģu, kuģu konstrukciju un ierīču ekspluatācijas lietderīgumu, kas nodrošina korozijas ātruma samazināšanos līdz pieņemam līmenim, b) aizsardzības kalpošanas termiņu kuģa konstrukcijām ne mazāku par vienu doka starplaiku, c) iespēju apvienot dažādas aizsardzības metodes, sarežģītu un kompleksu aizsardzības metožu izmantošanu, lai sasniegtu vēlamo korozijas samazinājumu vai novēršanu, d)metālietilpības pieejamību un aizsardzības metožu pielāgošanas vienkāršību kuģubūves, ekspluatācijas un kuģu remontu laikā, e) kuģa projektētā ātruma saglabāšanu un degvielas patēriņa samazinājumu, f) iespēju izmantot jaunus, progresīvus kuģu būves metālus un sakausējumus, pilnīgi jauna tipa kuģu radīšanu, g) augstu aizsardzības līdzekļu tehniski ekonomisko efektivitāti un kuģu darbības rentabilitāti. Rakstā ir īsa kuģu konstrukciju un ierīču korozijas analīze, kas ir pamats, lai veiktu padziļinātu un pamatīgu pētījumu par atsevišķu detaļu un to virsmas korozijas aizsardzību. Kuģu klasifikācijas kopienas nebeidz uzsvērt augsto koroziju, kas ietekmē kuģa metāla konstrukcijas un to sastāvdaļas. Ņemot vērā apskatīto kuģu konstrukciju un ierīču korozijas analīzi un pasaules tendences, autori atbilstoši valstī izvirzītajam prioritārajam zinātnes virzienam – Inovatīvie materiāli un tehnoloģijas paplašina RTU pētījumu par nanostrukturētiem daudzfunkcionāliem materiāliem un nano tehnoloģijām, novirzot to uz jūras kuģu detaļu un mezglu korozijas īpatnībām.

Александр Урбах, Гинтс Рийкурис, Илзе Стелпа. Особенности повреждения коррозии судовых структур и оборудования
Анализ коррозийных потерь представляет собой значительный вклад в развитие народного хозяйства Латвии и Европы в целом. Коррозия судов и судового оборудования занимает лидирующую позицию в списке коррозийных потерь, что является стимулом для дальнейших исследований и изобретений по защите от коррозии, таким образом, обеспечив судостроителей необходимыми антикоррозийными материалами. К возможностям каждого из методов можно выделить следующие обобщенные требования к ним, обеспечивающие: а) эксплуатационную надежность судов, судовых конструкций и изделий путем снижения общей скорости коррозии до допустимой величины; б) срок службы защиты судовых конструкций не менее одного междокового периода; в) возможность совмещения различных методов защиты — применения комплексных методов защиты —для достижения требуемого снижения или предотвращения коррозии; г) доступность, технологичность и простоту осуществления методов и средств защиты при строительстве, эксплуатации и ремонте судов; д) снижение металлоемкости, трудоемкости постройки и повышение длительности эксплуатационного периода судов; е) сохранение проектной скорости судов и снижение расхода топлива; ж) возможность использования новых прогрессивных судостроительных металлов и сплавов, создание принципиально новых судов и средств освоения Мирового океана; з) высокую технико-экономическую эффективность защиты от коррозии и повышение рентабельности эксплуатации судов. Статья представляет собой небольшой анализ коррозии конструкций судна и судового оборудования, что является основой для более глубокого и тщательного исследования коррозии отдельных деталей и защиты их поверхности. Судовые классификационные сообщества не перестают акцентировать высокую коррозийность металлических частей и конструкций судна. Обращая внимание на вышерассмотренный анализ коррозии конструкции судов и судового оборудования на фоне мировых тенденций, авторы в соответствии с выдвинутыми государственными приоритетами в развитии науки – инновационные материалы и технологии расширяют исследование РТУ о наноструктурированных многофункциональных материалах и нанотехнологии, ориентируясь тем самым на специфику коррозии судов и судового оборудования.