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The Cost Assessment of Hull Coatings Application done by Ship's Crew on Dry Cargo Ships

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ABSTRACT

Proper ship maintenance is one of the key factors that have impacts on successful ships operations. It is important that ship's crew and ship-owners strictly implement the required maintenance measures all in order to avoid accidents, unnecessary delays and possible detentions by organization conducting ship's surveillance and inspection. Properly maintenance planning on board ship and also in the shipping company (on a fleet level) is one of the main factors affecting the maintenance costs. According to available literature, the most important factors are maintenance scheduling, choosing maintenance strategy, crew efficiency, and choice of the shipyard. This research aims to identify the key factors that have impact on ship's hull maintenance planning and to provide a framework that can help the decision maker to identify and make optimal decisions on the required number of the crew engaged on the maintenance. Ship's masters and officers sailing on dry cargo ships were asked survey questions and interviews, all in order to obtain their experience regarding the components of the ship's hull protection by coatings. This article compares costs of deck protection by coating according to the number of the crew and maintenance tools as the variables having a significant impact on the costs of hull's maintenance. The results may be used by the shipping company or other interested party in order to obtain a comprehensive overview regarding the interdependence of the deck crew costs on the total cost of deck protection by coatings.

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1 Introduction

The reduction of ship's operating expenditures and increased incomes are the two basic issues in the shipping industry. Earnings from freight heavily depend on the external factors, including the trade market level. In most cases, the operating expenditures are supervised by the shipping companies. The management has to be familiar with the operating costs in order to prepare a proper financial budget. Besides the bunker costs, a significant part of the operating expenditures are the part of the ship maintenance costs. This value strongly depends on crew's efficiency. Therefore, crew's efficiency improvement can directly affect the reduction of operating expenditures.

Ship's maintenance should meet the requirements listed in ISM (International Safety Management Code), chapter 5. The maintenance should be performed according to the manufacturer's recommendations, and good seamanship practice. Factors influencing the maintenance process are presented on Fig. 1. A all on board ship vital equipment should have a clearly defined maintenance plan. According to ISM Code, the performed tasks should be recorded in the system as well as the notes of the crew members performing the task.

International maritime community has made considerable efforts to ensure the required safety level and to prevent accidents and pollution. Also, the ship-owner and the crew have to implement the required maintenance measures in order to avoid accidents. The cost of ship maintenance activities can make 10-15 % of shipping companies direct operating costs and they remain unchanged for a long time period [16]. According to available statistic data, provided by the European Maritime Safety Agency (EMSA) for the period 2011-2017, an inadequate maintenance is

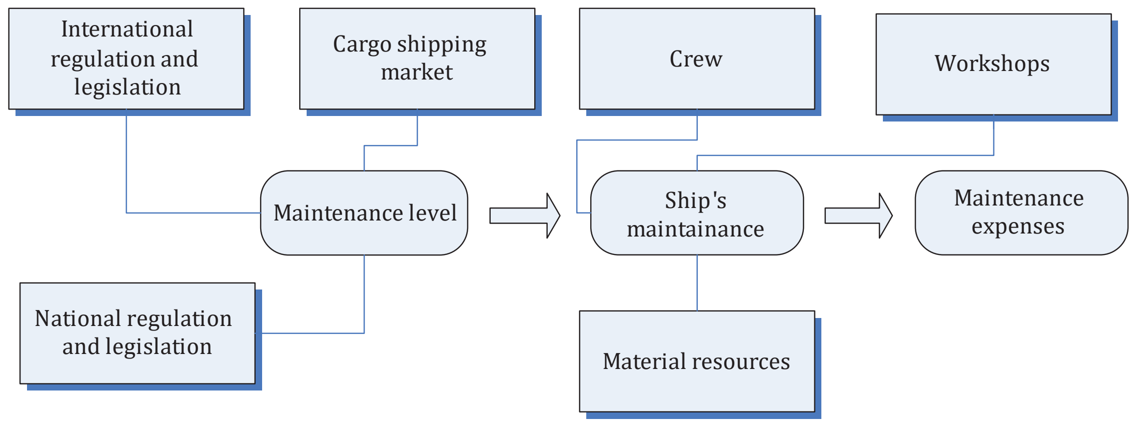

Fig. 1 Factors having impact on the maintenance process

Source: Authors

stated as a second cause of reported accidents [5]. Ship maintenance has always been part of the daily crew duties, all in order to preserve the condition of ships up to a reliable operational and required safety level [10]. Ships masters are expected to make efficient maintenance arrangements and always keep their ships in a safe and seaworthy condition. Furthermore, masters and responsible officers are required to have a high level of professionalism in supervising daily maintenance tasks and he/she should pay special attention to any possible damage on ship's structures and equipment.

Roughly speaking, ship maintenance can be divided into two categories: preventive maintenance and corrective maintenance. Preventive maintenance consists of routine procedures for keeping ship's required safety level and efficiency. This category of maintenance prevents or detects a failure in the earliest stage, and therefore eliminates any possibility of accident occurrence and also provides that ship's crew identifies hazards and ensures risks reduction in a cost-effective manner. Most commonly, ship accidents are the result of a chain of events and when combined, they may create casualties which leads to marine pollution, potential loss of life and/or property. In this respect, corrective maintenance (otherwise called also reactive maintenance) is the initial step in dealing with ship maintenance. Dhillon [3] describes corrective maintenance as the action performed due to apparent failures or found deficiencies and requires urgent corrective action to return it in operating condition. Experience shows that even well-maintained ships can suffer structural damage. Such damage, however, is generally not so significant when compared to in sub-standard ships and usually it may be detected in the early stage. The detected damage needs to be carefully inspected, reported to the responsible department of the shipping company and properly repaired according to ISM Code requirement [9].

Any significant damage should be reported to the classification society by the shipping company. The damage should be surveyed by the classification society's expert and his/her recommended corrective action will be performed. After completing the repairs, the expert will make another survey to determine whether the procedure was carried out in accordance with stipulated provisions. According to International Associations of Classification Societies IACS [7], a corrective maintenance procedure must consist of a process identifying the existing problem, defining the cause and proposinge as well as implementing and evaluatinge feasible solutions.

Ship's crew, with the appropriate company support, has a significant impact on ship's maintenance. This article provides survey findings from a sample of 75 experienced ship's' masters and bridge officers, 62 of them attended maritime courses on Faculty of Maritime Studies Rijeka and 13 come from the maritime crewing agency. The questionnaire of 17 questions regarding ship's hull maintenance was developed, tested and then given to them. Interviews were done with 15 experienced ships masters and bridge officers who attended courses on Faculty of Maritime Studies in Rijeka. Generally, survey questions and interviews have shown that the lack of proper maintenance frequently leads to failure of structures. The collected data were used for determining crew's efficiency in the considered hull maintenance process.

EMSA accident investigation reports frequently state that poor standards of procedures are a contributing factor to maritime incidents. Also, historical seafarer's confidential reports describe poor standards of shipboard operations and maintenance manuals [4]. Therefore, the prevention of ship's structural damage should be based on adherence to safety procedures in ship handling, good planning and carrying out the proper maintenance.

The cost of a crew is a substantial item in the overall costs of a ship-owner. The daily tasks should be appropriately delegated to the ship's crew in order to meet the various demands at sea or in a port. Ship's crew has a great impact on the ship's operational productivity in the seaborne trade, keeping in mind that the ship operates on the highly competitive global freight market. Accordingly, the cost and efficiency of the crew members need to be evaluated. The necessary data used in the article were obtained from the survey conducted among the ship's masters and officers and from shipping companies.

2 Factors affecting ship's hull maintenance

Generally, the model of ship's hull maintenance is changing under the influence of external conditions related to the development of maritime technology and shipping industry requirements. A ship at sea is isolated from onshore maintenance facilities and it is dependent on available on board resources. A significant factor that has a direct impact on hull maintenance is the ship's crew. Hull maintenance shall be described through following components: decks, cargo space, ballast tanks, cargo gear, deck gear, and superstructure.

2.1 Costs of the deck crew

The data on operating costs of a ship is usually company's business secret. Costs for the same type and size of the vessel can be widely different, due to the diverse crew costs [14]. A deck crew on dry cargo ships generally consists of a boatswain, able bodied seamen's (AB) and ordinary seamen (OS). The minimum deck crew is defined by the minimum crew manning certificate. The guidelines for the application of principles set in minimum safe manning are provided by IMO [8]. The costs incurred by the shipowner for each member of the deck crew can be categorised as:

- crew wages,
- cost of food,
- other crew costs.

Crew wages a one of the greatest amounts in overall costs of the ship. Also, crew wages may vary greatly from ship to ship, dependings on the nationalities of the crews [11]. The company is obliged to pay the agreed-upon wages to every crew member regardless of the ship's level of commercial utilisation. Crew wages include eight working hours, overtime, and work on Sundays and holidays. Cost efficiency is critical, therefore, technical and crewing departments have geographically moved to Asia where the manpower-intensive activity may often be undertaken by operating companies exploiting lower salaries in the region [11].

Food costs per crew member may vary considerably from one shipping company to another. Some shipping companies place no limits on the amount of food costs.

Other crew costs involve insurance costs, health care costs, and crew exchange costs. If a crew member fails to comply with the provisions stipulated in the employment agreement and leaves the ship before the termination of the agreement, he/she shall bear the cost of repatriation.

Costs per deck crew member are an important element when comparing the costs associated with actions in the ship repair yard.

2.2 Working hours and availability for maintenance

Working hours of deck crew anticipated for maintenance can mostly be seen as the total number of feasible working hours of a deck crew either daily or for a specific time period.

The largest number of feasible working hours in a given time period (in most cases, one year) should be reduced for the time during which it is not possible to carry out any maintenance or during limitations for doing the ship maintenance. Clearly, this primarily depends on the navigation area and the shipping line. The greatest number of feasible working hours is also considerably reduced by watchkeeping duties (at sea and anchorage, manoeuvring), holidays, Sundays and unplanned maintenance.

Watchkeeping at navigation and anchorage is stipulated by the International Convention on Standards of Training, Certification and Watchkeeping (STCW 78/75) [11]. Watchkeeping must be present while at sea, together with the officer on the navigational bridge during hours of darkness. The hours of darkness are covered by three navigational watches, meaning, each day at sea should be reduced by 12 hours and the number of hours spent on navigational watch should be deducted from the total number of feasible working hours. In addition, when visibility is low, or any other similar circumstances exist, a watchkeeping also needs to be hold on the navigational bridge during daytime as well. Therefore, the number of feasible working hours is even more thus reduced. The time spent on a navigational watchkeeping is calculated into the deck crew working hours. Watchkeeping, while the ship is at anchorage, should be maintained at all times. Every year, cargo, passengers and fishing vessels are attacked by pirates seeking to gain goods by hijacking and selling cargo and/or ransoming crew. Most incidents involve attacks and thefts from vessels while a vessel is at anchor or in ports [12]. In this area, additional crew members may also be engaged in the anchor watch. A deck crew member, while obtaining a watch at anchorage cannot perform maintenance tasks. The time spent in anchor watchkeeping is calculated in the working hours.

Maintenance work on ships is generally not carried out on Sundays and holidays unless it is essential for the safety of ship and crew or for performing tasks crucial for the commercial utilisation of the ship. Hence, the annual number of feasible working hours is reduced for those time those periods, except in cases when maintenance was in fact carried out on those days. Watchkeeping at sea, anchorage and manoeuvring is carried out on Sundays and holidays.

During mooring/unmooring operations and "stand by" period, the entire deck crew is engaged and maintenance work cannot be performed.

The usual maintenance tasks are not carried out during bad weather. Clearly, the number of bad weather days depends on the navigation area. The time when a deck crew cannot work due to bad weather conditions refers only to the period covering the working hours of the deck crew.

Many dry cargo ships are at sea most of the time, sometimes they calls a port only long enough to load and unload cargo (especially ro-ro ships and container ships). Nowadays in most ports, chipping the rust from open hull surfaces is strongly prohibited. Therefore, hull surfaces treatment is not usually conducted while the ship is berthed since in most ports, the coating is limited. The available time of a deck crew can be expressed in a following manner:

$$\tau_r = tgrs - ts - tmp - tnp - tvu \quad (1)$$

where:

τ_r – available time of a deck crew,

tgrs – largest number of feasible working hours per year,

ts – time spent in watchkeeping,

tmp – time spent in manoeuvring and at alert,

tnp – time on Sundays and holidays,

tvu – time of bad weather conditions.

Usually, most of a deck crew's available time will be spent on hull maintenance. The time for hull maintenance is not evenly distributed on hull elements. Parts of the hull having the effect on a ship's safety and cost-effectiveness require the highest proportion of available maintenance time. Ship and hull maintenance are usually analyzed in the early stages of ship design [15].

2.3 Hull components maintained by deck crews

The ship can be seaworthy and ready for cargo operations if all major components, regarding safety and commercial utilisation, are operational. If any of the major components is not operational, they will require maintenance.. The maintenance plan will be agreed by the master and the competent department (usually technical department) of the shipping company. The maintenance coefficients for individual components will be determined on the base of the available deck crew working hours for hull maintenance. The maintenance coefficients will be determined for the following components:

- decks,
- cargo space,
- ballast tanks,
- cargo gear,
- deck gear, and
- superstructure.

The ship operates in a complex environment and the hull is exposed to seawater and weather. Seawater properties such as salinity, temperature, oxygen content, pH level and chemistry can vary [1]. Ship constructional steel corrodes easily in the marine atmosphere. The upper part of the ship's hull, deck and deck equipment are subjected to atmospheric corrosion.

According to the done survey questions and interviews, maintenance of deck surfaces on vessels older than six years require the highest maintenance coefficient. Usually, the corrective coating repairs are taken when a coating is physically damaged or shows a minor grade of corrosion. In case of the presence of obvious deterioration signs, the entire coating should be renewed. Due to limited maintenance budget, low-cost coatings (usually with low performance) are available for on-board use. The coating may be removed by pneumatic or electric-powered tools and this kind of work does not require any specially trained crew. The coating application process is usually supervised by a chief officer. Knowledge of coating characteristics and adherence to the manufacturer's instructions will contribute to the quality and durability of protective coatings.

The deck crew is engaged on the deck corrective coating maintenance during ballast voyage. In most cases, localised corrective maintenance is primarily carried out due to the limited time between two cargo loadings. Spots affected by corrosion are properly cleaned and prepared for a new coating.

Protective coatings and cathode protection should prevent corrosion in ballast tanks. Ballast tanks are exposed to atmospheric corrosion when the ship is loaded (ballast tanks are empty) and to seawater caused corrosion, while sailing in ballast condition [18]. Ballast tanks full of seawater are influenced by electrochemical corrosion. During ship's exploitation, the protective coatings in tanks may deteriorate and such damage is most often repaired while the vessel is in a ship repair yard. Bulk carriers are an exception since the crew may maintain the top ballast tanks during navigation.

A ship's cargo gear is also exposed to the seawater and weather conditions. Corrective coatings on the cargo gear are commonly applied while a ship is in a ship repair yard. Most parts of the cargo gear, due to its construction, are not available during ship exploitation. Corrective actions are generally performed on damaged coatings on the accessible parts of the cargo gear. The maintenance of the cargo gear running parts should be carried out according to the manufacturer's instructions. In the manufacturer's instructions service, the intervals are indicated and also allow spare parts. When a damage to the strands exceeds limit values, wire rope is changed. A general rule of thumb for ship's cargo gear wires would be breakage in 10 % of the visible strands in any length of a wire. If this number is exceeded, then the wire should be removed from service [17]. Regular visual inspection, ideally before and after cargo operations, should be carried out on board to check for damage and defects. The deck crew and part of the engine crew are engaged in maintaining the cargo gear equipment.

2.4 Distribution of maintenance working hours per hull structure component

The total available hours for maintenance of the ship's hull system can be presented as the sum of the planned time spent on individual hull components and hours required for emergencies. The planned time for each element is determined by multiplying the maintenance factor and the available number of hours, and it can be expressed as:

$$Tzt = \lambda_p \cdot T_t \quad (2)$$

where:

Tzt – available time for maintenance of a ship's component,

λ_p – planned maintenance coefficient for individual hull elements,

T_t – available time for hull maintenance.

Hence, it can be concluded that the available time for hull maintenance (Tt) is the sum of all individual maintenance times of each element, including the time planned for emergencies.

$$T_t = \sum_{1=1}^{n} Tzt_i + t_{id} \quad (3)$$

where:

T_t – available time for hull maintenance,

Tzt_i – available time for maintenance of each individual element,

t_{id} – time planned for emergencies.

Clearly, the efficiency of maintenance also depends on accurately planning time to be spent on each structural element by using the appropriate tools, proper coating and the proper number of crew members. The approximate areas for considering components of the ship's structure maintained by deck crew can be determined by applying specific equations. Also, the maintenance cost is contained in the same equations. The total expenses of hull components include incurred costs for preparing surface and coat application. It may be compared to the cost of similar work carried out by ship repair yards.

3 Hull maintenance costs during the ship's exploitation

The surfaces taken into the account are: deck, holds, hatch covers and ballast tanks. The available maintenance hours and the maintenance efficiency for the treated surfaces depend primarily on the following factors:

- used equipment,
- degree of corrosion, and
- the crew's skills.

The tools used by the crew have a significant influence on the efficiency of the maintenance process. The following is usually used on board ship: electrical and pneumatic tools and sand blasting tools. Manual tools are usually used for treating smaller and "hard to reach areas". The best surface preparation results can be achieved by using the sand blasting method. This is the most commonly used method of preparing a surface for the paint application in a repair shipyard. When properly carried out, abrasive blasting removes old paint, rust, salts, fouling, etc and provides a good mechanical key (blast profile) for the new coating [2].

The corrosion of any metal surface can be classified by its behaviour in which it manifests its existence. Each form can be identified and classified by visual observation of its resulting behaviour. Uniform corrosion is considered as an even attack across the surface of a material. It is the most common type of corrosion and belongs to the most benign type Opposite of this type of corrosion, we may find pitting corrosion. This type of corrosion is typically localized and it results in holes in the metal and it requires additional time for treatment.

The skills and motivation of the crew also have a great impact on efficiency. Various obstructions that could protract treatment should be taken into consideration when planning the required time for carrying out a specific job. Hence, the planned treatment of a surface can be expressed in a following manner:

$$A_{jo} = (\sum_{i=1}^{m} Sr_i \cdot Aob_i) \cdot k_3 \cdot k_1 \quad (4)$$

where:

A_{jo} – treated surface area of an element in a time unit, with regard to the efficiency coefficient and scope of the procedure,

Sr_i – type of tool for surface treatment,

Aob_i – average treated surface area in time unit using specific tools for treatment,

k_1 – share of surface area to be treated relative to the overall surface area of the element,

k_3 – efficiency coefficient of hull element treatment[1],

m – number of tools for surface treatment.

The type of tool used has a considerable effect on the scope of treatment. Background research taken for this article shows that approximately 1 m^2/h can treated by using electrical and pneumatic tools and grinding machines, while up to 10 m^2/h can be treated by using sand blasting apparatus. With regard to the available time, used tools and the number of deck crew members assigned to the job, the surface area that can be treated is expressed the following formula:

$$A_o = A_{jo} \cdot Tzt \cdot k_2 / n \quad (5)$$

[1] The efficiency of treating individual hull elements can be diminished as a result of various obstructions and impediments.

where:

A_o – possible surface area that can be treated in the available time,

Tzt – average available time for the treatment of a hull element,

k_2 – time coefficient for treatment of a hull element,

n – number of deck crew members assigned to surface treatment.

The hull treatment coefficient can reach up to 0.75 of the total time planned for protective coating of the hull, according to the research background taken for this article. Based on the surface area and the cost of working hours, it is possible to determine the cost of treatment of a particular area.

3.1 Cost of surface treatment

The treatment cost per surface unit includes: the cost of the crew members working hour, the cost of materials, depreciation and the cost of spare parts. The depreciation of treatment tools and the cost of spare parts and expendable supplies will depend primarily on the type of tool used. The treatment cost per surface unit can be calculated in a following manner:

$$Tr_j = (Bp \cdot Crs)/((\sum_{i=1}^{m}(Sr_i \cdot Aob_i)) \cdot k_3) + Tap \tag{6}$$

where:

Tr_j – cost of treatment per surface unit,

Bp – number of crew members handling treatment tools,

Crs – the average cost of a crew members working hour,

Sr_i – type of used tool,

Aob_i – average treated area in a time unit by using a specific tool,

k_3 – efficiency coefficient of a hull element,

m – number of tools used for treatment,

Tap – value of tools depreciation, the cost of spare parts and consumables per unit of area.

The cost of treatment per area unit done by the crew is important information; therefore, later there can be made a comparison with the cost for the same treatment in the shipyard. The total cost of surface treatment is equal to:

$$UT_{ob} = A_o \cdot Tr_j \tag{7}$$

where:

UT_{ob} – treatment cost of the entire surface,

A_o – possible treatment area according to available time,

Tr_j – treatment cost per unit area.

The treatment costs of the total area are based on the unit cost that includes all impacts factors.

3.2 Application of coating

A protective coating is applied once the surface has been treated and prepared. It is applied by the deck crew under the supervision of a chief officer. Duration and quality will depend on the previously prepared surface, weather conditions and adherence to the recommendations of the coatings manufacturer.

Given the efficiency coefficient and the surface to be coated, the painted area of the hull element in of time unit can be calculated by using the following mathematical formula:

$$A_{j_p} = (\sum_{i=1}^{m} Sp_i \cdot Anp_i) \cdot k_6 \cdot k_4 \tag{8}$$

where:

A_{j_p} – the painted area of the hull element in the time unit, based on the efficiency coefficient and the area to be coated,

Sp_i – tool type for the application of coating,

Anp_i – average painted area in time unit, by using a specific tool,

k_4 – share of the area to be coated relative to the element's total area,

k_6 – efficiency coefficient of coating application on hull element,

m – number of used tools for coating application.

The coating application tools used for this are a major factor affecting the size of the painted area. As per conducted research, approximately 3 m^2/h can be painted by brush application; 20 m^2/h, by roller application; and up to 30 m^2/h, by spray application.

Given the available time (Ap), the possible surface area that can be coated is expressed as follows:

$$A_p = A_{jp} \cdot Tzt \cdot k_5 / n \tag{9}$$

where:

A_p – possible area that can be coated in the available time

Tzt – average amount of available time for applying a coating to a specific hull element,

k_5 – time coefficient for applying a coating to a specific hull element

n – number of deck crew members assigned to coating.

The coating application coefficient is generally less than 0.25 of the total time planned for protective of hull elements as per a conducted survey.

The depreciation of treatment tools and the cost of spare parts and expendable supplies are considerably smaller when compared to the mentioned costs of treatment. The cost of coating application per unit of surface can be expressed as:

$$Trp_j = (Bp \cdot Crs)/((\sum_{i=1}^{m}(Sp_i \cdot Anp_i)) \cdot k_6 \cdot k_4) + Tpa \tag{10}$$

where:

Trp_j – coating application cost per unit area

Bp – number of crew members operating by coating application tools,

Crs – crew member's one working hour cost price (average)

Sp_i – type of coating application tool,

Anp_i – average for the painted area in a unit of time using a specific tool,

k_6 – coating application efficiency coefficient[2],

m – number of coating application tools

Tpa – coating application tool depreciation, the cost of spare parts and expendable supplies per unit of surface area.

The total coating application cost can be calculated in the following manner:

$$UT_{ob} = A_p \cdot Trp_j \qquad (11)$$

where:

UT_{ob} – total coating application cost,

Ap – possible surface area that can be treated, given the available time,

Trp_j – coating application cost per unit area.

The total coating application cost does not include the coating cost needed to protect a given surface. The coating cost can be determined by using the same mathematical expression applied in calculating the coating cost in a ship repair yard:

$$Tp = ((UAnp\ Cj)/Ajz) \cdot k_7 \qquad (12)$$

where:

Tp – cost of coating

$UAnp$ – total area to be coated

Cj – coating price of unit measure (usually, one litre),

Ajz – area that can be protected by a unit measure of coating,

k_7 – share of the area to be coated relative to the overall area.

All surfaces need to be rinsed with fresh water before treatment. This certain small cost is not taken into consideration.

3.3 The total cost of the protective coating during exploitation

The total cost of the protective coating of a ship's hull, incurred by a shipping company over a specific time period, is calculated by adding up the protective coating costs of the individual hull elements. The total surfaces treating costs, the costs of the individual elements and the coating application costs will be determined separately. The total protective coating costs of the above mentioned hull elements is the sum of the total surface treatment cost, total coating application costs and coating costs.

The total protective coating cost on board dry cargo ship is an estimated value and it can be used for comparison with the cost of protection by coating for the same elements which may be done in ship repair yards. It is very important for the shipyard management to gather the required information about the repairing expenditures for a specific ship. Lesser repairing costs are strong foundation for staying competitive. The competitiveness is the key factor to survive in any business. For ship repairing activities, the ship repairing cost is very much dependent on ship repairing labour. So, the reduction in repairing mandays can directly be translated into a reduction in repairing expenditures [13].

Case study

This case study shall compare the costs of deck protection by coatings, with a varying a number of crew members and maintenance tools. The used data were obtained through a survey of mates and masters sailing on dry cargo ships.

Proper maintenance scheduling on board ship and also in the shipping company on a fleet level is one of the main factors affecting the maintenance planning and costs. The ship is sails in different climate conditions, and the characteristics of the voyage may vary, which has an impact on maintenance possibilities. Therefore, it is vital to choose the most convenient component for maintenance on each voyage and it also requires close attention when setting up maintenance planning for ships.

In this case study, the costs of deck protection by coating are compared by making simulations; the number of crew members and used tools are taken as variables that have a significant impact on the hull maintenance costs. The costs are expressed in USD on an annual basis.

Clearly, the number of crew members engaged and the tools used have a substantial effect on maintenance. In Table 1, variations are made by the number of crew members and the number of tools used in protecting decks with coatings. The average cost of a crew member is determined on the basis of the data obtained from a shipping company and by masters and mates sailing on dry cargo ships. The example is based on an 8-hour working day.

A significant influence on the available maintenance time has the ratio between navigation and ship's standing time. In the given example it is assumed that a ship has spent 131 days in navigation, 113 days in port and 36 days at anchorage. The number of available working hours of three crew members amounts to 2052 and it increases for each newly embarked deck crew member. Typically, all the available time will not be used for the maintenance of hull elements. The appropriate coefficient is determined

[2] The efficiency of coating application can be diminished as a result of various obstructions and impediments affecting efficiency.

according to the maintenance requirements of individual hull elements and is used to estimate the maintenance time of a hull element. In the provided example, the coefficient of 0.7 means the total available time. That means that 70 % of available time for maintenance will be spent on the hull's elements.

Table 1 Results of variations to the number of crew and tools on efficiency and costs

POSITION	**Number of members**	**Number of members**	**Number of members**	**Number of members**
Boatswain	1	1	1	1
Able seamen	2	2	3	3
Ordinary seamen	0	1	1	2
Cadet	0	0	0	0
Other average costs per crew member (annual); *Top*	7000	7000	7000	7000
Total cost of deck crew (annual)	78600	101200	126200	148800
Average cost per crew member	26200	25300	25240	24800
Annual theoretical hours	8760.00	11680.00	14600.00	17520.00
Average price of a working hour of a deck crew member	8.97	8.66	8.64	8.49
Available time for maintenance depends on deck crew number.	2052.00	4308.00	6564.00	8820.00
Hull system elements from 1 to n	deck	deck	deck	deck
Average available time for treatment hull element	861.84	1809.36	2756.88	3704.4
SURFACE TREATMENT				
Type of tool	Number of tools; *Sr*	Number of tools; *Sr*	Number of tools; *Sr*	Number of tools; *Sr*
Electrical or pneumatic tools (chipping tools)	1	2	2	2
Grinding machines	1	1	1	2
Manual tools	1	1	2	2
Sand-blasting apparatus	0	0	0	0
Surface area of hull element treated in unit of time, given the efficiency coefficient and scope of treatment	2.20	3.20	3.40	4.40
Surface area that could be treated given the available time	525.21	1176.81	1518.49	2200.41
Cost of treatment per unit of surface area	13.67	12.26	14.14	13.01
Total cost of surface treatment	7177.12	14428.23	21473.75	28630.83
COATING APPLICATION				
Coating application tools	Number of tools; *Sp*	Number of tools; *Sp*	Number of tools; *Sp*	Number of tools; *Sp*
Rollers	2	2	3	3
Brushes	1	2	2	3
Spray guns	0	0	0	0
Surface area of hull element painted in a unit of time, given the efficiency coefficient and surface area to be coated	41.00	42.00	62.00	63.00
Surface area that could be coated given the available time	1578.32	3552.68	4580.83	6612.35
Cost of coating application per unit of surface area	0.76	0.93	0.80	0.91
Total cost of coating application	1194.05	3286.86	3651.31	6009.78
Cost of coating	986.45	2220.42	2863.02	4132.72
TOTAL COST OF HULL'S COMPONENT (Deck) PROTECTION BY COATING	9357.62	19935.52	27988.08	38773.33

Source: Authors

The time planned for deck maintenance is the product of time anticipated for hull maintenance and the deck maintenance coefficient. Efficiency depends on the tools used for deck maintenance. The number of tools used is based on the number of crew members and the time available for deck maintenance. Deck protecting by coating is based on two primary procedures: surface treatment and application of coating.

Surface treatment on ships is typically carried out by using the tools listed in Table I and the types of selected tools have a significant effect on the treatment quality and represent one of the basic impact factors on the coating durability, all according to the conducted survey.

The deck treated area in a time unit depends on the number of crew members, on the number and productivity of used tools, and on various obstructions and impediments that can have an adverse effect on the efficiency. The cost per unit of treated surface area, as well as the total cost of coating protection, is primarily based on the efficiency and the average price per working hour.

According to experience indicators and on the basis of the conducted survey, an average of 1 m^2 surface per 1 hour can be treated with electric and pneumatic tools. Given the conditions under which electrical and pneumatic tools are used on board a ship, their useful tool life is substantially reduced. In this review, useful tool life is estimated at approximately 1500 hours of use.

Annually, the surface of 525 m^2 of the deck area can be protected by coatingsannually if three deck crew members work on this job respecting all STCW requirements. Expenses for the considered job are 9357 USD. The deck area of 2200 m^2 could be protected by coating if three additional crew members are employed with full work time on maintenance. Expenses for this protection area by coatings are 38873 UDS. The difference in the size of the area protected by coatings is not proportional to the number of newly employed crew members because those three newly employed crew members have to be engaged in maintenance as their full time job.

4 Conclusion

Maintenance of the ship is a very important requirement for it operation during its life cycle. It should meet the requirements listed in ISM and other international and national regulations. Today, maintenance budget is strictly limited and proper maintenance planning on board ship is one of the main factors affecting maintenance expenses. The costs referring to ship maintenance activities be 10-15 % of a shipping company`s direct operating costs. Preserving the condition of ships up to a reliable operational and required safety level has always been part of the daily duties of the crew. Ship's crew, with the appropriate company's support, has a significant impact on the maintenance. The research background taken for this article shows that the lack of proper maintenance often results in deterioration of ship's structures. Rapidly evolving technologies in shipping industry require evaluation of the costs and efficiency of the crew members.

The time anticipated for hull maintenance is not evenly distributed on hull elements. The highest proportion of available maintenance time is required for the hull parts that have an impact on a ship's safety and cost-effectiveness. The maintenance efficiency on board ships primarily depends on human and material resources.

The total protective coating cost on board of a dry cargo ship is an estimated value and it can be used for comparing costs for protection by coating for the same elements which may be done in ship repair yards. In the case study, the costs of deck protection by coating are compared by simulating the number of crew members and maintenance tools as variables that have a significant impact on the hull maintenance cost. The case study has made a cost comparison of deck protection by coatings by varying a number of crew members.

The data used data were obtained through a survey of mates and masters on dry cargo ships.

The deck area protected by coatings in a time unit depends on the number of crew members, on the number and productivity of used tools, and on various obstructions and impediments that can have an adverse effect on the efficiency.

Number and quality of crew members is an issue which always needs discussion. Number of the crew members may vary depending on the type of the ship. Crew costs, in most cases can make up to 60 % of ship's operating expenditures. Good shipping companies, especially those operating tankers and chemical and gas carries, are planning to increases finances for hiring qualified crew.. The relevant authorities decide on the minimum number of crew on each ship. But shipping company may employ additional number of crew members. A bigger crew means higher costs for shipping company. Ship-owners are aware of the importance of coatings in maintaining ships, which makes them efficient, safe and profitable. For the types of ships that have been discussed in this article, as well as other types of ships, the cost-effectiveness of hull maintenance by crew in relation to the shipyard cost is determined by comparative analysis. Considering the fact that the cost of manpower is increasing and on the other hand companies are trying to limit the costs, it is assumed that the maintenance will mostly be done in shipyards.

This hypothesis may be the material for future research.

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