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MULTIATTRIBUTE DECISION MAKING METHODOLOGY FOR MAINTENANCE STRATEGY WITH ECOLOGICAL CONSIDERATIONS

Abstract

Environmental/deteriorative factors related to the operation of a ship affect its ability to maintain speed over a period of time. The impact of hull roughness on the economics of operations have indicated that as ships become measurably rougher each year in service, it slows down, or demands more fuel for a given speed. Decision support problem for the ship operation strategy is presented using multi-attribute synthesis procedure. Models applied: (1) friction resistance model, (2) income/expenses economy model, (3) antifouling paint (biocide-leaching) ecology model; (4) wetted surface treatment model. Criteria functions (attributes/objectives) form the core of the decision making process: the economy i.e. profit; pollution i.e. biocide emissions from antifouling coatings and accessibility i.e. number of voyages. Optimization of hull surface management practices is described including variation of optimum hull cleaning and coating schedules. Ship performance and economic benefits with respect to: speed, optimum docking intervals, fuel, relevant voyage/port cost projections, port fouling severity, biocide emission and wetted (steel substratum) surface blasting procedures, are discussed. The Suezmax tanker operation strategy, regarding improvement of ship operation (using multicriterial decision making), presents an improvement with a reasonable reliability/accuracy for the ship-owner's definition of management strategy, based on economical and environmental aspects.

Key words: hull roughness, friction resistance, anticorrosive and antifouling coatings, fouling

VIŠECILJNO DONOŠENJE ODLUKE O STRATEGIJI ODRŽAVANJA BRODA UZIMAJUĆI U OBZIR UTJECAJ NA OKOLIŠ

Sažetak

Veliki je broj čimbenika okoliša i deteriorativnih uvjeta u službi broda koji utječu na sposobnost održanja brzine broda u određenom vremenskom periodu. Utjecaj hrapavosti oplakane površine iznimno je važan za poslovanje broda. Ispitivanjem utjecaja oplakane površine na brzinu i snagu, dokazano je da se hrapavost brodova u službi godinama kontinuirano povećava te se zahtijeva veća snaga za održanje izvorne brzine. Za potrebe više-atributne sinteze (optimizacijske metode) za kreiranje projekta poslovanja broda, razvijeni su i objedinjeni slijedeći modeli: (1) model porasta otpora, (2) ekonomski model prihoda i rashoda poslovanja, (3) ekološki model vezan za ispuštanje biocida iz antivegetativnih premaza, (4) model obrade oplakane površine.Tri kriterija (atributi i ciljevi) koja definiraju jezgru procesa odlučivanja su ekonomski kriterij (profit brodovlasnika), ekološki kriterij (stupanj zagađenja-dinamika izlučivanja biocida iz antivegetativnih (AV) premaza te kriterij društvene koristi (dostupnost-maksimalni broj putovanja). Optimizacija postupka održavanja površine trupa vršena je variranjem operacija čišćenja i premazivanja. Model uključuje promjenu pripadajućih performansi i ekonomskih efekata u ovisnosti o brzini broda, intervalima dokiranja, planiranim troškovima goriva i drugim relevantnim troškovima u luci i plovidbi. Primjenom prikazanih modela, analizirana je strategija poslovanja Suezmax tankera koja s dovoljnom točnošću/pouzdanošću može poslužiti brodovlasniku pri optimzaciji strategije poslovanja ovisnoj o ekonomskim učincima i utjecaju na okoliš.

Ključne riječi: hrapavost substrata, otpor trenja, antivegetativni i antikorozivni premazi, obraštaj

1. Introduction

After the complete ban of Tributyltin compound (TBT) antifouling (AF) coatings (lifetime of these coatings has expired at the end of 2007), several types of hybrid and TBT free coatings AF are now on the market. These products include copper and copper compounds as the principal biocide. Share of Fouling Release Coatings (FRC) (without biocide) today is insignificant due to high prices, but recorded a steady growth. The new inert hard coatings combined with underwater cleaning are not discussed in this article since the paper concentrates on the transition period.

The basic rule that applies, everything that is not prohibited is allowed (with respect to the degree of toxicity of biocides), gives a ship owner/ship operator a full freedom to use high-performance coatings, which also means the maximum degree of environmental pollution if it is long enough to guarantee protection against fouling. As the economic criterion only prevails, there is no ethical awareness or mechanism that would force shippers to use less toxic AF coatings.

2. Maintenance strategy depending on the level of pollution with antifouling coating

There are two basic strategies of hull wetted area maintenance over the lifetime of the vessel (see Fig. 1): (A) The most efficient leaching of biocides, (C) Biocide free.

As a compromise, by using a third strategy (B), after certain period (T), the shipowner may, by force of legislation or own environmental awareness, apply a biocide free coating (FRC). In doing so, it is presumed that AF coatings with biocides are used in the first period as per sketch.

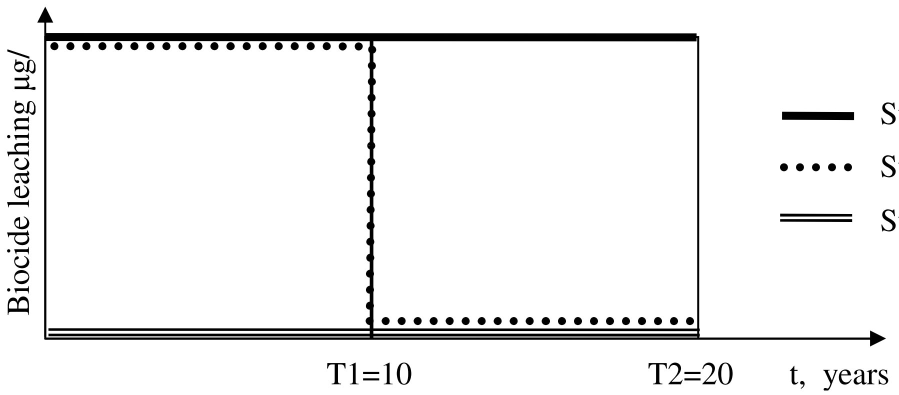

Fig. 1. A three basic strategies of hull wetted area maintenance over the lifetime of the vessel

Slika 1. Tri osnovne strategije održavanja oplakivane površine trupa kroz životni vijek plovila

The choice of today's AF coatings regarding the lifetime of protection i.e. effective leaching of biocides (months) aiming to the docking interval:

- AF 24: docking after 24 months; (20 yrs/ 2yrs=10 dockings in total.)
- AF 36: docking after 36 months; (20 yrs/ 3yrs = 6-7 dockings in total.)
- AF 60: docking after 60 months; (20 yrs/ 5yrs = 4 dockings in total.)

Two comparative curves (see Fig. 2) AF Self Polishing Copolymer (SPC) TBT free coating and the latest generation of new conventional Controled Depletion Polymer (CDP) coating are used as a basis for quantification of copper compounds leaching.

Minimum Inhibitory Concentration (MIC) or the effective lethal dose concentration leaching, based on copper compounds should be as long as possible over 10 $mg/cm^2/day$. The intersections of the curves are deter-mined exactly at these points i.e. 24 months (730 days), 36 months (1095 days) and 60 months (1824 days). By the definition, at lower leaching values (≤ 10 $mg/cm^2/day$), the AF coating is exhausted and fouling starts immediately.

By using those premise, three similar hypothetic AF coating curves, with different time of effective copper compounds leaching (24, 36 and 60 months) are created (see Fig. 3).

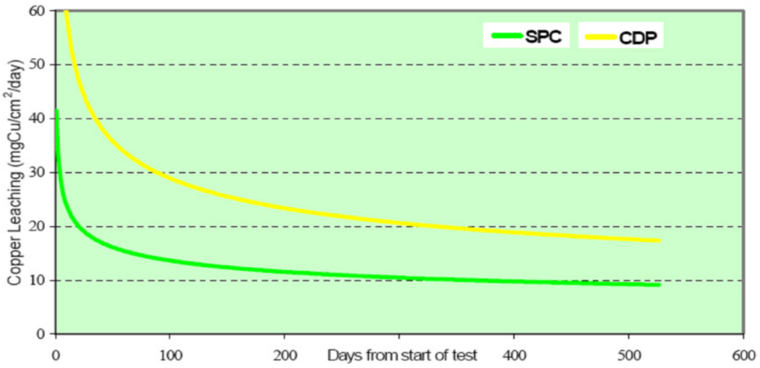

Fig. 2. AF SPC TBT free vs CDP copper leaching rates [1]

Slika 2. Usporedne krivulje izlučivanja bakra za AF SPC TBT *free* i CDP premaze [1]

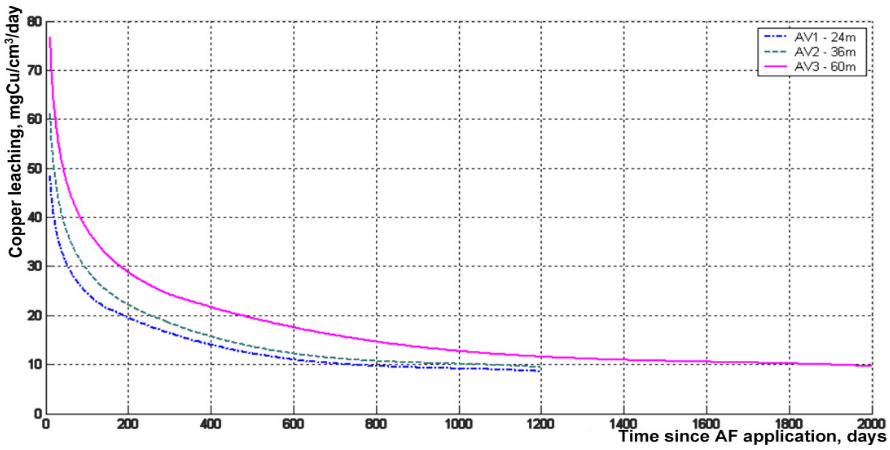

Fig. 3. AF coating curves according to the effective biocide lifespan

Slika 3. Krivulje izlučivanja bakra iz tri anti vegetativna (AV) premaza tijekom vremena

Number of used copper leaching rate values are quoted in the literature, ranging from 3,9 mg/cm^2/day [2] to 20 mg/cm^2/day [3]. The average leaching rate could be calculated as 17 mg/cm^2/day ([4],[5]).

A calculation is made for Suezmax tanker, described in this paper, for eight dockings within 20 year exploitation period, assuming the average docking every 2,5 years [6]. The total applied AF coating quantity during lifetime should be about 320 t or 40 t per docking. Integration of the area under the curve, following the dynamics of exponential leaching, gives that 23 t of copper compounds (7.16% of the total mass applied) will be leached during a ship's lifetime. A calculation is made based on the following assumptions [7]:

Wetted area = 19 000 m^2

Coating thickness: 2×125 μm DFT, 36 month effective protection

Average AF coating characteristic: 1,1 l/m^2 (ρ= 1,92 kg/dm^3)

Total AF coating weight applied per docking; 1,1 x 1,92 x 19 000 = 40 128 kg

MIC copper = 10 mg/cm^2/day

The average amount of copper leaching is always higher than the lethal dose:

(MIC) copper: 2 875 / 2.5 / 365 / 19 000 = 16.5 mg/cm^2/day > 10 mg/cm^2/day

3. Identification and Formulation of Ship Operating Strategy as Design Problem

3.1. Ship Operating Strategy- Analysis Model

Based on the AF strategies the mathematical model was developed, as described in the previous section. Software tool for analysis of the ship operation policy strategy has been implemented using MS Excel and FORTRAN. MS Excel is used for input and post processing of the results (see Fig. 6 - Fig. 8). The calculation modules are implemented in FORTRAN and built as a dynamic link library. Analysis model calculation modules include the following models:

- friction resistance model as hull roughness penalty predictor, based on ITTC 1978 formula [8],
- income/expenses economy model,
- antifouling paint biocide leaching ecology model,
- wetted surface treatment model.

Models refer to the operating criteria used today by the ship operators, the standard policy of docking with the available data on the leaching of biocides into the environment.

3.2. Problem identification

For the design of ship operations with respect to the AF and docking strategy, several requirements can be identified and transferred to the problem objectives:

- to maximize profit
- to minimize biocide leaching from AF paints (strategies A,B or C)
- to minimize number of dockings (in accordance with the Rules of Classification Societies)
- to achieve maximum number of voyages regarding four types of coating (AF 24, AF 36 and AF 60 months of protection, and FRC (60 months)
- introduce the possibility of blasting when average hull roughness exceeds threshold of 500 µm (empirical data)

In the sequel, a detail elaboration of identified parameters, variables, objectives and constrains is given.

3.2.1. Design parameters

The parameters are divided into those related to the characteristics of the selected vessel, cash flows of income and expenditure results, average hull roughness characteristics of selected sailing area and the parameters associated with the chosen AF coating:

$\mathbf{p} = \{\mathbf{p}_S, \mathbf{p}_I, \mathbf{p}_E, \mathbf{p}_H, \mathbf{p}_{AF}\}^T$

where each np_i-tuple contains parameters related to:

$\mathbf{p}_S$ characteristics of the selected ship;

$\mathbf{p}_I$ income;

$\mathbf{p}_E$ expenditure;

$\mathbf{p}_H$ hull roughness penalty predictor [8] ;

$\mathbf{p}_{AF}$ steel substrate surface treatment and the selection of AF coating system.

Basic ship data parameters include length, width, drought, trial speed, deadweight, propulsion power and efficiency, etc.

Parameters related to the income include expenses like amortization, insurance, energy, crew, maintenance, price of dockings, etc.

Parameters related to the expenditure include freight rate, voyage time, loading and unloading in port, etc.

Parameters calculated by the hull roughness penalty predictor (ITTC 1978) includes ship hull initial roughness, roughness increase rate, roughness after docking, etc.

The last set of parameters, $\mathbf{p}_{AF}$ define the steel substrate surface treatment and the selection of AF coating system. Steel substrate surface treatment can be:

- Standard (anti-corrosive touch up and application new antifouling coating system)
- Extra (complete blasting to the bare substrate and application of new AC and AF coating)

Choosing the latter system (B-extra) is proposed as the threshold of general hull roughness exceeds 500 microns (empirical data).

Possible choices for the coating system includes:AF1 (24 months protection), AF2 (36 months protection), AF3 (60 months protection) and FRC (60 months protection).

3.2.2. Design variables

The variables, given in (nd+1)-tuple **x** are defined as:

$\mathbf{x} = \{x_{nd}, x_{hb}, x^{i}_{nv}, x^{i}_{af}\}^{T}$; i=1,…nd+1

where:

x_{nd} – number of dockings;

x_{hb} – hull blasting (binary variable);

x^{i}_{nv}– number of voyages in a period i between dockings;

x^{i}_{af} – the choice of coating types regarding biocide leaching efficiency in a period i between two dockings where i=0 corresponds to the AF applied on the new ship (AF 24=1, AF 36=2, AF60=3 and FRC=4).

As can be seen from the given expression, the first variable defines the total number of ship's dockings *nd*, while the second defines the possibility of hull blasting if average hull roughness exceeds 500 μm. The number of the remaining two sets of variables is directly dependent on the number of dockings (the first variable). The first of those sets define the number of voyages in a period or segment *i* between two dockings, while the second determines the of antifouling treatment applied during the last docking.

3.2.3. Design Objectives

The achieved values of objectives **y**, obtained from the related objective functions, are dependent on the sets of parameters **p** and design variables, **x**:

$\mathbf{y} = \{y_1, y_2, y_3\}^{T}$;

where corresponding values denote:

y_1 economic criterion: maximize profit (*Profit*)

y_2 environmental criterion: minimize the pollution by biocide leaching from AF coatings (*CuPol*);

y_3 social benefit: maximize number of voyages i.e. availability (*NumVoy*).

Above, in italic, encompassed between brackets, are given aberrations that are used later in the case study and associated figures.

3.2.4. Design Constraints

Necessary conditions for ship operating procedures eligibility are defined by the next constraints:

- 20 years - t (voyage) ≤ ship age ≤ 20 years; The remaining time between the last docking and outlay is less than the time of a voyage).
- $x^{i}_{af} \geq x^{i-1}_{af}$; If one of the types of AF = 4; i.e. once a FRC system has been adopted, any classic AF coatings (types 1, 2 or 3) shall not be applied in future.
- If x^{i}_{af} =4 and $x^{i-1}_{af} \leq 3$ then hull blasting is scheduled. In the case of transition from conventional coating system (AF 24, 36 and 60 months) to the FRC coatings, the whole wetted area shall be blasted to the bare steel prior new anticorrosive and FRC application.
- It is not anticipated to have docking within 24 months and the maximum range between two docking is 36 months (according to the Classification Society Rules: 36 + 3 months)

4. Pareto supported decision making environment

OCTOPUS-Designer, as a tool for Pareto supported decision making – PSD **Error! Reference source not found.**, provides interactive design environment with different optimization algorithms, surrogate modeling, etc. It has been applied in the both design phases (nondominated solution generation and preferred solution selection) for the case study given in the next section.

The work on OCTOPUS Designer started back in 1990, see [10], but has recently been redefined [11] to enable easy implementation of newly developed components, together with the flexible graphical user interface which enables easy problem definition (Δ-components) and problem solving (Σ-components) as well as visualization of the output and the final design selection (Γ-components). Although the framework is designed to allow flexible integration of general type of analysis modules, the tool has been tailored to match demands of general ship design ([12], [13]) and structural ship design ([14], [15]).

Sequential adaptive generation of non-dominated designs (SAGeN) is used in the first phase of PSD applied on Suezmax tanker operation strategy. It implies testing of feasible designs for the dominance in the Pareto sense. Nondominated designs are used as centers of subspaces (mini-cubes) in the design space for further sequential ("chain") generation of non-dominated candidates for the final design selection e.g. [10]. Basic difference from standard Monte Carlo strategy is adaptive bounds as functions of current non-dominated point. Fractional Factorial Designs (FFD) constructed from the Latin squares can be applied for efficient generation of designs and has proven efficient in higher cycles of adaptive design generation in subspaces around the non-dominated designs.

5. Suezmax tanker operation strategy – case study

Using the previously defined analysis modules and the problem identification, Suezmax tanker operation policy strategy has been designed and used as the case study.

The business management planning strategy and environmental impact due to biocide leaching from antifouling paints are presented in this paper for the Suezmax tanker Alan [6], with the following characteristics:

Length, LOA/LPP, m.................281,20/270,0
Breadth, B, m...............................48,20
Design draught, TD, m..................16,00
Displacement, Δ, t............................190 039
Deadweight, DWT, t.....................153 144
Main Engine: MAN B&W 6S70 MC: MCR 16 780 kW
Speed, VT = 15,04 trial at SCR14 270 KW.

Upper and lower bounds for the Suezmax tanker case study design variables are given in the Table 1 together with the design variable step.

Table 1. Design variables bounds and step

Tablica 1. Granice i korak projektnih varijabli

Variable	Min	Max	Step
x_{nd}	6	8	1
x_{hb}	0	1	1
x^{i}_{nv}	21	32	1
x^{i}_{af}	1	4	1

5.1. Analysis of Results

As the result of the first phase of Pareto-supported decision making (PSD) a finite number of nondominated vessel operating procedures a generated

After completing the optimization with SAGeN, 134 nondominated designs (≡ vessel operating procedures) whose characteristics are expressed in the form of the table (the upper part of Fig. 4), and associated diagram spanned between three objectives: earnings, the total number of voyages and quantity of leached copper compounds.

Based on the above described strategy, it is possible (from the total Pareto front) to separate the preferred designs (operating procedures), see the images marked with spheres. In the second exploitation period, designs which do not leach copper compounds are marked with the spheres unlike facing the cones that indicate all the other designs that leach copper.

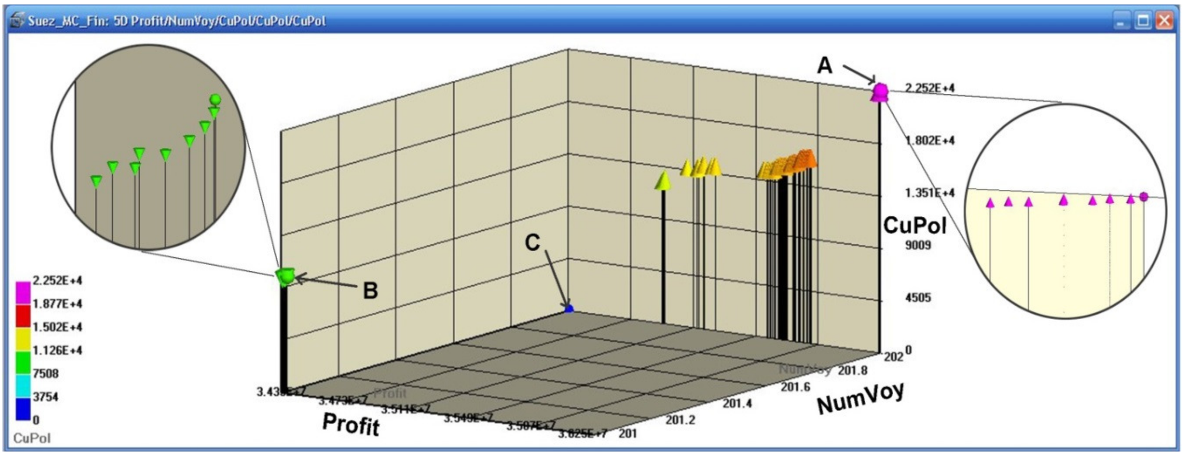

Fig. 4. Pareto front with resulting nondominated designs (≡ operating procedures of the ship)

Slika 4. Pareto fronta s finalnim nedominiranim projektima (≡ strategijama eksploatacije broda)

From the part of Pareto front around the designs A and B it is evident that in this area there are several designs close to the value of the design objectives. Enlarged display of the Pareto fronts around three best designs from the strategies A, B and C, marked (A, B and C) in Fig. 6, and surrounding designs are shown magnified in the same figure. The strategy A (the maximum profit and unlimited copper leaching), in an amount of 22 520 kg of leached copper during the lifetime, is marked by the purple ball. Earnings of the vessel is marked with a green ball (36.24 million USD) and the blue sphere represents the number of voyages (202). It can be seen that all nondominated solutions have 201 or 202 total voyages. Visualization of gridlines between 201-202 has only a symbolic role, because it is not achievable, i.e. 201.2 or 201.8 are not integer values.

All diagrams presented in Fig. 5, on the axes present the number of voyages and selected type of AF coating protection for each time period between the docking, and total profit on the vertical axis. Body color shows the copper compounds leaching for each design.

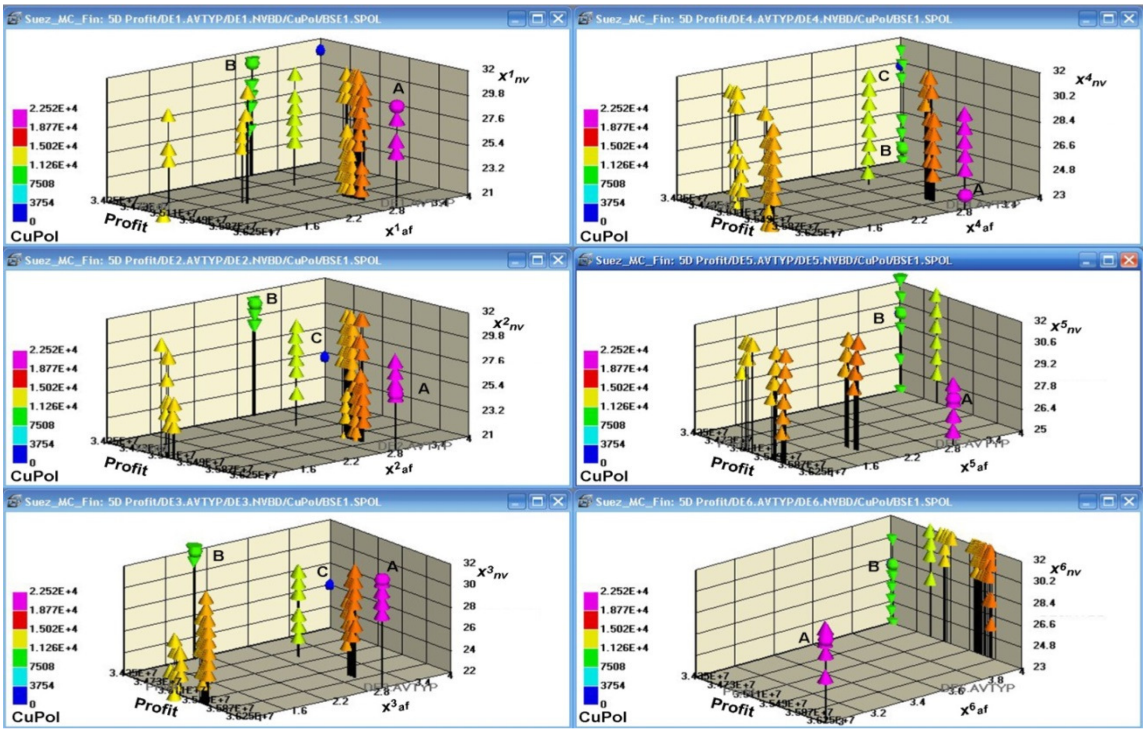

Fig. 5. Distribution of the design variables for nondominated designs with marked solutions (A), (B) and (C)

Slika 5. Distribucija projektnih varijabli za nedominirana rješenja s markiranim rješenjima (A), (B) i (C)

6. Detailed review of the selected solutions with discussion

Individual views of the selected design solutions, based on the three strategies (A), (B) and (C), are summarized as follows:

6.1. Design No. 78: Suezmax Alan, strategy A

The design (see **Fig. 6**) is characterized with max. earnings / max. copper compounds leaching. Number of voyages between docking: 30, 26, 32, 24, 28, 30 and 32 = 202 voyages.

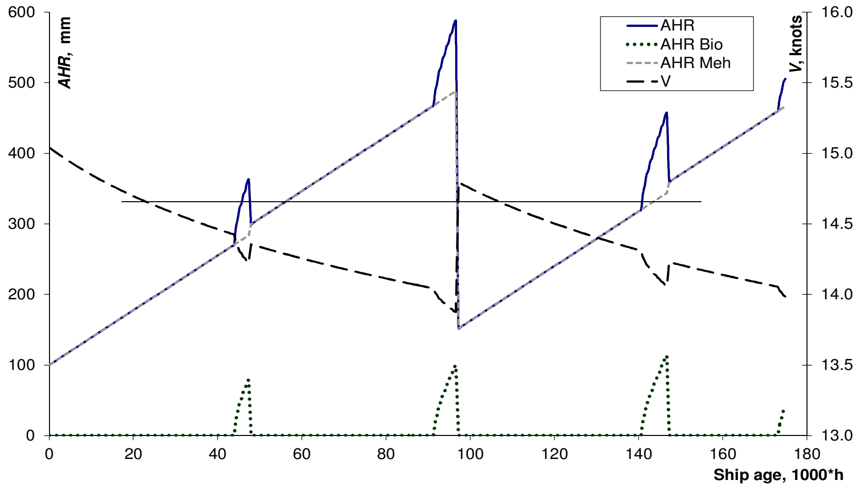

Fig. 6. Average hull roughness and speed vessel diagram for strategy A

Slika 6. Dijagram ovisnosti prosječne hrapavost trupa i brzine plovila o starosti broda za strategiju A

Earnings: US$ 36,245,250. Pollution: More than 22.5 tons of copper compounds have been leached during lifetime. Biocide AF coating type: I-V docking: Type 3AF (60 months); Docking No.VI: Type2AF (36 months). There is no docking (No.VII) due to expense: total elapsed time 175

185 hrs (19,999 yrs) or remaining time (175 200 – 175 185)= 15 hrs. Leaching time i.e. effective AF coating duration: 157 370,23 hrs (~90% total time). Complete blasting to the bare substrate and application of new AC and AF coating is applied after 11,4 years in service (AHR ≥500 µm).

6.2. Design No. 118 Alan Suezmax, strategy B

This design (see Fig. 7) is characterized as the design with copper compounds leaching only in the first period of exploitation. Number of voyages between docking: 31, 31, 32, 24, 30, 28 i 25 = 201.

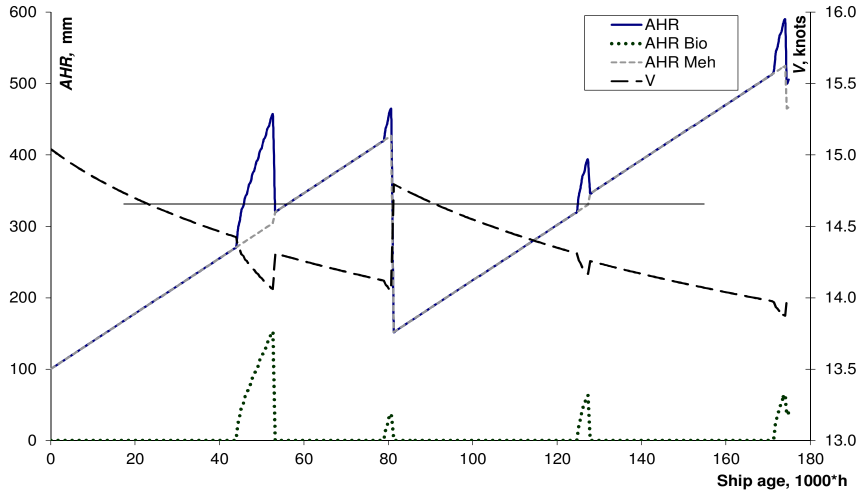

Fig. 7. Average hull roughness and speed vessel diagram for strategy B

Slika 7. Dijagram ovisnosti prosječne hrapavost trupa i brzine plovila o starosti broda za strategiju B

Earnings: US$ 34 387 710. Pollution: More than 10 tons of copper compounds have been leached during lifetime (10 088 kg). Biocide leaching time i.e. effective AF coating duration: 157 010 hrs (~90% total time). Types of coatings applied: Docking No(I and II): Type 3 (AF 60); docking No III: Type 2 (AF 36), Docking No (IV, V and VI): Type 4 (FRC 60); at docking No VII: application coating type 4 (FRC 60) was not made as the ship went to the expense, after 174 371 hours. Complete blasting to the bare substrate and application of new AC and FRC coating is applied after 9,13 years in service (AHR ≥500 µm) at docking No. IV. Total remaining time (175 200-174 371) = 829 hours, but not enough for another voyage at the end of the exploitation period of the ship.

6.3. Strategy B1

Since the remaining time of Design 118 is quite large (829 hours), it is interesting to show the case when the determined exploitation period of the ship (20 years) is slightly exceeded with and additional voyage. As distinguished to overdue time of just 60.73 hours, the financial effect of this additional voyage is significantly greater. Thus, the vessel would sail to the expense at 260.73 175 hours (174 371 + 889.73 hours), with one more voyage, ie a total of 202 voyages, as accomplished in the strategies A and C. In this case earning is ≈ 35 MUS$ which is 1.78% higher (without additional voyage: US$ 34,387,710). In any case, it should prefer the effect of earnings with extra voyages over the minor exceed of the sailing time. However, as always such a decision is in the hands of a shipper.

6.4. Design No. 15 strategy C

This design (see **Fig. 8**) is characterized with no copper compounds leaching in both periods. Number of voyages between docking: 31, 25, 26, 30, 30, 28, 32= 202 voyages.

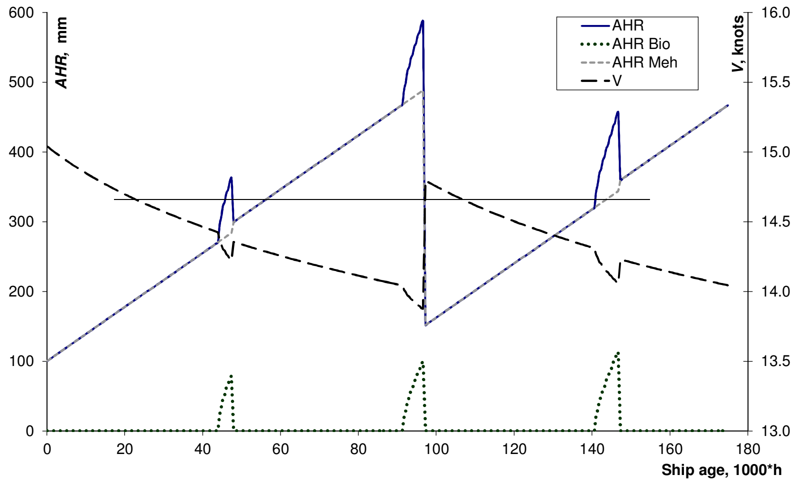

Fig. 8. Average hull roughness and speed vessel diagram for strategy C

Slika 8. Dijagram ovisnosti prosječne hrapavost trupa i brzine plovila o starosti broda za strategiju C

Earnings: US$ 34 350 900. Pollution: There are no copper compounds leaching during lifetime. AF coating type: Type 4 (FRC 60) during lifetime. Total remaining time (175 200- 175 180.7) = 19,3 hours. Complete blasting to the bare substrate and application of new AC and FRC coating is applied after 11,4 years in service (AHR ≥500 μm)

7. Discussion

Table 2 presents the summary of the preferred designs with respect to the three elaborated strategies (A, B, C) and one additional extension (B1).

Among the final strategies (A and C) there is no difference when referring to the voyage objectives. The limit of unused hours for strategy A is 15 hours or 19.3 (C). Therefore, the optimum of 175 200 hours is almost completely reached. However, the other two objectives, earnings and environmental pollution, are significantly different. With maximum environmental pollution by 22 tons of leached copper compounds, the difference in earnings is almost 1.9 MUS$.

Table 2. Summary of selected designs

Tablica 2. Sažeti prikaz odabranih projekta

Strat.	Num. Voy.	Age (h)	Profit M US$	Num. Dock.	Leached copper, kg
A	202	175 185	36,25	6	22 523
B	201	174 371	34,39	6	10 088
C	202	175 181	34,35	6	0
B1	202	175 261	34,99	6	10 088

As expected, the optimization showed that the earnings are the highest when implementing strategy A (maximum pollution), while they are the lowest for the strategy C (FRC coating).

The strategy B offers a compromise solution, because only in the second part of the exploitation period the toxic compounds are replaced with an expensive but environmentally friendly FRC coating. However, the maximum number of voyages has not been reached as one of the objectives.

The relatively small difference in earnings between strategies B and C is actually caused by the remaining time: Strategy B: 829 hours, Strategy C: 20 hours. Additional voyage that slightly violate 20 years ship usage limit and increases earning for 600 000 US$ (Strategy B1) is probably feasible solution in a shipping practice.

One of the important points of the strategy's B sensitivity analysis, is determination of the transition time from conventional AF to FRC paints. Chronologically this point can be either below or above 10 years (model example of work) which will be governed by the decisions of the regulatory institutions. By selecting the strategy B (or better B1), a compromise solution is achieved which would probably satisfy the ship owners and environmentalists (for now).

For each of the three strategies a hull blasting procedure is anticipated once a AHR threshold limit is reached, which typically ranges from 400-600 μm. However, it implies the application of the new anti-corrosive and antifouling system.

Regarding the strategy C, the current cost expensive FRC coatings implementation is still a real obstacle. Therefore, it is probably just the question of time when the antifouling coatings based on copper compounds will suffer the same fate as the TBT coatings that is, to be completely banned. With that in mind, the application of strategy B or strategy C it is quite probable.

8. Conclusions

The increasing environmental awareness leads to the conclusion that the application of biocides and copper will be limited or completely prohibited in the future (an analogy with TBT coatings). Just for this reason, paint makers are turning to the completely new technologies. It is also worth to mention the new inert hard coatings that are completely without any antifouling or fouling release properties. These coatings are STC (*surfaces treated composites*), glass flake reinforced vinyl ester, with a very long life; combined with underwater cleaning [16].

Today there are no unified, scientifically based procedures for the ships maintenance, as opposed to the exact defined rules for the vessel design and construction under the classification societies supervision. The future monitoring of ships operations and the selection of preferred strategy will probably rely on similar multi-criteria optimization based computer models.

Environmental effects of three alternative strategies of biocide emissions from antifouling coatings, as conceptual choices during entire life span of the ship, are demonstrated, as a contribution to decisions to be made in the transition period. The approach based on the multi-criteria decision making process in ship operation policy presents an improvement, with a reasonable reliability in terms of the procedure accuracy, for the ship operator strategy management.

The full cooperation of ship-owners, shipbuilders and institutes with the growing environmental requirements will be crucial for the future vessels operating strategies.

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