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ECONOMIC SUBSTANTIATION OF TECHNOLOGY OF RESEARCH OF FUEL SYSTEMS OF SHIP DIESELS

Professor D.Sc. Konstantin SHAPOSHNYKOV *
Black Sea Research Institute of Economy and Innovation, 65029, Ukraine
k.s.shaposhnykov@gmail.com
PhD Student Mykola SLOBODIANIUK
Institute of Naval Forces National University «Odessa Maritime Academy», 65029, Ukraine
nikgavr1234@gmail.com

Abstract
The article is devoted to substantiation of technology of research of fuel systems of marine diesels. The necessity of economic estimation of technologies of control over work of fuel system of marine diesel is substantiated. According to the literature, the need to use a combination of economic and technical methods in research has been clarified. Using the problem-target approach and economic-methodical components, the technology of development of the control program taking into account economic components is offered. As a result of structuring the purpose of control over the high-pressure fuel system, technical and economic indicators are determined taking into account the sequence of interrelated categories "goal"-"activity"-"scenario"-"means"-"result". The mathematical apparatus of solving the problem of ensuring the reliability and efficiency of the marine diesel fuel system, with further assessment of economic costs during the implementation of the control program.

Key words: *economic justification, research technology, economic and technical problems, problem-based approach, control program, alternative scenarios, economic costs, economic potential.*

JEL Classification: *O32, C18*

I. INTRODUCTION

The merchant navy plays a key role in economic trade in terms of traffic. The technical condition and accident rate of ships affects the cost of shipping. Ship accident statistics are compiled by relevant factors and are reflected annually in world, national and regional reports (see http://www.iacs.org.uk; see http://emsa.europa.eu/publications/technical-reports-studies-and-plans/item/2303-annual-overview-of-marine-casualties-and-incidents-2014.html; see http://www.ukrstat.gov.ua).

The value of shipping always strives to achieve the highest profit. They reflect a qualitative assessment of the level of use of the vessel.

Cost optimization during the use of the ship's energy system is one of the factors of economic operation of the ship, which includes indicators of: efficient fuel consumption; reliability (engine and its systems); permissible (environmental) emission level, etc (Suvorov, 2004). These figures are formed in general by the operation of the diesel engine and its high-pressure fuel system.

The organizational changes that have taken place in the technologies of construction and economic operation of marine diesel engines require adjustments to previously developed methods that have contributed to their reliable operation and trouble-free operation. These changes have significantly affected the design improvement of diesel fuel systems and, as a consequence, the emergence of new design economically sound solutions that improve their performance.

Considering the high-pressure fuel system of a marine diesel engine, there is a need to develop an economically sound technology to control the operation of the fuel system. Therefore, it is important to economically assess the efficiency of the power plant in all operating modes, with the determination of the economic ratio of fuel consumption per unit of path, which creates the need to have and use theoretical and methodological support technology for high pressure fuel systems for marine diesels.

II. CURRENT RESEARCH, ANALYSIS OF ISSUES AND PURPOSE OF RESEARCH

Research on high-pressure fuel systems of marine diesels ends not only with the improvement of technical results, but also with the need to clarify the economically comparable component, taking into account the variety

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of fuel systems, diesel engines and marine power systems, etc.

The economic justification was carried out at different stages of design. At work (Yurinets, 2011) the technology of scientific researches, the basic information on structuring of scientific researches, mathematical research of a problem, the analysis of activity of object of management, absolute and relative sizes and a graphic way of the data representation, kinds and features of an estimation of results of scientific researches which form basic indicators of criteria and provide an estimation were considered. Both technical and economic components to justify the relevant decisions.

One of the components of research technology is the formation of different scenarios. So in the study (Obertur, 2015) a method of forming a scenario of antipodes, "strong" control influences - scenarios of antipodes, as a means of emergency management to stabilize the situation. The tool is to formalize the possible modes of operation of the transient control system of the object. Moreover, each mode may include several transients separated by control points. With the subsequent establishment of a management program for each transition process and actions on the "checklists". This method reflects the basic requirements of modern theory of automated control, which are to take into account information, energy and material patterns and constraints.

Adaptation of this means gives the chance to develop constant control over work of elements of fuel system of a high pressure of the ship diesel engine that will give the chance to improve reliability indicators, to increase service life and as a result to receive economic effect.

Research overview (Golikov, 2009; Golikov, 2000; Golikov, 2012; Eryganov, 2008), cited in the literature, indicates that the use of atypical methods in research technologies lead to unexpected conclusions, which are aimed at reducing accidents, increasing service life, increasing the level of automation, making a profit, which are relevant studies today.

The purpose of the study is the economic justification of research technology for monitoring the performance of marine diesel fuel systems.

In accordance with the purpose, a program of control over the high-pressure fuel system of marine diesel in a combination of economic and technical research methods has been developed.

III. Economic Substantiation of High Pressure Fuel System Research Technology

When you open this document, select “Page Layout” from the “View” menu in the menu bar (View | Page Layout), which allows you to see the footnotes. Then type over sections or cut and paste from another document and then use markup styles. The pull-down style menu is at the left of the Formatting Toolbar at the top of your Word window (for example, the style at this point in the document is “Text”). Highlight a section that you want to designate with a certain style, and then select the appropriate name on the style menu. The style will adjust your fonts and line spacing. Do not change the font sizes or line spacing to squeeze more text into a limited number of pages. Use italics for emphasis; do not underline.

There is a need to develop a comprehensive approach to solving the problems of economic evaluation of control technology for the fuel system of marine diesel, which would meet the needs and interests in the development of the maritime industry. This approach should allow to define on a general basis strategy of the control program thus achievement of the set purposes with the minimum expenses will be a criterion of its efficiency.

The problem-oriented approach reflects the strategy of development of the control program taking into account formation of initial conditions, change of stages and directions of consumption, investment policy and criteria of efficiency.

Problem-targeted approach is based on a number of system features: problem orientation, ultimate goal, complexity, priority and maximum cost-effectiveness of problem solutions.

Using the problem-based approach and economic and methodological components, we will consider the technology for developing a program to control the reliability and efficiency of the high-pressure fuel system (HPFS) marine diesel, which is shown in fig. 1.

Considering the blocks of the model, we determine the main directions of implementation of each block.

Block 1. Identification and analysis of economic and technical problems. Statistics of marine diesel engines indicate that the problem of reliability depends on the performance of the elements of the high-pressure fuel system.

To solve each specific problem, it is necessary to determine the content of the goal that ensures their solution, namely:

1. Understanding the program content and plan of activities, a list of different types of work aimed at achieving a certain goal, define methodological approaches to the formation of the program.

The first requirement for determining the methodological approach is to take into account the specific, economic and technical conditions of operation of the object. In this case, the object is the operation of the marine

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diesel engine, which operates in alternating modes in different weather conditions.

The second requirement is the continued recognition of the achievement of an appropriate level of reliable operation of the high pressure elements of the marine diesel fuel system.

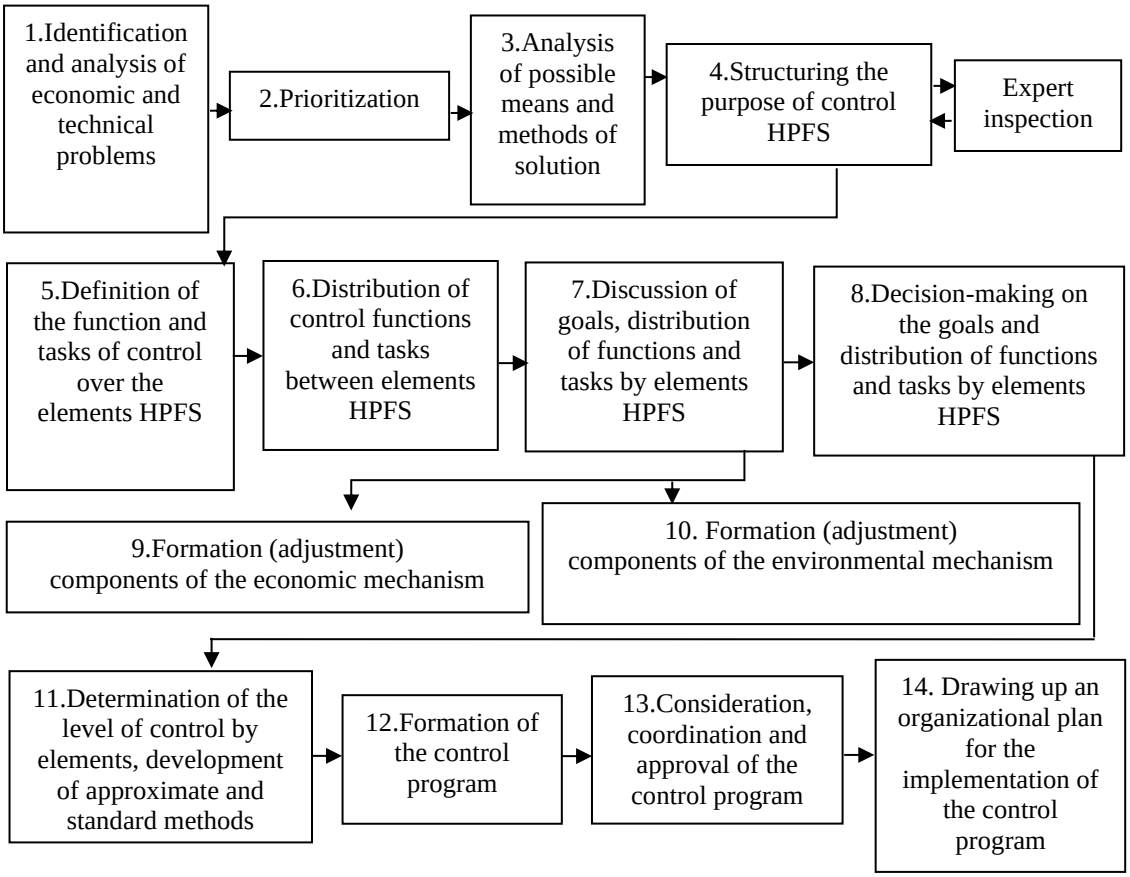

Figure 1 – Model control program with economic components.
Source: developed by the author

The third requirement is knowledge of technical standards that exist and are established regarding the terms of continuous operation of high pressure elements of the fuel system.

The answer to the question - "where?", what areas should develop the construction of marine diesels and their systems, based on the analysis of specific operating conditions of the existing level of technology. That is, it is an analysis of the relationship between the existing level of construction of marine diesel engines and the specific conditions of their development. It is necessary to look for a compromise and focus on the best value for money. The performed analysis will allow to reveal the corresponding priorities.

Block 2. Defining priorities. The issue of setting priorities for the creation of high-pressure fuel system elements is related to both the availability of appropriate resources and the ability to identify the main problem in assessing the reliability and performance. Therefore the priority of the decision is connected, first of all, with manufacturers of systems of the diesel engine.

Block 3. Analysis of possible means and solutions. This unit is directly related to unit 2 and is based on the analysis and forecast of available resources.

The implementation of block 3 can be carried out only with the use of scientific methods of the obtained forecast.

The problem of realization of "input" and "output" is important for this block. That is, in the first case it is necessary to ensure the realization of resource potential; in the second - to expand the market of manufactured marine diesel engines, based on the criteria of reliability and performance.

Block 4. Structuring the purpose of control HPFS. The implementation of block 4 is carried out by solving the purposefulness of the problems. Various technical features are determined taking into account the sequence of interrelated categories "goal" - "activity" - "scenario" - "means" - "result".

Block 5. Definition of functions and tasks of control over elements HPFS. With the structure of the purpose the concrete list of functions and tasks on performance of the control over reliability and quality of work of

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elements of a high pressure of fuel system is formed. Based on the analysis of the set of control tasks, a matrix of tasks is formed with the indication of functional and information connections. With the help of the matrix it is possible to select the optimal composition of control functions focused on the implementation of the main and auxiliary tasks. The process of building a goal structure and management functions is complex and requires appropriate professional requirements from developers.

Block 6. Distribution of control functions and tasks between elements HPFS. It is formed in a modular way, communication between modules is carried out on the principle of sequence and feedback. The control logic shows that the distribution of functions must meet, on the one hand, the requirements of increasing the level of reliability and efficiency of high pressure elements of the fuel system, and on the other - the development of strategy for scientific and technical, economic and environmental development.

Blocks 7, 8. Discussion of the purpose, distribution of functions and tasks on elements HPFS. Decision-making on the purpose and distribution of functions and tasks by elements HPFS. The developed structures of the purpose and consideration of function of management pass a stage of coordination with participation of the customer, the manufacturer, scientific institutions, etc. Based on the results of the discussion, the main and auxiliary tasks are formed and adjusted. Before carrying out the decision-making process, it is advisable to conduct an expert assessment. Expert assessments are a scientific method of analyzing complex technical problems.

Blocks 9, 10. Formation of components of economic and ecological mechanisms. The practice of introducing new technologies in the maritime transport industry has revealed a number of shortcomings that have prevented the successful implementation of the decisions taken. First of all, this is due to the fact that in the formation of new high-pressure fuel systems it is not possible to achieve economic and environmental indicators of the regulatory level. As a result of the considered stage it is necessary to make the comparative table which contains, on the one hand, indicators of economic and ecological needs, on the other, - the regulatory requirements characterizing qualitative work of elements of a high pressure of fuel system.

Block 11. Determination of the level of control by elements, development of approximate and standard methods. The effectiveness of control over the system of functioning depends on its organization, on how correctly and timely the issues of rational combination and orderliness of all elements of interaction are solved. It is necessary to determine the algorithm of activity in accordance with its direction. The result of the implementation is the definition of provisions regarding job responsibilities, standards for the organization of work.

Blocks 12, 13. Formation of the control program, consideration, coordination and approval of the control program. Implementation of blocks 1 – 11 is a preparatory stage of the control program. The results obtained during the implementation of the blocks, provide the opportunity to compile a program as a set of measures to ensure the ultimate goal of the work.

On the basis of the analysis of results the following is formed: the list of the actions responsible for realization of each action, terms of maintenance of step-by-step performance of works, necessary resources for performance of actions, the focused efficiency of action, executors and co-executors of works.

The prepared draft program is considered by the relevant organization and is subject to approval.

Block 14. Drawing up an organizational plan for the implementation of the control program. The plan for the development of the control program must be organized, ie a clear order of interaction of all participants in the development. The organization or officials are determined. The organizational structure of program development which reflects interrelation of actions of participants and the schedule of performance of works is developed.

One of the important elements of the control program is the structuring of the purpose of control HPFS.

The development of a method for monitoring the reliability and performance of high-pressure elements of the marine diesel fuel system is to form a means of generating antipodes (alternative scenarios) with an algometric sequence of actions of operators required for the transition from emergency to normal or extreme.

By antipode we mean finding the object (fuel system) in normal or at least extreme situations. Antipode control is the process of removing the control object from the emergency situation, ie maintaining the reliability and efficiency of the high pressure elements of the marine diesel fuel system.

The process of generating antipodes covers the structure of the system, controls, values of state parameters and provides maximum use of forces, means and available resources to compensate for the energy of developing negative events, pursuing many possible logical models of system behavior, which after decision can be considered the final process changes in her condition.

In general, the generation of antipodes is a technology for the formation of management scenarios to counteract what will objectively occur in a given emergency for further selection of the error-free strategy of further actions of vehicle operators, formed by the results of observation and identification of situations.

The theoretical basis for solving the problem of ensuring reliability and performance are the processes described by the vector differential equation in the form of Cauchy for deterministic controlled systems and scenario approaches.

In most cases, when modeling the process of transition of a prognostic nature, a probabilistic approach is

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used, which takes into account different random variables depending on the results of the experiment.

To describe the process of transition from the basic elements, the concept of the probability distribution function is used, which characterizes the distribution of a random variable of an odd number of values.

It is calculated by a known equation:

$$F(x) = P(X< x), \quad (1)$$

where $F(x)$ – function of random variables; X – random variable; P – probability of the event; x – variable that takes all the values of the numerical axis.

Equation (1) makes it possible to determine the numerical values of the probability of the event within: $0 \le F(x) \le 1$.

In the case where there is a distribution of random continuous quantities, the law of normal distribution (Gaussian distribution) is used, which takes into account the density of the probability distribution.

The formula of the description has the form:

$$f(x)=\frac{1}{\sigma\sqrt{2n}}e^{\frac{(x-m)^2}{2\sigma^2}}.$$

The probability distribution function for the law of normal distribution has the form:

$$f(x)=\frac{1}{\sigma\sqrt{2n}}\int_{-\infty}^{x}e^{\frac{(x-m)^2}{2\sigma^2}}dx,$$

where σ – a measure of the magnitude of the scattering of values of a random variable; m – the center of distribution that corresponds to the maximum value $f(x)$; n – number of tests.

At lower values σ, which characterizes the magnitude of the deviations of the values of a random variable, graph $f(x)$ has a larger maximum and focuses on a narrower interval, and the schedule $F(x)$ more gentle.

Most suitable for determining a normally distributed random variable X, there is a distribution by exponential law, which has the form:

$$f(x)=\begin{cases}0, x>0\\ \lambda e^{-\lambda t}, x\ge 0\end{cases};$$

the distribution function is determined:

$$F(x)=\int_{0}^{x}f(\xi)d\xi=\begin{cases}0, x>0\\ 1-e^{-\lambda t}, x\ge 0\end{cases}.$$

Determining the probability due to the normal distribution of a random variable will take on a half-interval

$\int_{a}^{b}$

$$P(a\le X<b)=\int_{a}^{b}f(x)dx=\frac{1}{\delta\sqrt{2n}}\int_{a}^{b}e^{\frac{(x-m)^2}{2\sigma^2}}dx.$$

A new variable is introduced $u=\frac{x-m}{\sigma}$, then

$$P(a\le X<b)=\frac{1}{\sqrt{2n}}\int_{\frac{a-m}{b}}^{\frac{b-m}{a}}e^{\frac{u^2}{2}}du.$$

Due to the introduction of the Laplace function $(\Phi(z))$, the probability equation will take the form:

$$\Phi(z)=\frac{1}{\sqrt{2n}}\int_{u}^{-z}e^{\frac{u^2}{2}}du.$$

Replacing the integration variable $u=-u$, we will receive

$$\Phi(-z)=-\frac{1}{\sqrt{2n}}\int_{u}^{-z}e^{\frac{u^2}{2}}du=-\Phi(z).$$

According to the theoretical results of the work, taking into account the introduced notation, equality can be rewritten as:

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$$P(a \le X < b) = \frac{1}{\sqrt{2n}} \left[\int_0^{\frac{b-m}{a}} e^{\frac{u^2}{2}} du - \int_{\frac{a-m}{b}}^{0} e^{\frac{u^2}{2}} du \right] = \Phi\left(\frac{b-m}{\sigma} \right) - \Phi\left(\frac{a-m}{\sigma} \right).$$

The presented equations allow to calculate the probability of finding the value of a normally distributed random variable in any predetermined segment (*a, b*) numerical axis using the values of the function $\Phi(z)$.

In developing the method of generating the antipode - maintaining reliability and performance, were also used mathematical constructions of the emergency scenario, including components of the emergency that occur in a dynamic process, provided by "scenes", and the composition of these scenes in the scenario form a trajectory. plot ", - provided in general form (Velichenko, 1996):

$$S = US_i, \quad i \in I, \tag{2}$$

where I – a set that includes all the scenes of the emergency; S_i – scene, a separate dynamic process of an emergency event, which is determined in the phase space

$$D_i = (u)[S_i] = 0, \tag{3}$$

where $D_i = (u\ )$ – an operator that relates the current state of the scene to its initial state and control effects u; $[S_i]$ – the boundaries of the stage with the adjacent boundaries S_k, which are described by equations and may depend on control ν

$$B_{ki}(\nu_i)[S_i] = 0; \tag{4}$$

– transformation of scenes $S_i \to S_k$.

In case of reaching the limit *i*– her scenes of the final values of its phase variables are transformed into the initial conditions of the subsequent *k*– her scenes according to the equation:

$$Init(S_k) = R_k i(\omega_i)[End(S_i)], \tag{5}$$

where $R(\omega)$ – an operator that may depend on control ω;

– scenario S^A consists of successive scenes that pass from one to another $S_j, j \in I^A \in I$:

$$S^A = \{S_j^A\} = \{S_1^A \to S_2^A \to S_3^A \to \ldots . S_n^A\}. \tag{6}$$

The sequence of scenes of the scenario is not fixed and is determined by the conditions of the first emergency scene of controlled and uncontrolled influences on a negative event in the process of its development. With the help of such a mathematical model, we can give both problems of modeling the dynamics of its scenes (3) and modeling of structural changes (4), (5) to a single integral fragmentary continuous catastrophic process (6) in a compact phase space.

Based on the above scenario approach, it is assumed that the developed method of generating antipodes should represent the antipodes in the form of a script, plot, scenes and pictures (state) due to a clear determination of pictures (states) by graphoanalytical methods; of scenes containing algorithms of use of technical means and resources, including number and actions (roles) of participants of transport process in the considered period by heuristic methods, and the scenario characterizing the order of passing of scenes with use of logical methods.

In the process of generating antipodes for each scenario, the initial, final conditions and constraints are set, as well as intermediate situations and conditions in which the object is in the control system. Limitations of its scope in the generation of antipodes are: the initial state of the constant velocity of the object for the transition; the final state of the constant velocity of the object for the transition; energy resource; human resource.

Estimation of economic costs (E) to develop a control program can be evaluated as a mathematical expectation of the expression

$$E = E_t \cdot p - B \cdot q \qquad (\text{at } p = 1),$$

where E t – estimated economic potential for t years; p – the probability of a positive study result; B – extra costs with a negative result; q – the probability of a negative result of scientific research.

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IV. CONCLUSION

The results of the study indicate the need to assess the economic feasibility of research technologies for various systems, including marine fuel systems. It is necessary to determine the possibility of implementing the proposed control program.

The method of the program of control over reliability and operability of elements of a high pressure of fuel system, an estimation of expenses for realization is important at definition of its operational possibilities and economic expediency.

Using a problem-based approach, the control program consists of blocks, each of which is formed on the basis of identified problems and solutions aimed at ensuring effective control over the specifics of the high-pressure fuel system of the marine diesel engine. Researchers receiving from the element control system HPFS relevant information on the costs of performance and reliability, make appropriate decisions on the economic feasibility of testing.

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