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Research and Evaluation of the Operating Characteristics of Used Ship Engine Oil Using the Process Parameter Matrix Method

The marine engine circulating oil change interval suggested by manufacturers is a guideline based on general scale statistics and laboratory testing. At the same time, the actual remaining oil life can significantly correct the time and money spent by the chief mechanic service on system maintenance. In the present work, a method has been developed that makes it possible to increase the service life of mechanisms and the reliability of ship equipment under operating conditions. The effect is achieved by identifying and analyzing the most significant and influential parameters of the lubricant used. An array of physical and chemical data on lubricants, taking into account the equipment's time to failure, is processed by a special computer program for monitoring the state of a marine engine in operating mode. The developed software package allows more accurate and timely maintenance of the SPP (ship power plant)

Keywords: *process parameter matrix method, motor oil, ship engine, oil analyses.*

1. INTRODUCTION

The degradation process of operational, technical systems and their elements is continuous and inevitable due, among other things, to thermodynamic laws. However, it is possible to slow down wear and tear, providing systemic influence on the components of the process and destroying mechanisms. The analysis of these factors can provide the basis for choosing actions to adjust the engine maintenance process when making decisions on preventative measures when designing structures and generally when assessing equipment reliability.

In the engine-oil system, any changes in random processes that take place within them and between them, along with inversions of physical and chemical characteristics of the elements of this structure, are of particular interest [1,2]. The quality of used oil changes over time, and, as a consequence, the value of this factor in relation to indicators of engine reliability changes as well. The level of oil degradation within the system is expressed by the "falling out" of operating parameters describing the characteristics of the lubricant. Operating parameters are generally presented in Figure 1.

The decision to control and extend the life cycle of a marine engine motivates the creation of fresh wear management strategies and the introduction of new algorithms for the mathematical modeling of processes. Increasing the efficiency of using oils in power plants is associated with the difficulty in determining the limit state, which depends on the mass of factors that affect the aging of the oil. At present, having an extensive set of data on the operation of the system based on changes in parameters in various operating conditions, it is possible to create reliable algorithms using artificial neural networks [3,4]. The search for new solutions for predicting faults in the power plant is, in general, quite intensive.

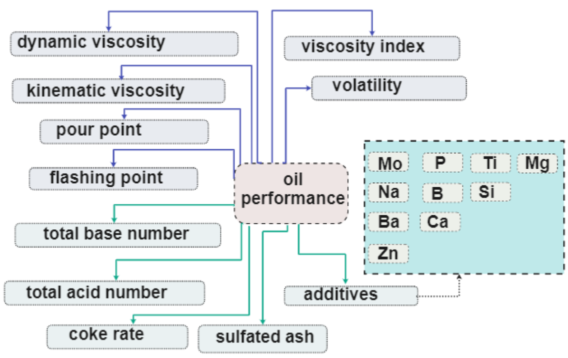

Figure 1. Main characteristics of engine oils

The results of creating models of simulators of the power plant of sea vessels intended for qualitative analysis are presented by Johansen T.A. and Sørensen A.[5]. J.F. Hansen et al. [6] used the creation of a state-space mathematical non-linear model as a means to further improve the fuel efficiency of marine engines. The results presented in Villar A., Fernández S., Gorritxategi E., Ciria J. I., & Fernández L. A. [7] show that the development of a sensor for field monitoring of insoluble sediment, water content, and BN and viscosity in engine oil, is an important step in reducing shipping time and costs. However, there are very few scientific publications that consider the aspect of creating software for assessing the state of power plant elements

Received: January 2023, Accepted: July 2023
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doi: 10.5937/fme2304497M

based on laboratory studies of used engine oil with a subsequent forecast of the state of engine elements. Based on the fact that the fundamental provisions of the presented solutions for extending the life cycle of a marine engine have been disclosed by the scientific community, technological solutions have been found in general; however, there is still little applied and prac–tical research on the implementation of these ideas and solutions. The analysis technique presented in the paper for creating an intelligent program allows the prediction of changes in the "oil-engine" system, allowing for estimation of the speed of the degradation process of engine elements.

When analyzing certain parameters, it is necessary to understand the functions that each of the presented characteristics performs, as well as the levels of acceptability of each value [8-10]. When operating in high-temperature ranges and high interval loads, the oxidation rate of oil increases, which leads to the formation of abrasive solid particles; their contact with the engine system elements leads to the appearance of wear particles. Thus, the analysis of viscosity and oil contaminants is one of the most important indicators of the lubricant.

The reliability of marine vessel engine operation must be ensured by operative and qualified maintenance actions, while the type and frequency of actions to ensure the operability of mechanisms directly depends on the awareness of the technical condition of operating mechanism elements [11]. Decision-making is a comp–licated task, and, as a rule, it is a combination of past experience, method of expert evaluations, and timely diagnostics based on the results of the physical and chemical parameters of oil [12,13]. To avoid undesi–rable consequences due to incorrectly made or not made decisions on the maintenance of engine-oil system elements, we recommend precise forecasting and system approach to ensure specified operation levels, taking into account the residual life of the lubricant.

The analysis of the matrix of process parameters (MPP) [14], based on system processing of the data of physical and chemical indicators of oil, will allow to support the decision on maintenance of the ship engine and thereby increase reliability when operating the technical system.

2. MATERIALS AND METHODS

The results of analyses and accurate predictions based on verification calculations [15] can serve as a basis for a clear understanding of the technical condition of the engine oil system. Problems arising when determining the level of the system's technical condition, when the mechanism shows no signs of inoperable or emergency condition, and the data of analyses indicate their presence and vice versa, lead, in fact, to heuristic methods of decision making, based on experience and the practical research base [16]. The creation of modern decision methods and schemes concerning reliability is based on the development and implementation of intelligent programs that are based on the acquired experience and individual approach to the technical structure [17,18]. The simplicity of software product development in Python and the ability to supplement and improve the program library provide an opportunity to create databases of the causes and consequences of failures.

The developed intellectual program for an esti–mation of an engine-oil system condition allows analyzing the entered statistical data concerning the physical and chemical composition of the used oil to compare them with values of controlled parameters, with their limiting parameters that give the ability further to receive the information on the reasons of occurrence and development of malfunctions (Fig. 2).

In this work, the results of laboratory research of the oil of the exploited ship diesel engine were used when processing analyses by the MPP method. The data were processed by the software complex in Python programming language.

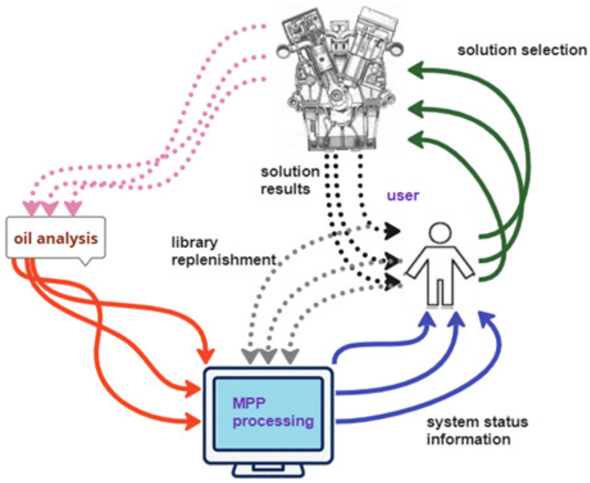

Figure 2. Concept of the ergative system functioning with the application of the software based on the MPP method

The new software complex based on the process analysis matrix method is the key element of the created ergative system. The first step in making the matrix is to form a list of parameters required to determine the scale of the degradation process occurring in the system. In the given example, all parameters of the analyzed material according to reports of laboratory research of motor oils of the ship's diesel engine MAN B&W Diesel Den 6L28/32A have been realized. The study's material was taken from the analysis of various manufacturers who conducted research on oils from 2007 to 2021. To make it clear, the method was tested on one of the oils used during the period of engine running time from 7121 to 22460 hours.

3. STAGES OF MPP MAKING

When making the matrix, we need to normalize the quantitative values, i.e., to bring each parameter (E_{ij}) to a dimensionless numerical value on a scale from 0 to 10. That is because the parameters have different units of measurement. Before conversion into coded values, the limiting values of factor variation are set, i.e., limits of variation: R_{vk}- the upper control limit, R_{nk} - the lower control limit. Most commonly, data on limit values can be obtained from reference books or from the lubricant manufacturer. If regulations and manufacturers do not specify limit values, they can be determined individually by processing the data set according to the normal distribution and physical and chemical properties of the parameter being analyzed. Figure 3 shows an example of determining the boundary values based on a statistical analysis of the samples. Alkaline number (Fig. 3, a) has a working range with the best performance - the "green zone", and productivity goes down as it approaches the limits of the upper or lower allowable limits. The elements of metallic impurities, such as iron, normally, in the physical sense, have only one permissible limit, i.e., the "green zone" will be limited to a one-sided tolerance (Fig. 3, b).

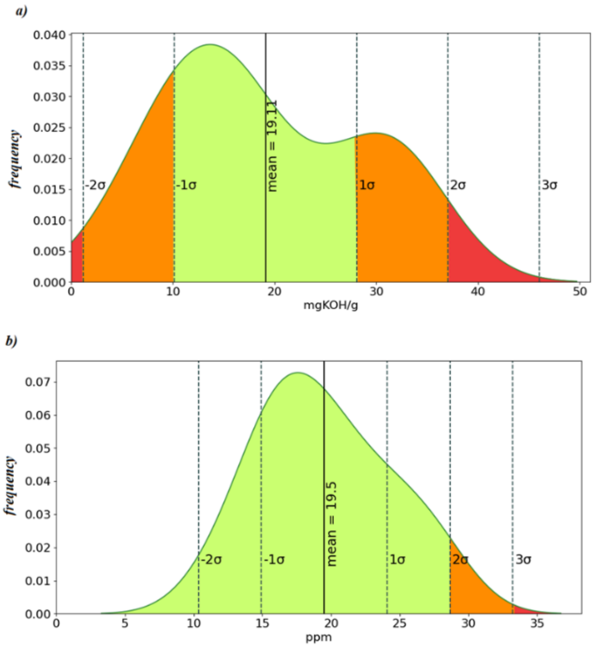

Figure 3. Normal distribution curves created on the basis of statistical data of oil analyses: a) BN, (mgKOH/g); b) Fe, (ppm)

Parameters that have one acceptable limit are those whose parameter values at the lowest or the highest point of their concentration are preferable. When translating to coded values of elements, the actual values of which have one acceptable limit - preference is given to the presence of this element at the lowest control limit (R_{nk}). In this case, expression (1) is used for normalization:

$$E_{ij} = 10 \cdot \frac{R_d - R_{vk}}{R_{nk} - R_{vk}} \quad (1)$$

where E_{ij} is the normalized element of the matrix, R_d is the actual value of the parameter.

For parameters with values close to the upper reference limit, e.g., flash point, the highest score is respectively assigned to values close to the upper reference limit. In this case, expression (2) is used for normalization:

$$E_{ij} = 10 \cdot \frac{R_d - R_{nk}}{R_{vk} - R_{nk}} \quad (2)$$

Figure 4 illustrates the determination of the actual value of the lubricant parameter in relation to the upper and lower control limits with the determination of the rating scores. Thus, Figure 4(a) shows that the average value of the mass fraction of iron content, according to our calculations, is 12 ppm, the limit values declared by the manufacturer are 2-140 ppm, and when determining the rating, the highest score is assigned to the boundary with the lowest value. Determining the actual value of a lubricant's parameter in relation to the upper and lower limit (Figure 4 b), in turn, shows the BN (base number) criterion, where the manufacturer's declared value is defined as BN > 7.5, which in turn tells us that the starting point of the "green zone", will be determined by this numerical expression.

According to statistical data processing, the upper control limit of the alkaline number will be 28.479 mgKOH/g.

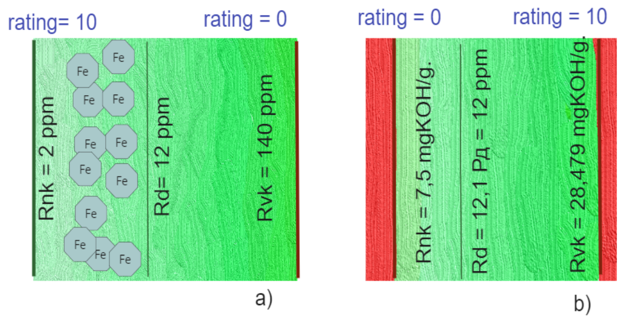

Figure 4. Determination of limit and mean values of a) Fe, (ppm); b) BN, (mgKOH/g)

The next step, after converting all lubricant parameters into coded values, is to compose a matrix. Rows of the matrix are normalized physicochemical parameters. Thus, according to the obtained analyses of laboratory studies, each of the coded values forms the matrix body, while the columns indicate the running time in hours (eq. 3).

$$\begin{array}{c|ccccccc|} & T_1 & T_2 & \dots & \dots & T_j & \dots & T_m \\ \hline P_{11} & E_{11} & E_{12} & \dots & \dots & E_{1j} & \dots & E_{1m} \\ P_{12} & E_{21} & E_{22} & \dots & \dots & E_{2j} & \dots & E_{2m} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ P_i & E_{i1} & E_{i2} & \dots & \dots & E_{ij} & \dots & E_{im} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ P_n & E_{n1} & E_{n2} & \dots & \dots & E_{nj} & \dots & E_{nm} \end{array} \quad (3)$$

when analyzing oil performance with the help of this matrix, it is necessary to take into account how one or another element behaves during different time intervals. For this purpose, the mean value and the standard deviation of each investigated parameter in coded values should be set row by row. A low standard deviation and mean value of the studied parameter, in coded units close to 10 reflects a well-functioning system, while a high standard deviation shows high variability in the series of a particular element.

For each variable in a system, it is possible to assess its overall effectiveness by determining the mean value and the standard deviation and calculating the parameter's performance index.

When calculating only the mean value, the true position in the structure may be misrepresented by the predominance of too-high values over too-low values;

in this regard, it is necessary to summarize the data values of each observational parameter in reverse.

We determine the index of efficiency of each of the parameters (IEF) as follows:

$$IEF_i = F_i \cdot m,\ i = 1, 2, ..., n \tag{4}$$

where

$$\frac{1}{F} = \sum_{j=1}^{n} \frac{1}{M_{ij}} \tag{5}$$

M_{ij} - data point in the matrix profile, m - rows, n - columns. When the numerical value of the profile data point approaches zero, the picture of the vulnerability of the studied parameter is observed, and accordingly, the efficiency index also approaches zero.

4. RESEARCH RESULTS

The process parameter matrix was compiled and evaluated on the basis of data from laboratory tests of engine oil for 15,339 hours of operation of a ship's diesel engine. The manufacturer specified the data of the control limits of the elements. Calculations of mean and standard deviation are presented in Tab. 1.

Table 1. Mean and standard deviation of the oil elements

Parameter	Average	std
Viscosity@ 100C	14,50	0,41
Flash point (SETA)	190,00	0,00
BN (mgKOH/g)	19,11	9,37
Insolubles %wt	0,29	0,26
Water (Vol%)	0,11	0,07
Al (Aluminium)	5,50	1,78
Cr (Cromium)	0,42	0,67
Cu (Cupper)	0,25	0,45
Fe (Ferrum)	19,50	4,78
Ni (Nickel)	39,50	14,31
Pb (Lead)	0,42	0,67
Sn (Tin)	0,83	1,27
Na (Sodium)	33,78	8,12
Si (Silicon)	14,00	3,36
V (Vanadium)	119,75	36,35
Sb (Antimony)	0,50	0,85

Conversion into coded values was performed as required, using formulas (1) and (2), after which the matrix of process parameters with coded values was made (Tab. 2).

According to Table 2, the coded values for some elements are below zero, which in the short-term forecast indicates serious deviations in the system operation, and in the long-term, after determining the index of performance parameters over a time interval, indicates that there is a need to make a repair plan to identify the cause of the system destabilization.

5. APPLICATION OF THE PROCESS PARAMETER MATRIX IN THE DEVELOPMENT OF A COMPUTER PROGRAM FOR THE ANALYSIS OF THE OIL-ENGINE SYSTEM

The proposed method is designed to use another possibility to determine the level of serviceability of the oil system of the ship's engine with the use of the most accessible means for the service personnel. Deve–lopment of specialized software on the basis of the MPP method is not a trivial task, as it requires integration with various software and hardware complexes currently applicable for the assessment of technical conditions of ship mechanisms. Today the requirement of ISMC (the International Safety Management and Pollution Prevention Code) provides that "the company should define the equipment and technical systems, which sudden failure can cause dangerous situations" [19]. In this regard, having an additional source of analytical data on engine performance can serve as a tool in decision-making on the timing and types of maintenance and repair work of the power system [20].

In order to provide an effective visual categorization of the technical condition of the oil system when applying the process parameter matrix method, we propose to display the data for the user in the form of color values (Table 3). After determining the IEF for visual perception, the data is colored with values from dark red, where the index values go into minus values, to light green, which means the effective operation of the system for this parameter.

By using this approach to evaluate the oil system, it is possible to monitor not only the stability of the system at the time of analysis but also to detect at what point the failure occurred and the impact of the measures taken to eliminate the causes of the failure, whether it's the replacement of components and parts or a change of lubricant.

6. DISCUSSION

Natural wear and tear of ship power plant mechanisms under load are considered to be one of the main, but not the only, source of engine failures. The reasons for the failure of nodes and parts of the ship engine may include individual design features of the power plant; poor-quality materials of node parts, miscalculations during their installation; engine operation in overload mode; use of oils, and fuel of inappropriate characteristics [21]. To reveal the problem, regular analyses of the oil composition state are used, among other things, through control of measured parameters and volume of metal inclusions fractions. Nowadays, many vessels, in addition to the availability of all sorts of sensors and regulated means of technical systems control, have software that helps to manage maintenance and planning of works on inspection and repair, including power engineering equipment.

In order to make a full prediction, it is required to create a "library" of possible consequences when the analyzed parameter exceeds the limit values. Thus, when calculating the efficiency index, in addition to the color highlighting of the elements whose values fall into the red zone (IEF from -10 to 6,1), there should be a pop-up window with an offer to pay attention to certain mechanisms, which wear or defect affects the change of this parameter (Fig. 5). Formation of a database for the library, proposed on the basis of overall statistics on the frequency of failures of particular SPP mechanisms and related to this failure - changes in the oil parameters.

Table 2. Matrix of process parameters with coded values.

Equipment hours	7121	8392	9662	10930	12198	13480	13655	14890	16373	17490	19560	22460	IEF
Al (Aluminium)	9,50	9,25	8,50	8,50	8,50	8,25	8,25	8,00	8,25	8,75	9,00	8,75	8,60
Cr (Cromium)	10,00	10,00	9,75	9,50	10,00	9,75	9,75	10,00	10,00	10,00	10,00	10,00	9,89
Cu (Cupper)	10,00	10,00	9,94	9,94	10,00	10,00	9,94	10,00	10,00	10,00	10,00	10,00	9,98
Fe (Ferrum)	9,14	8,86	8,57	8,00	8,79	8,43	8,14	8,29	8,71	8,93	8,86	8,57	8,59
Ni (Nickel)	4,75	1,75	-0,50	-2,25	2,25	-2,75	-6,00	-4,00	1,75	6,00	2,00	-1,50	-8,41
Pb (Lead)	10,00	10,00	10,00	9,94	9,94	10,00	10,00	10,00	9,94	10,00	10,00	9,88	9,97
Sn (Tin)	9,50	10,00	9,75	9,00	9,50	10,00	10,00	10,00	10,00	9,75	10,00	10,00	9,78
Na (Sodium)				4,86	6,57	5,57	5,14	4,00	5,29	6,71	5,43	3,00	4,90
Si (Silicon)	8,20	8,00	7,40	7,00	7,00	6,80	6,60	6,80	6,20	6,60	7,60	8,20	7,14
V (Vanadium)	-2,00	-9,00	-17,00	-20,80	-8,60	-19,60	-25,40	-22,60	-9,40	-7,60	-9,00	-16,40	-8,70
Viscosity@ 100C	6,02	6,24	6,27	6,39	6,02	6,02	6,63	6,51	5,90	6,02	6,99	7,59	6,35
BN (mgKOH/g)	2,19	2,15	0,24	-0,05	4,39	5,20	3,29	4,24	10,39	11,96	11,58	10,82	-0,83
Water (Vol%)	7,80	7,60	7,60	7,00	9,20	4,40	9,00	6,60	9,00	8,00	8,00	8,60	7,45
Flash point (SETA)	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67
Insolubles %wt	8,20	7,60	9,33	9,33	9,33	9,33	9,33	8,67	9,33	6,33	5,67	4,47	7,64

Table 3. Illustration of a graphical illustration of the results obtained using the MPP method

	COLOR GRADIENT OF IEF VALUES											
Equipment hours	7121	8392	9662	10930	12198	13480	13655	14890	16373	17490	19560	22460
Al (Aluminium)	9,50	9,25	8,50	8,50	8,50	8,25	8,25	8,00	8,25	8,75	9,00	8,75
IEF	9,50	9,37	9,06	8,92	8,83	8,73	8,66	8,57	8,53	8,55	8,59	8,60
Cr (Cromium)	10,00	10,00	9,75	9,50	10,00	9,75	9,75	10,00	10,00	10,00	10,00	10,00
IEF	10,00	10,00	9,92	9,81	9,85	9,83	9,82	9,84	9,86	9,87	9,88	9,89
Cu (Cupper)	10,00	10,00	9,94	9,94	10,00	10,00	9,94	10,00	10,00	10,00	10,00	10,00
IEF	10,00	10,00	9,98	9,97	9,97	9,98	9,97	9,98	9,98	9,98	9,98	9,98
Fe (Ferrum)	9,14	8,86	8,57	8,00	8,79	8,43	8,14	8,29	8,71	8,93	8,86	8,57
IEF	9,14	9,00	8,85	8,62	8,65	8,62	8,54	8,51	8,53	8,57	8,60	8,59
Ni (Nickel)	4,75	1,75	-0,50	-2,25	2,25	-2,75	-6,00	-4,00	1,75	6,00	2,00	-1,50
IEF	4,75	2,56	-2,46	-2,41	-4,10	-3,79	-4,00	-4,00	-6,31	-7,93	-14,47	-8,41
Pb (Lead)	10,00	10,00	10,00	9,94	9,94	10,00	10,00	10,00	9,94	10,00	10,00	9,88
IEF	10,00	10,00	10,00	9,98	9,97	9,98	9,98	9,98	9,98	9,98	9,98	9,97
Sn (Tin)	9,50	10,00	9,75	9,00	9,50	10,00	10,00	10,00	10,00	9,75	10,00	10,00
IEF	9,50	9,74	9,75	9,55	9,54	9,61	9,67	9,71	9,74	9,74	9,76	9,78
Na (Sodium)				4,86	6,57	5,57	5,14	4,00	5,29	6,71	5,43	3,00
IEF				4,86	2,79	5,58	5,46	5,09	5,12	5,30	5,32	4,90
Si (Silicon)	8,20	8,00	7,40	7,00	7,00	6,80	6,60	6,80	6,20	6,60	7,60	8,20
IEF	8,20	8,10	7,85	7,62	7,49	7,36	7,24	7,18	7,06	7,01	7,06	7,14
Viscosity@ 100C	6,02	6,24	6,27	6,39	6,02	6,02	6,63	6,51	5,90	6,02	6,99	7,59
IEF	6,02	6,13	6,17	6,23	6,18	6,16	6,22	6,25	6,21	6,19	6,26	6,35
BN (mgKOH/g)	2,19	2,15	0,24	-0,05	4,39	5,20	3,29	4,24	10,39	11,96	11,58	10,82
IEF	2,19	2,17	0,59	-0,25	-0,32	-0,39	-0,46	-0,54	-0,61	-0,68	-0,75	-0,83
Water (Vol%)	7,80	7,60	7,60	7,00	9,20	4,40	9,00	6,60	9,00	8,00	8,00	8,60
IEF	7,80	7,70	7,67	7,49	7,78	6,90	7,13	7,06	7,24	7,30	7,36	7,45
Flash point (SETA)	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67
IEF	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67
Insolubles %wt	8,20	7,60	9,33	9,33	9,33	9,33	9,33	8,67	9,33	6,33	5,67	4,47
IEF	8,20	7,89	8,32	8,55	8,70	8,80	8,87	8,84	8,90	8,55	8,17	7,64

The database also allows the operator to add the recorded failures (replacements, repairs), thus adapting to the individual features of the serviced SPP. Analyzing the information received from added databases will allow us to specify further the boundary values used in the MPP method for each concrete type and model of a ship engine.

In a functioning power plant, oil contamination is a regular process, which is caused by penetration into the oil system of incomplete combustion products, wear particles of mechanisms, and elements generated as a result of oxidation and thermal effects. It is impossible to prevent oil aging, but it is definitely possible to postpone this process, keeping the stable operation of the engine. Software programs installed on modern ships, aimed at control and accounting of technical elements, with the integration of an oil analysis program based on the MPP method, can give good results in both the long and short term - improving the control of the technical condition of power plants and improving the process of subsequent maintenance and repair. This, in turn, directly impacts the safety, energy efficiency, manufacturability, and environmental friendliness of ships' fuel-energy systems.

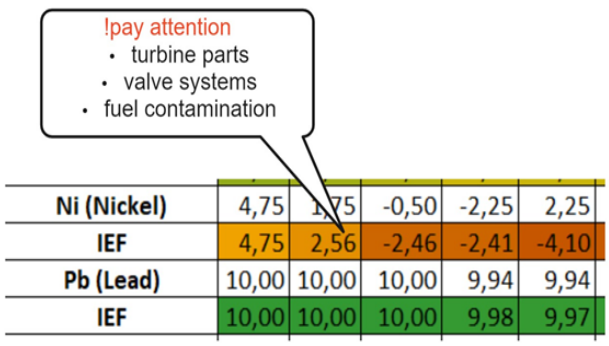

Figure 5. Example of a pop-up window of the process parameter matrix

7. CONCLUSION

The developed methodology of data processing regarding physical and chemical properties of lubricants used in SPP on the basis of MPP allows to predict of changes in the state of the technical oil-engine system over time and also controls the process of lubricant performance loss, evaluates the rate of degradation processes of engine elements, plan operations on its maintenance and repair and evaluate their subsequent efficiency. The proposed data processing methodology underwent analytical testing and served as a basis for developing the software program. Let us outline several tasks for the software complex being created based on the MPP method.

Firstly, the program will simplify the decision-making by a chief mechanic's service on planning maintenance of controlled mechanisms;

Secondly, when regularly conducted analyses of used oil are loaded, the program based on MPP will provide digital and graphical information about the condition of the controlled system at any interval of engine operating time. This, in turn, allows us to determine the time interval within which an event occurred, resulting in a parameter deviation from the limits of the norm. The program can serve both as an individual program and as an add-on - by integrating into larger and more complicated software complexes to plan technical maintenance of mechanisms in the fleet.

Thirdly, the software developed based on the MPP method will allow forming a database of analytical information necessary for increasing the quality of ship engine development, especially regarding fatigue and dynamic loadings, corrosion, and friction influences. These materials will allow manufacturers and engine designers to conduct a comparative analysis of the results of the application of the designed mechanism with the original design solutions and expectations (mean time to failure, specifics of equipment failure). Such analytics will be vital for the subsequent development of a complex of measures for improvement of the quality of maintenance and repair of ship power plants since the accumulation of the data and the analysis of spent oils on each certain engine in time provides an understanding of the most frequent failures of elements, allowing to characterize the failures of certain engine models in certain time intervals [22].

In addition to the tasks mentioned above, the prospects for further development of this software include the development of an intelligent system with the ability to recognize defects and determine the risks of the emergency situation.

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NOMENCLATURE

SPP	Ship Power Plant
MPP	Matrix of Process Parameters
Eij	Normalized element of the matrix
Rvk	Upper control limit
Rnk	Lower control limit
Rd	Actual value of the parameter
IEF	Parameter Efficiency Index
Mij	Data point in the matrix profile
m	Rows
n	Columns
T	Operating time in hours
P	Parameter

ИСТРАЖИВАЊЕ И ЕВАЛУАЦИЈА РАДНИХ КАРАКТЕРИСТИКА КОРИШЋЕНОГ БРОДСКОГ МОТОРНОГ УЉА КОРИШЋЕЊЕМ МЕТОДЕ МАТРИЦЕ ПРОЦЕСНИХ ПАРАМЕТАРА

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Интервал замене уља у циркулацији бродског мотора који су предложили произвођачи је смерница заснована на општој статистици и лабораторијским испитивањима. Истовремено, стварни преостали век трајања уља може значајно кориговати време и новац који главни механичарска служба потроши на одржавање система. У овом раду развијен је метод који омогућава повећање радног века механизама и поузданости бродске опреме у условима рада. Ефекат се постиже идентификацијом и анализом најзначајнијих и најутицајнијих параметара употребљеног мазива. Низ физичко-хемијских података о мазивима, узимајући у обзир време до квара опреме, обрађује посебан компјутерски програм за праћење стања бродског мотора у радном режиму. Развијени софтверски пакет омогућава прецизније и благовремено одржавање СПП (бродске електране)