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INTELLIGENT SYSTEM FOR MONITORING THE OPERATIONAL PROPERTIES OF SHIP POWER EQUIPMENT

The peculiarity of monitoring the technical condition of ship vehicles is that during the service life the main energetic installation is not changed, but its continuous maintenance and periodic repairs are carried out. In the organization of such activities, the leading role

* *postgraduate student, Kherson State Maritime Academy, Kherson-Odesa, ORCID: 0009-0004-7992-8369, yanenko9494@gmail.com*

belongs to technical diagnostics, which allows you to determine the technical condition of the material, as well as predict possible changes for a certain period. Intelligent system of monitoring of operational properties of ship power equipment with Markov circuits, probabilistic dynamics elements, calculations on probabilistic models, multi-criteria optimization of diagnostic parameters, simulation and scenario generation is proposed. In detail, the content of the main structural units of the system for monitoring the operational properties of ship power equipment is considered. The input information was a generalization of experience in the operation of vehicles. The stages of construction of Markov circuits are described in relation to diagnostics of turbochargers, the feature of which is a replacement of discrete time by a continuous sequence of states. Considered by a separate unit of calculation on probabilistic models on the basis of spectra of vibration signals by combining their main discrete features and establishing new diagnostic parameters. The visualization of relationships consists in the construction of digraphs of interactions of the main structural elements of the SES taking into account probabilistic models. Multi-criteria optimization in the presented system is considered from the standpoint of statistical criteria and their convolution. Simulation and generation of basic scenarios is described, from the point of view, the conversion of analog data about workflows to digital form. Provided information support and tools of the system for monitoring the operational properties of ship power equipment.
Key words: *monitoring, technical operation, ship vehicles, intelligent systems, diagnostics, failure, risks, uncertainty.*

Яненко А.В. Інтелектуальна система моніторингу експлуатаційних властивостей суднового енергетичного обладнання. *Особливість моніторингу технічного стану суднових транспортних засобів складається у тому, що протягом терміну служби головну енергетичну установку не змінюють, а здійснюють її неперервне технічне обслуговування та періодичні ремонти. В організації таких заходів провідна роль належить технічному діагностуванню, що дозволяє визначити технічний стан матеріалу, а також прогнозувати можливі зміни на певний період. Запропоновано інтелектуальну систему моніторингу експлуатаційних властивостей суднового енергетичного обладнання за допомогою ланцюгів Маркова, елементів ймовірнісної динаміки, розрахунків по ймовірностним моделям, багатокритеріальної оптимізації діагностичних параметрів, симуляції та генерації сценаріїв. Докладно розглянуто змістовий сенс основних структурних блоків системи моніторингу експлуатаційних властивостей суднового енергетичного обладнання. Вхідною інформацією було узагальнення досвіду експлуатації транспортних засобів. Описуються етапи побудови ланцюгів Маркова стосовно діагностики турбонагнітачів, особливістю яких є заміна дискретного часу безперервною послідовністю станів. Розглянуто окремим блоком обчислення за ймовірнісними моделями на основі спектрів вібраційних сигналів шляхом поєднання їх основних дискретних ознак та встановлення нових діагностичних параметрів. Візуалізація зв’язків полягає у побудові орграфів взаємодій основних структурних елементів суднової енергетичної установки з урахуванням імовірнісних моделей. Багатокритеріальна оптимізація у представленій системі розглядається з позицій статистичних критеріїв та їх згорток. Симуляція та генерація основних сценаріїв описана з точки зору перетворення аналогових даних про робочі процеси у цифрову форму. Надано інформаційну підтримку та інструментарій системи моніторингу експлуатаційних властивостей суднового енергетичного обладнання.*
Ключові слова: *моніторинг, технічна експлуатація, суднові транспортні засоби, інтелектуальні системи, діагностика, відмова, ризики, невизначеність.*

Description of the problem.

Introduction. The intensity of use of ship vehicles, violation of operating rules, cyclic sign-shifting loads and various manifestations of the external environment, which cannot be taken into account, lead to a decrease in the accuracy of determining the current state of the material. Regular and peak loads that affect the material of vehicles during their operation cause changes in structure and affect the strength of the material. In addition, the shortcomings of existing complexes are due to the fact that they reveal an already formed defect ignoring the moment of its origin. They are associated with equipment stops for repair and preventive work, the need to take into account a large number of different indicators, low quality of predictive assessments and low diagnostic performance. Based on this, an important issue of operation and maintenance of vehicles is the creation of models, methods and diagnostics based on new information parameters of identification and prediction of diagnostic objects. The practical direction of such works is to change the inter-repair cycle for diagnostics of ship's power equipment elements by moving from works on regulations to works on the actual condition of equipment.

There is an aging of the marine fleet. The youngest vessels are bulk carriers with an average age of 11.1 years, followed by container ships with an average age of 13.7 years, then oil tankers with an average age of 19.7 years. This is explained by the fact that it is quite difficult to determine the ways that technological development can take, which fuels will be most effective, how the standards for carbon emissions will change. Therefore, the tendency to operate older ships continues. There is a need to create intelligent technical diagnostic systems that combine expert and experimental information with probabilistic forecasting dynamics. This optimization of the monitoring process allows to increase the reliability and reliability of the equipment.

Setting the problem. Any deviation of material properties from the set value provided by the technical documentation is a defect. Disadvantages of materials performance monitoring systems are:

– static;
– large amounts of various operational information;
– limitations in the time and space covered by the solution;
– lack of systemicity in the analysis of information;
– subjectivism of expert assessments;
– unreasonable timing of scheduled works;
– low diagnostic performance;
– scanning and surface preparation for inspection.

The fight against these shortcomings can be carried out through measurements, the creation of identification and modeling techniques, software and mathematical support. There is a need to improve equipment, optimize processes and technologies, ensure timely diagnostics and reliability of equipment condition prediction.

Analysis of latest research and publications. The basis for making decisions on the possibility of further operation of the equipment is the results of the assessment of the residual resource [1-3]. The residual resource is the total operating time of the object from monitoring its technical condition to the limit state. In this sense, the marginal state of the equipment is understood as the state in which further operation of the equipment is impractical [4-6]. If the technical regulations do not set standards for assessing compliance with the requirements to the device, it is subject to expert evaluation. If the number of load cycles exceeds, the calculation of the residual resource of the equipment is included in the industrial safety examination [7-8]. When the technical documentation of the equipment is established by the standard uptime, it can be continued by calculating the residual resource [9-10]. The residual resource is established on the basis of technical diagnostics according to the program, including examination of the technical condition of vehicles, examination of mechanical properties, microstructure and chemical composition, prediction and evaluation of structural elements, analysis of results, issuance of conclusions [11-13].

Prospective work on uncertainty assessments in diagnostic systems is reflected in [14-17]. Elements of construction of intelligent systems of technical diagnostics using Markov circuits and probability dynamics of failures are reflected in works [18-19]. Frequency-time failure of bearing service life is given in [20]. In [21] vibration characteristics are considered and classification of defects is given on the basis of which the use of specific methods of vibration analysis is justified. Based on the generalization of experience in the operation of elements of ship vehicles, a system of technical operation of ship vehicles has been developed [22]. An overview of the cited sources indicates an unabated interest in the problem of intellectualization of monitoring the operational properties of structures during their operation, which excludes or at least reduces the subjectivism of technical condition assessments.

The purpose of the work is to build an intelligent system for monitoring the operational properties of ship power equipment taking into account the specific features of its operation.

The objectives of the study are:

- formulation of ways to improve monitoring and technical diagnostics of ship's power equipment elements;
- establishment of internal combustion engine and turbocharger failure statistics;
- detection of failure causes.

Summary of the main material (research methods, problem solving to achieve the goal). Parameters of diagnostics of turbochargers were used as research materials: housing, compressor, turbine, seals, rotor, bearings, oil pumps, as well as probabilistic estimates of their failures, obtained on the basis of a large statistical material. Markov circuits and elements of probabilistic dynamics, calculation by probabilistic models, multi-criteria optimization of diagnostic parameters, simulation and scenario generation were used as research methods. Estimates of residual resource in the absence of information about peak and extreme loads on equipment during inter-repair cycles during the operation of products are tested with the use of a number of limitations and limitations of estimates caused by dynamic changes in the environment and stochasticity of processes, that is, there is a risk situation.

There is no single definition of risk and uncertainty. There is only general terminology that is interpreted depending on the specific situation. The word risk, according to the established terminology, has such an interpretation as an effect on luck in the hope of a happy occasion, possible danger, unpredictability of results. Any risk is characterized by an alternative event. The main difference between risk and uncertainty is whether the quantitative probabilities of the occurrence of certain events are known or not.

Uncertainty is not generated by the completeness of information, the chance of the manifestation of external unstable connections, the result of the intersection of independent processes and events. The risk is directly related to decision-making. The notions of uncertainty are ambiguous, while risk has a quantitative dimension. In this case, you should first identify the risks, and then take a number of precautions to reduce or eliminate them.

Risk assessment methods are built taking into account the use of the scenario and the development of negative, in particular, emergency situations, the theory of fuzzy sets and expert assessments, the causal relationships of the occurrence and development of extreme situations.

Understanding the nature of risk and identifying it is related to the probability of danger. On the other hand, risk is a potential opportunity for profitability. Risk is a necessary attribute of transport technologies. The main difficulty in modeling risk situations is to build models adequate to the real situation. If there are in reality several states of the external environment and specific internal conditions of transportation, they correspond to different target functions. This, in turn, determines various alternatives to management. If none of the alternatives dominate the others, a multi-criteria optimization problem arises. Synthesis of multi-criteria optimization ideas is based on probabilistic estimates of results and search for solutions in which the values of target functions are equally acceptable for both suppliers and sea carriers.

Technical diagnostics covers the field of knowledge, including the theory, methods and means of identifying the state of objects. Technical diagnostics are performed during scheduled shutdowns of technical devices and equipment. Visual inspection, hydraulic tests, flaw detection methods, process and mechanical tests are used to identify the condition of the elements of the ship's equipment. Visual inspection and hydraulic tests are used to ascertain the causes of damage. Flaw detection is carried out on board the vessel, and during repair.

Modern systems of technical diagnostics, which use transport in practice, refer to complex objects, characterized by their single use by high risk and uncertainty, due to strong environmental impact, therefore, a whole set of measurements is used to improve the reliability and reliability of the leads.

Diagnostic methods allow to detect gradual failures of technological equipment, determine wear and residual resource, monitor changes in the conditions of controlled objects during inter-repair cycles. And at the same time, the diagnostic system allows you to determine only the information taken from sensors, actuators, controllers. The construction of diagnostic systems that allow to carry out a comprehensive technology for monitoring failures during the technical operation and maintenance of ship vehicles, providing prompt, as objective as possible information about the diagnostic object, is an important scientific and technical task.

Main results and their discussion.

Mathematical models describing the monitoring of technical condition should describe in detail the internal and external characteristics of the processes of interaction between operational and information factors.

Conceptual model of intelligent system for monitoring operational properties of ship power equipment in the form of separate structural units is proposed (Fig. 1).

The content of each of the blocks of this scheme is considered in detail.

Performance of diagnostic works in transport is determined by technical specifications and standards. The initial unit of the presented intelligent system (Fig. 1) is associated with the analysis of input information, technical and design documentation, determination of diagnostic intervals according to the regulations.

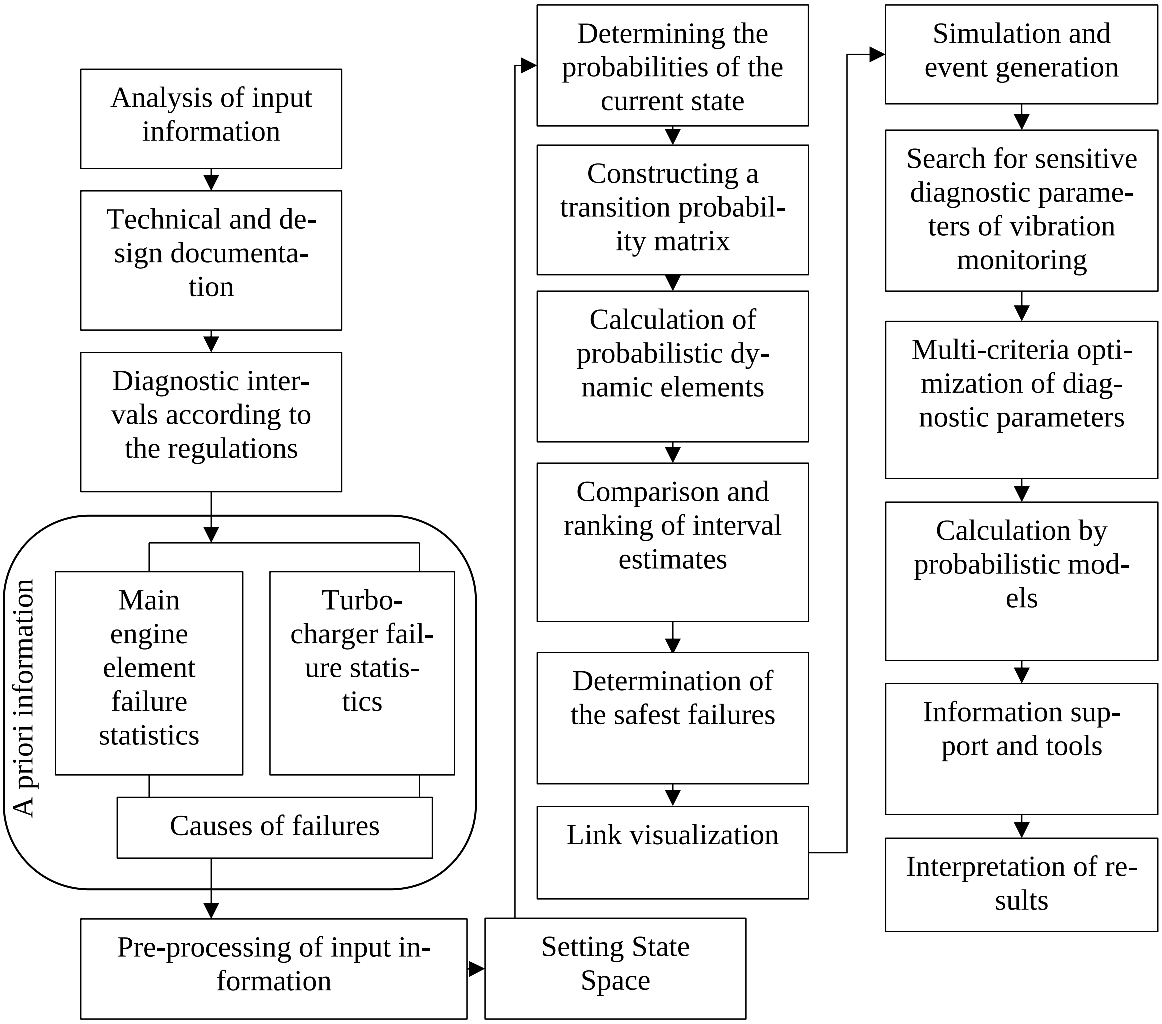

Fig. 1 – Intelligent system for monitoring the operational properties of marine vehicles

Efficiency of performance monitoring is determined by the possibility of transfer of diagnostic works according to the regulations with equipment shutdown to their current state (Fig. 2).

If the condition of the diagnostic object is characterized by the absence of a defect, diagnostics should be carried out with the equipment stopped, in accordance with the requirements of the regulations (Fig. 2a). In case of defect detection, go to state monitoring and perform diagnostics depending on the predicted approach to the state of failure (Fig. 2b).

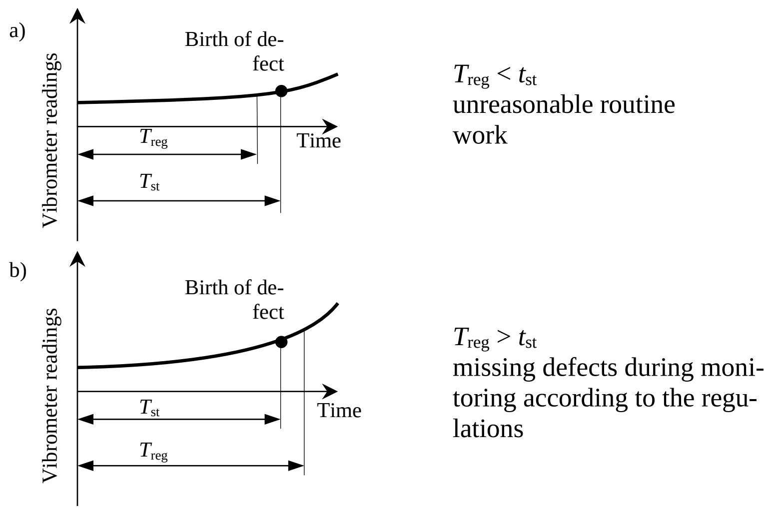

Fig. 2 – Comparative assessment of monitoring effectiveness by regulation and status

Monitoring efficiency can be determined due to the ratio of periodicity of routine works t_{reg} to determination of their need according to the state of t_{st} according to the formula

$$E = \frac{t_{reg} - t_{st}}{t_{reg}}. \quad (1)$$

These methods require a priori knowledge of past situations and operating parameters. The next basic unit of the presented intelligent system for monitoring the operational properties of the ship's power equipment is extensive a priori information on the statistics of failures of the main engine and the installation turbochargers during their operation.

As the experience of operating marine vessels shows, the main task of technical diagnostics is to determine the technical condition of the main engines and elements of power plants.

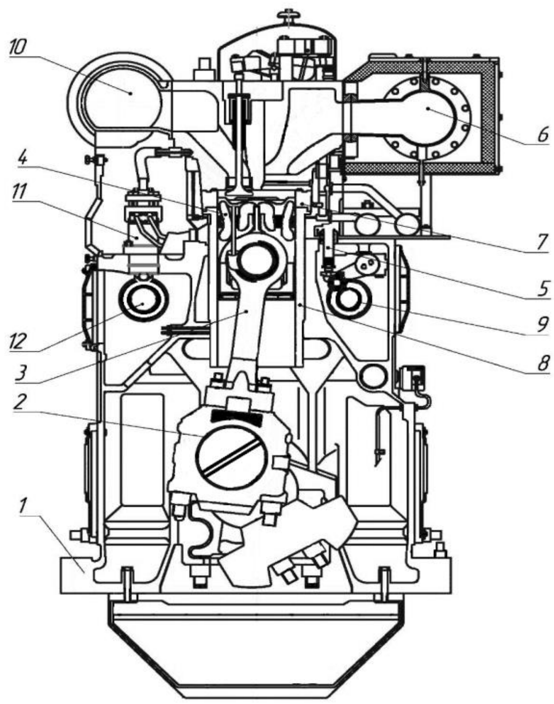

Fig. 3 – Engine cross section MAN B&W L32/40

Marine vehicles include diesel power plants, which include the main engine frame – 1, crankshaft – 2, connecting rod – 3, piston – 4, gas distribution mechanism – 5, exhaust manifold – 6, cooling jacket

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– 7, cylinder liner – 8, camshaft – 9, exhaust manifold – 10, high-pressure fuel pump – 11, fuel camshaft – 12 (Fig. 3). In addition, the power plant includes turbochargers, shaft lines, diesel generators, recycling and auxiliary boilers, mechanisms and devices.

Table 1 shows the relative failure rate of the marine internal combustion engine elements.

Table 1

Statistics of the relative failure rate of elements of marine internal combustion engines

№	*Unit*	*Relative failure rate*
1	Cylinder liner	0,042
2	Cylinder head	0,017
3	Valve mechanism	0,072
4	Gas distribution mechanism drive	0,032
5	Fuel pump	0,090
6	Nozzle	0,105
7	Fuel injector valve	0,054
8	Turbocharger	0,096
9	High pressure pipeline	0,096
10	Crank and connecting rod mechanism	0,021
11	Cranked the bearings	0,014
12	Air distributor	0,121
13	Hinged mechanisms	0,240

These data confirm the need for the introduction of new technical diagnostics.

The turbocharger is the most loaded unit of the engine, which operates under conditions of high temperature differences and dynamic loads, so any deviations of the engine characteristics affect the operation of the turbine and can lead to failure. Turbocharger – indicator of engine condition. The main task of using turbochargers on internal combustion engines is to increase power when reducing specific fuel consumption, as well as reduce the toxicity of exhaust gases.

Ship turbochargers include: gas-admission casing – 1, turbine nozzle ring – 2, turbine wheel – 3, insert – 4, gas outlet casing – 5, air intake casing – 6.1, silencer – 6.2, insert – 7, compressor wheel – 8, diffuser – 9, compressor casing – 10 (Fig. 4).

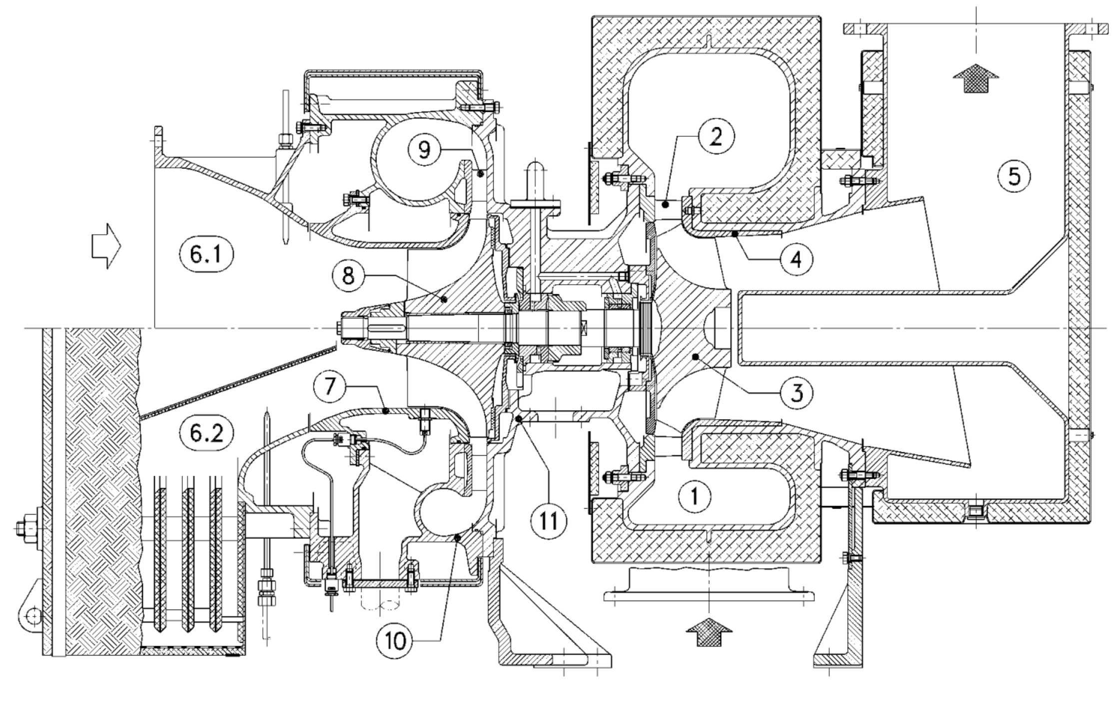

Fig. 4 – Turbocharger NR34/S

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The turbocharger is a single-stage centrifugal compressor with a blade diffuser. Exhaust gas from the main engine enters the turbine impeller through the nozzle apparatus. The work blades are twisted, have a bandage and a Christmas tree mount on the wheel. The crankshaft is protected from hot gases by a casing and the compressor impeller by a layer of insulation and a diaphragm.

The most common fault detection of turbocharger assemblies is given in Table 2.

Table 2

Statistics of the reasons for failure of turbocharger units

№	*Turbocharger detail*	*Failure rate, %*
1	Casing	9.0
2	Compressor	0.5
3	Turbine	4.8
4	Sealing	16.7
5	Rotor	15.2
6	Bearings	43.8
7	Oil pumps	10.0

According to Fig. 1, another structure-forming unit of the intelligent system for monitoring the operational properties of the ship's power equipment is the analysis of the causes of failures. The most common cause of failures of ship turbochargers is the ingress of foreign particles into the oil and then into the turbine or compressor wheel, which leads to a violation of the rotor balancing. This type of failure causes the bearings to fail.

The causes of failures may be violations of manufacturing processes and hidden defects of the material. It is also possible inaccurate design and disruption of operation. Failures according to strength parameters are found in the folding of the surface of the products or in the form of cracks during bending and torsion.

In general, the cause of failures is degradation of the parameters and characteristics of materials due to physical and chemical processes.

According to statistics, the largest number of failures is accounted for by the wear factor (Table 3).

Table 3

Statistics of causes of failures of turbochargers assemblies

№	*Type of damage*	*% from the total number of refusals*
1	Wear and tear	44,7
2	Breakage of elements	11
3	Contamination of filters and systems	8,5
4	Erosion, corrosion, cavitation	6,6
5	Leakage of nodes	5,7
6	Material aging	3,7
7	Jamming elements	3,7
8	Other reasons	16,1

In the structure of all failures of turbochargers, the majority is caused by braking and jamming of the rotor shaft due to overheating of the housing, the signs of which are oil leaks from the turbine side. Along with this, there is a strong overheating of oil, its rapid aging and the formation of deposits on the details of the turbocharger. Thanks to the diagnostics of supercharging units, it is possible to prevent premature wear of parts and extend the service life of the turbocharger.

One of the most common reasons for failure is the wear of the elements of the mechanisms. Statistics indicate that in some cases, failures due to wear of surfaces reach 50-80% of all types of failures occurring during operation. Among the failures of elements of ship power plants, the most common are failures of rolling bearings. Rolling bearings are located in support bearing of propeller shaft in main engine frame bearings, in thrusters. Damage to rolling bearings is determined by measuring vibration. Wear causes changes in the trajectory of displacement of the center of mass and the appearance of shock pulses. Factors of wear can be metallurgical and operational. The metallurgical ones include cracks and shells, the operational ones – through the eyes of corrosion, drilling of working surfaces, dents and potholes, destruction of surfaces (Fig. 5). From the picture of characteristic damage, you can determine the causes of their appearance.

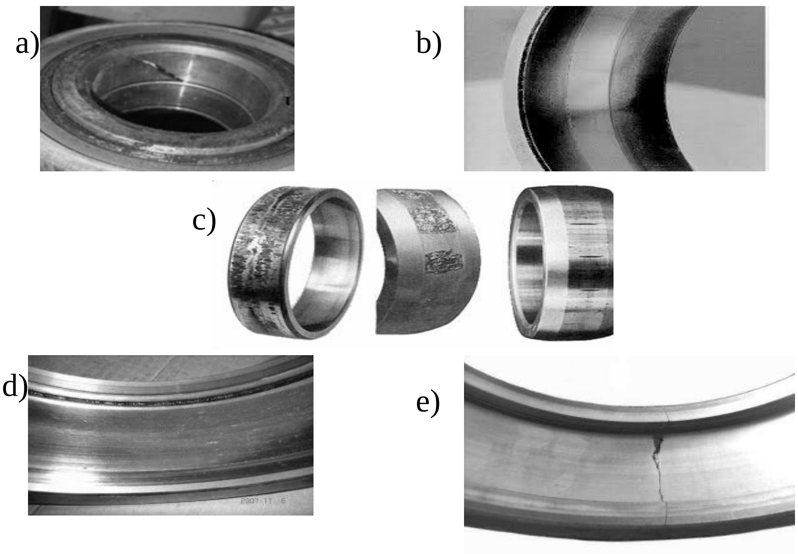

Fig. 5 – Rolling Bearing Operational Defects: a) inner clip defect; b) external clip defect; c) corrosion damage, d) contact fatigue damage, e) cracks

The next structural unit of the intelligent monitoring system Fig. 1 is to determine the probabilities of the current state of the equipment. The technical condition of the materials of the elements of ship vehicles can be in a finite set of states, which consists of a subset of operable states and a subset of incapable states. The division of the set into subsets is determined by the health conditions. Health conditions are set in the space of diagnostic indicators of the health area within which the products perform their functional purpose.

In the conditions of operation of ship's power equipment elements under the influence of unpredictable extreme loads, the identification of their technical condition is probabilistic and the diagnostic process begins without any amendments to the situation, according to the regulations. In case of obtaining new information on detection of defects within the interval of routine work, violations of the diagnosis cycle occur, that is, changes in the start point of diagnosis. Thus, the change in position of the reference point is random, characterized by a discrete temporal and finite number of possible states. Such a process will be Markovsky, since the following states of the starting point of the diagnosis process are independent of the previous ones. Markov chains characterize a stochastic process in which the conditional probability distribution of future states depends only on the current state of these processes.

A separate structural unit of intelligent monitoring systems is the construction of a matrix of transient probabilities of the dynamics of identification of ship's power equipment elements during the loading process. When modeling complex technical lenses, the key is to display the structure of interactions and transitions. According to the failure structure shown in Table 2, the diagnostic system can be in one of seven conditions. Transient probabilities P_{ji} independent of time, but dependent only on j and i

$$P = \begin{vmatrix} P_{11} & P_{12} \dots & P_{1n} \\ P_{21} & P_{22} \dots & P_{2n} \\ \dots & \dots & \dots \\ P_{n1} & P_{n2} \dots & P_{nn} \end{vmatrix}, \quad (2)$$

$$\text{where } 0 \leq P_{ji} \leq 1 \sum_{i=1}^{n} P_{ji} = 1 \quad (3)$$

Choosing as the main parameter of diagnostics the serviceability in terms of failures of these elements in terms of conditional probabilities form a matrix of transient probabilities T [4].

$$\text{т} = \begin{vmatrix} 0{,}09\ 0{,}005\ 0{,}048\ 0{,}167\ 0{,}152\ 0{,}438\ 0{,}1 \\ 0{,}09\ 0{,}008\ 0{,}051\ 0{,}15\ 0{,}18\ 0{,}431\ 0{,}09 \\ 0{,}08\ 0{,}006\ 0{,}068\ 0{,}169\ 0{,}151\ 0{,}446\ 0{,}08 \\ 0{,}08\ 0{,}007\ 0{,}054\ 0{,}152\ 0{,}163\ 0{,}474\ 0{,}07 \\ 0{,}07\ 0{,}005\ 0{,}062\ 0{,}141\ 0{,}172\ 0{,}44\ 0{,}11 \\ 0{,}09\ 0{,}007\ 0{,}056\ 0{,}15\ 0{,}166\ 0{,}421\ 0{,}11 \\ 0{,}08\ 0{,}006\ 0{,}064\ 0{,}159\ 0{,}161\ 0{,}43\ 0{,}1 \end{vmatrix} \qquad (4)$$

The unit for calculating probabilistic diagnostic elements provides for calculating conditional probabilities at each step of the system. Transformational probability conditions in the transition process at the next stage of the matrix can occur as the set of rows of the transition matrix to the matrix itself.

The next unit of the intelligent monitoring system (Fig. 1) is the comparison and ranking of interval estimates. Ranking performed using the prior information of Table 2 and the transition probability matrix showed that P(1)>P(2)>P(3)> P(4)>P(5)>P(6)>P(7) that is, the probability of missing defects by the intelligent monitoring system decreases every single step [4]. This indicates the effectiveness of the proposed intelligent monitoring system for ship's power equipment elements.

To visualize the proposed conceptual model of intelligent diagnostics and monitoring of MPP elements using Markov circuits, a simulation model was created in the form of a oriented digraph (Fig. 6). When constructing the digraph, their specific part is closed as components of the corresponding parameters, i.e. elements of turbochargers (Table 2). Other relationships were as arcs given that the total input and output probabilities must be.

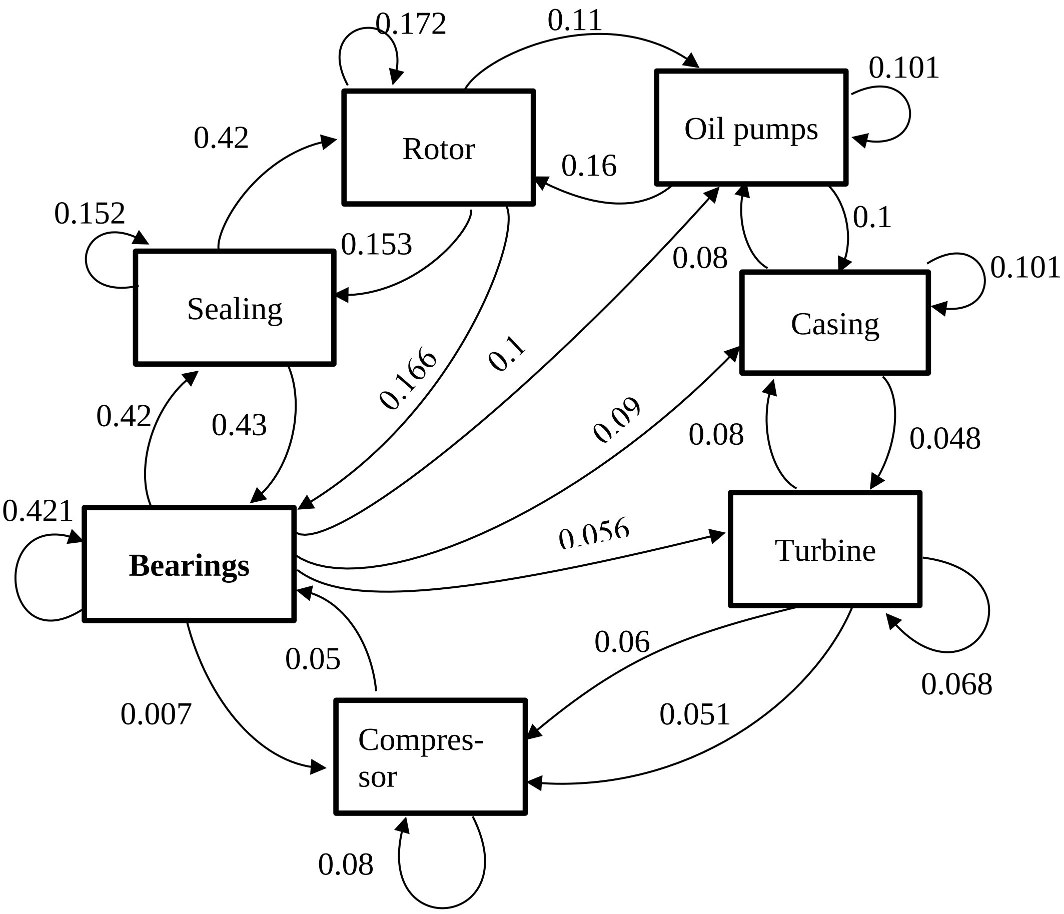

Fig. 6 – Diagram of diagnostics and monitoring of elements of turbochargers

The digraph is presented, characterizes the composition and structure of failure statistics, on the basis of which the most dangerous structural elements that pose the greatest threat during operation are identified. Such elements are most confirmed by failures in the operation of turbochargers are bearings and seals. This is presented in the form of the corresponding unit of the intelligent element monitoring system in the ship's power equipment (Fig. 1).

A separate structural unit of the intelligent monitoring system (Fig. 1) is simulation and event generation. Simulation and generation of events in the process of uncertainty of extreme loads allows you to configure the system for any information situation. The process of converting analog operating process data must be digitally displayed. The use of digital technologies to assess the limit state of elements of ship power plants will dramatically increase the accuracy of equipment state assessments.

A separate block in the presented intelligent monitoring scheme (Fig. 1) is the search for sensitive diagnostic parameters. Any rotating equipment vibrates during its operation. For each mechanism, there is a certain set of vibrations, which allows you to diagnose the mechanisms as a whole and its individual parts. Periodic vibration diagnostics consists in regular measurement of vibration by installing sensors, after which measurements are made at certain frequencies. However, it is not possible to estimate the state of the mechanism between measurements. Non-destructive monitoring of dynamic equipment of ship power plants, based on analysis of spectral characteristics of vibration signals, established trends and thresholds, requires, in addition to measuring vibration parameters, the mandatory treatment of a large number of characteristic features. Such features in the time domain include mean, standard deviation, asymmetry, excess, full swing, rms, cross factor, form factor, impulse factor, limiting factor, energy. In the frequency domain, such statistical characteristics of vibration signals as the average spectral value, standard spectral deviation, spectral asymmetry, spectral excess are determined. The listed spectral characteristics do not produce direct changes in vibration, but are realized by calculations on special programs. These information parameters, based on using the methods of the main components when reducing dimensions and combining with signs of spectral characteristics and noise suppression.

The next unit of intelligent system for monitoring operational properties of ships power equipment elements is multi-criteria optimization of diagnostic parameters. The complex structure of vibration signals and the diversity of their stochastic characteristics leads to the need to prioritize their use. Optimization parameters are based on a change in the main diagnostic feature as it approaches the degradation state. The efficiency matrix includes statistical characteristics of vibration signals, criteria for statistical solutions of Laplace, Wald, Hurwitz, adaptive and multiplicative convolution and practical implementations of vibration diagnostics.

The platform for visual development of data analysis scenarios and the construction of interactive interactions involves the use of structured and unstructured information, integration of multi-criteria vibration characteristics into new diagnostic parameters. The main task of multi-criteria approach to selection of optimal diagnostic characteristics of monitoring is equivalence with.

Of great practical interest is the following block – the production of calculations on probabilistic models. Figure 7 [23] illustrates the prediction of the remaining bearing service life based on a priori parameters and recent measurements. The model is presented as a spreading strip around the forecast point. It is able to detect the degradation trend in real time and update its a priori parameters when a new observation becomes available. This allows the residual resource to be estimated based on pre-set thresholds. At the same time, integration of artificial intelligence and machine learning technologies is achieved. Training is carried out using a set of experimental sampling.

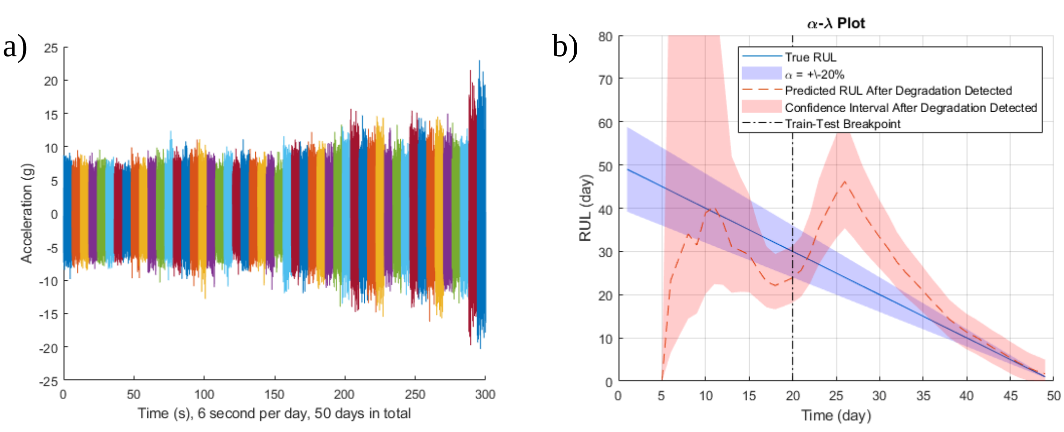

Fig. 7 – Exponential degradation model: a) form of vibration signal, b) prediction of residual resource

The content of the information support unit and the tools of the intelligent monitoring system of the ship's power equipment elements is as follows. Information support tools for intelligent monitoring of operational properties of ship's power equipment elements consists in the development of expert systems, knowledge base, data entry and transformation rules, software certified according to information security requirements in the field of diagnostics and control systems. The intellectual monitoring toolkit involves the use of such a widespread concept of information technology as the Internet of Things. Internet of Things is a connection of various physical and technical diagnostic elements, sensors, software and networks for data exchange and recording devices.

The intelligent monitoring toolkit is designed to provide a complex of information technology interactions from users to applications and databases. This allows you to understand the causes of defects during operation, reducing the risks that can arise due to normal operation failures, online platforms and applications. In addition, diagnostics is provided by optimizing the characteristics of multicomponent vibration signals, reducing the level of errors by introducing new diagnostic parameters and predicting the development of malfunctions when assessing the residual resource.

The presented information support of the intelligent system for monitoring operational parameters also follows that the main direction of improvement of technical diagnostics is connected not only with the determination of deviations from normative values, but with the definition of diagnostic signals sensitive to local defects.

Conclusions

The intelligent monitoring system of ship's power equipment elements monitors and analyzes real-time streams of experimental and statistical data based on intelligent algorithms of processing and methods of probabilistic dynamics using Markov circuits, calculations on probabilistic models, multicriteria optimization of diagnostic parameters, simulation and scenario generation. Intelligent monitoring can be performed automatically without the need for human involvement. It highlights key features of the facility, and identifies new opportunities and development segments of damage accumulation during operation. The intellectual component of the diagnostic system consists in the use of mathematical algorithms and software products that minimize subjectivism in making conclusions about the extension of the equipment resource and prognostic models about the achievement of the residual resource.

The greatest danger in the operation of transport facilities is defects that occurred during operation. At the same time, it is necessary not only to detect a defect, but to carefully measure its parameters and process the characteristics of diagnostic signals using special algorithms and programs. Intelligent monitoring system of ship's power equipment elements makes it possible to know their conditions at every moment of time and determine in advance the possible problems of further operation. The advantages of the considered methodology are the possibility of detecting hidden defects, obtaining information on the state of equipment located in difficult-to-reach places, monitoring and obtaining information about the defect at the stage of its origin, reducing the risk of emergency situations due to timely detection of defects.

Risk analysis of failures at hazardous facilities consists of systematic use of all available information and probabilistic modeling based on the spectrum of diagnostic signals, by combining their main discrete features and establishing new diagnostic parameters to identify hazards and undesirable events. Combining subjective expert and objective elements of technical diagnostics of operational parameters with methods of processing available information by methods of mathematical modeling and probabilistic dynamics, a reliable method of monitoring the equipment working during its operation can be obtained.

Areas of research on the effects and mechanisms of generation and distribution of diagnostic signals at different stages of material loading were further developed, on the basis of which the information parameters of the technical operation of ship vehicles were determined, which must be taken into account to improve the quality of diagnostics in conditions of risk and uncertainty.

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РИЗИКИ ПОДІЙ ТА СЦЕНАРІЇ ПАДДІНГТОНСЬКОЇ КАТАСТРОФИ 1999 РОКУ

Аварія під Лондоном у жовтні 1999 року шокувала не лише Велику Британію. Зіткнення двох поїздів показало очевидну неадекватність існуючих моделей управління поїздами на Великій Західній головній лінії залізниць Великобританії. Фахівці найрізноманітніших галузей знань неодноразово повертаються до цієї проблеми,

* *д-р техн. наук, професор, ДВНЗ «Приазовський державний технічний університет», м. Дніпро, ORCID: 0000-0002-9922-5618*