раметров при изменении частоты вращения коленчатого вала.

График рис. 4 показывает почти идеальное совпадение расчетных и экспериментальных данных. Модель (10) с учетом периодической составляющей адекватна исходным данным.

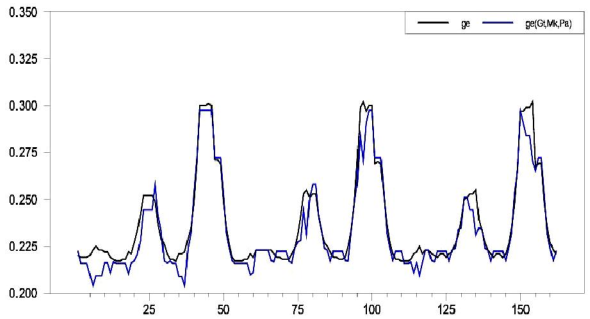

Рис. 4. Расчетная и экспериментальная последовательности

Заключение

Предложенный подход к оценке состояния машиностроительных изделий по информативным параметрам в ходе испытаний объединяет методы спектрального и многомерного статистического анализа. В результате снижаются погрешности моделирования многомерных случайных процессов при изменении режимов испытаний, существует возможность достоверного и точного прогноза значений параметров и, как следствие, предупреждения возможных отклонений режимов функционирования ДВС в ходе испытаний от номинальных режимов.

Список литературы:

1. Первухина Е.Л. Оценка состояния машиностроительных изделий в ходе производственных испытаний после сборки / Е.Л. Первухина, В.В. Голикова, П.К. Сопин // Сборка в машиностроении, приборостроении, Россия. – 2009. – №10.– С. 3-9. 2. Первухина Е.Л. Статистическое моделирование машиностроительных изделий по диагностическим параметрам / Е.Л. Первухина, В.В. Голикова, П.К. Сопин // Проблемы машиностроения и надежности машин РАН, Россия. – 2008. – №6. – С. 89-95. 3. Осипов К.Н. Определение режимов приемосдаточных испытаний ДВС / К.Н. Осипов // Прогрессивные технологии и системы машиностроения: междунар. сб. науч. тр. – 2011. – Вып. 41. – С. 261 – 266. 4. Box G.E. Time Series Analysis, Forecasting and Control / G.E. Box., G.M. Jenkins, G.C. Reinsel. – New Jersey: Prentice Hall, 1994.– 598 p. 5. Enders W. Applied Econometric Time Series / W. Enders. – New York: John Wiley & Sons, 1995 – 433 p.

Bibliography (transliterated):

1. Pervuhina E.L. Ocenka sostojanija mashinostroitel'nyh izdelij v hode proizvodstvennyh ispytanij posle sborki / E.L. Pervuhina, V.V. Golikova, P.K. Sopin // Sborka v mashinostroenii, priborostroenii, Rossija. – 2009. – №10.– S. 3-9. 2. Pervuhina E.L. Statisticheskoe modelirovanie mashinostroitel'nyh izdelij po diagnosticheskim parametram / E.L. Pervuhina, V.V. Golikova, P.K. Sopin // Problemy mashinostroenija i nadezhnosti mashin RAN, Rossija. – 2008. – №6. – S. 89-95. 3. Osipov K.N. Opredelenie rezhimov priemosdatochnyh ispytanij DVS / K.N. Osipov // Progressivnye tehnologii i sistemy mashinostroenija: mezhdunar. sb. nauch. tr. – 2011. – Vyp. 41. – S. 261 – 266. 4. Box G.E. Time Series Analysis, Forecasting and Control / G.E. Box., G.M. Jenkins, G.C. Reinsel. – New Jersey: Prentice Hall, 1994.–598 p. 5. Enders W. Applied Econometric Time Series / W. Enders. – New York: John Wiley & Sons, 1995 – 433 p.

UDK 621.435

A.V. Goncharenko, ph.D

MATHEMATICAL MODELING OF THE SHIP'S MAIN ENGINE RANDOM OPERATIONAL PROCESS

Introduction

The main engine (ME) of a transport vessel works as a part of the ship's propulsion complex (SPC). This work is characterized by quasi-stationary modes of operation at distant voyages of a long duration, but transitive modes at maneuvering, passing narrows (straights, channels, river mouths, etc.), shallows, calling to ports, and so on. Such modes are dictated by operators (the subjects of operation) proceeding the ideas of expediency and appropriateness. At this, the process that is going on, as a rule, happens mostly without failures of equipment, and, therefore does not disturb execution of the voyage task.

However, sometimes, at operational conditions, the process of the system transition from one state into others is being realized occasionally in a random way. Such phenomena are character for unexpected sudden failures that occur instantly. For example, failures of cylinders. And that, in its turn, can make difficulties for fulfillment of the voyage task.

Urgency of researches

Thus, consideration of an operation process requires a very attentive approach to the quite possible equipment failures and probable restorations of the equipment up state. Therefore, the stochastic rather than determined problem setting allows taking into account the output of the ship's power installation and ship's speed more accurately. Hence, the proposed mathematical modeling of the random process of an operation of the ME as a part of a SPC is an important and actual task.

The innovation of the given article is in trying to apply a random processes theory to solving the problems of SPC operation in multi-alternative operational situations.

The problem setting in the general view relates to some important science and practical problems of the monitoring of the equipment aboard ship in terms of subjective analysis. Considering a random operational process one has to make allowance for the operators' subjective preferences and their uncertainty.

Analysis of the latest researches and publications

In the work [1], it is being considered the modes of loading of main ship diesels, influence of external factors upon the mode's indexes and parameters, restriction and barrier characteristics, performance curves, methods and systems of control that provide for a diesel operation without overloading. A considerable attention is paid to the working process and change of the modes parameters and indexes at loading, to a diesel's thermal and mechanical tension, plotting and correction of the restriction characteristics. It is considered the principles of a searching system for a ship hydromechanical complex optimal work mode. Analyzing the reliability of modern ship diesels, it is revealed that they do not ensure for the reliable, failure-free work within the guarantied useful lives [1, P. 67]. It is shown the statistical estimates of the reliability and survival functions, failure-free work probabilities [1, P. 213], resulted in the ship's speed indexes and parameters, speed characteristics of the vessel [1, P. 215].

In the book [2], it is analyzed the peculiarities of interaction of the SPC.

In the work [3], amongst others issues, it says about energy transformations that is spent upon the ship's motion [3, P. 132], as well as about estimating the reliability measures [3, P. 178] and the system of the working process of diesels control with ensuring for their work on the optimal running modes [3, P. 189]. At that, attention was being paid to specific fuel-oil consumption for a mile distance passed at a certain given ship's speed.

At the work [4], it is analyzed the work of the main ship's diesel as a part of the hydro-dynamical complex "engine-propeller-hull". It is evaluated the influence of the state of the ship's hull, meteorological conditions, and factors of the ship's depth upon the loss of her speed. It is investigated dynamical modes of the ME running at the ship's maneuvering, suggested methods of assessment of the heat and mechanical overloading in the processes of the engine loading, given recommendations for assigning the restriction characteristics of a diesel and choosing the loading pace at the maneuvering of a ship. The acquired results and recommendations are connected with the criteria of the transporting effectiveness of the sea and river vessels. Control of a diesel's running modes, as a part of a SPC in particular, is carried on by the criterion of fumeness [4, P. 245]. It is delivered the principles of formation of a generalized purpose function of a diesel's control [4, P. 283].

At the work [5], there are suggested solutions, with the help of means of technical diagnostics, to such tasks of the ship's propulsion and her power plant (SPPP) technical operation as optimization of the ME running mode with taking into consideration its technical state change, prevention to sudden, unexpected instant, and gradual failures, revealing the ship's speed loss due to her hull fouling, and others. It is adduced the data concerning the main defects of the plunger couples of the types of two-stroke crosshead reversible supercharged 50 centimeter bore and 110 centimeter stroke (TCRS 50/110) and TCRS 74/160 engines. These are the wearing of the precise surfaces of sliding parts of pair plungers and liners. On the average, about 80% of plunger pairs are defected on the causes of the mentioned surfaces wearing, losing of hydraulic tightness lower than the allowed limits, as well as because of jamming and scratching. Actual useful life of a plunger couple lies, on an average, within the limits of 6-13 thousand hours. The fuel-oil injectors' tips, apertures are the most vulnerable, fragile, weak elements of the fuel-oil apparatuses. For ship diesels of the TCRS type, damages of the tightening end (around 49%), hangings of the sprayer needle (about 17%), loss of tightness (approximately 19%), and others are pertaining to the number of character defects of sprayers. The total useful life of the sprayers of the mentioned diesels with making allowance for their periodic prophylactic repairs is estimated approximately in 8-10 thousand hours [5, P. 144]. It is shown the scheme of the assessment for the loss of the speed because of the fouling and degradation of the technical state of the ME by the passport diagram [5, P. 184, fig. 84]. It is presented a nomogram for the determination of the output loss as a result of a diesel technical state worsening [5, P. 185, fig. 85]. It is performed the comparison of the calculation and experimental data at the assessing of the ship's speed [5, P. 188, table 18].

In the article [6], it is said about that still the problem of an internal combustion engine (ICE) brake horse power (BHP) determination remains actual. The absence of a possibility for a reliable control of the ME outputs for middle and small ships makes researchers find new methods of the output's measuring. In particular, it is pointed out that the BHP of ICE is one of the major energetics indexes of the ME, which is necessary for a proper operation and appropriate choice of the specified continuous rating (SCR), for normalizing of fuel-oil and lubricating oil consumptions, as well as for the estimation of the technical state of the engine and its residual life. Indirect methods have a deviation or inaccuracy in about 10-12%. In case of a decrease of the technical state indexes, that value of the error may reach even a greater magnitude.

In the book [7], it is presented the main information concerning the technical use of the ship ICE, maximally providing for their operational reliability level. The great attention in the book is paid to a choice of rational modes of engines running, ensuring their reliable operation in ships specific sailing conditions. It is described in details the running of an engine with turned off cylinders [7, P. 70]. In operational practice of ship engines, it is sometimes happens the necessity of turning off of one or several cylinders because of the impossibility to stop the engine (passing the narrows, dangerous in the navigational sense places). Usually, such a thing happens due to a failure of components and elements of the fuel-oil injection system (injectors, high pressure pumps, breakage of the high pressure pipelines).

Thus, mainly, stochastic approach, if it is even paid attention to in the mentioned above works, presents in the statistical estimates of probabilities, up state duration. Calculations of SCR have deterministic character although. Randomness, therefore, requires more attention, being directly taken into account.

In works [11-13], there were researched the water-coal slurries, atomization characteristics, and subjective and legislative factors in engine building. This approach needs further development in combination with SCR and reliability.

Researching a random process, it is also necessary to take into consideration the uncertainty of operators' subjective preferences [14-16].

The task setting

Hence, the ship's speed as well as the output of the ME, SCR play sometimes the main role, at least not the last, for controlling the operational processes of the main SPPP.

In this article, it is suggested to consider a mathematical modeling of a random process of operation of the ME [10], which would comprise the previous researches results as well as, at this, make allowance for possible sudden failures, randomness and uncertainty, and, as a consequence, the change of the SPPP state, SCR, and BHP of ICE, show the change of the ship's speed in time. That is the purpose of the given paper.

The main content (material)

Let us consider the process of the ME operation in a simplified manner, which is principally allowable for a rough problem setting.

The problem formulation

We will understand the process of transition of the ME, as a system, from some states into others as the random process of the ME operation. The transitions from a state into another state occur in a random way. At the given problem setting, we will consider random processes with discrete states. We assume that the system – ME, is characterized by a set of discrete states (finite – that corresponds to the possibility of a certain number of failures, those, however, cannot happen absolutely simultaneously). The random transitions of the ME between these states have a character of instant, immediate sudden spasmodic changes. A transition of the ME from a state into another state is possible at any moment in time, thus, at the given problem setting, we deal with a random process with indiscrete continuous time. In such a case, it is necessary to solve a peculiar probability problem related with the work of the so called system of mass service (SMS) [8, 9].

In order to describe a random process occurring in a discrete system with a continuous time, first of all, it is necessary to analyze causes that induce the system transitions from a state into another state, like, for example, the causes presented in the works [1-7]. For a SMS, a flow of claims is the major factor that stipulates the going on system's processes. Therefore, the mathematical description of the ME operation process starts with the description of the claims flow.

In theory of probabilities, the sequence of events that happen one by one at some moments in time is understood as a flow of events. In our case, these are the failures of the ME cylinders (the claims for service, maintenance), and returning them into the up state (the served claims).

It is convenient to consider random processes with discrete states using a scheme, which is called a graph of states [8, 9]. In the scheme, it is conventionally represented the possible states of the system and signified (with the help of arrows) the possible transitions between the states.

For each cylinder of the ME, as a system, such a scheme consists of two states: S_0 – up state, S_1 – down state, shown in the fig. 1.

Taking into account the failure and restoration intensities, the transitions: $S_0 \rightarrow S_1$ – are realized as a result of failures occurring in the system (in the given case with a ME cylinder), $S_1 \rightarrow S_0$ – corresponds to the repair finishing (restoration of the ME cylinder to the up state), we obtain the marked graph of states.

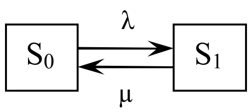

Fig. 1. Graph of a cylinder states

In the marked graph of states fig. 1, it is symbolized: λ – failure intensity, μ – restoration intensity. Thus, we acquire a system of differential equations (equations by Erlang):

$$\left.\begin{aligned} \frac{dp_0(t)}{dt} &= -\lambda \cdot p_0(t) + \mu \cdot p_1(t), \\ \frac{dp_1(t)}{dt} &= \lambda \cdot p_0(t) - \mu \cdot p_1(t). \end{aligned}\right\}, \qquad (1)$$

where $p_0(t)$ – probability of a cylinder up state as a function of time t; $p_1(t)$ – probability that at the moment of time t the cylinder will be in the down state.

Integration of the equations system (1) at the initial conditions: $p_0(0) = 1$; $p_1(0) = 0$ (at the initial moment, the cylinder is in the up state) gives the dependences $p_0(t)$ and $p_1(t)$.

Considering the ME as an aggregate of its cylinders, we obtain the system of the differential equations for the one channel system with a restricted queue according to the number of the possible states, fig. 2:

$$\left.\begin{aligned} \frac{dp_0(t)}{dt} &= -\lambda p_0(t) + \mu p_1(t), \\ \frac{dp_1(t)}{dt} &= -(\mu+\lambda) p_1(t) + \lambda p_0(t) + \mu p_2(t), \\ &\ldots\ldots\ldots\ldots\ldots\ldots \\ \frac{dp_k(t)}{dt} &= -(\mu+\lambda) p_k(t) + \lambda p_{k-1}(t) + \mu p_{k+1}(t), \\ &\ldots\ldots\ldots\ldots\ldots\ldots \\ \frac{dp_n(t)}{dt} &= -\mu p_n(t) + \lambda p_{n-1}(t). \end{aligned}\right\}, \qquad (2)$$

where $n-1$ – number of cylinders, at the failure of which the ME is in the up state; $p_n(t)$ – probability of the ME failure as a function of time.

Knowing the probability of the ME running with this or that number of cylinders change in time and a cylinder output, we may calculate the expectation (E) of the ME BHP as a function of time:

$$E(N_e) = \sum_{i=0}^{n-1} p_i(t) \cdot N_{e_i}, \qquad (3)$$

where N_e – ME BHP, random variable; i – number of cylinders failed; N_{e_i} – ME BHP on the condition that the number of cylinders i has failed.

The summing up is conducted up to $n-1$, since at the failure of n cylinders, the ME transits into the down state.

In the similar way, it is found the E of the ship's speed:

$$E(v) = \sum_{i=0}^{n-1} p_i(t) \cdot v\left(N_{e_i}\right). \qquad (4)$$

where $v\left(N_{e_i}\right)$ – ship's speed as a function of the ME output, function of the random variable.

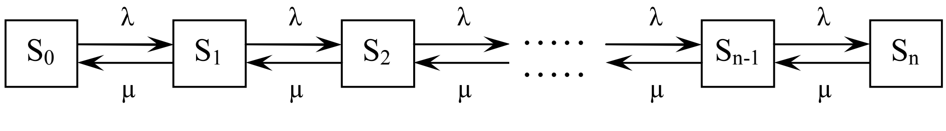

Fig. 2. Graph of the ME states

The problem solution

For solving the systems (1, 2) we will apply the integral Laplace's transformations. In case, when the failure intensities λ and μ are constant values in time, for the system (1), the Laplace's transformation yields a system of equations:

$$\left.\begin{aligned} p\cdot X(p)-1+\lambda\cdot X(p)-\mu\cdot Y(p)=0 \\ p\cdot Y(p)-\lambda\cdot X(p)+\mu\cdot Y(p)=0 \end{aligned}\right\}, \qquad (5)$$

where p – complex parameter; $X(p)$ and $Y(p)$ – images (transformants) of the originals (probabilities) of the $p_0(t)$ and $p_1(t)$ correspondingly; from where:

$$X(p)=\frac{p+\mu}{p^2+p\cdot(\lambda+\mu)}=\frac{p+\mu}{p\cdot(p+\lambda+\mu)}=$$

$$=\frac{1}{p+\lambda+\mu}+\frac{\mu}{p\cdot(p+\lambda+\mu)}, \qquad (6)$$

$$Y(p)=\frac{\lambda}{p+\mu}\cdot X(p)=\frac{\lambda}{p+\mu}\cdot\frac{p+\mu}{p\cdot(p+\lambda+\mu)}=$$

$$=\frac{\lambda}{p\cdot(p+\lambda+\mu)}. \qquad (7)$$

Corresponding originals:

$$p_0(t)=x(t)=\frac{\mu}{\lambda+\mu}\cdot\left(1-e^{-(\lambda+\mu)t}\right)+e^{-(\lambda+\mu)t},$$

$$p_1(t)=y(t)=\frac{\lambda}{\lambda+\mu}\cdot\left(1-e^{-(\lambda+\mu)\cdot t}\right). \qquad (8)$$

It is obviously, that the normalizing condition is accomplished for every moment in time:

$$p_0(t)+p_1(t)=x(t)+y(t)=\frac{\mu}{\lambda+\mu}\cdot\left(1-e^{-(\lambda+\mu)t}\right)+$$

$$+e^{-(\lambda+\mu)t}+\frac{\lambda}{\lambda+\mu}\cdot\left(1-e^{-(\lambda+\mu)t}\right)=1. \qquad (9)$$

In case, if it is considered a marked graph of states and transitions that is modeling the possibility of failure of two cylinders, then the system of the differential equations, proceeding from the general (2), will be the following one:

$$\left.\begin{aligned} \frac{dp_0(t)}{dt}&=-\lambda\cdot p_0(t)+\mu\cdot p_1(t), \\ \frac{dp_1(t)}{dt}&=-(\mu+\lambda)\cdot p_1(t)+\lambda\cdot p_0(t)+\mu\cdot p_2(t), \\ \frac{dp_2(t)}{dt}&=-\mu\cdot p_2(t)+\lambda\cdot p_1(t). \end{aligned}\right\}. \qquad (10)$$

The initial conditions are: $p_0(0)=1$, $p_1(0)=$ $=p_2(0)=0$. In an analogous way to (5), the Laplace's transformation yields the system of the equations:

$$\left.\begin{aligned} p\cdot X(p)-1+\lambda\cdot X(p)-\mu\cdot Y(p)=0 \\ p\cdot Y(p)-\lambda\cdot X(p)+(\lambda+\mu)\cdot Y(p)-\mu\cdot Z(p)=0 \\ p\cdot Z(p)-\lambda\cdot Y(p)+\mu\cdot Z(p)=0 \end{aligned}\right\}, \qquad (11)$$

where $Z(p)$ – image of the original (probability) of the $p_2(t)$; from where:

$$X(p)=\frac{p^2+2\cdot\mu\cdot p+\lambda\cdot p+\mu^2}{p\cdot\left(p^2+2\cdot(\lambda+\mu)\cdot p+\lambda^2+\lambda\cdot\mu+\mu^2\right)}=$$

$$=\frac{p^2+a\cdot p+b}{p\cdot(p+c)\cdot(p+d)}, \qquad (12)$$

$$Y(p)=\lambda\cdot\frac{p+\mu}{p\cdot(p+c)\cdot(p+d)}=$$

$$=\frac{\lambda}{(p+c)\cdot(p+d)}+\frac{\lambda\cdot\mu}{p\cdot(p+c)\cdot(p+d)}, \qquad (13)$$

$$Z(p)=\frac{\lambda^2}{p\cdot(p+c)\cdot(p+d)}, \qquad (14)$$

where $a=\lambda+2\cdot\mu$, $b=\mu^2$, $c=\lambda+\mu-\sqrt{\lambda\cdot\mu}$, $d=\lambda+\mu+\sqrt{\lambda\cdot\mu}$.

The originals:

$$p_0(t)=x(t)=\frac{1}{c-d}\cdot\left(c\cdot e^{-c\cdot t}-d\cdot e^{-d\cdot t}\right)+$$

$$+\frac{a}{d-c}\cdot\left(e^{-c\cdot t}-e^{-d\cdot t}\right)+\frac{b}{c\cdot d\cdot(c-d)}\times$$

$$\times\left[(c-d)+d\cdot e^{-c\cdot t}-c\cdot e^{-d\cdot t}\right], \qquad (15)$$

$$p_1(t)=y(t)=\frac{\lambda}{d-c}\cdot\left(e^{-c\cdot t}-e^{-d\cdot t}\right)+$$

$$+\frac{\lambda\cdot\mu}{c\cdot d\cdot(c-d)}\cdot\left[(c-d)+d\cdot e^{-c\cdot t}-c\cdot e^{-d\cdot t}\right], \qquad (16)$$

$$p_2(t)=z(t)=\frac{\lambda^2}{c\cdot d\cdot(c-d)}\times$$

$$\times\left[(c-d)+d\cdot e^{-c\cdot t}-c\cdot e^{-d\cdot t}\right]. \qquad (17)$$

By the formulas of (3, 4), it is found the E of the ME output and the ship's speed.

Practical application of the problem solution

Let us consider the operation of the SPPP with the ME of 8 TCRS 60/195-10 (MAN Diesel, former MAN-B&W, original B&W designation is 8L60MC; manufacturing plant, the license holder, licensee designation is ДБ-32). Let us presume that a possible up state allows four cylinder failures. The marked graph of states is presented in the fig. 3.

From the source of information [10], we get the necessary for the modeling technical data.

The systems of equations by Erlang, similar to the systems (1, 2, 10):

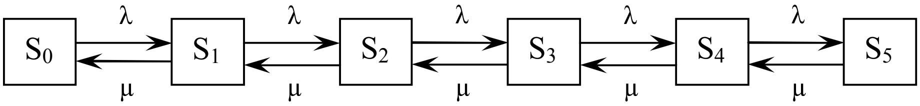

Fig. 3. Graph of the ME 8 TCRS 60/195-10 (ДБ-32) states

$$\left.\begin{aligned}
\frac{dp_0}{dt} &= -\lambda(t)p_0 + \mu(t)p_1,\\
\frac{dp_1}{dt} &= -(\mu(t)+\lambda(t))p_1 + \lambda(t)p_0 + \mu(t)p_2,\\
\frac{dp_2}{dt} &= -(\mu(t)+\lambda(t))p_2 + \lambda(t)p_1 + \mu(t)p_3,\\
\frac{dp_3}{dt} &= -(\mu(t)+\lambda(t))p_3 + \lambda(t)p_2 + \mu(t)p_4,\\
\frac{dp_4}{dt} &= -(\mu(t)+\lambda(t))p_4 + \lambda(t)p_3 + \mu(t)p_5,\\
\frac{dp_5}{dt} &= -\mu(t)p_5 + \lambda(t)p_4.
\end{aligned}\right\} \quad (18)$$

For intensities of $\lambda(t)$ and $\mu(t)$, let us apply models that reflect processes of elderliness of engineering. At the first approach, for a rough problem setting, it is important just a mere fact that the failure intensities increase in the course of time:

$$\lambda(t) = \frac{1}{1000} + k \cdot t\,, \quad (19)$$

where k – coefficient; and the restoration intensities diminish:

$$\mu(t) = \frac{150}{5 + n \cdot t}\,, \quad (20)$$

where n – coefficient.

The researches results

For the values of $k = 1 \cdot 10^{-3}$, $n = 1 \cdot 10^{-2}$ the results of calculations of $\lambda(t)$ and $\mu(t)$ is shown in the fig. 4.

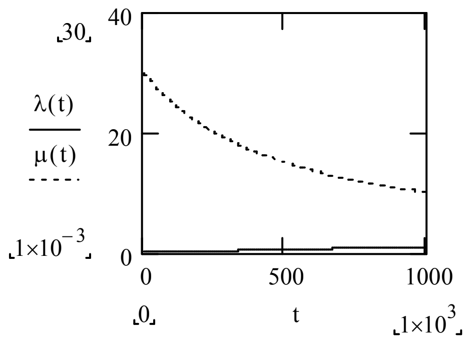

Fig. 4. Models of intensities of $\lambda(t)$, $\mu(t)$

Integration of the equations system of (18) with taking into account (19, 20), at the initial conditions of: $p_0(0) = 1$ (at the initial moment, all cylinders of the ME are in the up state); $p_1(0) = p_2(0) = \ldots = p_5(t) = 0$, gives the dependences of the $p_i(t)$.

The results of modeling calculations are represented with the traces in the plot of the fig. 5.

In addition to the traces of the corresponding probabilities concerning the ME being in this or that state, in the fig. 5, it is illustrated the sum of the probabilities:

$$\Sigma = p_0(t) + p_1(t) + p_2(t) + p_3(t) + p_4(t) + p_5(t) = 1\,,$$

for every moment in time, the normalizing condition is accomplished; there also shown the traces of the dependences: $1 - p_5(t)$, $1 - (p_5(t))^2$, $1 - (p_5(t))^3$ – probabilities of being in the up state for a SPPP equipped with one, two or three main engines of the mentioned type correspondingly.

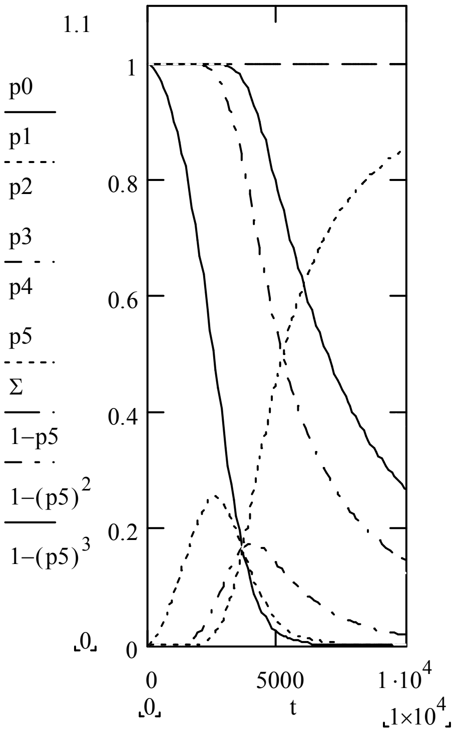

Fig. 5. Probabilities of the ME cylinders failures

The results of the E calculations for the BHP ENe by the formula of (3) is demonstrated in the fig. 6.

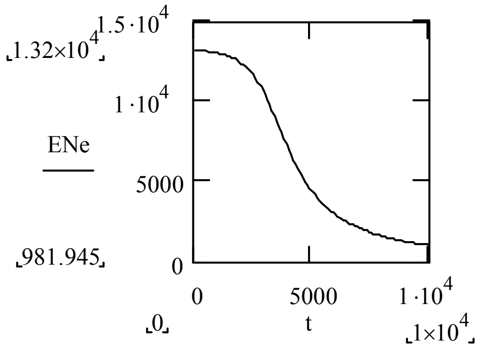

Fig. 6. E of the ME BHP

The results of the E calculations for the v1 – expectation of the ship's speed by the formula of (4) is demonstrated in the fig. 7. Also, there is the trace of:

$$v = v[E(N_e)]$$

in the fig. 7 that shows the change of the ship's speed in time dependently upon the E of the ME BHP. That demonstrates the complete correspondence with the well known Jensen's inequality (theorem) [16, part II, chapter 7, § 7.6, P. 103, (2)] in the parametrical form.

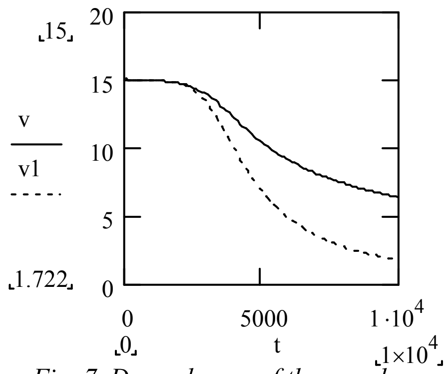

Fig. 7. Dependences of the speeds

Measure of uncertainty

For an active system functioning, it is not only probabilities and their entropy that express a measure of the system's uncertainty, but also the preferences functions and entropy of the subjective preferences.

For operational purposes, in particular, it is suggested, as the measure of the considered system uncertainty, the kind of pseudo-entropy that contains the entropy of the active element's subjective preferences with respect to the set of achievable alternatives in the view of Boltzmann's or Shannon's type:

$$\overline{H}_{\max - \frac{\Delta\pi}{|\Delta\pi|}} = \frac{H_{\max} - H_{\pi}}{H_{\max}} \frac{\Delta\pi}{|\Delta\pi|}, \qquad (21)$$

where $\overline{H}_{\max - \frac{\Delta\pi}{|\Delta\pi|}}$ – relative hybrid composed pseudo-entropy function of subjective preferences; $H_{\max}$ – the maximal value of the subjective preferences entropy [14, P. 100]:

$$H_{\max} = \ln N,$$

where N – number of achievable alternatives; H_{π} – entropy of the active element's subjective preferences π, with respect to the set of achievable alternatives, in the view of Boltzmann's or Shannon's type [14, P. 98, (3.1)]:

$$H_{\pi} = -\sum_{i=1}^{N} \pi(\sigma_i) \ln \pi(\sigma_i); \quad \sigma_i \in S_a|_{\sigma_0},$$

where $\pi(\sigma_i)$ – function of subjective preferences; σ_i – i[th] achievable alternative; S_a – set of the achievable alternatives; σ_0 – alternative of the initial state of the active system assessing the operational problem-resource situation; $\Delta\pi$ – preferences prevailing/dominating factor/index:

$$\Delta\pi = \sum_{j=1}^{M} \pi(\sigma_j^+) - \sum_{k=1}^{L} \pi(\sigma_k^-),$$

where σ_j^+ – positive and σ_k^- – negative alternatives correspondingly; M – number of positive alternatives; L – number of negative alternatives correspondingly:

$$M + L = N .$$

Substituting the corresponding values for themselves into the equation of (21), we obtain the extended unfolded expression:

$$\overline{H}_{\max-\frac{\Delta\pi}{|\Delta\pi|}} = \frac{\ln N + \sum_{i=1}^{N} \pi(\sigma_i) \ln \pi(\sigma_i)}{\ln N} \times$$

$$\times \frac{\left[\sum_{j=1}^{M} \pi\left(\sigma_j^+\right) - \sum_{k=1}^{L} \pi\left(\sigma_k^-\right) \right]}{\left| \sum_{j=1}^{M} \pi\left(\sigma_j^+\right) - \sum_{k=1}^{L} \pi\left(\sigma_k^-\right) \right|} .$$

The results of modeling for four alternative problem-resource operational situation are presented in the fig. 8.

The suggested pseudo-entropy (21) has several advantages compared with the traditional uncertainty measure in the view of the Shannon's or Boltzmann's entropy.

Its magnitude changes from –1 up to 1 and at this being the measure of certainty dependently upon the positive or negative preferences domination, unlike the traditional entropy that has the zero value as the point of certainty, but saying nothing to a researcher regarding whether it is positive or negative thing. Its relative value is also more informative than the absolute one of the entropy, because the closer the pseudo-entropy to its marginal values, the more assuredness in the subjective preferences it describes showing the positive or negative direction, i.e. right or wrong making a decision. Though this function is breakable at zeroth prevailing/dominating index/factor, it brings the information about a leap change of the active system sureness, the so called zeroth pseudo-entropy values of the second kind. The first kind of uncertainty it is when the entropy has maximum.

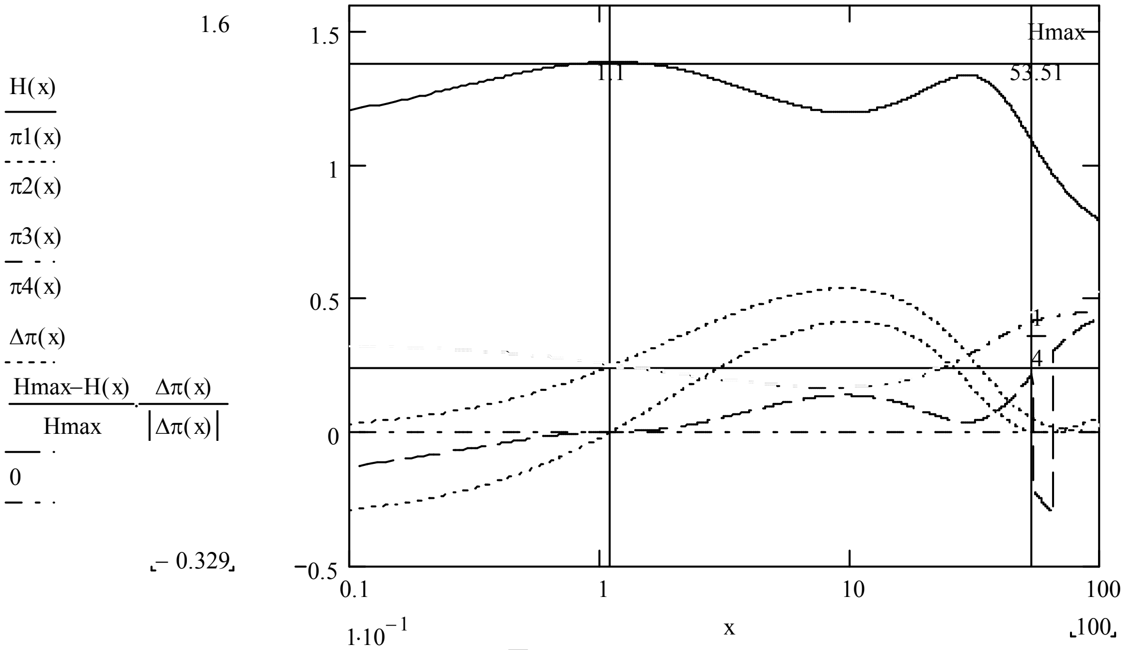

Fig. 8. Advantages of the pseudo-entropy $\overline{H}_{\max-\frac{\Delta\pi}{|\Delta\pi|}}$ compared to the traditional entropy H_π

Conclusions

The idealized problem setting of an SPPP operational process modeling in the view of – the ME running as kind of SMS, at the assumptions made, gives the possibility to analyze the principal character events. That allows making substantiated decisions regarding, for instance, consumption of fuel-oil and oil materials as well as other spent materials needed to reliable technical usage, also effective maintenance and overhaul. The policy of logistics planning can be more reasonable. It is expedient to evaluate the subjective uncertainty with the suggested relative hybrid composed pseudo-entropy function (21).

Prospects of further researches

The simplified variant of an SPC functioning shows how the workability of the main SPPP will depend upon the states of separate cylinders of the ME. For further researches it should be obtained statistical estimates of parameters for the formulae (1-21). Applying the entropy approach, it is necessary to investigate a hybrid functional of the subjective analysis variation principle.

References:

1. Суворов П.С. Управление режимами работы главных судовых дизелей / П.С. Суворов. – Одесса: ЛАТСТАР, 2000. – 238 с. 2. Мануилов В.П. Эксплуатация судовых энергетических установок / В.П. Мануилов. – М.: Транспорт, 1979. – 168 с. 3. Суворов П.С. Рабочие процессы и режимы судовых двигателей внутреннего сгорания: учебное пособие / П.С. Суворов. – Одесса: ОНМА, 2007. – 192 с. 4. Суворов П.С. Динамика дизеля в судовом пропульсивном комплексе / П.С. Суворов. – Одесса: ОНМА, 2004. – 304 с. 5. Шишкин В.А. Анализ неисправностей и предотвращение повреждений судовых дизелей / В.А. Шишкин. – М.: Транспорт, 1986. – 192 с. 6. Фомин Н. и др. Разработка методики по определению эффективной мощности СДВС для судовых условий / Н. Фомин и др. // Речной транспорт. – 2005. – № 2. – С. 62-63. 7. Обеспечение надежности судовых дизелей на эксплуатационных и особых режимах работы / М.А. Малиновский, А.А. Фока, В.И. Ролинский, Ю.З. Вахрамеев. – Одесса: ФЕНИКС, 2003. – 150 с. 8. Овчаров Л.А. Прикладные задачи теории массового обслуживания / Л.А. Овчаров. – М.: Машиностроение, 1969. – 324 с. 9. Вентцель Е.С. Теория вероятностей / Е.С. Вентцель. – М.: В. Школа, 2000. – 458 с. 10. Дизель судовой ДКРН 60/195-10. Техническое описание. ДБ32-ТО. – Брянск: ПО БМЗ, 1986. – 191 с. 11. Гончаренко А.В. Аналіз параметричних досліджень реологічних властивостей водовугільних суспензій для застосування у суднових двигунах внутрішнього згоряння / А.В. Гончаренко // Авиационно-космическая техника и технология. – 2009. – №8(65). – С. 90-95. 12. Goncharenko A.V. Fuel oil atomization characteristics smoothed by a logarithm normal distribution for marine diesel engines / A.V. Goncharenko // Двигатели внутреннего сгорания. – 2010. – №2. – С. 34–40. 13. Касьянов В.А. Субъективные предпочтения и правовое воздействие как факторы развития двигателестроения / В.А. Касьянов, А.В. Гончаренко, С.В. Кружкова // Авиационно-космическая техника и технологи. - 2010. – Вып. 7 (74). – С. 182–189. 14. Касьянов В.А. Субъективный анализ: монография / В.А. Касьянов. – К.: НАУ, 2007. – 512 с. 15. Касьянов В.А. Элементы субъективного анализа: монография / В.А. Касьянов. – К.: НАУ, 2003. – 224 с. 16. Де Гроот М. Оптимальные статистические решения / М Де Гроот. – М.: Мир, 1974. – 491 с.

Bibliography (transliterated):

1. Suvorov P.S. Upravlenie rezhimami raboty glavnyh sudovyh dizelej / P.S. Suvorov. – Odessa: LATSTAR, 2000. – 238 s. 2. Manuilov V.P. Jekspluatacija sudovyh jenergeticheskih ustanovok / V.P. Manuilov. – M.: Transport, 1979. – 168 s. 3. Suvorov P.S. Rabochie processy i rezhimy sudovyh dvigatelej vnutrennego sgoranija: uchebnoe posobie / P.S. Suvorov. – Odessa: ONMA, 2007. – 192 s. 4. Suvorov P.S. Dinamika dizelja v sudovom propul'sivnom komplekse / P.S. Suvorov. – Odessa: ONMA, 2004. – 304 s. 5. Shishkin V.A. Analiz neispravnostej i predotvrawenie povrezhdenij sudovyh dizelej / V.A. Shishkin. – M.: Transport, 1986. – 192 s. 6. Fomin N. i dr. Razrabotka metodiki po opredeleniju jeffektivnoj mownosti SDVS dlja sudovyh uslovij / N. Fomin i dr. // Rechnoj transport. – 2005. – № 2. – S. 62-63. 7. Obespechenie nadezhnosti sudovyh dizelej na jekspluatacionnyh i osobyh rezhimah raboty / M.A. Malinovskij, A.A. Foka, V.I. Rolinskij, Ju.Z. Vahrameev. – Odessa: FENIKS, 2003. – 150 s. 8. Ovcharov L.A. Prikladnye zadachi teorii massovogo obsluzhivanija / L.A. Ovcharov. – M.: Mashinostroenie, 1969. – 324 s. 9. Ventcel' E.S. Teorija vero-jatnostej / E.S. Ventcel'. – M.: V. Shkola, 2000. – 458 s. 10. Dizel' sudovoj DKRN 60/195-10. Tehnicheskoe opisanie. DB32-TO. – Brjansk: PO BMZ, 1986. – 191 s. 11. Goncharenko A.V. Analiz parametrichnih doslidzhen' reologichnih vlastivostej vodovugil'nih suspenzij dlja zastosuvannja u sudnovih dvigunah vnutrishn'ogo zgorjannja / A.V. Goncharenko // Aviacionno-kosmicheskaja tehnika i tehnologija. – 2009. – №8(65). – S. 90-95. 12. Goncharenko A.V. Fuel oil atomization characteristics smoothed by a logarithm normal distribution for marine diesel engines / A.V. Goncharenko // Dvigateli vnutrennego sgoranija. – 2010. – №2. – S. 34–40. 13. Kas'janov V.A. Sub#ektivnye predpochtenija i pravovoe vozdejstvie kak faktory razvitija dvigatele-stroenija / V.A. Kas'janov, A.V. Goncharenko, S.V. Kruzhkova // Aviacionno-kosmicheskaja tehnika i tehnologi. - 2010. – Vyp. 7 (74). – S. 182–189. 14. Kas'janov V.A. Sub#ektivnyj analiz: monografija / V.A. Kas'janov. – K.: NAU, 2007. – 512 s. 15. Kas'janov V.A. Jelementy sub#ektivnogo analiza: monogra-fija / V.A. Kas'janov. – K.: NAU, 2003. – 224 s. 16. De Groot M. Optimal'nye statisticheskie reshenija / M De Groot. – M.: Mir, 1974. – 491 s.

УДК 629.424.3

О.Б. Богаєвський, д-р техн. наук, А.Н. Борисенко, д-р техн. наук

ПОКАЗНИКИ ОЦІНКИ ЕФЕКТИВНОСТІ ЕНЕРГОЗБЕРЕЖЕННЯ ТЕПЛОВОЗНОГО ДИЗЕЛЬ-ГЕНЕРАТОРА

Вступ

Одним з напрямків підвищення енергозбереження існуючих тепловозних дизель - генераторів (ДГ) є впровадження сучасних систем управління частотою обертання колінчастого валу (КВ) і потужності, які дають змогу ефективно впливати на режим холостого ходу, сталі режими в усьому діапазоні навантажень і перехідні режими, які визначаються характером експлуатаційної роботи. Для тепловозних дизель-генераторів характерна експлуатаційна робота з багатьма переключеннями режимів, причому переходи можуть бути як тривалими, так і короткими, залежно від швидкості руху, вантажу, профілю колії тощо. Суттєвий вплив на витрати палива, особливо в перехідних режимах, має суб'єктивний чинник – навички машиніста.