Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2014, 37(109) pp. 5–9
ISSN 1733-8670

2014, 37(109) s. 5–9

Method of the assessment of the river craft technical condition on the basis of the microstatistics

Igor B. Arefyev[1], A.V. Volovik[2], A.A. Klavdiev[2]

[1] Maritime University of Szczecin
70-507 Szczecin, ul. Henryka Pobożnego 11, e-mail: i.arefyev@am.szczecin.pl
[2] National Mineral Resource University "Mining"
199106, Petersburg, VO, 21-Line, 2, Russia, e-mail: kss59@mail.ru

Key words: reliability, navigation, weather, river boat, operation

Abstract

One of the major problems of transport systems is the movement organization without catastrophes. It is particularly important for the rolling stock of the river fleet. In this paper, the authors propose the evaluation method of the technical condition of inland waterway vessels on the statistics of accidents and disasters of previous navigation. The method is based on the statistics for the "small samples".

Introduction

The United Europe water transport is important in transport of mass, construction and oversized cargo, energy, seasonal importation of agricultural products. It is an exceptional role in the local hiking and crossing water obstacles (ferries). However, in some regions of the North-Eastern Europe navigation is interrupted annual by freeze-up. In these areas on navigable rivers and canals ice can be up to 3 months per year [1, 2].

Objectively, the conditions of fluctuating water levels during floods and low water, change of speed and flow direction in the channel its clogging. However, even in the free water, the river vessel is severely limited by dimensions of the channel.

These conditions make from any river vessel an object of the increased danger. The security problem of the river vessel operation is complex. It consists of four main positions [3, 4]:

1. Technical indicators of vessel and its systems,
2. Compliance of characteristics of vessel course to the set standards,
3. Level of condition of navigation means for ensuring movement,
4. Ecology requirements and protection of water environment.

Understanding the importance of any specific problems, related to safety on inland waterways, we will analyze in the first point.

Forecasting problem of a technical condition of the river vessel during the period between navigation

Operation of the river crafts in Northern and the North Eastern Europe regions has important feature which distinguishes them from sea vessels and vessels river- sea: long break in the work connected with freeze-upon the rivers and ports [5]. This time is used for increase technical conditions of a vessel for the following navigation: repair and preliminary treatment, elements replacement prevention. The main task in this period – a guarantee of vessels technical condition, their fade-free operation during the following navigation. Result of the task solution – justification of an indicator of guaranted time of an operating time of a vessel an refusal T_H [5].

Under failure of the river craft as an object of movement we have to understand any event connected with its technical condition, which led to accident. Let's agree, that failure of any functional ship device (gear) is comparable to work refusal of a vessel as a whole [6, 7]. On an example, refusal of power installation or a propulsion complex, failure in operation of the navigation system leads to accidents, locking of a ship course.

It is difficult to calculate and predict T_H for objects like "river vessel". Statistics of accidents and accidents for previous years (navigation) are rare or casual events [8]. For a specific waterway, such statistics are single. Therefore, forecasting of actions for preliminary treatment of ship devices and to their maintenance depends on objectivity and completeness of basic data about accidents and accidents in the previous years. We need to predict a technical condition this type of vessel group, when releasing them in the next navigation. It is necessary to take T_H for such period, as the lower bound of time, an operating time to full vessels of the chosen type [8].

Classical approach is to monitor the refusal which requires many statistics as in previous years. On this statistics the border of an operating time of a vessel to the full T_H is established [9]. Such situation is determined by an arrangement of critical area in the division in time between failures [10, 11]. The statistics dealing causes of accidents are small for technical reasons for river crafts. As a result, there are difficulties when using limit distributions (for example, the *t*-statistics) which meet normal distribution at the volumes of selection of $n \geq 30$ events. In the conditions of small selections the lower bound of critical area is often negative. It contradicts physical sense of the analysis: time between failures is a positive random variable.

From stated becomes clear that, the mathematical apparatus allowing precisely to describe and predict critical areas of an assessment of a technical condition of a vessel before navigation (before its release in operation) is necessary. This device has to provide making decision on a safety guarantee when the statistical material is limited by objective conditions: analysis of "rare" events. The result of such decisions will increase efficiency planned and maintenance, will lower expenses for fleet repair bases and shipowners. The preliminary treatment of technical elements, their repair or replacement, will have the purposeful character based on calculations of level of expected refusals [12].

There is an entropy paradox. The greatest information is formed by the message about events that would be expected were the least likely (accidents). In such situation, we draw a conclusion, that entropy approach can serve as theoretical justification for probe of small number of supervision (small selections).

In fact, we will assume that information on a condition of a vessel, depends on number of *n*-situations of emergency and catastrophic character. Then it is possible to claim: exists such *n* at which its further growth doesn't conduct to increase in information on a technical condition of a vessel. In the information field follows the saturation moment. Further collection of information doesn't add anything new, except expenses. Apart from the "excess" information is capable "to choke up" selection, to distort the general assessment of a technical condition of a vessel [13]. We can gain "big selection effect" for the long period of supervision. The condition of expediency of probability theory, the service of operation won't be able to choose a reasonable hypothesis for decision-making [3, 14].

Problem of forecasting of the river craft technical condition

The aim of an assessment and forecasting of a condition of any technical object procedure of determination of its reliability in use falseness. It can be accepted, as a measure of safe work for navigation for the river craft. If in this region there is no concept "time between navigation (freeze-up)", it is possible to take fixed time of technical inspection or planned preliminary treatment of a vessel for such period. In any case, it is necessary to address to a classical task of the theory of reliability. In order to provide the expected limits of the evaluation time in a confidential working range of the vessel, before its refusal.

Then the objective is formulated as follows:

1. In the established region, on waterways of river float data on a technical condition of *n* river crafts of the same type are obtained.
2. Casual values ($t_i, i = \overline{1,n}$) failure of vessels of this type (accident) are recorded.
3. It is required to define the lower bound T_H of work of a vessel before possible refusal for technical reasons.

The solution of this task doesn't cause difficulties, if an array of the obtained data rather big (big selections). In reliability theory it is possible to carry massifs to such selections with $n \geq 10$ [15]. However, selections of smaller volume require more detailed formalization of stochastic process. This task belongs to tasks extreme. Then we need make an introduction of the communications considering distribution of extreme variation row. Such distributions are called as distributions of extreme values of a random variable (Fig. 1).

The solution of similar tasks is based on use of theorems the distribution of the extreme [4, 14]. It is expedient to use the practical appendix of the specified theorems at formalization of the moments of supervision of the critical area for the population $t \le T_H$. They difficult give in to formalization: distribution of extreme serial statistics is behind limit area of the analysis [1]. However, in some cases, it can be presented in an explicit form (Fig. 1).

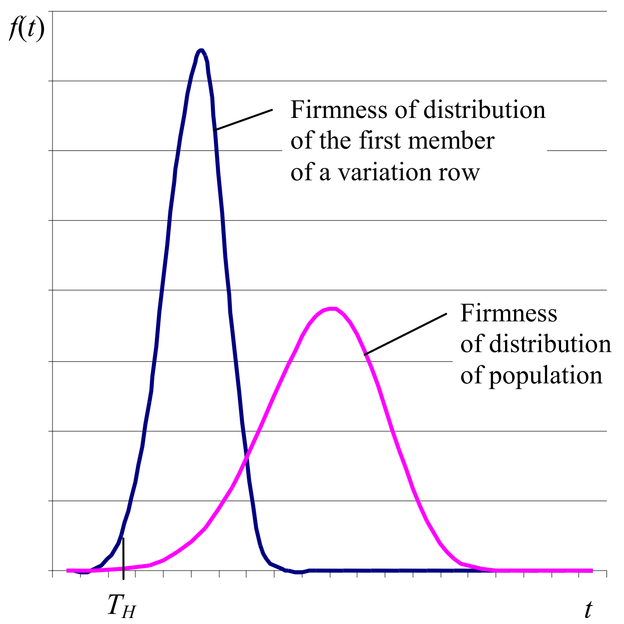

Fig. 1. Distributions of extreme values of a random variable (critical area $t \le T_H$)

It is important for us to define the lower bound of reliable operation of a vessel to the full T_H. Then, it is expedient to use distribution of the first member of a variation number of random variables. About it only the average assessment of an operating time to the full is known.

In this case function of quantiles will become [14]:

$$T_H = \frac{nT}{n-1}\left[1-(1-\alpha)^{\frac{n-1}{n}}\right] \qquad (1)$$

where: T – average operating time of a vessel to the full; n –the volume of the massif of the registered cases of refusals and accidents; α –significance value.

In the table 1 are dismissed the lower bound of an operating time to the full vessels of this type in the concrete geographical region of float. Time of average operating time is known of this type of vessel to the full T only. It is chosen from the analysis of the massif of previous accidents for technical reasons n (selection volume). The significance value is defined as $\alpha = 0.1$. Calculations were carried out on conditional and experimental data (1).

It allows to compare the received results. Exponential distribution has been set to the basis principle of maximum entropy, when T is known [14, 15]. Here the time T the value $T = 1000$ hours is accepted. It is the conditional size of movement time for river craft in standard flight on the rivers and ports with an ice situation. It corresponds to flight duration within 1.5 months [1].

Results of calculations are presented in the figure 2.

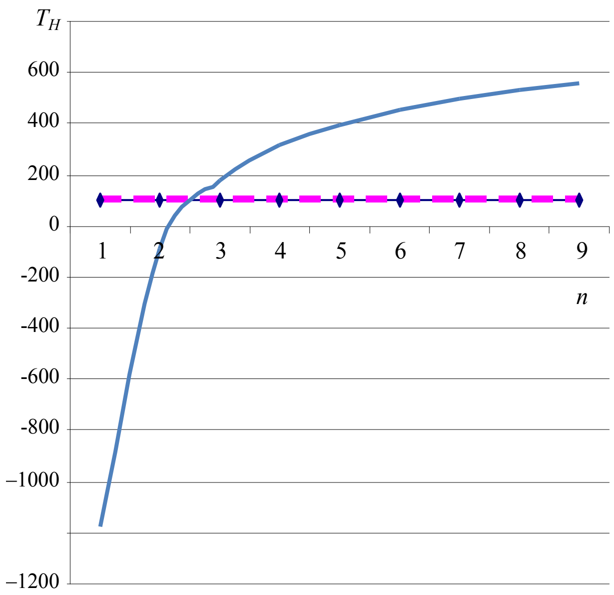

Fig. 2. Schedules of functions of the lower bound of an operating time of a vessel on refusal depending on selection volume

The analysis of data on the table 1 and figure 2 testifies that at $n \le 4$ a classical mode of definition of the lower bound of a time between failures we don't accept. It becomes negative and loses physical meaning. With increase n, since the 4th, this mode gives the overestimated assessment in comparison with theoretical (more than 100%).

Table 1. Assessment of the lower time bound of a time between failures the river craft during navigation [own study]

1	T (1000 hour)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
2	Array n	2	3	4	5	6	7	8	9	10
3	α	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
4	T_H	102.63	101.75	101.31	101.04	100.87	100.74	100.65	100.58	100.52
5	T_H in t-criterion	–1176	–88.7	181.1	314.3	397.5	455.8	499.7	534.4	562.6
6	T_H (theory)	105.36	105.36	105.36	105.36	105.36	105.36	105.36	105.36	105.36

Assessment of the lower bound of expected refusal of a vessel in the conditions of small selections

Let's compare the offered version of the decision of the theoretical. The schedules of the lower bounds of a time between failures are shown in figure 3.

The analysis of data in figure 3 testifies, that in our case rare events bear more information, than often meeting: at $2 \leq n \leq 5$ convergence of settlement estimates is on the average 20% higher than received theoretically. For a further increase in fixed information n on accidents and accidents there is saturation. Apart from expansion of amount of data demands increase during the collection of statistic, but essentially doesn't change the value of received information. The mistake doesn't exceed 5%. It is quite acceptable for objects of this type.

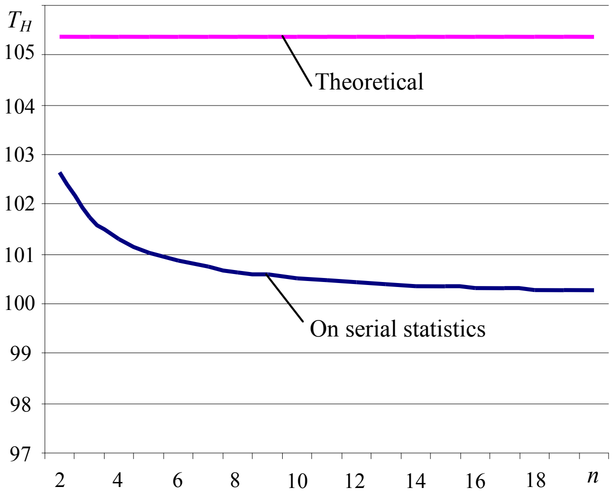

Fig. 3. Comparison of the lower bounds of an operating time of a vessel on refusal

From here, the important conclusion for practice follows: the assessment of the lower bound of safe operation for the river craft during navigation can be given at the selection volume about emergencies in the previous periods to $n = 6$. Further collecting information is useless for making decision on a technological level of a vessel condition for the next navigation period of its operation. This conclusion is confirmed theoretically: if analyzing change mean of population of an extreme of a variation row (a population mean of the lower bound of a time between failures $M(T_H)$), it is enough to take average size T_H in expression (1) on all possible α values:

$$M(T_H) = \int_0^1 \frac{nT}{n-1}\left[1-(1-\alpha)^{\frac{n-1}{n}}\right]\mathrm{d}\alpha = \frac{n^2}{2n^2-3n+1}T \qquad (2)$$

The graph of dependence of this function from n at $T = 1000$ hours is submitted in figure 4.

The analysis confirms the conclusion drawn above that, since $n = 6$ informations are sated. It is visible on asymptotic nature of change $M(T_H)$ at $n > 6$.

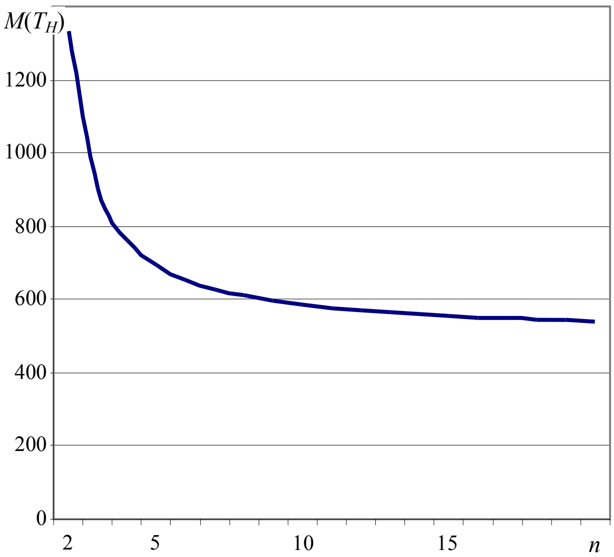

Fig. 4. The dependence of the population of the lower bound of vessel operating time on refusal $M(T_H)$ of number of n accidents for previous navigation

Let's estimate influence of a significance value on convergence of serial and theoretical estimates. For this purpose we will equate quantiles of the corresponding distributions:

$$\frac{nT}{n-1}\left[1-(1-C\alpha)^{\frac{n-1}{n}}\right] = -T\ln(1-\alpha) \qquad (3)$$

Where the inviscid coefficient of significance levels:

$$C = \frac{1}{\alpha}\left[1-\left(1+\frac{n-1}{n}\ln(1-\alpha)\right)^{\frac{n}{n-1}}\right] \qquad (4)$$

The figure 5 shown that with growth α the residual C grows and it grows with growth n. It is possible to show that for almost significant ranges of change $n \in [2; 10]$ and $\alpha \in [0.01; 0.1]$ the residual C dosen't exceed 5%. Therefore, at the solution of a wide range of tasks on the assessment of the lower bound of expected refusal for this type of vessel in the conditions of small selections application formula (1) gives a toe-out of the theoretical value no more than 5%. The nature of function of firmness of serial statistics at various values of its parameters we will find according to (5):

$$f(t) = \frac{1}{T}\left(1-\frac{n-1}{nT}t\right)^{\frac{1}{n-1}} \qquad (5)$$

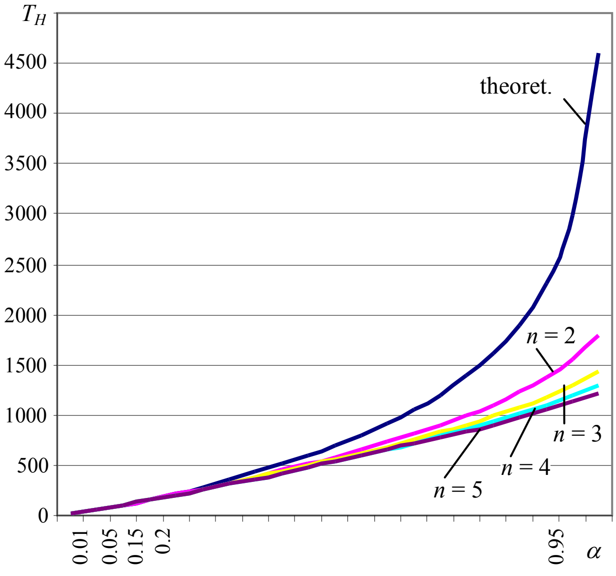

Fig. 5. A graphical representation of the function of quantile

The graphical interpretation of this situation is shown in figure 6.

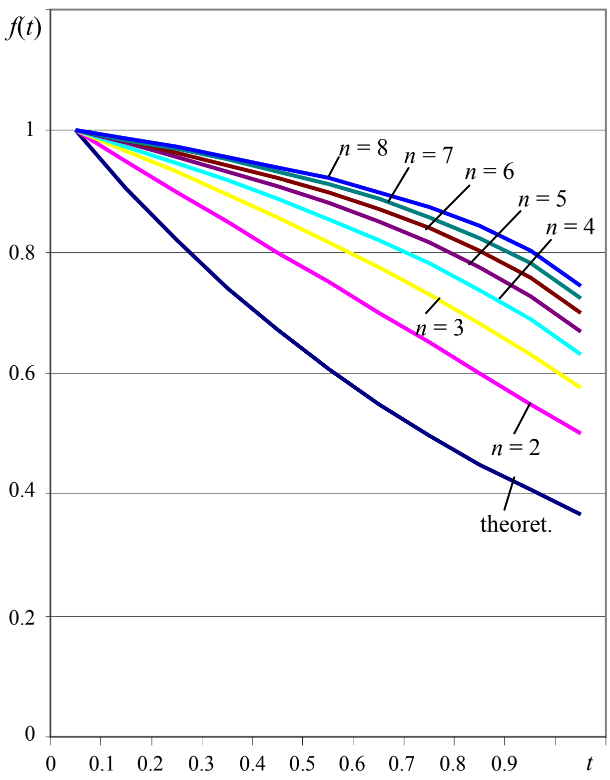

Fig. 6. Functions of firmness serial statistics

For simplicity here $T = 1$ and the left critical areas are presented. It is easy to be convinced that for $n = 2$ function (5) degenerates in a straight line and it is closest to theoretical (exponential) distribution. For $n > 6$ the line practically merge in critical areas. Let's remind that it is a question of the smallest (left) border of distribution.

Conclusions

The method presented in the work can predict work organization to improve the technological level of river crafts during the period between navigation.

The result of objective solution, takes into account the ststistic of accidents, as a result of technical condition of tis type of vessel, during the previous period of their operation (navigation).

The method is based on statistics of "small selections". This allows to claim that in forecasting assessing the level of technological the river craft, there is an objective decision on its accident-free operation in the following navigation.

Implementation of the received decisions gives the chance to plan the work on the current and planned repairs of river crafts during the period between navigation.

References

1. Arefyev I.B., Trojanowski J.: Avtomatizaciâ sudopropuska na vnutrennih vodnyh putâh (Automation crossing vessels for inland shipping), SPb, SPGTU, 2007.
2. http://bibliofond.ru/view.aspx?id=26836
3. Arefyev I.: Adaptation of integral Charakteristics Method for an Estimation of Critical Navigational Situations in Difficult Rout Sections. Vol. 18, No. 2A, 2009.
4. Klavdiev A.A., Pasevič V.: Adaptivnye tehnologii informacionno-veroâtnostnogo analiza transportnyh sistem (Adaptive technology for information and probabilistic analysis of transport systems). SZTU, Sankt-Peterburg 2009.
5. Chiu S., Tavella D.: Data mining and market intelegence for optimal marketing returns. Elsevier, 2008.
6. Danier H.H.: Operational Risk. Modeling Analytics. Wiley and Sons, 2006.
7. Knoge D., Yang S.: Social Network analysis. Sage Publications, 2008.
8. Cox E.: Fuzzy modeling and genetic algoritms for data mining and exploration. Morgan Kaufman Publishers, San-Francisco 2005, 230–238.
9. Sobczyk M.: Statystyka. PWN, Warszawa 2007.
10. Kleinbaum D.G., Klein M.: Logistic Regressin. Second edition, Springer Science + Businiess Media, New York 2002.
11. Wiadomości statystyczne nr 5 (Statistical News No. 5). Warszawa, Gmach GUS.
12. Hill T., Lewicki P.: Statistica. Metods and application. Stat Soft Inc., Tulsa 2006.
13. Kenny D.A., Kashy D.A., Gook W.L.: Dyadic data analysis. Guilford Press, New York 2006.
14. Ivčenko B.P., Martyščenko L.A., Tabuhov M.E.: Upravlenie v ekonomičeskih i socjalnyh sistemah (Management in the economic and social systems). SPb, „Nordmed-Izdat", 2001.
15. Gnedenko B.V., Belaiev U.K., Soloviev A.D.: Matematičeskie metody v teorii nadežnosti (Mathematical methods in the reliability theory). Nauka, 1965.