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AN EXAMPLE OF APPLICATION OF SOFTWARE FOR ASSESSMENT RELIABILITY DISTRIBUTION

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Abstract: *The paper presents a algorithm for estimation and selection of optimal reliability distribution. Reliability estimation is performed by means of the author's own software solution which is based on the selection of one of the six most frequently used theoretical distribution functions (exponential, Weibull, normal, lognormal, Rayleigh and gamma).*
An example of failure of bearings in centrifugal pumps of water supply pumping stations is analyzed. The software solution enables simple data input, necessary calculations and graphical representation of reliability indicators, as well as the nonparametric estimation of statistical hypotheses
Key words: *reliability, software, failure, centrifugal pumps*

1. INTRODUCTION

Starting from the fact that reliability is established in the design phase, ensured in the manufacturing phase, and confirmed and maintained in the exploitation phase, it can be seen that reliability is present during the entire life of a technical system.

Modern technical systems, and particularly those utilized for support to normal life of citizens, such as water supply, heating, electricity supply, are required to have a high level of reliability and be suitable for maintenance, and at the same time to have low costs and as short periods of time for elimination of failures as possible.

This paper established reliability indicators in elements using bearings of a centrifugal pump for water supply as an example. The authors used their own software solution for testing all distributions in order to establish which of them best describes the distribution of a random variable. On the basis of the results obtained, it is seen that experimental failure times in are best approximated by means of Weibull and normal distributions, which was confirmed on the functions of reliability, failure time density and failure rate.

Development of software solutions can considerably speed up research into the field of reliability, especially in the application of statistical methods of calculation.

2. APPLICATION OF STATISTICAL METHODS IN RESEARCH INTO RELIABILITY

Researchers in the field of reliability often express their dissatisfaction with deviations between the values of reliability obtained by calculations (foreseen) and the values that are really achieved during exploitation. That is why new approaches have been sought in order to eliminate weaknesses of the theory and practice of the classical prognosis of reliability of technical systems based on statistical data on the failure rate of elements.

In the strict application of the statistical approach, which is still widely used, failures are treated as abstract accidental events, and the condition of elements is reduced to only two conditions: uptime and down time. The method of estimation of reliability of elements or systems is then reduced to two steps. Firstly, the statistics of element failures is formed on the basis of testing or monitoring operation. Then, the probability theory is applied in order to determine which theoretical function of failure distribution density best corresponds to it (exponential, normal, Weibull, etc.) and it is then used in the reliability model, which serves for quantitative determination of reliability indicators, e.g. probability of proper operation.

Selection of the reliability indicator distribution represents the final goal of every procession of results in the field of reliability and the highest level of output information obtained on the basis of a certain number of empirical data. More precisely, the goal is to establish which distribution law among those that are theoretically developed and prepared in the form of tables for practical application corresponds most to the obtained experimental data. This is a very "sensitive" phase of calculation because its results influence all further conclusions and decisions regarding their practical application.

3. FOUNDATIONS FOR DEVELOPMENT OF THE SOFTWARE SOLUTION

One of the final goals in the research into reliability of technical systems is establishment of the theoretical distribution of the random variable, time IN OPERATION or time IN FAILURE. Based on the characteristics of distributions which most frequently occur in the problems of reliability (quality, readiness, maintenance, etc.) the conditions which characterize certain theoretical laws can be distinguished. Thus:

- in the case when the mean value and the standard deviation ($\overline{T}_{ur} = \sigma$) are approximately equal and when the failure rate is constant $\lambda(t) = const$, the possibility of approximation of the main set of data should be examined by means of the exponential distribution,
- when the mean value and the median are approximately equal, the hypothesis on the normal distribution ($\overline{T} = t_{50}$) should be checked,
- in the case when the failure rate rises in time and the mean value is higher than the standard deviation $(\lambda(t+\Delta t) > \lambda(t) \ \forall\ t \in (0,\infty)\ i\ \overline{t} > \sigma$, the hypothesis on the Weibull distribution should be checked. The influence of the Weibull distribution parameter on the form of distribution should be checked for:
    - $0,5 < \beta < 1,5$ - the exponential distribution should be examined,
    - $1,5 < \beta < 2,5$ – the Rayleigh distribution should be examined, and if it does not satisfy, the logarithm-normal distribution should be checked,
    - $2,5 < \beta < 4,5$ – the possibility of approximation by means of the normal distribution should be examined,
- when the failure rate $\lambda(t)$ increases, and then decreases in time, the possibility of approximation by means of the logarithm-normal distribution should be checked,
- if the failure rate decreases and if the mean value is smaller than the standard deviation ($\overline{T}_{ur} < \sigma$), the Weibull distribution with the parameter whose form is smaller than 1 ($\beta < 1$) should be examined,
- in the case when none of the previous conditions is satisfied, and
    - it is known that the initial data represent the minima of the random variable, the hypothesis on the distribution of minimum (extreme) values should be checked, or
    - when it is known that the initial data represent the maxima (extremes) of the random variable, the possibility of approximation by the distribution of maximum (extreme) values and/or by the gamma distribution should be examined.

The described procedure is presented as an algorithm in Figure 1.

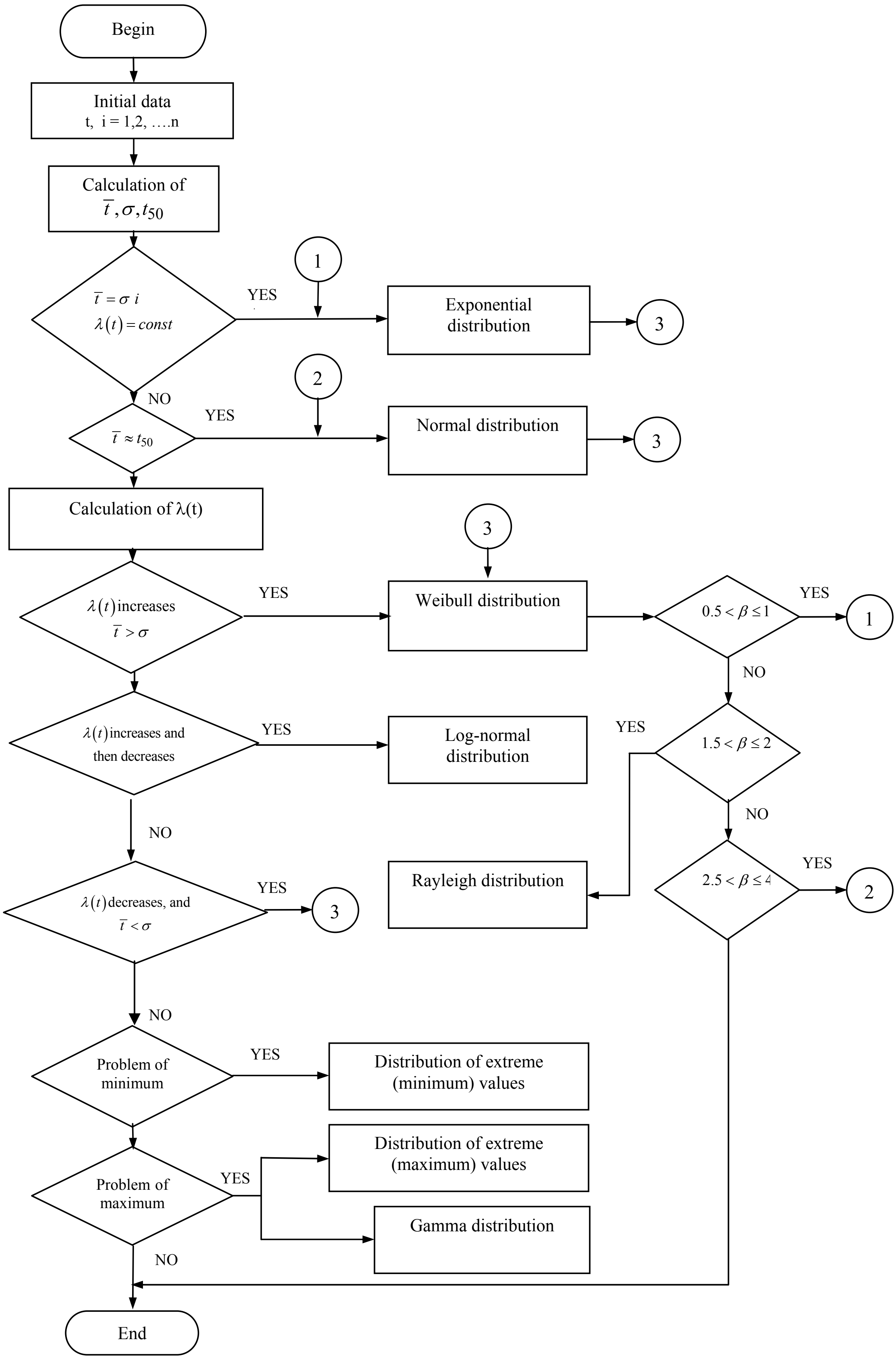

Fig. 1: Algorithm for determination of the reliability distribution law

4. ESTABLISHMENT OF RELIABILITY INDICATORS ON A CONCRETE EXAMPLE

For the purpose of establishing the theoretical law of element reliability distribution, a software solution based on the previous theoretical postulates was developed.

The bearing of the centrifugal pump for water supply was chosen as the element for establishing reliability indicators.

Data on failures were taken from several pumps of the same type which operate in several pumping stations in approximately the same modes of operation so that it can be considered that the sample is homogeneous. These are the reasons why the data presented in Table 1 can be statistically processed for the purpose of establishing reliability characteristics.

Table 1: Failure time in the bearing of the centrifugal pump presented in intervals and at the moment of occurrence of failure

Interval	1	2	3	4	5	6
Interval width; Δt [days]	200-500	500-800	800-1100	1100-1400	1400-1700	1700-2000
No. of failures $N(\Delta t)$	2	4	6	5	2	1
Failure times	252, 428	511, 632, 729, 793	832, 893, 954, 976, 1014, 1058	1155, 1209, 1314, 1377, 1379	1452, 1556	1820

If there are experimental data on failure times in certain elements, it is certainly the best way for statistical procession and estimation of the theoretical reliability distribution.

If there are no experimental data about failures, then the failure times in the given time period can be generated by means of random number generators.

On the basis of the statistical data for the condition of the centrifugal pump bearing, the values of parameters of theoretical functions of distribution, which approximate failure times in the best way, are determined analytically, with the application of the authors' own software solution.

The mentioned analysis established that the Weibull and normal laws of distribution best describe the reliability of the described bearing.

After establishing the theoretical distribution of reliability indicators (reliability function, unreliability function, failure time density function, failure rate function), statistical testing of distribution was performed by means of the $d\alpha$ test for 5 levels of significance: 0.01; 0.05; 0.1; 0.15; and 0.20.

For all levels of significance, in hypotheses on Weibull and Gauss distributions, each of the mentioned functions of reliability indicators of the centrifugal pump bearing can be accepted.

If none of the theoretical functions of distribution which describe the time of failure occurrence is found, then the distribution of extreme values is established, starting from minimum and then maximum ones. Distributions of extreme values are determined for minimum and maximum failure times per interval.

In this concrete example, it is interesting to emphasize that the minimum failure times of the bearing per interval are subjected to the Gumbel distribution, while the maximum failure times per intervals are subjected to the logarithm-normal distribution.

This offers the possibility for estimation of minimum and maximum times of bearing operation.

5. CONCLUSION

The indicators of element reliability were established in this paper on the bearing of the centrifugal pump for water supply. In order to see which distribution best describes the distribution of the random variable, all distributions were tested by the authors' own software solution, and one of its output results is presented in Figure 2. On the basis of the obtained results it is found that experimental failure times are best approximated by the Weibull and normal distributions, which is confirmed by functions of reliability, failure time density and failure rate.

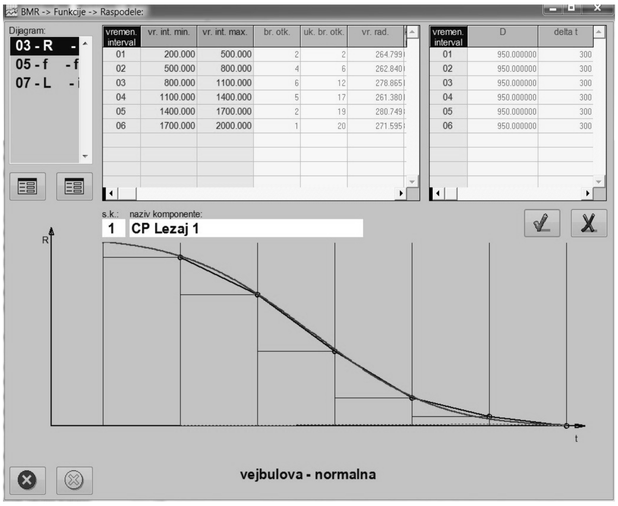

Figure 2: Experimental and theoretical functions of reliability of the centrifugal pump bearing

6. ACKNOWLEDGEMENT

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ПРИМЕР ЗА ПРИЛОЖЕНИЕ НА СОФТУЕР ЗА ОЦЕНКА НА РАЗПРЕДЕЛЕНИЕ НА НАДЕЖДНОСТ

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Ключови думи: *надеждност, софтуер, недостатъчност, центробежни помпи.*

Резюме: *Статията представя алгоритъм за оценка и избор на оптимално разпределение на надеждност. Оценката за надеждност се извършва чрез решение с помощта на авторски софтуер, което се основава на избора на една от шестте най-често използваните теоретични функции за разпределение (експоненциална, Weibull, нормална, lognormal, Rayleigh и гама).*

Анализиран е един пример за повреда на лагерите в центробежни помпи за водоснабдяване. Софтуерното решение дава възможност за опростено въвеждане на данни, необходими изчисления и графично представяне на показателите за надеждност, както и непараметрична оценка на статистически хипотези.