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FAILURE RATE-BASED CRITERION FOR SELECTING A DISTRIBUTION LAW WHEN STUDYING THE RELIABILITY OF TECHNICAL OBJECTS. CASE STUDIES

The selection of a distribution law describing the failures of a particular technical object is not a purely approximation task. The distribution law must correspond to the physical nature of the causes of failure. This determines the conclusions and decisions made based on the results of the reliability study. The main difficulties arise when the obtained statistical data can be described by several distribution laws based only on Pearson or Kolmogorov-Smirnov goodness of fit criteria. For example, if it is concluded that failures follow a normal distribution, this means that there is no single underlying cause of failure and that differences in the time to failure are caused solely by random variations while the Weibull distribution similar to it is caused by fatigue failure. If the Gamma distribution is observed, then failures occur as a result of damage accumulation, and the exponential distribution is caused by sudden failures and cannot be used to describe object failures due to wear and aging. The fundamental difference between these distribution laws is the nature of the failure rate. The criterion developed based on the method of maximum likelihood allows analysis of empirical data in terms of the greatest correspondence to the theoretical failure rate of one of the distribution laws

$$L_f = - \sum_{i=1}^k \ln(f_{li}) \rightarrow \min \quad (1)$$

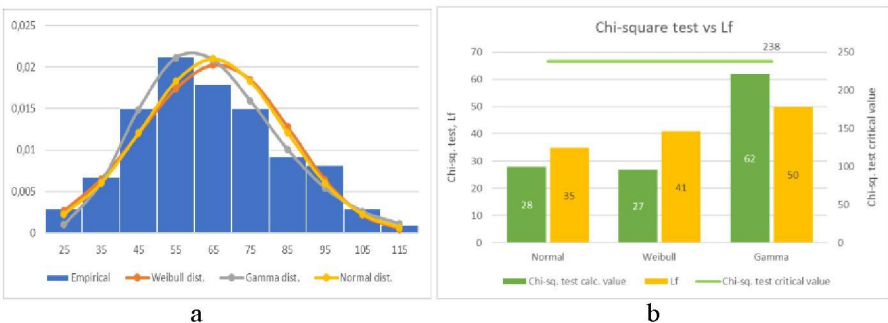
Here $f_{\Delta_i} = f_{\chi^2}(\Delta_i, \nu_i)$ is the Chi-square distribution density for the argument Δ_i and the number of degrees of freedom ν_i .

This criterion was investigated in detail based on a simulation experiment using generated samples, as well as based on a small number of physical experiments. For a more reliable and justified use of the criterion, it is necessary to verify it based on the results of independent real-life studies of as many physical objects as possible and compare it with the conclusions drawn by the authors based on other considerations.

Fig. 1 shows the results of the turning cutters tool life study according to P. Katsev (1974). As can be seen, the three theoretical distributions are very close to the empirical histogram (Fig. 1a). All of them meet Pearson's chi-square goodness of fit criterion (Fig. 1b). Still, the nature of the failure rate curves is totally different (not shown here). Based on the value of the L_f criterion (Fig. 1b), the empirical distribution corresponds to a normal one, which coincides with the author's conclusions.

Fig. 2 shows the results of the bearing reliability study according to E. Zaretsky et al. (2017). The theoretical gamma and Weibull distribution curves are very close to each other. To the empirical histogram (Fig. 2a). The theoretical normal distribution curve is slightly different. However, all three demonstrate compliance with Pearson's chi-square goodness of fit criterion (Fig. 2a, Fig. 2b). The same can be said for the failure rate curves, which is quite natural given the properties of the above distributions. From the values of the L_f criterion, the empirical distribution corresponds to the Weibull one, which coincides with the author's conclusion as well as with well-known facts from the wide engineering practice.

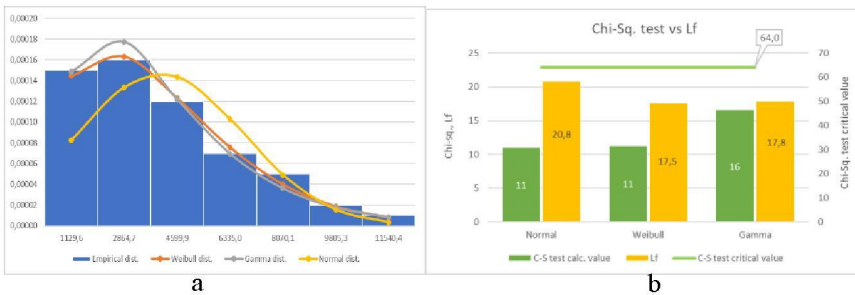
In total, 8 cases were analysed and the results of that confirm the relevance of the L_f criterion.



a – empirical histogram vs theoretical distributions;

b – Pearson chi-square test and L_f criterion.

Figure 1 – Results of turning cutters reliability study.



a – empirical histogram vs theoretical distributions;
b – Pearson chi-square test and L_f criterion.
Figure 2 – Results of bearings reliability study.