FAILURES FLUCTUATIONS BASED ON MEAN TIME BETWEEN FAILURES AND REPORTING PERIOD

FLUKTUÁCIE PORÚCH ZÁVISLOSTI OD STREDNEJ DOBY MEDZI PORUCHAMI A SLEDOVANÉHO OBDOBIA

Tomáš STEJSKAL

Abstract
Mean time between failure determined by the machine and equipment failure. When planning costs it is necessary to know the likely rate fluctuations failures. This can largely disrupt budget items. The basic premise is thus to create a suitable calculation model. This contribution is dedicated to this.

Key words
Failure, fluctuation, MTBF

Itroduction

The actual parameter mean time between failures only specifies failure rate of a machine or device. Only indirectly determines the estimated cost items necessary to repair the damage. Therefore, it may happen that at a higher failure rate, the total cost of repairing damage will be lower than in lower failure rates. It is therefore appropriate to statistically assess the likelihood of potential costs of various disorders. Based on it’s the predicted maximum fluctuations rate as a worst case cost of which is necessary to count by the machine operate. The issue of fluctuations failures is not limited to mechanical units, but also to monitor the process. Fluctuation signals can be monitored also the monitoring of the operation of technical systems [2].

Character of failures distribution

In the case of different failures that are independent we can assume an exponential distribution. General conditions for the emergence of exponential distribution are [1]:

- The object consists of a large number of sub objects that may show a fault condition.
- Individual sub-objects are independent of each other in time, especially with regard to the appearance of failure.
- Probability of failure of any sub object is not a significantly more important than other once.

In most cases, these conditions are fulfilled. Computational schemes are based on the exponential distribution.
When planning maintenance costs are, is useful to know fluctuations failures rate for any reporting period. Furthermore, it is convenient to divide the various possible faults in different cost levels.

The calculation of the fluctuations failures rate during the reporting period

Failures fluctuation with exponential distribution depends on the mean time between failures and the size of the reference interval. Thereby longer the interval, and mean time to this shorter interval, the fluctuations are smaller. This fact can be easily verified in experimental modelling spreadsheet editor. The computational model can be obtained from the following two ways. The task is to estimate the maximum fluctuation failures during the reporting period, if known mean time between failures.

The first way:
Exponential distribution has a memoryless property. This means that at any point in time is determined by the same probability, a fault occurs. It is similar to the case of random walking, after any step is the same probability of execution step to the right also left. The standard deviation of the "k" action taken is equal to the $\sqrt{k}$ .This result follows from the properties of the binomial distribution, which is also random walking. In the case of exponential distribution is the standard deviation equal to the MTBF. (Mean time between failures). Distribution of random walking for many experiments is close to a normal distribution. So, rule six sigma (Fig. 1.).

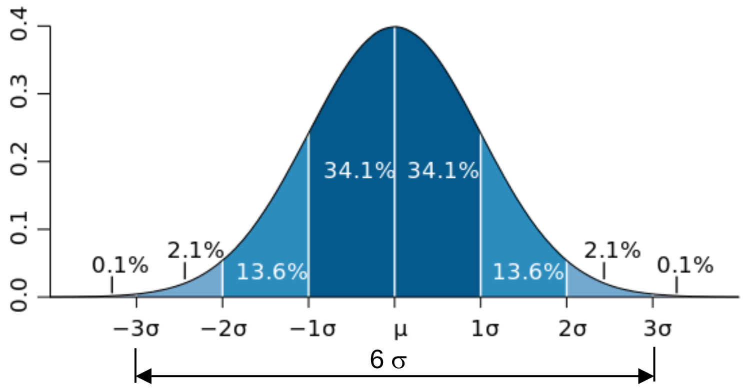

Fig.1: Normal distribution

If, on average, performed n failures during the reporting period, then the standard deviation is $\sqrt{n}$. Then the actual number of possible faults pays that fall into the following intervals:

$$n_s = n \pm \sqrt{n} \qquad (1)$$

True in an average of 69% of cases, because it is the interval – two sigma. For six sigma interval will apply:

$$n_s = n \pm 3\sqrt{n} \qquad (2)$$

The parameter $k\sqrt{n}$ is a measure of distribution of fluctuations for the reporting period. It is appropriate to note that in case of fluctuation which is at most equal to the larger $3\sqrt{n}$ is likely to only 0.1% of observed period.

The second way:
Poisson distribution expresses the probability of a certain number of events per unit time. Expresses the probability that will be implemented exactly the number of "events" at a fixed time interval, while knowing the mean value of these events for that period of time (even if these events are not mutually dependent on one another).
In case, is known frequency by the implementation of the observed phenomenon (i.e. the average number of events appearing in the period), then the equation for the probability has the following form:

$$f(k,n) = \frac{n^k.e^{-n}}{k!} \quad \text{for} \quad k = 1,2,... \tag{3}$$

n - is a positive real number, which indicates the mean number of events that fall on the selected time interval.

Of the Poisson distribution properties follows:

Median

$$E(t) = n \tag{4}$$

Variance for the Poisson distribution

$$D(t) = \sigma^2 = n \tag{5}$$

The standard deviation for the Poisson distribution

$$\sqrt{D(t)} = \sigma = \sqrt{n} \tag{6}$$

Defining of confidence interval for the unknown probability distribution is as follows:

$$\alpha = E(t) \pm k.\sqrt{D(t)} \tag{7}$$

k - is the multiple of determining the size of the interval.

In the case of an unknown distribution, the confidence and credibility will determine by Chebyshew inequality [3]. This says that the probability that the variable “t” fell outside the confidence interval of median $E(t)$ is less than the value $\frac{1}{k^2}$. Thus, the following applies:

$$P(\ |t - E(t)| > \mathrm{k}.\sqrt{D(t)}) < \frac{1}{\mathrm{k}^2} \tag{8}$$

In case of fluctuations will then pay that fall into the α interval of reliability:

$$n_s = n \pm k.\sqrt{n} \tag{9}$$

Example

The task is to estimate the maximum fluctuations in costs in one month if, MTBF = 100 hours, mean time to repair MTTR = 1.5 hours. The cost per hour of downtime N_h= 500 euros. The average cost per repair N_r= 20 euros. It’s given a two-shift operation.

Monthly average occurs in n = T / MTBF failures.

$$n = \frac{320}{100} = 3.2 \quad \text{failures / month}$$

For the case six sigma pays:

$$n_s = n \pm 3\sqrt{n} = 3.2 \pm 3\sqrt{3.2} = 3.2 \pm 5.36$$

It is unlikely event of fluctuations. For practical purposes we can be interested in what is the probability of the maximum fluctuation in one year by monthly statements. It is therefore necessary to choose the opposite approach for solutions. To determine the average fluctuations that are already exceeded at 12% i.e. one month per year, then it is necessary to change the multiple factor "k". So that corresponded to one twelfth of a year. I.e. $\frac{1}{12} = 0.08333 \rightarrow 8.3\%$. This corresponds to the quantile = 1.37 (Fig. 2). Then the fluctuation rate is as follows:

$$n_s = 3.2 \pm 1.37.\sqrt{3.2} = 3.2 \pm 2.02$$

Duration of downtime T_p in the worst month:

$$T_p = n_{s\max}.MTTR = 5.4 \times 1.5 = 8.1 \text{ hours}$$

Cost of downtime N_p :

$$N_p = T_p.N_h = 8.1 \times 500 = 4050 \text{ euros}$$

The total average cost of downtime and repairs:

$$N_T = N_p + n_{s\max}.N_r = 4050 + 5.4 \times 20 = 4158 \text{ euros}$$

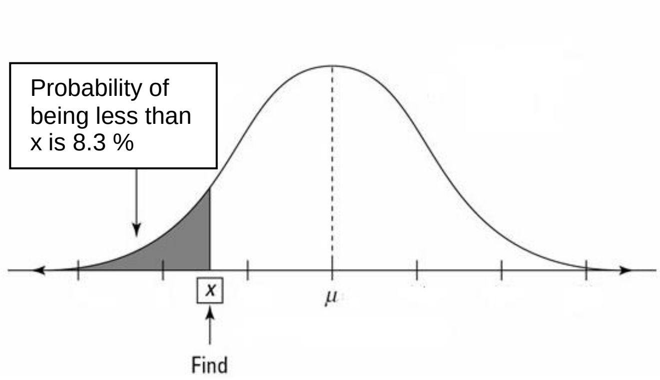

Fig.2: Quantile - normal distribution

Summary

Suitable computing model allows estimation of fluctuations failures correctly predict the rate of cost of damages in case of disturbances. It's only a partial result. Calculations must also support authenticity of estimated mean time between failures, resulting in a minimum amount of data in the sample. We must also distinguish between significant and insignificant problems in terms of production efficiency.

Kľúčové slová

poruchy, fluktuácie, MTBF

Contribution was created under projects KEGA 047TUKE-4/2011, VEGA 1/0810/11 and ITMS 26220220164 applied research.

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Kontaktná adresa

Ing. Tomáš STEJSKAL PhD.
TU, Strojnícka fakulta, Katedra výrobnej techniky a robotiky, Nemcovej 32, 042 00 Košice
e-mail: tomas.stejskal@tuke.sk, tel: 055/6023238