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EVALUATION OF COMPONENT SURVIVAL PROBABILITY IN AIRCRAFT OPERATION

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Summary. The subject of this diploma paper is handling the issue of probability of failure to components in the programming environment of MS Excel based on the Weibull distribution. We came way is possible using the free software package to calculate the probability of failure, respectively, the probability of survival component. We address and introduction to the issue of the probability of survival, describing concepts such as reliability, durability risk. In view of the fact that, for determining the probability of failure to the component respectively survival should be properly estimated symbol probability distribution, in this work we analyze, clarify the distribution of all types of modeling, such as exponential, Poisson, gamma, log - normal and normal distribution. It contains all the necessary information that we have so that we can recognize this issue and so that we can successfully calculate the probability of failure to the components. So also it details the Weibull distribution, the specifics and the way including all necessary formulas. The second part is devoted to specific examples in which we described the procedures to calculate the probability of failure and how to create the algorithm in the programming environment of MS Excel to calculate the probability. The work includes instructions for calculating the probability shows how we can draw graphs of the probability of failure to the components and how we can determine, respectively, to calculate the probability at different numbers of loading cycles. It stresses the importance of calculations and thus also factors that have the probability of failure calculations great impact and the sheer importance of estimating survival probability respectively failure of component in aviation.

Keywords: Weibull analysis, Probability o failure, Survival graph, component, reliability, risk, modeling, continuous distribution, discrete distribution, Commands Ms Excel

1. EVALUATION OF COMPONENT SURVIVAL PROBABILITY IN AIRCRAFT OPERATION

The acceptable level of safety has been, is and will be one of the most important requirements in aviation. In the early days of aviation, when aircraft had most of the similar structure of the wings, fuselage chassis and powertrain was possible deterministic rules proposed procedures, including the calculation procedures used by safety factors. The level of safety has been verified only by historical experience of similar structures. Nowadays, when the development of aviation technology advancing rapidly, and the components are becoming increasingly complex, this level of security is not enough. The solution was found in the safety analysis and reliability tests of individual components that allow us to predict when the component is damaged or on which it is to be replaced in order not to compromise the security of air transport. When analyzing the reliability of components is mostly on empirical environmental data, which are obtained either by experiment or observation of samples evaluated components. Reliability qualification mainly used methods of mathematical statistics and probability theory, which is the fundamental nature of the use of appropriate theoretical distributions.

2. THE BASIC DEFINITION OF RELIABILITY

Reliability is a quality product to meet the prescribed period required functions while maintaining the operating parameters of the technical specifications of the product; It expressed manu- facturers characteristics such as reliability, durability, serviceability, availability and so on.

Life is the product's ability to perform a required function to limit state defined technical conditions. It is expressed numerically example life-cycle or period of use.

Reliability - property products meet the prescribed function without failure over a specified time in specified conditions. Numerically, it is expressed for example. probability of failure-free operation in a specified time interval, medium time trouble-free operation and failure rate.

Probability of failure - the likelihood that within a certain time after commissioning a fault of the product. This is determined by dividing the number of products with a failure in a given time interval to the total number of products at entry.

Instead of a failure - the probability of failure of the product occurs as infinitely small time unit, after a given time with the proviso that up to now the problem is connected. Is determined by the ratio number of breaches of products for small unit of time after a given time the number of intact products to this point.

Modeling parameters of confidence there are a number of standard statistical distribution. But only a relatively small number of statistical distribution is able to satisfy most of the needs in terms of reliability. Their use depends in each case on the nature of the data we have available. This chapter explains the most commonly used types of distributions, used in the analysis of reliability, examples of applications and criteria for their use.

3. CONTINUOUS DISTRIBUTION

3.1. Normal (Gaussian) distribution

Normal distribution in reliability has two main applications. In both areas, it is in particular a component analysis, showing a failure in areas of wear. Separation of disorders caused by wear and tear is close to normal, so the use of this distribution for evaluation or estimate of reliability is valid. Another use is in the analysis of selected devices and their ability to meet defined requirements. The two parts made at the same specification are not always exactly the same. The variability of parts then leads to the variety of systems that the pieces consists. Therefore, the design must take into account this diversity, otherwise the system may not meet specification requirements due to the combined impact of variability of the components. Quality management is another area of application. Central Limit branch is the basis for the use of the normal distribution. It says that a large number of identically distributed random variables with finite mean and variance is normally distributed. The probability density function for the normal distribution is:

$$f(t) = \frac{1}{s\sqrt{2\pi}} . e^{\left[-\frac{1}{2}\left(\frac{t-\mu}{\sigma}\right)^2\right]}$$

where: $-\infty < t < \infty$

μ = median

σ = standard deviation, which is the square root of the variance

3.2. A log-normal distribution

It represents the distribution of a random variable, which is logarithmic natural logarithm in a normal distribution. It is therefore a normally distributed random variable *ln (t)*. The probability density is given by:

$$f(t) = \frac{1}{\sigma t\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{ln(t)-\mu}{\sigma}\right)^2} \qquad \text{pre } t \geq 0$$

where median is: $e^{\mu+\frac{\sigma^2}{2}}$

a mean square deviation: $\left[e^{(2\mu+2\sigma^2)} - e^{(2\mu+\sigma^2)}\right]^{\frac{1}{2}}$

where: μ = median and square deviation (SD) *ln(t).*
σ = square deviatoin (SD) *ln(t).*

3.3. Exponencial distribution

In the area of reliability it is one of the most important division. It is mainly used to predict the reliability of electronic equipment. Exponential distribution is useful only if you know the right use. It describes a situation in which the failure frequency which is constant and we demonstrate that the failure is generated by a Poisson process. The advantages are:

- Mathematically it is very acceptable,
- It has a wide applicability,
- Includes a simple, easy to estimate a parameter (λ)
- The additive, which means that the sum of independent variables is exponentially distributed allocation exponentially.

3.4. Discrete distribution

The binomial distribution is used in situations where there are only two outcomes and success or failure while the probability remains the same in all the experiments. It is particularly useful in evaluating the quality of work and reliability. The probability density function of this distribution is:

$$f(x) = \binom{n}{x} p^x q^{n-x}$$

where: $\binom{n}{x} = \frac{n!}{(n-x)!x!}$ a $q = 1 - p$

f(x) is the probability of achieving good results over *X*, (*N x*) of poor performance in a sample of *n* determinations, where *p* is the probability of achieving a good result (success) and *q* (or *p*-1) it is the probability of a poor outcome (failure). The probability of achieving *R* (or less) success in *n* trials or cumulative distribution function is determined by the relationship:

$$F(x;r) = \sum_{x=0}^{r} \binom{n}{x} p^x q^{n-x}$$

The distribution is quite often used in the analysis of reliability. It is considered an extension of the binomial distribution if n is infinite. The practice is used in approximation to the binomial distribution with $n \geq 20$ and $p \leq 0.05$.

As events are divided by the Poisson distribution, they occur at a constant average intensity, and the number of events occurring at each time interval is the number of events occurring at any other time interval independent. The number of failures in a given time, for example, using the equation:

$$f(x) = \frac{a^x e^{-a}}{x!}$$

where: *a* is the expected number of faults and *x* is the number of faults.

4. WEIBULL DISTRIBUTION

Reliability qualification using methods of mathematical statistics and probability theory, the basic idea is the use of appropriate theoretical distributions. One of these is the division of the Weibull distribution, which is widely applied as a theoretical model for statistical modeling of reliability components. This division is able to model data sets, whose values are greater than 0. The first publications on the Weibull distribution were published in 1951. Since then there has been a spread and popularity of this division especially in the analysis of reliability and durability of components and parts. A version of probability density function is:

$$f(t) = \frac{\beta}{\eta} . \left(\frac{t-\gamma}{\eta}\right)^{\beta-1} . e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}}$$

β is shape parameter
η is a scaling parameter or characteristic life
γ is the minimum lifetime

The most common case in practice is the reliability when it is 0 γ (assuming the start of failure at t=0) and the probability density function is then passed to the form:

$$f(t) = \frac{\beta}{\eta} . \left(\frac{t}{\eta}\right)^{\beta-1} . e^{-\left(\frac{t}{\eta}\right)^{\beta}}$$

Relationship for instantaneous failure rate for a trouble-free passes to the form:

$$R(t) = e^{-\left(\frac{t}{\eta}\right)^{\beta}}$$

$$h(t) = \frac{\beta}{\eta} . \left(\frac{t}{\eta}\right)^{\beta-1}$$

4.1. Weibull distribution in Microsoft Excel

Modeling data using Weibull analysis requires some preparation and, in particular collection of the necessary data. In our case it was the number of cycles to damage the component to 10 samples. After the test and determining the required input data such as the number of cycles to damage to components, it is necessary to create a table containing the following elements.

4.2. Preparing to analyze

• In cell A1 "Design Cycles" (Table 4), we will inscribe the number of cycles over which the individual has been damaged samples. Individual samples we have ordered from the lowest number of cycles at which the sample has failed the highest.

• In cell B2 "Rank" (Table 1) - (Table 4), thus ranking. The cells in this column contain a sequence of individual samples, in this case from 1 to 10th

• In column C, enter the name "Median Ranks" (Tab. 4). This calculation can be achieved by several methods, the most frequently used in the median position.

• In cell C1, enter thus marking Median Ranks cell C2 and enter the formula: = ((B2-0.3) / (10 + 0.4)). We copy this formula from cell C2 to cell C11.

• Cell D1 is called 1 / (1-Median Rank) and cell D2 enter the formula: = 1 / (1-C2) . Copy the formula to cell D11.

	A	B	C	D	E	F
1	Design Cycles	Rank	Median Ranks	1/(1-Median Rank)	ln(ln(1/(1-Median Rank)))	ln(Design Cycles)
2	384 558	1	0,067307692	1,072164948	-2,663843085	12,8598499
3	483 331	2	0,163461538	1,195402299	-1,72326315	13,088457
4	508 077	3	0,259615385	1,350649351	-1,202023115	13,13838829
5	515 201	4	0,355769231	1,552238806	-0,821666515	13,15231239
6	615 432	5	0,451923077	1,824561404	-0,508595394	13,33007974
7	666 686	6	0,548076923	2,212765957	-0,230365445	13,41007445
8	726 044	7	0,644230769	2,810810811	0,032924962	13,4953659
9	755 223	8	0,740384615	3,851851852	0,299032932	13,53476835
10	807 863	9	0,836538462	6,117647059	0,593977217	13,60214777
11	848 953	10	0,932692308	14,85714286	0,992688929	13,6517591

Figure 1 Input data for the calculation of Weibull

• E1 cell will contain the name of the ln (ln (1 / (1-Median Rank))) to put the cell E2 formula = LN (LN (D2)). The formula will copy the E11.

• Finally we transform data cycles. In cell F1, enter the name of ln (Design Cycles) and in cell F2 formula: = LN (A2) by copying again after cell F11.

4.3. Parameter Estimation of Weibull

Cumulative distribution function can be converted so that it appears in the familiar shape of the line. $Y = mx + b$. This design is achieved with the help of non-linear transformation of the cumulative distribution function of the Weibull distribution function at linear.

Comparing this equation with a simple equation of the line, we see that the left side of the equation corresponds to the value Y, $\ln x$ corresponds to the value X, β corresponds to the value m, and - $\beta.\ln\alpha$ responds b. Thus, when performance linear regression to estimate a parameter Weibull distribution follows directly from the slope of the line.

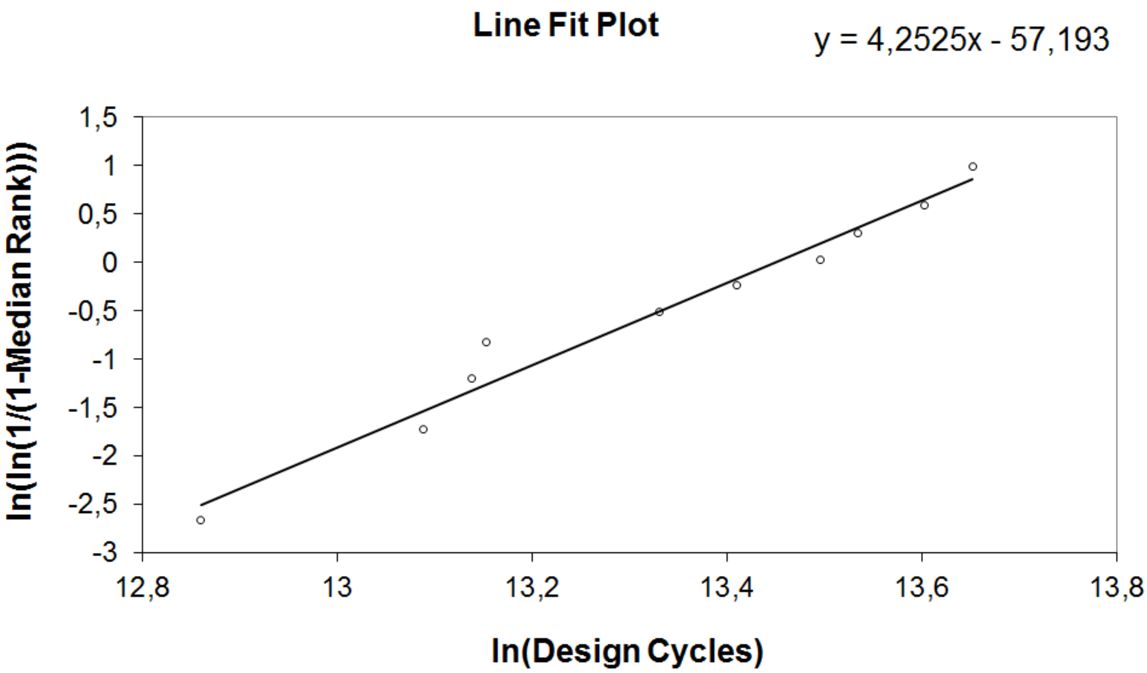

Figure 2 Graph linear regression equation of the line

Parameter α is calculated from the relationship: $\alpha = e^{-\left(\frac{b}{\beta}\right)}$

In this step, we have prepared all the raw data for processing Weibull analysis.

• In cell A17 enter the label cycles, which represents the number of cycles over which we view the likelihood of damage to components

• In cells A18 to A46 enter specific values cycles

• In cell B17 (Design) deposits formula = 1-WEIBULL (A18; B $ 14, B $ 15; TRUE), with the help of which will plot the probability of damage to the components at the individual number of cycles. [10]

In case you enter the formula: = WEIBULL (A18; B $ 14, B $ 15; TRUE), MS Excel draw graphs of survival probability component. This formula is the calculation where x = the number of cycles. Substituting the values of the previous data thus x, α and β can be calculated using the formula likelihood of damage to the components for a specific number of cycles:

$$R(300{,}000)_{Design\ A} = e^{-\left(\frac{300{,}000}{693332{,}6228}\right)^{4{,}25}} = 0{,}9720$$

From the above formula that, after 300 000 cycles, the probability of survival of the component 97.2%. This complicated calculation has been replaced in MS Excel the above formula = 1-WEIBULL (A18; B $ 14, B $ 15; TRUE).

Table 1 The number of cycles and the likelihood of survival component

Coefficients	Beta/Alpha
4,2525	4,2525
-57,193	693332,6228
Cycles	**Design**
0	1,0000
50 000	1,0000
100 000	0,9997
150 000	0,9985
200 000	0,9950
250 000	0,9870
300 000	0,9720
350 000	0,9468
400 000	0,9081
450 000	0,8529
500 000	0,7796
550 000	0,6883
600 000	0,5823
...	...

Based on data (Tab. 1) to create a graph that renders us a probability curve component damage. In case of using the formula = 1-WEIBULL (A18; B $ 14, B $ 15; TRUE), we will plot the survival probability component.

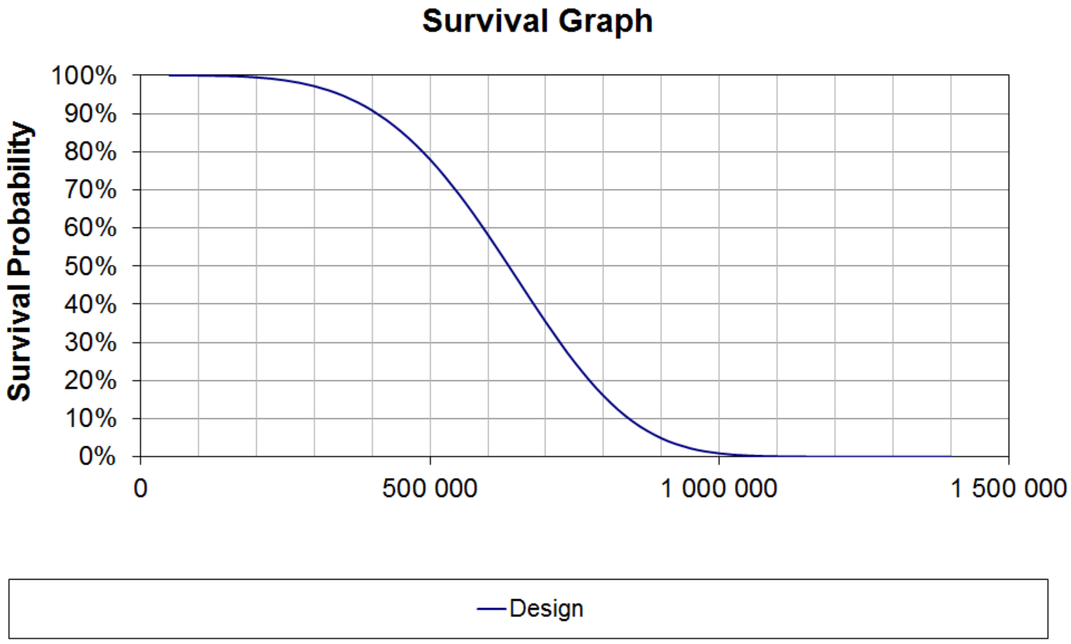

Figure 3 Survival Graph

Weibull strength distribution is mainly in its universality. Depending on the parameter value is able to zoom in, respectively, show exponential, normal or even asymmetric distribution. The versatility of this division also supports MS Excel program that offers us many options for processing the issue, without the need to purchase expensive and complicated statistical software packages. Therefore, this program is very popular with the majority of engineers who work with this topic.

5. LITERATURE LIST

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