Research on Electronic Product Storage Reliability Based on Similar Product Prediction

Zenghui Cui, Zhaolong Xuan, Tianpeng Li, Qingxi Yang
Army University of Engineering Shijiazhuang Campus, Shijiazhuang 050003, China
380896012cui@163.com

Abstract. For the long-term storage of some electronic products, the life value of the electronic product is calculated in combination with the non-work failure rate model, and the life value is applied to the similar product prediction method to obtain information about the storage reliability of the electronic product. The calculation process of the non-work failure rate model and the prediction method of similar products is introduced, and the application examples are used to verify, reduce the error when using the entire system life information for estimation, and improve the accuracy of storage reliability.

1. Introduction
With the development of the electronics industry, electronic products have been applied to various fields of human life, and gradually become indispensable basic components. However, in some special industrial fields, electronic products, as the core key components, occupy an absolute proportion of long-term storage during their lifetime, which requires that electronic components must have the ability to achieve a certain degree of reliability after long-term storage, so it is very important to study the storage reliability of electronic products.

At present, there are many methods for evaluating the storage reliability of products, including natural environmental storage, accelerated life (degradation) tests, similar product prediction, weak link life, etc [1]. These methods have their own advantages and disadvantages, and there are many related studies. The data stored in the natural environment is the most reliable and can reflect the real situation of the product, but it has the disadvantages of long time and manpower and material resources; accelerated life (degradation) test technology and theory are relatively mature, but most of them are from single environmental factors or double environmental factors are considered, which is inconsistent with the actual environment; the weak link life is based on the principle of the barrel, the weak link of the product is analyzed to determine the life of the entire system; similar product prediction is suitable for products with strong inheritance, using similar products historical data and environmental data to evaluate the reliability of new products[2].

Electronic products generally exist as part of a system. When there is no reliability information for electronic products, the lifetime value specified at the time of delivery of the entire system is generally used[3]. In this paper, the non-work failure rate model is used to estimate the life information of electronic products, which is more accurate than the life information of the entire system. The estimated life of the electronic product is applied to the similar product prediction method, the reliability-related information will be more accurate.

2. Prediction of reliability parameters of similar products
For electronic products, the main factors that affect their failure under long-term storage conditions are the product's structural characteristics, sealing, storage environment and stress level. If the above characteristics of the two products are similar, the failure characteristics can be considered to be similar, at least the two can refer to each other [4].

2.1. Life distribution and accelerated model determination
Life distribution is the distribution of life random variable [5]. Common life distributions include exponential distribution, weibull distribution, and lognormal distribution. The exponential distribution is suitable for the failure modes associated with electronic products, the weibull distribution is suitable for the life distribution of most electronic, mechanical and electromechanical products, and the lognormal distribution is suitable for the life mode of failure modes caused by fatigue failure [6]. From experience [7], weibull distribution has strong plasticity, and its shape parameters take appropriate values to obtain different life distributions such as exponential distribution and lognormal distribution.

Combining the characteristics of weibull parameters, when the life of the electronic product is unknown, it is preliminarily selected to obey the weibull distribution, and the reliability distribution function is as follow:

\[ R(t) = \exp[-(t / \eta)^m] \]  

In the formula, \( m \) is the shape parameter and \( \eta \) is the characteristic life.

From the perspective of accelerated life test, products with good sealing performance can choose temperature to do single-stress accelerated test. The accelerated model generally uses arrenius model [8] to express:

\[ \ln \eta = \alpha + \beta / T \]  

In the formula, \( \alpha, \beta \) is the acceleration parameter and \( T \) is the absolute temperature.

It can be seen from formula (1) and formula (2) that in order to analyze the reliability of the electronic product through accelerated testing, it is necessary to have certain a priori information on the above four variables.

2.2. A priori information estimate
When choosing the lowest reliability, the calculated storage life should meet its specified storage life. According to formula (1), when the reliability is \( R_L \), its life \( t_L \) is as follow

\[ t_L = \eta_L [\ln(1 / R_L)]^{1/m} \]  

In the formula, \( R_L \) is the lower limit of storage reliability, and \( t_L \) is the lower limit of reliable storage life.

The logarithmic transformation of formula (3) is as follow:

\[ \ln t_L = A + B / m \]  

In the formula, \( A = \ln \eta_L, B = \ln[\ln(1 / R_L)] \).

Summarize the life information of similar products, as shown in Table 1.

| Table 1 Similar product life information |
|-----------------------------------------|
| Product       | Shape parameter \( m \) | Characteristic life \( \eta \) | Acceleration parameter \( \alpha \) | Acceleration parameter \( \beta \) |
|---------------|-------------------------|-----------------|-----------------|-----------------|
| Similar products \( X \) | \( X_1 \) | \( X_2 \) | \( X_3 \) | \( X_4 \) |
| Similar products \( Y \) | \( Y_1 \) | \( Y_2 \) | \( Y_3 \) | \( Y_4 \) |

The calculation steps are as follows:
1) According to formula (4), combining the shape parameter values and characteristic life values of similar products X and Y, the value of A and B can be obtained.

2) Take the specified storage life of the entire system at the factory as the life value $t_L$, and bring it into formula (4) to obtain the shape parameter of the electronic product, and bring the shape parameter into formula (3) to obtain the value of the characteristic life lower limit $n_L$.

3) Bring the acceleration parameters of similar products in Table 2 into formula (2), and use the least square method to obtain the acceleration parameters $\alpha$ and $\beta$ of the electronic product.

3. Estimation of storage life of electronic products
Electronic products are generally applied to a large number of integrated circuits, resistors, capacitors, diodes, transistors and other electronic components [9]. During the long-term storage of these electronic components, in addition to the prescribed performance testing, most of the time it is in a non-working state, so the non-working failure rate prediction model in GJB/Z 108A-2006 can be used to preliminarily judge its storage reliability, and then use the relevant failure rate equation to estimate the life value of the entire electronic product.

3.1. Electronic component failure rate prediction
Due to different manufacturing processes, materials and functions of electronic components, the non-operating failure rate prediction models are also different from each other. Here, only the failure rate models of semiconductor monolithic integrated circuits, diodes and general capacitors are listed. Other models can be found in the 108A manual.

Non-operating failure rate model of semiconductor monolithic integrated circuits:

$$\lambda_{NP} = \lambda_{NB} \pi_{NE} \pi_{NJ} \pi_{NP} (\pi_{NY} + \pi_{NF}) \pi_{CYC} \pi_{SL}$$

Diode non-operation failure rate model:

$$\lambda_{NP} = \lambda_{NB} \pi_{NE} \pi_{NJ} \pi_{NT} \pi_{CYC}$$

General capacitor non-operation failure rate model:

$$\lambda_{NP} = \lambda_{NB} \pi_{NE} \pi_{NJ} \pi_{NT} \pi_{CYC} \pi_{Nch}$$

The terms and corresponding symbols involved in the model are shown in Table 2:

| Term                               | Symbol |
|------------------------------------|--------|
| Non-work failure rate              | $\lambda_{NP}$ |
| Non-working basic failure rate     | $\lambda_{NB}$ |
| Non-working environment coefficient| $\pi_{NE}$ |
| Non-working quality factor         | $\pi_{NJ}$ |
| Non-operating temperature coefficient| $\pi_{NT}$ |
| Packing factor                     | $\pi_{NP}$ |
| Equipment power on-off cycle coefficient| $\pi_{CYC}$ |
| Product maturity factor            | $\pi_{AP}$ |
| Non-working surface mount factor   | $\pi_{Nch}$ |
3.2. Estimated failure rate of electronic products

In the case of long-term storage, the failure of any component on an electronic product will cause its performance to decrease or the failure to occur. The type of reliability model can be analyzed according to the specific electronic product. Now suppose that the reliability model of the electronic product is a series model and the failure rate expression is as follow[10]:

\[ \lambda(T) = \sum_{i=1}^{k} n_i \lambda_i(T) \]  \hspace{1cm} (8)

In the formula:
- \( \lambda_i(T) \): Failure rate of the i-th component at the storage temperature \( T \);
- \( n_i \): The number of i-type components;
- \( k \): The type of components of the product.

3.3. Storage reliability calculation

In the actual storage process, the temperature stress suffered by electronic products is not constant, and the daily temperature will vary from high to low, with a certain temperature difference. If all the temperatures experienced by electronic products are taken into account, it will cause a very large amount of calculation. If only a certain temperature value is used and it does not reflect the real storage environment, the temperature can be segmented to collect the temperature for one year for each temperature segment, the middle temperature is taken as the temperature value of the segment, and the total time of each temperature segment is counted, which can not only reduce the calculation amount, but also reflect the real storage environment. The lower limit of the reliability of the whole machine is specified as \( R_L \), and the lower limit of its reliable life storage can be estimated according to the following formula [11]:

\[ t_L = \frac{1}{\lambda} \ln\left( \frac{1}{R_L} \right) \] \hspace{1cm} (9)

In the formula:
- \( t_L \): the lower limit of reliable life storage;
- \( \lambda = \sum_{j=1}^{N} \sum_{i=1}^{k} n_i \cdot \lambda_i(T_j) \);
- \( t_j \): Duration of the segment temperature \( T_j \).

According to the composition of the components in the electronic product, list the parameters such as the name, bit number, model, quality standard, packaging structure and other parameters of the component in detail. Find and calculate the non-operating failure rate of each electronic component through the method described in section 3.1. It is assumed that the overall failure rate of electronic products is:

\[ \lambda(T) = 1.1856 \times 10^{-6} / h \]

In the long-term storage environment, the lower limit of the reliability of the electronic product is \( R_L = 0.9 \), then the formula (9) can be used to calculate the lower limit of the reliable storage life of the device is

\[ t_L = \frac{1}{\lambda} \ln\left( \frac{1}{R_L} \right) = 88867h = 10.14a \]

Substituting the lower limit of the reliable storage life into the second step of the calculation procedure in Section 2.2, the resulting shape parameters, characteristic life and acceleration parameters will be more in line with the actual product and more relevantly recognized.
4. Conclusion
To sum up, this paper combines the "Electronic Equipment Non-operating State Reliability Prediction Manual" and the failure rate equation to estimate the life value of electronic products in non-operating state, and uses this value as a similar product reliability prediction method. The product life value avoids the disadvantage of using the entire system value to predict the parameters without prior information, and greatly improves the accuracy of the obtained reliability parameters. The design of the accelerated test program and data for the next step Statistical analysis is of great significance. However, this reliability calculation is based on the fact that the failure modes of each component are independent, ignoring the correlation between each component, and the aging rate of different components to temperature is not the same, and the failure rate may be combined. It will be improved, so there is a certain error in the calculation results [12].

Acknowledgments
This research is supported by environmentally adaptable technology foundation projects.

References
[1] Zhao Y, Yang J, Ma X. Reliability data analysis[M]. Beijing: National Defense Industry Press, 2011(in Chinese).
[2] Ma D. Research on the life prediction method of electrical products based on data driving[D]. Hebei University of Technology, 2016(in Chinese).
[3] Qian Q, Li D, Zhu H. Reliability prediction of electromechanical products based on system similarity[J]. Journal of Sichuan Military Engineering, 2007,28(2):35-37(in Chinese).
[4] Wang S. A comparative study of several life distributions [D]. Zhejiang: Zhejiang Technology and Business University, 2014(in Chinese).
[5] Chen X, Zhang C, Wang Y, et al. Technology and application of accelerated life testing[M]. Beijing: National Defense Industry Press, 2013(in Chinese).
[6] Wang G. Theoretical method of small sample test of electronic system[M]. Beijing: National Defense Industry Press, 2003(in Chinese).
[7] Lin Z, Jiang T, Cheng Y, et al. Research on the Alens model[J]. Reliability and Environmental Testing of Electronic Products, 2005(6):12-14(in Chinese).
[8] Huang T, Jiang T. Summary of statistical acceleration model in accelerated life test[J]. Equipment Environmental Engineering, 2010,07(4): 57-62(in Chinese).
[9] Zhang S, Wang X, Li X. Design of accelerated storage test scheme for electronic complete machine[J]. Quality and Reliability, 2011(2) (in Chinese).
[10] Yang J. Research and Application of Non-Working Reliability Prediction Model: The Eleventh Academic Annual Meeting of Reliability Branch of Chinese Electronics Society, 2002[C] (in Chinese).
[11] Su C, Mou C, He J, et al. Evaluation method of acceleration factor and authenticity of the whole-stage accelerated storage test [J]. Tactical Missile Technology, 2015(1):37-41(in Chinese).