UNCONVENTIONAL RELIABILITY GROWTH MODEL

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1. Introduction

The reliability of new material structures intended to signal processing is one component of their quality. An electronic device has three phases of existence: the development phase, production phase and working phase. The development phase is very important for reliability growth. In this phase the constructor implements three basic components of reliability - reliability, longevity and maintainability in the electronic device.

It is difficult to present a precise (specific) definition of the reliability growth model. The reliability growth model provides usable instructions for the constructor to realize construction changes, corrective interventions in the development phase of the electronic device. In this contribution we proposed and also verified an unconventional reliability growth model of new electronic structures [1].

2. Definition of Reliability Growth Model (RGM)

Let $X(n)$ be one-parametric discrete stochastic process of reliability increase of the electronic device, where n is for example time, number of failures in time interval, number of experiments. Let this stochastic process be asymptotically stationary and ergodic on parameters m_i. Let s_1, s_2, …, s_k be assessment statistics dependent on process $X(n)$ for parameters m_1, m_2 , … , m_k, of function $f(m_1, m_2, …, m_k; X)$. Then the function $f(m_1, m_2, …, m_k; X)$ is the reliability growth model [2].

It can be for in formulated in terms of the Poisson process.

The Poisson process is a process representing „full - stochastic occurrence“ on an event (for example failure creation of a device) in time. This model is a process with continuous time t and discrete values of a stochastic process. It is a model with independent step increases [3].

The principle of reliability growth models, which is based on the Poisson process homogeneity testing, is in fact that a system is either non-stationary or stationary. It means that, if there are many early failures, as well as high intensity inherent failures in the system, the constructor must do construction changes with the goal to increase the reliability of the system. A Poisson process with non-stationarity is a non-homogenous Poisson process, a Poisson process with stationarity is a homogenous Poisson process. The reliability growth model is finished in time t_b (boundary time), from time t_b process is statistically stationary.

A generally stochastic process has different types of non-stationarity with its four basic characteristics [4]:

- mean value $m(t)$,
- dispersion $D(t)$,
- correlation function $R(t_1,t_2)$,
- density of probability distribution $f(t)$ in time t.

New unconventional reliability growth models are based on a simple idea of Poisson homogeneity testing in time reliability tests of repairable systems. The goal is to find boundary time t_b using statistical methods, from which the Poisson process is homogenous (stationary).

For homogeneity mean value of Poisson process testing it is necessary to know actual data from the experiment – number of failures in a set up time interval Δt (for example Δt = 20 hours) in sequence 0-20 h, 20-40 h, 40-60 h,..... . Again we need information if in actual time interval is failure 0., 1., 2., ..., i-s. Zero failure means no failure in the operating ability of systems.

The statistic estimation of mean value $\hat{m}(t)$ in time t_k, k = 1, 2, 3,... we calculated using the equation [4] :

$$\hat{m}(t_k) = \frac{\sum_{i=0}^{k} n_i . i}{N} = \frac{\sum_{i=1}^{k} n_i . i}{N} \quad , \tag{1}$$

N – number of systems in a reliability test, i – integer .

For homogeneity testing of mean value of Poisson process it is necessary to know statistic estimation of dispersion $\hat{D}(t)$ in actual times t_k. We can calculate it using the equation [4] :

$$\hat{D}(t_k) = \frac{\sum_{i=0}^{k} n_i \left[i - \hat{m}(t_k)\right]^2}{N-1} = \frac{\sum_{i=1}^{k} n_i \left[i - \hat{m}(t_k)\right]^2}{N-1} \quad . \tag{2}$$

In next steps we applied first (fragile) criterion of Poisson process homogeneity testing with mean value $m(t)$, second (strong) criterion with mean value $m(t)$ and third criterion with mean value $m(t)$. We found the boundary time t_b, in which it is possible to finish process RGM.

3. Experimental results

For verification of proposed RGM algorithm based on the Poisson process homogeneity testing of mean value $\hat{m}(t)$ and RGM based on Poisson process homogeneity testing of dispersion $\hat{D}(t)$ we used data from a real reliability test. In the reliability test were 160 electronic systems, the time of the whole test was 1000 hours, the time interval Δt was 20 hours.

Input data were times of first, second, ..., r-s failure in 20 hours time intervals. We calculated number of first n_1, second n_2,...r-s n_r failures in time moments 20, 40, 60,..., 1000 hours. Using algorithm from chapter 2 we calculated estimations of mean values in time moments t_k = 20, 40, 60, ... ,1000 hours Poisson process.

The calculations showed, that the first part of the renewal function (from 0 to 220 hours) it is non-linear – non-homogenous Poisson process with non-stationary increases. Second part, in time interval 220 – 1000 hours, better in time interval 500 – 1000 hours is possible to approximate by linear dependence. This is a homogenous Poisson process with stationary increases of failures.

We calculated for every time moments t_k values of estimation of dispersion $\hat{D}(t)$.

First (fragile) criterion

We calculated absolute value of relative increase of mean value $\hat{\delta}_m$ (auxiliary statistical parameter). On the base of experience we can say, that boundary value is $\hat{\delta}_m$ = 0,03 and then we can determine boundary time t_k – the time moment for begining of homogenous Poisson process.

Second (strong) criterion

We calculated values of average transposition mean quadratic deviations $\hat{\delta}_{kl}$. Using the equation [5]:

$$\Delta t_{opt} = \frac{t_{\max} - t_{\min}}{1 + 3{,}3\log_{10} m} \quad , \tag{3}$$

t_{max} = 1000 hours, t_{min} = 20 hours, m = 50, we calculated Δt_{opt} = 148 hours. We round this value of interval to Δt_{opt} = 140 hours. Then boundary time for homogenous Poisson process is t_b = 220 hours. RGM model is finished.

Third criterion

We used statistic increases of mean values $\Delta\hat{m}_k$ in time moments 0-140, 140-280, 280-420,…, 840-980 hours. We created a graph of values $\Delta\hat{m}_k$. We found approximation line y = const using method of minimum squares. Using the graph we define boundary time t_k – the Poisson process is homogenous. It is t_k = 500 hours. Applying censorship value from time interval (420-560) hours boundary time is t_k = 350 hours.

4. Discussion

Unconventional reliability growth models of electronic devices (hardware) are very specific tools used during development phase. We verify algorithms of new model on data from real reliability test of electronic devices.

The advantage of new reliability growth models is the simplicity of processing results of experiment, undemanding calculation and authentic results if number of tested electronic devices is sufficient (minimum 30).

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