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LIFETIME PREDICTION METHOD FOR ELECTRON MULTIPLIER BASED ON ACCELERATED DEGRADATION TEST

METODA PROGNOZOWANIA CYKLU ŻYCIA POWIELACZA ELEKTRONÓW OPARTA NA PRZYSPIESZONYCH BADANIACH DEGRADACJI

Electron multiplier (EM) is a kind of highly reliable and long-lifetime vacuum electronic device applied widely in spectrometry, space exploration and atom frequency standard. It is a critical device which might constrain the related technology. A challenge remains for researcher and engineer how to predict the life span of EM. Firstly, degradation mechanism of EM is investigated. It shows that the secondary emission ratios of each multiplier electrode reduces gradually with operating time, which results in the degradation of the key performance index of EM, i.e. the gain of electric current. So an accelerated degradation test (ADT) methodology using dual stresses is proposed to predict the life span of EM. Secondly, the ADT plan with dual stresses is designed and carried out by the corresponding test system established. Finally, the data analysis procedure is presented, and its validity is investigated by model verification. The presented method can sharply reduce testing time and cost because of using accelerated stress which can accelerate degradation process of EM. This method can also provide a new way to lifetime and reliability prediction for other products with long lifetime and high reliability.

Keywords: *electron multiplier, accelerated degradation test, lifetime prediction, reliability.*

Powielacz elektronów (EM) to elektroniczne urządzenie próżniowe o wysokiej niezawodności i długim cyklu życia, które znajduje szerokie zastosowanie w spektrometrii i badaniach przestrzeni kosmicznej, a także w atomowych wzorcach częstotliwości. Jest to urządzenie krytyczne, które może stanowić ograniczenie dla technologii, w której jest wykorzystywane. Wyzwaniem dla naukowców i inżynierów pozostaje pytanie, jak przewidzieć żywotność EM. W pierwszej kolejności w artykule zbadano mechanizm degradacji EM. Badanie pokazało, że współczynniki emisji wtórnej elektrody powielacza maleją stopniowo wraz z upływem czasu pracy, co prowadzi do degradacji kluczowego wskaźnika wydajności EM, to znaczy wzmocnienia prądu elektrycznego. W oparciu o ten fakt, zaproponowano metodę prognozowania żywotności EM zasadzającą się na metodologii przyspieszonych badań degradacji (ADT) z wykorzystaniem podwójnych naprężeń. Następnie zaprojektowano i zrealizowano plan ADT z podwójnymi naprężeniami za pomocą odpowiedniego systemu testowego. Na koniec przedstawiono procedurę analizy danych, a ich wiarygodność zbadano poprzez weryfikację modelu. Przedstawiona metoda może znacznie zredukować czas i koszty badań dzięki wykorzystaniu przyspieszonych naprężeń, które mogą przyspieszyć proces degradacji EM. Metoda ta może również umożliwić nowy sposób przewidywania niezawodności i cyklu życia produktów o długim cyklu życia i wysokiej niezawodności.

***Słowa kluczowe**:* *powielacz elektronów, przyspieszone badanie degradacji, prognozowanie cyklu życia, niezawodność.*

1. Introduction

Electron multiplier (EM) is a kind of electronic device multiplying incident current for particles detection. It is widely applied in spectrometry, space exploration and atom frequency standard. And it is a critical device which might constrain the related technology.

The gain of EM will degrade gradually with operating time. It is regarded as a “failure” that the EM cannot multiplies incident current with a specified gain when the gain is below a threshold value. So lifetime of EM is usually defined as operating duration in use conditions before its gain degrades to the threshold. Lifetime of EM directly constrains operating lifetime of its engineering system, so it is a key problem for researchers and engineers how to predict the lifetime of EM in application.

EM is a kind of highly reliable products, and its gain degrades very slowly, so traditional accelerated life tests will provide little help, because no failures are likely to occur in a reasonable test duration, which brings a great challenge to data analysis procedure. Even if degradation tests are applied to lifetime prediction for EM, problems will still remain because decrease of EM gain is not obvious and it is impossible to obtain a good estimate within a reasonable period.

To overcome this problem, degradation data can be collected under higher levels of stress and allowing extrapolation the reliability and lifetime information at the use condition. This is called an accelerated degradation test (ADT) [5, 6]. ADT provides a new feasible approach to the problem that there is little or even a lack of failure data in application of accelerated life tests.

Researches about ADT have been widely focused on because of the advantages of ADT stated above. In statistical analysis and engineering application aspect, Nelson surveyed pertinent literature [6]. Meeker and Escobar proposed degradation models that correspond to physical-failure mechanisms and methods to estimate model parameters and confidence intervals for quantities of interest [4]. Whitmore, Park and Padgett presented degradation models based on Wiener and

Gauss stochastic process which can describe randomness of measurements well [7, 8, 10]. But these models are difficult to be widely applied for its complicated computation progress. In optimal design of test plan aspect, Yu and Tseng presented an on-line procedure for terminating an ADT [13]. Under the constraint that the total experimental cost does not exceed a pre-determined budget, Yu and Chiao studied the problem how to design an accelerated degradation test where the degradation rate follows a reciprocal Weibull distribution and a Normal distribution [11, 12]. Liao and Tseng proposed an approach to optimal design for step-stress ADT based on stochastic diffusion process [3]. Wang presented a simulation-based optimal design approach to constant stress ADT using mixed-effect degradation model to overcome problems in analytical optimal methods [9].

When ADT is applied to predict lifetime of products, the degradation mechanisms of the products at accelerated stress must accord with those at use conditions to ensure correctly extrapolating the reliability and lifetime information at accelerated stress to use condition. There always exists a limit for single accelerated stress above which degradation mechanisms will change. So if dual stresses are applied, we can not only obtain high test efficiency but also easily ensure the consistency of degradation mechanisms.

It is observed in pilot experiments that degradation speed of EM gain can be accelerated by the voltage *U* between electric poles of EM and by the intensity of incident current *I*. Therefore, a method is presented in this paper that lifetime prediction for EM is conducted based on ADT with dual stresses of *U* and *I*. Firstly, degradation mechanism of EM is investigated. It shows that the secondary emission ratios of each multiplier electrode reduces gradually with operating time, which results in the degradation of the key performance index of EM, i.e. the gain of electric current. So an accelerated degradation test (ADT) methodology using dual stresses is proposed to predict the life span of EM. Secondly, the ADT plan with dual stresses is designed and carried out by the corresponding test system established. Finally, the data analysis procedure is presented, and its validity is investigated by model verification.

2. Degradation Mechanisms of EM

2.1. Gain of EM

EM operates on the theoretic basis of electron secondary emission. The process comprises of the following three stages: (1) incident particles interacts with electrons in an emitter and a part of the electrons are stimulated to a higher energy level; (2) A part of stimulated electrons move towards the interface between the emitter and the vacuum; (3) the electrons arriving at the emitter surface whose energy is above the surface barrier are emitted into the vacuum.

A secondary emission ratio is a key performance index in a secondary emitting process of EM. It can be defined as the ratio of the number of secondary emission electrons N_2 to the number of the primary particles N_1:

$$\delta = N_2 / N_1 \tag{1}$$

The secondary emission ratio δ is a function of voltage *E* between electric poles of EM, i.e.:

$$\delta = a \cdot E^k \tag{2}$$

where *a* is a constant; *k* is an index determined by the structure and material of electric poles within the interval of 0.7~0.8 commonly [1].

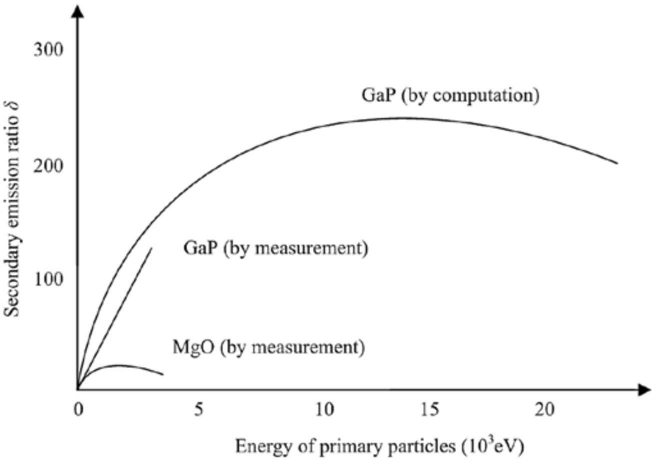

Fig. 1. The characteristics of secondary emission ratios of commonly used secondary emitters

The characteristics of the secondary emission ratios of commonly used secondary emitters are shown in Figure 1 [1]. It shows that secondary emission ratios increase firstly and then decrease with an increase of the energy of primary particles. When the energy of primary particles is low, stimulated electrons occur near the surface of an emitter. The probability of escape is large but the number of stimulated electrons is small, so δ is small. When the energy of primary particles increases, the number of stimulated electrons increases soon, but the probability of escape become small, and the overall effect is that δ increases. However, when the energy of primary particles is very large, stimulated electrons occur deeply in the emitter and the probability of escape becomes very small, so δ becomes small accordingly in general despite of large number of stimulated electrons.

If the number of electric particles is transformed to electric current, the secondary emission ratio of the *i*th electric pole can be defined as:

$$\delta_i = I_i / I_{i-1} \tag{3}$$

where I_{i-1} and I_i are the incident and output current of the *i*th electric pole respectively.

Write the incident current as I_{in}, and output current of the anode of EM as I_{out}, then:

$$I_{out} = I_{in} \cdot \alpha \cdot \delta_1 \cdot \delta_2 \cdots \delta_n \tag{4}$$

where α is the collecting efficiency of dynodes. So, the gain of EM *G* can be written as:

$$G = I_{out} / I_{in} = \alpha \cdot \delta_1 \cdot \delta_2 \cdots \delta_n \tag{5}$$

If α=1 and operating voltage of EM *U* is equally allocated to *n* dynodes, by combining (2) the relationship between *G* and *U* can be expressed as:

$$G = (a \cdot E^k)^n = a^n \left(\frac{U}{n+1} \right)^{kn} = A \cdot U^{kn} \tag{6}$$

where $A=a^n/(n+1)^{kn}$.

2.2. Degradation Failure of EM

The main failure mode of EM is that the gain of incident current decreases with operating time, i.e. gain degradation. The main reasons for degradation of the gain of EM include surface erosion of dynodes, small splitting crack inducing gas leakage, vaporization of material of secondary emitter, and the variation of vacuum atmosphere during operation [2].

Degradation rate of EM gain is related to the energy of incident particles [1]. Higher energy of incident particles accelerates the heating process of electric poles and then intensifies vaporization of material of secondary emitters or accelerates surface erosion of the emitters. So the degradation speed of gain become fast. Energy of incident particles is determined by intensity of incident current and voltage between dynodes. Bigger intensity of incident current and higher voltage between dynodes, higher the energy of incident particles can get. Figure 2 shows the curve of EM gain versus operating time under different intensity of incident current [9], where the corresponding operating current are respectively 1 μA, 4 μA and 10 μA. It can be seen from the figure that EM gain degrades faster if the intensity of incident current is bigger.

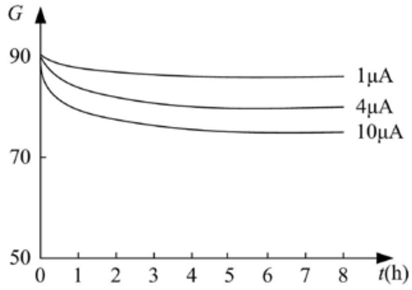

Fig. 2. Curve of EM gain versus operating time under different intensity of incident current

Therefore, degradation process of EM gain can be accelerated by increasing the intensity of incident current and voltage between dynodes in ADT for EM, which can shorten degradation lifetime of EM and reduce test cost consequently.

3. ADT Plan for EM

Voltage between dynodes U and intensity of incident current I are chosen as accelerated stresses on the basis of the analysis above. In order to reduce sample size and test cost, a fractional factorial design based on statistical design of experiment are applied. The design as shown in Table 1 is used by considering that higher accelerated stress levels can accelerate degradation rate of EM which induces higher test efficiency. The test plan comprises of 5 subtests of constant stress ADTs with dual stresses.

Table 1. Double stress ADT plan of EM

	D_1	D_2	D_3
U_1	—	—	(U_1, D_3)
U_2	—	—	(U_2, D_3)
U_3	(U_3, D_1)	(U_3, D_2)	(U_3, D_3)

According to the result of pilot experiment, the highest levels of accelerated stresses at which degradation mechanisms will not change from at use condition, i.e. voltage and intensity of incident current are taken the value of 2700V and 5×10^{-11}A respectively, i.e. U_3=2700V, $D_3=5\times10^{-11}$A, above which degradation mechanisms will change. The lowest levels of accelerated stresses are set as the value near use condition as possible to ensure precisely extrapolation, so U_1=2500V, $D_1=0.9\times10^{-11}$A. The intermediate levels of accelerated stresses are set as U_2=2600V, $D_2=2\times10^{-11}$A for equal intervals.

An ADT system for EM is established according to the test design above. The system comprises of the following five parts as shown in Figure 3: ionization wire, focus electrode, power system of EM, output ammeter, temperature control system of cesium stove, vacuum system, and test tank of EM.

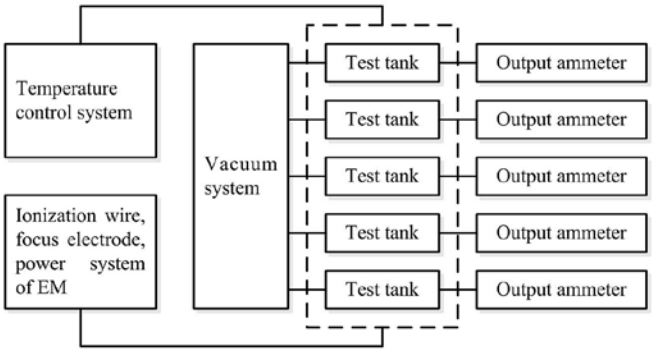

Fig. 3. ADT system of EM

Only 25 test units can be taken into the whole test under the constraint of test budget. Five units are allocated to each sub-test to meet basic requirements of statistical analysis. Performances of EM need effective inspection in ADT to obtain degradation path of test units during test process. The gain of EM is taken as the main index of performance that needs to be inspected in ADT. Equally spaced time interval is used to inspect the gain of EM for the convenience of data recording. ADT must be reasonably censored by the constraint of test time and cost. An approach of dynamic termination is applied in the ADT of EM that on-line and real-time ADT data are analyzed to obtain reasonable censored time [13]. If the relative rate of change of the asymptotic mean lifetime is smaller than a specified value, the whole test will be terminated.

4. Analysis Procedure for ADT Data of EM

4.1. ADT Data of EM

ADT for EM is conducted based on test system and test plan above. Test data as shown in Figure 4 are obtained. In the figure, y-coordinate is relative gain, i.e. the ratio of gain to its initial value, and x-coordinate is test time in hours). It shows that relative gains degrade gradually and there exist local fluctuations in each degradation curve, induced by variation of environmental factors such as temperature and vacuum. The gain of EM is sensitive to such factors, but small amplitude of fluctuation of gain has no significant effect on analysis results.

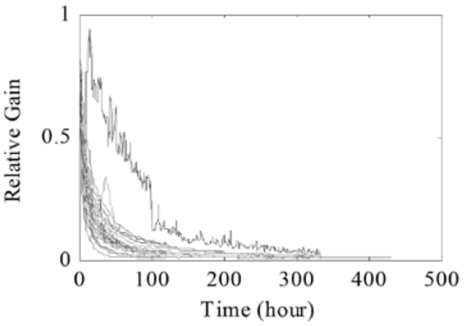

Fig. 4. ADT data of EM

4.2. Analysis Procedure

(1) The Problem

Levels of use stresses and accelerated stresses $S^{(1)}$ and $S^{(2)}$ are:

$$\begin{aligned} &S_0^{(1)} < S_1^{(1)} < \cdots < S_{l_1}^{(1)} \\ &S_0^{(2)} < S_1^{(2)} < \cdots < S_{l_2}^{(2)} \end{aligned} \tag{7}$$

where l_1 and l_2 are the numbers of levels of two stresses respectively. Use (i, j) to briefly denote a combination of S_i and S_j. The test plan is shown as Table 1 where S_i=U_i, S_j=D_j.

N test units sampled from a batch of products are allocated to each level combination of accelerated stresses with an equal number of units n, so

$$N = n \cdot L \tag{8}$$

where L is the total number of combinations of stress levels. The problem is how to analyze the degradation data obtained in the test to predict reliable lifetime of EM under use stress level.

(2) Model assumptions

A1 Theoretic degradation path under use stress level (0, 0) and accelerated stress level (i, j) can be expressed by a mixed-effect model of:

$$\begin{aligned} &G(t \mid S_i^{(1)}, S_j^{(2)}) = \exp(-\beta_{i,j,k} t^{\alpha}), \\ &t > 0, \\ &i, j = 0, 1, \cdots, l, \\ &k = 1, 2, \cdots, n \end{aligned} \tag{9}$$

where G is a function of relative gain; $\beta_{i,j,k}$ ($\beta_{i,j,k}$>0) is a parameter of random effects which denotes the degradation rate of No. k test unit under the combination of stress level (i, j) ; α (α>0) is a constant which denotes fixed effects. The reciprocal of $\beta_{i,j,k}$ follows Weibull distribution, i.e.

$$\beta_{i,j,k}^{-1} \sim \text{Weibull}(m, \eta_{i,j}) \tag{10}$$

where m is the shape parameter and $\eta_{i,j}$ is the scale parameter. So the observed degradation path can be expressed as:

$$H(t \mid S_i^{(1)}, S_j^{(2)}) = G(t \mid S_i^{(1)}, S_j^{(2)}) + \varepsilon_{i,j,k}(t) \tag{11}$$

where $\varepsilon_{i,j,k}$ is the measurement error which is independent from each other and follows normal distribution, i.e. $\varepsilon_{i,j,k} \sim N(0, \sigma_\varepsilon^2)$.

A2 The shape parameter m is independent from levels of the accelerated stresses so m keeps constant for different stress levels; the relationship between $\eta_{i,j}$ and the stress levels can be described by the following accelerated model:

$$\begin{aligned} &\ln \eta_{i,j} = a_0 + a_1 \varphi_1(S_i^{(1)}) + a_2 \varphi_2(S_j^{(2)}) + a_3 \varphi_3(S_i^{(1)}, S_j^{(2)}), \\ &i, j = 0, 1, \cdots, l \end{aligned} \tag{12}$$

where a_0, a_1, a_2, a_3 are the parameters to be estimated from test data; φ_1, φ_2, φ_3 are the known functions of accelerated stress levels. Eq. (12) can be written as a matrix formulation:

$$\mathbf{H} = \mathbf{J} \times \mathbf{a} \tag{13}$$

where $\mathbf{H}$=[ln$\eta_{0,0}$ ln$\eta_{0,1}$ ln$\eta_{1,1}$ … ln$\eta_{l,l}$]$^{\mathrm{T}}$, $\mathbf{a}$=[a_0 a_1 a_2 a_3]$^{\mathrm{T}}$, and

$$\mathbf{J} = \begin{bmatrix} 1 & \varphi_1(S_0^{(1)}) & \varphi_2(S_0^{(2)}) & \varphi_3(S_0^{(1)}, S_0^{(2)}) \\ 1 & \varphi_1(S_0^{(1)}) & \varphi_2(S_1^{(2)}) & \varphi_3(S_0^{(1)}, S_1^{(2)}) \\ 1 & \varphi_1(S_1^{(1)}) & \varphi_2(S_1^{(2)}) & \varphi_3(S_1^{(1)}, S_1^{(2)}) \\ \vdots & \vdots & \vdots & \vdots \\ 1 & \varphi_1(S_l^{(1)}) & \varphi_2(S_l^{(2)}) & \varphi_3(S_l^{(1)}, S_{l1}^{(2)}) \end{bmatrix}.$$

(3) Method for statistical analysis

Based on the assumption A1, theoretical degradation path of EMs in a dual constant stress accelerated degradation test (CSADT) is shown as Figure 5 where combinations of stress level are (0, 0), (0, 1), (1, 1) respectively.

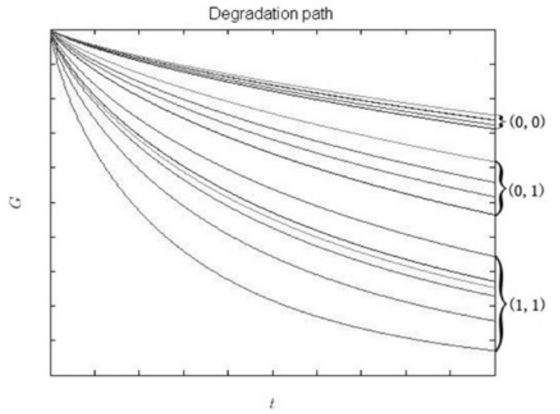

Fig. 5. Theoretical degradation path of EMs in a dual stress CSADT

The framework for solving the problem of statistical analysis consists of four major steps labeled (A)–(D) as follows:

(A) The estimation of α, $\beta_{i,j,k}$

The least-squares estimator (LSE) $\hat{\alpha}$ of $\hat{\beta}_{i,j,k}$, can be computed by minimizing:

$$SSE(\alpha, \beta_{i,j,k}) = \sum_t [H(t) - G(t)]^2 \tag{14}$$

where $H(t)$ is the observed degradation path as Eq. (11) and $G(t)$ is the theoretical degradation path as Eq. (9). And the variance of system measurement error σ_ε^2 can be estimated by:

$$\hat{\sigma}_\varepsilon^2 = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{r - n_\nu} SSE(\alpha, \beta) \tag{15}$$

where r is total measurement times of each test units, and n_ν is the number of parameters of α, $\beta_{i,j,k}$.

(B) The estimation of $m_{i,j}$, $\eta_{i,j}$

Based on the $\hat{\beta}_{i,j,k}$ estimated in (A), the maximum likelihood estimator (MLE) $\hat{m}_{i,j}$, $\hat{\eta}_{i,j}$ of $m_{i,j}$, $\eta_{i,j}$ can be computed by Eq. (10). Because the distribution parameter m keeps constant for different stress levels as Assumption A2, m can be estimated by:

$$\hat{m} = \frac{1}{L} \sum_{i=1}^{l} \sum_{j=1}^{l} \hat{m}_{i,j} \tag{16}$$

(C) The estimation of a_0, a_1, a_2, a_3 in accelerated model

On the basis of the estimator of $\eta_{i,j}$, the estimation ($\hat{a}_0, \hat{a}_1, \hat{a}_2, \hat{a}_3$) of (a_0, a_1, a_2, a_3) in accelerated model can be computed by:

$$\hat{\mathbf{a}} = (\mathbf{J}^{\mathrm{T}}\mathbf{J})^{-1}\mathbf{J}^{\mathrm{T}}\hat{\mathbf{H}} \tag{17}$$

where $\hat{\mathbf{H}} = [\ln \hat{\eta}_{0,0} \quad \ln \hat{\eta}_{0,1} \quad \ln \hat{\eta}_{1,1} \quad \cdots \quad \ln \hat{\eta}_{l,l}]^{\mathrm{T}}$, $\hat{\mathbf{a}} = [\hat{a}_0 \quad \hat{a}_1 \quad \hat{a}_2 \quad \hat{a}_3]^{\mathrm{T}}$.

(D) The estimation of the 100pth percentile of the EM's lifetime distribution

Let D denote the critical level for EM's degradation path under the use stress level (0, 0). The EM's lifetime τ is suitably defined as the time when the theoretical degradation path under use stress level (0, 0) crosses the critical level D for the first time, that is:

$$G[\tau \mid (0,0)] = D \tag{18}$$

From Eq. (9), τ can be expressed as:

$$\tau = \left(\frac{-\ln D}{\beta_{0,0,k}} \right)^{1/\alpha} \tag{19}$$

It can be derived by combining (10) that τ follows a weibull distribution as:

$$\tau \sim \mathrm{Weibull}(m_\tau, \eta_\tau) \tag{20}$$

Where $\hat{m}_\tau = \hat{\alpha}\hat{m}$; $\hat{\eta}_\tau = [\hat{\eta}_{0,0} \cdot (-\ln D)]^{1/\hat{\alpha}}$. Thus, the estimation of the 100pth percentile of EM's lifetime distribution can be expressed as follows:

$$\hat{\tau}_p = \hat{\eta}_\tau \cdot [-\ln(1-p)]^{1/\hat{m}_\tau} \tag{21}$$

(4) Analysis results of EM data in ADT

According to the method of data analysis stated above, results can be obtained as shown in Table 2. Analysis results show that the variance of estimation is small when accelerated model without interaction effects is applied, so estimation of a_3 is absent from Table 2.

The reliability curve of EM is shown in Figure 6 by accelerated model as Eq. (12), Eq. (20) and Eq. (21). And reliable life of EM under use stress level can be computed by the curve.

(5) Model checking

Analysis procedure above is based on the assumption of normal distribution of measurement errors, the assumption of Weibull distribution of reciprocal of degradation rate, and the assumption of normal distribution of fitting residual of accelerated model. All these assumptions are verified as follows.

Table 2. Estimation of model parameters in double stresses ADT of EM

$\hat{\alpha}$	$\hat{m}$	$\hat{a}_0$	$\hat{a}_1$	$\hat{a}_2$	$\hat{\sigma}_\varepsilon^2$
0.2747	3.904	12.29	-3.587	-0.6670	3.355×10^{-4}

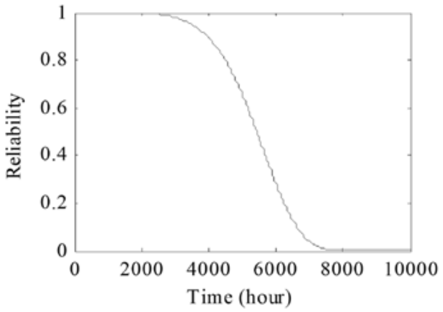

Fig. 6. Reliability curve of EM under use stress level

(A) Checking of normal distribution of measurement errors

Normal probability plot is used to validate the assumption that residuals generated in degradation path fitting process follow a normal distribution. The normal probability plot of the residuals of No.3 test unit under the stress level of (U_3, D_2) is shown in Figure 7. It can be seen from the figure that the residuals fit normal distribution well. The same conclusions can be obtained for other test units.

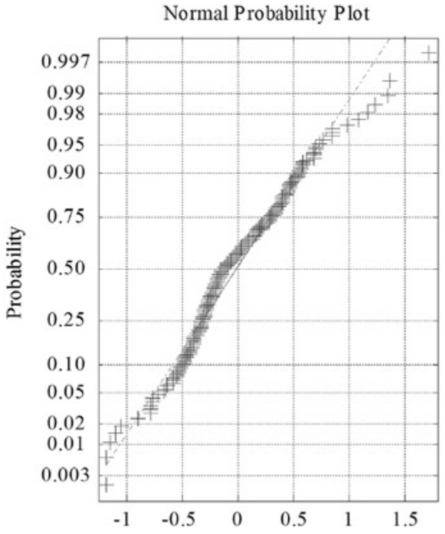

Fig. 7. Normal probability plot of residuals of No.3 test unit under a stress level of (U_3, D_2)(B) Checking of reciprocal Weibull distribution of degradation rates

(B) Checking of reciprocal Weibull distribution of degradation rates

Weibull probability plot is used to validate the assumption that reciprocal degradation rates follow a Weibull distribution. The Weibull probability plot of $\hat{\beta}_{i,j,k}^{-1}$ s under the stress level of (U_1, D_3) is shown in Figure 8. It can be seen from the figure that $\hat{\beta}_{i,j,k}^{-1}$ s fit Weibull distribution well. The same conclusions can be obtained for other combinations of stress levels.

(C) Checking of normal distribution of fitting residuals of accelerated model

Figure 9 shows the normal probability plot of residuals in accelerated model fitting. It can be seen from the figure that residuals

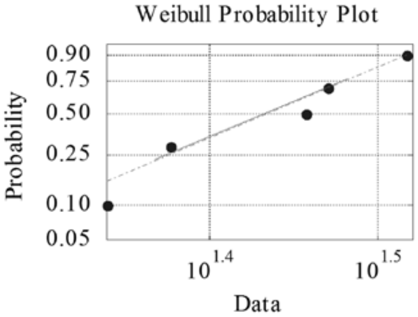

Fig. 8. Weibull probability plot of $\hat{\beta}_{i,j,k}^{-1}$*s under a stress level of* (U_1, D_3)

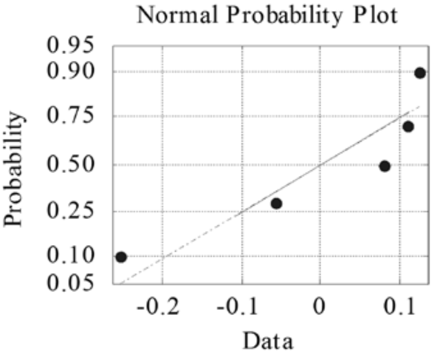

Fig. 9. Normal probability plot of fitting residuals of accelerated model

generated in accelerated model fitting process do not follow a normal distribution very good. But this will not affect the precision of point estimation of parameters in the accelerated model because the least-squares fitting method does not necessarily assume normally distributed errors when calculating parameter estimates. However, the method works best for data that does not contain a large number of random errors with extreme values. The normal distribution is one of the probability distributions in which extreme random errors are uncommon. And statistical results such as confidence and prediction bounds do require normally distributed errors for their validity. So it should be carefully to calculate interval estimation of parameters in the accelerated model and some other better methods can be applied in this case.

5. Conclusion

Electron multiplier (EM) is a kind of highly reliable and long-lifetime vacuum electronic device. It is a challenge in research of lifetime extending for EM and engineering application how to predict its operating lifetime. Analysis for degradation mechanism of EM indicates that secondary emission ratios of each multiplier electrode reduces gradually with operating time, which induces the key performance index of EM, i.e. the gain of electric current, to reduce gradually too.

Based on degradation mechanism above, an approach to lifetime prediction for EM using dual constant stresses accelerated degradation test (ADT) is presented together with the dual constant stress ADT plan, the data analysis procedure, and the model verification concerned. The applicability of accelerated degradation test to the long-term life span prediction for electron multiplier is demonstrated in this paper.

The presented methodology for EM life span prediction could reduce the testing duration and expense prominently. It may also be used as a reference for life span and reliability prediction for other similar products.

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