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Full Length Article

Comparison of reliability techniques of parametric and non-parametric method

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A B S T R A C T

Reliability of a product or system is the probability that the product performs adequately its intended function for the stated period of time under stated operating conditions. It is function of time. The most widely used nano ceramic capacitor C0G and X7R is used in this reliability study to generate the Time-to failure (TTF) data. The time to failure data are identified by Accelerated Life Test (ALT) and Highly Accelerated Life Testing (HALT). The test is conducted at high stress level to generate more failure rate within the short interval of time. The reliability method used to convert accelerated to actual condition is Parametric method and Non-Parametric method. In this paper, comparative study has been done for Parametric and Non-Parametric methods to identify the failure data. The Weibull distribution is identified for parametric method; Kaplan–Meier and Simple Actuarial Method are identified for non-parametric method. The time taken to identify the mean time to failure (MTTF) in accelerating condition is the same for parametric and non-parametric method with relative deviation.

1. Introduction

Reliability of the electronic component or engineering system can be determined from the failure rate using many techniques. These techniques are broadly classified as parametric method and non-parametric method. Non-Parametric methods are generally used for estimating the reliability characteristics. This method is very easy to use. The limitation of this method is that the results cannot be accurately extrapolated beyond the last reported failure rate. Parametric method is desirable to fit the failure rate to any statistical distribution, such as the exponential, normal, Weibull, or lognormal. This will result in a better understanding of the failure mechanisms, and the resulting model can be used for analytical evaluation of reliability parameters for the whole lifespan of the system.

Ceramic capacitor is one of the important electronic components that are used in many complicated devices and systems. Multilayer Ceramic capacitors (MLCC) are the most widely produced and used nano ceramic capacitors in electronic equipment that produces approximately one trillion pieces (1000 billion pieces) per year [1]. It is used in electronic industry for automotive applications, telecommunication applications, data processing, and other applications. As the reliability of a system or a device is mainly dependent on the reliability of its components, the evaluation of the reliability of the capacitors is very important to understand the reliable life of the overall systems and devices. In this study, reliability techniques are compared to evaluate the life of the ceramic capacitor using accelerated life testing [2]. Fig. 1 represents the nano ceramic capacitor.

This study examines C0G and X7R nano dielectric systems of two leading edge Base Metal electrode. The temperature coefficient of capacitor (TCC) should be within the range of ±15% for a temperature range of –55 °C to 125 °C for the X7R Multilayer Ceramic Capacitor (MLCCs) type. The Accelerated Life Testing (ALT) is used to identify the time to failure (TTF) of the nano ceramic capacitor under accelerated condition [3,4]. The highly accelerated reliability test conditions to actual reliability conditions are correlated using Prokopowicz and Vaskas (P-V) empirical equation. For nano ceramic capacitor reliability experiments and studies, the most extensively used model is the P-V model [5–12]. Because there are a lot of variations in activation energies and voltage coefficients, a range of case sizes and dielectric thickness coating values to be characterized for the dielectric system is given by Eq. (1).

$$\frac{t_1}{t_2}=\left(\frac{V_2}{V_1}\right)^n exp\left[\frac{E_a}{k}\left(\frac{1}{T_{1abs}}-\frac{1}{T_{2abs}}\right)\right] \quad (1)$$

Eq. (1) represents the P-V formula.where

t_1 = Actual time to failure
t_2 = Accelerated time to failure

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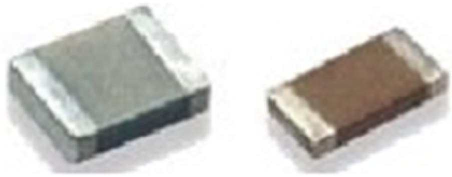

Fig. 1. Nano ceramic capacitor.

Table 1
Capacitance and voltage rating of nano ceramic capacitors.

	Case size	Voltage rating	Capacitance
X7R	603	50 V	100 nF
C0G	1206	25 V	100 nF

V_1 = Voltage under Actual condition
V_2 = Voltage under Accelerated condition
n = Voltage stress exponential
E_a = Activation energy for dielectric wear out = 0.5 eV
k = Boltzmann's constant (8.62 E-5 eV/K)
T_1 = Absolute temperature
T_2 = Accelerated Temperature

This study examines the case sizes of 0603 and 1206 with the commonly used voltage ratings in the electronics industry such as 25 V and 50 V. Table 1 shows the summary of nano capacitors values studied.

2. Experimental methodology

The experimental methodology is shown in Fig. 2 and explained below.

Step 1: Designing the Accelerated life test (ALT)

- Determining the failure mode and mechanism.
- Determining the stress types.
- Define the characteristics to be measured.
- Design the ALT.

Step 2: Conducting the Accelerated Life Test (ALT)

- Perform ALT as per the plan.
- Collect time to failure data.

Step 3: Evaluate the mean time to failure (MTTF) under Actual Working Conditions

- Finding the mean time to failure (MTTF) under accelerated conditions.
- Finding the mean time to failure (MTTF) under normal working conditions using suitable acceleration models.
- Estimating the reliability using Non-Parametric methods and comparing with parametric methods [13].

3. Experimental details

3.1. Accelerated life testing in test chamber (combined accelerated voltage and temperature)

The nano ceramic capacitor is placed in the test chamber, and capacitance variations are monitored in the visual display unit of the Test chamber. The test chamber reliability system was based on measuring the current leakages in the electrical device, which consist of a ripple of source and the measuring part. The current circuit in test chamber measuring the leakage current of ceramic capacitor, and the resistor, which was connected in series, changed the comparable voltage from the passing current, which was noted in real time scenario. The capacitors were tested under accelerated testing condition with combined temperature and voltage stresses [14]. A total of 50 nano ceramic capacitors were tested and the time to failure data were obtained based on the failure mode observed in the capacitors.

The details of the capacitors are given below:

Type of capacitor: Ceramic capacitor
Rated temperature: –55 °C to +100 °C
Rated voltage: 25 V to 50 V

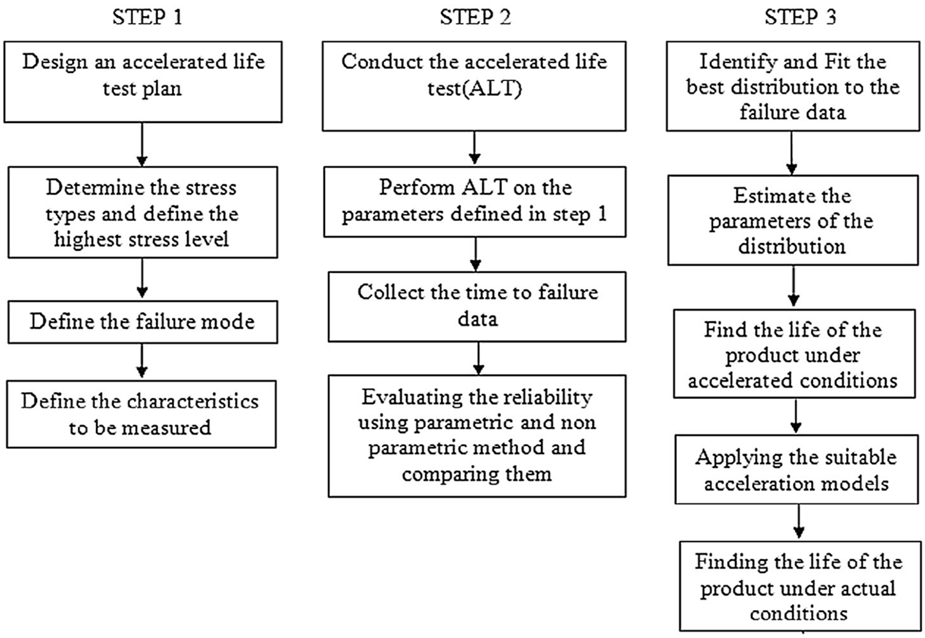

Fig. 2. Experimental methodology.

Fig. 3. Test chamber.

The device used to test the nano ceramic capacitor is Test Chamber and Voltmeter. Fig. 3 shows the capacitor test chamber and voltmeter. The nano ceramic capacitor is connected to the voltmeter and placed in the temperature oven. The capacitor is tested twice the rated voltage and temperature conditions. Drop in capacitance value is considered as the failure for nano ceramic capacitor. Table A1 (Appendix) shows the time to failure data of capacitor.

4. Results and discussions

4.1. Reliability evaluation by non-parametric methods

4.1.1. Time to failure data of capacitors

The time to failure data obtained in the accelerated testing of capacitors are shown in Table A1 (Appendix) in ascending order. In Non-parametric methods the failure data are analysed without assuming any particular distribution. Non-parametric methods are much simpler and easier to apply. The several methods for conducting a non-parametric analysis are Kaplan–Meier, simple actuarial and standard actuarial methods.

In this study the reliability analysis is done using the following methods:

(i) Kaplan–Meier estimator
(ii) Simple actuarial method.

4.2. Kaplan–Meier estimator

The Kaplan–Meier estimator is for estimating the survival function from lifetime data. A plot of the Kaplan–Meier estimate of the survival function is a series of steps of declining magnitude, which, when a large enough sample is taken, approaches the true survival function for that population [15]. The value of the survival function between successive distinct sampled observations is assumed to be constant.

The equation of the estimator of reliability and failure rate are respectively given by the following expressions:

$$\text{Reliability, } \mathrm{R}(\mathrm{t}_i)=\prod_{j=1}^{i}\frac{n_{j-r_j}}{n_j}; \quad i=1,\ldots\ldots\ldots\ldots m \tag{2}$$

$$\text{Failure rate, } Z(t_j)=\frac{r_j}{n_i * \Delta t_j} \tag{3}$$

where,

m = the total number of data points
n = the total number of units
Δt_j = time taken for r_j failures

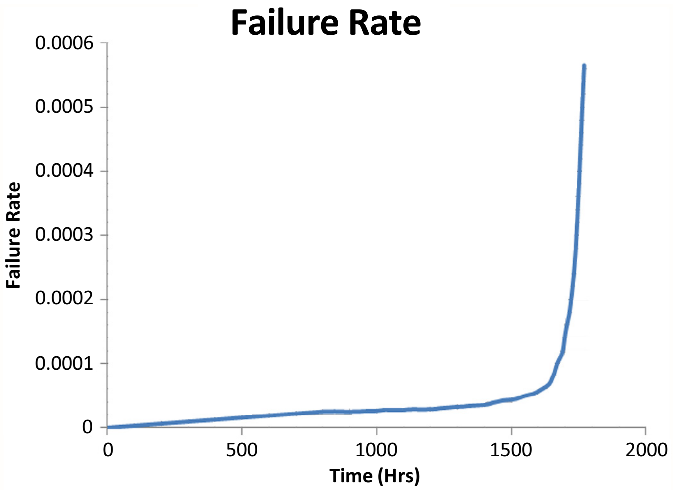

Fig. 4. Failure rate graph based on Kaplan–Meier method.

The variable n_j is defined by

$$n_j = n - \Sigma r_j \tag{4}$$

where r_j is the number of failures in the interval j, and n_j is the operating units in the interval j.

Table A2 (Appendix) gives the calculated reliability values based on Kaplan–Meier method. Based on the calculated reliability and failure rate values the graphs are drawn as shown in Fig. 4.

The calculated values of failure rate and reliability are used to draw the corresponding graphs as shown in Figs. 4 and 5 respectively. Fig. 4 shows the failure rate vs time graph based on Kaplan–Meier method. It shows that the failure rate increases as time increases. The graphs are compared with the corresponding graphs calculated using parametric methods, and they are found to be similar.

The reliability vs time graph is shown in Fig. 5. It shows that the reliability value decreases as time increases.

4.3. Simple actuarial method

The simple actuarial method is to calculate the number of failures in a time interval r_j versus the number of operating units in that time period, n_j. This method is very easy to apply in actual failure data analysis.

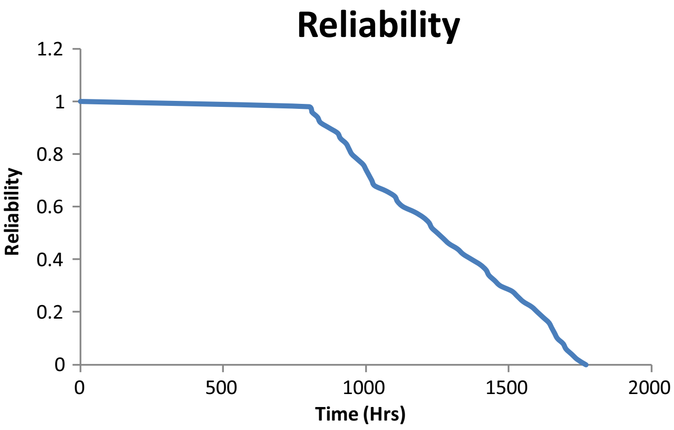

Fig. 5. Reliability vs time graph.

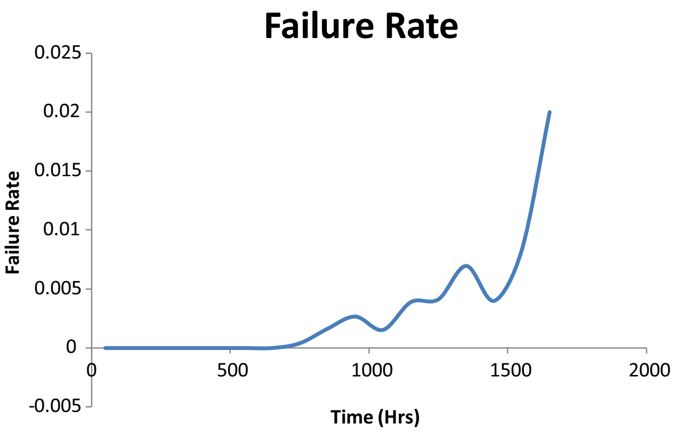

Fig. 6. Failure rate graph based on simple actuarial method.

The following equation is used to estimate the reliability:

$$\text{Reliability, } R(t_i) = \prod_{j=1}^{i}\left(1 - \frac{r_j}{n_j}\right); i = 1\ldots\ldots\ldots m \tag{5}$$

$$\text{Failure rate, } Z(t_j) = \frac{r_j}{n_i * \Delta t_j} \tag{6}$$

where

m = the total number of intervals
n = the total number of units

The variable n_j is defined by

$$n_j = n - \Sigma r_j \tag{7}$$

where r_j is the number of failures in the interval j, n_j is the operating units in the interval j.

Table A3 (Appendix) shows the calculation of reliability estimates using simple actuarial method.

Figs. 6 and 7 show the graphs drawn between Failure rate vs time and Reliability vs time respectively.

The failure rate is increasing with respect to time, which is similar to the failure rate graph drawn for the parametric method using Weibull graph, which has a beta value of 5.23 [15]. This shows that the failure rate obtained in simple actuarial method is accurate. The reliability graph shown in Fig. 7 is also similar to the reliability graph obtained in parametric method using Weibull. The failure rate increases with respect to time, and the reliability decreases with respect to time as expected. The shape of the failure rate graph and reliability graph is similar to the one obtained in Weibull for the obtained parameters.

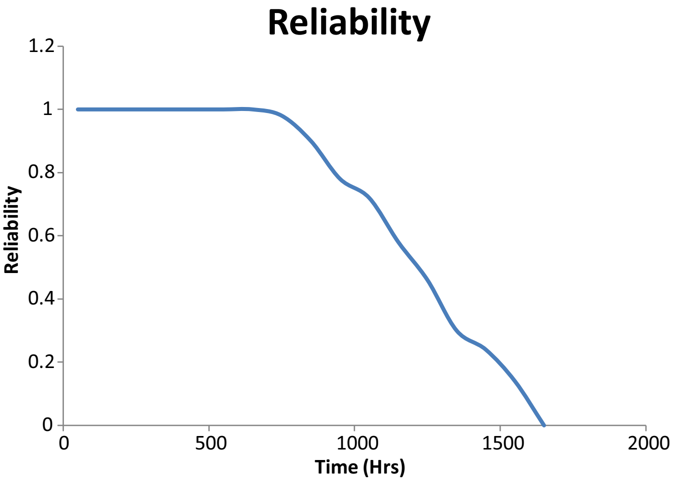

Fig. 7. Reliability graph based on simple actuarial method.

Table 2
Comparison of two non-parametric methods.

R(t)	Time (hours)	
	Non-parametric	
	Kaplan–Meier	Simple Actuarial
0.99	800	750
0.9	870	850
0.8	950	950
0.7	1020	1050
0.6	1130	1050
0.5	1250	1150
0.4	1370	1250
0.3	1470	1350
0.2	1600	1450
0.1	1670	1550
0.01	1740	1650

Table 2 gives the comparison of the reliability values calculated using the two non-parametric methods. From the comparison it is found that the estimated reliability values are closer to each other. Hence it can be concluded that the life estimation of capacitors using the various reliability evaluation methods are accurate. The comparison shows that the evaluated values between the Kaplan–Meier method and the simple actuarial method are similar. The comparison between the parametric method and non-parametric methods shows that the deviation in reliability values is less.

4.4. *Comparison between Kaplan–Meier and simple actuarian methods*

Table 2 gives the comparison of Kaplan–Meier and Simple Actuarial methods.

The mean time to failure under accelerating condition for Kaplan–Meier and Simple Actuarial method is 1261 hours and 1187 hours. Fig. 8 shows the graphical comparison of two non-parametric methods in evaluating reliability, and it is evident from the graph that the deviation in results is less.

4.5. *Reliability evaluation by parametric methods*

Reliability evaluation by parametric method is desirable to fit the failure rate to any statistical distribution, such as the exponential,

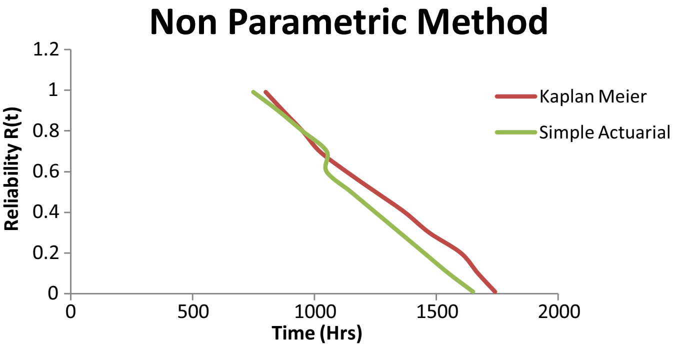

Fig. 8. Comparison of Kaplan–Meier and Simple Actuarial non-parametric methods.

normal, Weibull, or lognormal. This will result in a better understanding of the failure mechanisms, and the resulting model can be used for analytical evaluation of reliability parameters for the whole lifespan of the system.

These values shown in Table A4 (Appendix) are used to draw the Weibull plot to calculate the reliability values. From the corresponding calculated values shown in Table A4, the various graphs that were required to calculate reliability and failure rate were drawn. The Reliasoft Weibull ++ software has been used to plot the graphs. From the Weibull graph it is found that the slope parameter β is 5.3 and the size factor η is 1378.15 hours. The size factor eta is said to be the characteristic life in hours. In this test, it is concluded that it took 1378.15 hours for the 63.2 percent of the capacitors to fail under accelerated conditions. The values of the size and shape factors are used to find the reliability and failure rate for the tested ceramic capacitors.

Since the beta value is less than 6, it is justified that a two parameter Weibull could be the better option than a three parameter Weibull graph. The linear form of the cumulative distribution function for the Weibull graph is given by Eq. (8) [13]:

$$\mathrm{Ln}[\mathrm{Ln}1/(1-F(t))] = \beta \mathrm{Ln}(\mathrm{time}) - \beta \mathrm{Ln}(\eta) \tag{8}$$

where

F(t) = cumulative distribution function
β = shape parameter
η = size parameter

4.6. Two parameter Weibull graph

Fig. 9 shows the two parameter Weibull graphs for the reliability test data of the capacitor when subjected to accelerated combined temperature and voltage.

4.7. Failure rate graph for Weibull distribution

Fig. 10 shows the graph between failure rate and time. The shape parameter value is more than two, which is evident from the graph as the failure rate is increasing with respect to time. The failure shown in Fig. 5 is similar to the failure rate observed in the bathtub curve during the wear out stage. The failure rate for the Weibull distribution is calculated from Eq. (9) shown below [15].

$$\lambda(t) = (\beta/\eta\beta)(t)\beta - 1 \tag{9}$$

where

λ (t) = failure rate at time t
t = time
β = shape parameter
η = size parameter

4.8. Reliability graph for Weibull distribution

Fig. 11 shows the graph between reliability and time. The reliability graph shown in the figure is similar to the standard reliability graph for the Weibull in which the shape parameter value is greater than 3. The reliability function for the Weibull is calculated as shown in Eq. (10) given below [15]:

$$R(t) = \mathrm{Exp}[-(t/\eta)\beta] \tag{10}$$

where

R(t) = reliability at time t
t = time
β = shape parameter
η = size parameter

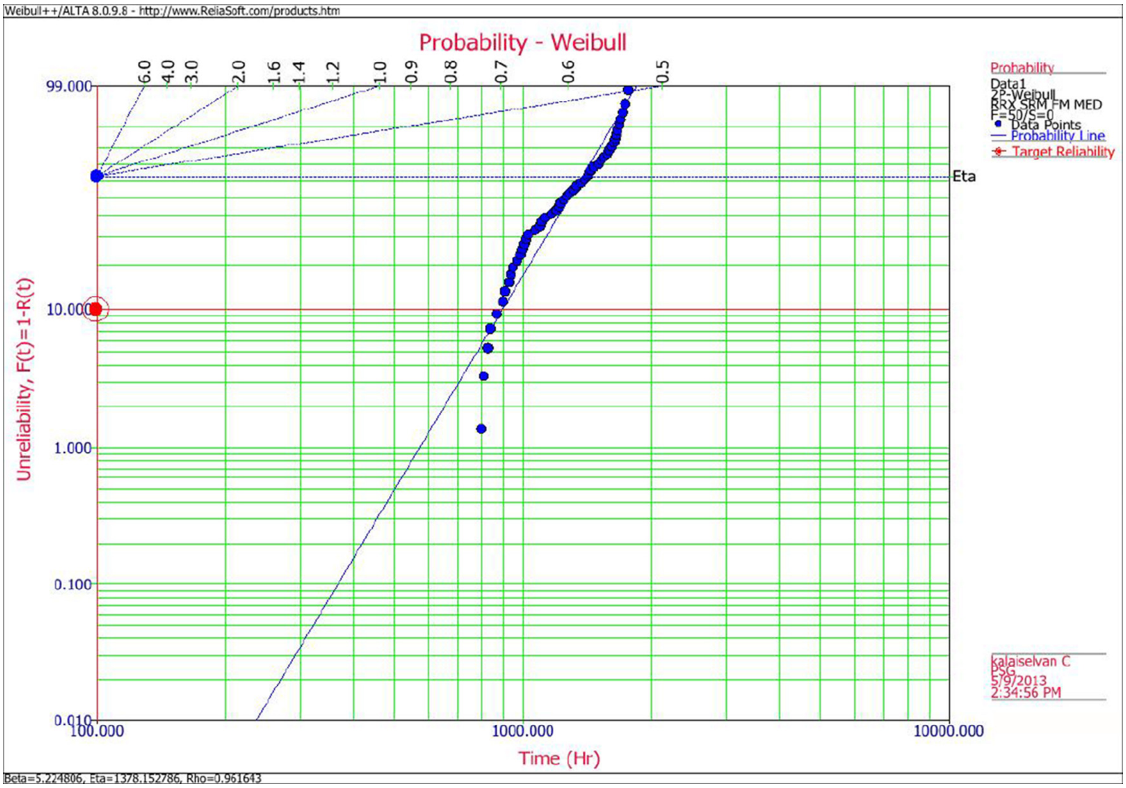

Fig. 9. Two-parameter Weibull graph.

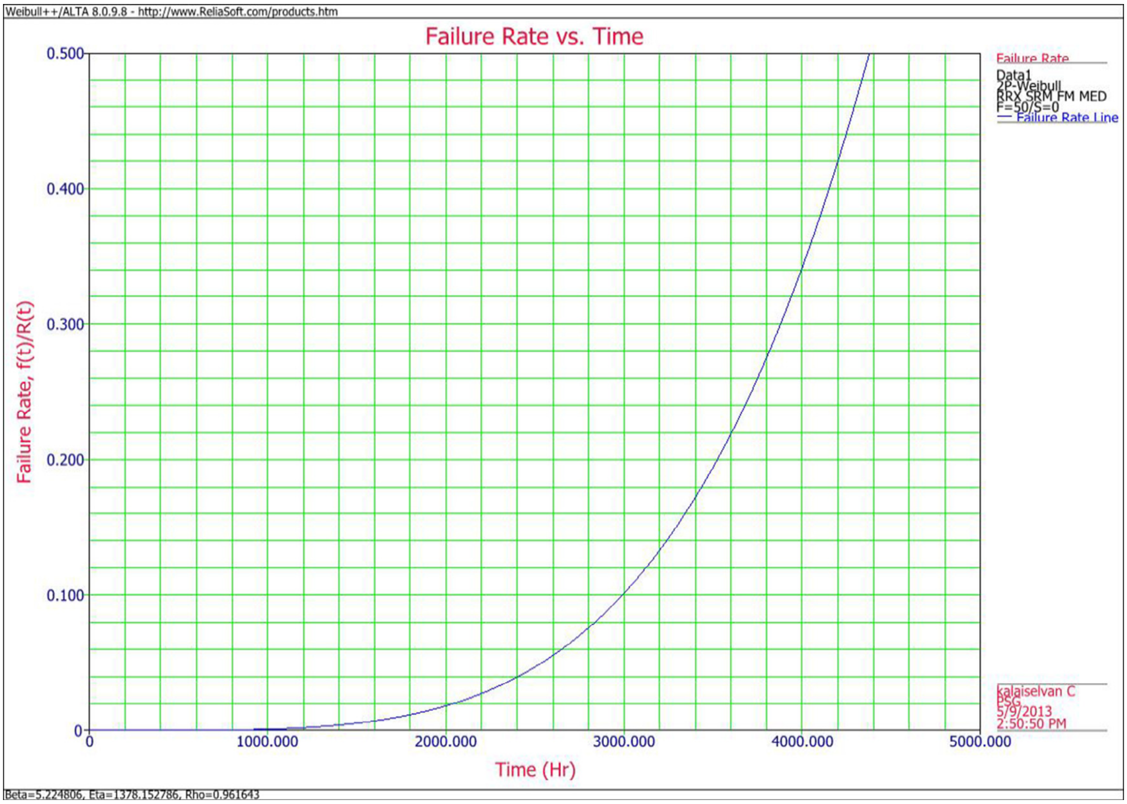

Fig. 10. Failure rate graph.

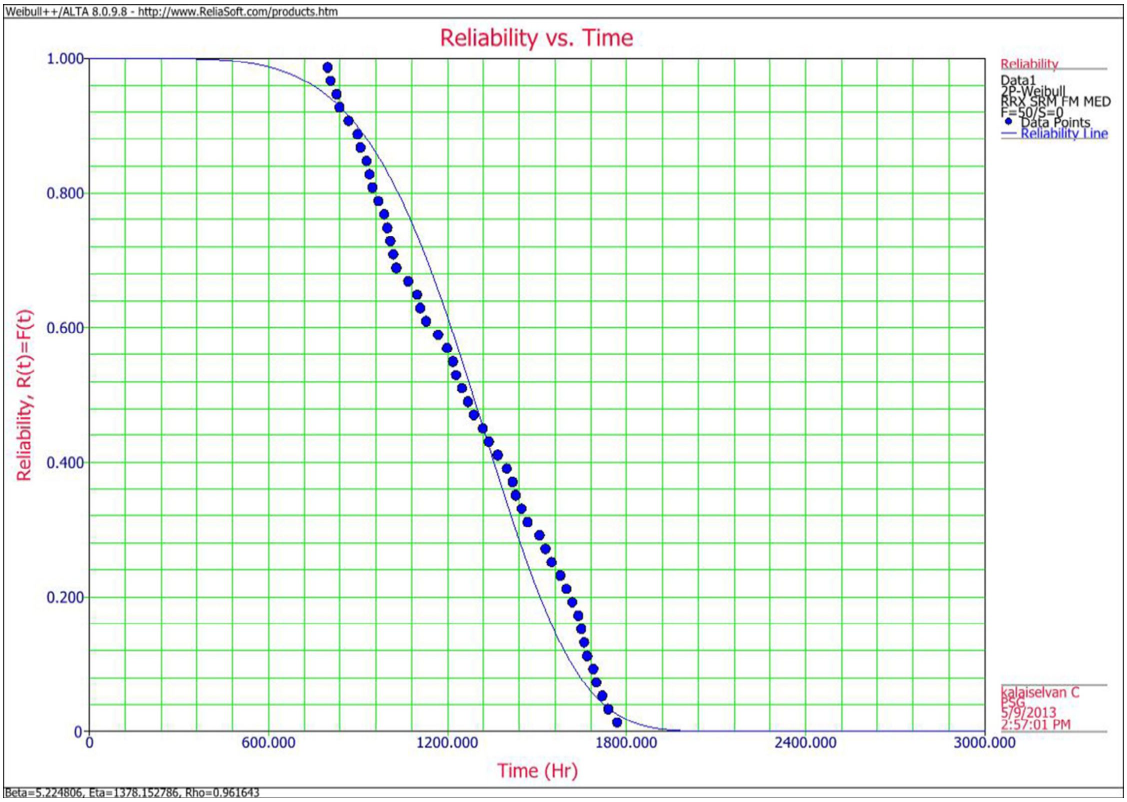

Fig. 11. Reliability graph.

For the two-parameter Weibull distribution, it is given as shown below in Eq. (11).

$$F(t) = 1 - \mathrm{Exp}[-(t/\eta)\beta] \qquad (11)$$

where

t = time
β = shape parameter
η = size parameter

4.9. *Calculation of shape parameters, size parameters and MTTF of capacitor under accelerated conditions*

From the two Weibull analyses, the following parameters are determined

- Shape parameter $\beta = 5.22$
- Size parameter $\eta = 1378.15$

The mean time to failure (MTTF) of the two parameter Weibull is calculated using Eq. (12) given below [14].

$$T = \eta \cdot \Gamma(+1) \qquad (12)$$

where

T = mean time to failure
η = size parameter
β = shape parameter
$\Gamma\ (+1)$ = gamma function evaluated at the value of $(+1)$

The MTTF of capacitors calculated using Eq. (12) under accelerated conditions is found to be 1275 hours.

The comparison between the parametric method and non-parametric method shows that the deviation in reliability values is less.

4.10. *Calculation of MTTF under actual conditions using acceleration model*

From the parametric and non-parametric method, the MTTF of capacitors under accelerated conditions is found to be 1275 hours. The PV model is used to find the life of capacitors at normal conditions for stresses relating to voltage and temperature given in Eq. (1). Now, substituting the following values in Eq. (1), the time t_1 is found to be 97,116.12 hours, which corresponds to 11.08 years.

t_1 = Actual time to failure
t_2 = Accelerated time to failure =1275 hours
V_1 = Voltage under actual condition =50 V
V_2 = Voltage under accelerated condition = 100 V
n = Voltage stress exponential = 2
E_a = Activation energy for dielectric wear out = 0.5 eV
k = Boltzmann's constant (8.62 E-5 eV/K)
T_1 = Absolute temperature = 348.2 K
T_2 = Accelerated Temperature = 423.2 K

5. Conclusions

In this study, the nano ceramic capacitors have been tested under accelerated temperature and voltage stresses condition to generate more failure date within a short period of time. Comparative study has been done for Parametric and Non-Parametric method to identify the mean time to failure. The time taken to identify the mean time to failure (MTTF) under accelerating condition is the same for parametric and non-parametric method with relative deviation. The time to failure data generated from the life test converts accelerated condition data into normal use condition data using Prokopowicz and Vaskas (P-V) empirical equation.

Appendix

Table A1
Time to failure data of capacitor.

S. No	Rank(i)	Hours
1	1	800
2	2	810
3	3	830
4	4	840
5	5	870
6	6	900
7	7	910
8	8	930
9	9	940
10	10	950
11	11	970
12	12	990
13	13	1000
14	14	1010
15	15	1020
16	16	1030
17	17	1070
18	18	1100
19	19	1110
20	20	1130
21	21	1170
22	22	1200
23	23	1220
24	24	1230
25	25	1250
26	26	1270
27	27	1290
28	28	1320
29	29	1340
30	30	1370
31	31	1400
32	32	1420
33	33	1430
34	34	1450
35	35	1470
36	36	1510
37	37	1530
38	38	1550
39	39	1580
40	40	1600
41	41	1620
42	42	1640
43	43	1650
44	44	1660
45	45	1670
46	46	1690
47	47	1700
48	48	1720
49	49	1740
50	50	1770

Table A2
Calculated values of reliability using Kaplan–Meier method.

I	Time to failure (t_j)	No. of failures (r_j)	No. of units at the beginning of the observed time (n_j)	Failure rate, $Z(t_j)$	$(n_j - r_j) / n_j$	Reliability, $\Pi\,((n_j - r_j) / n_j)$
1	0	0	50	0	1	1
2	800	1	50	0.000025	0.98	0.98
3	810	1	49	0.0000252	0.979592	0.96
4	830	1	48	0.0000251	0.979167	0.94
5	840	1	47	0.0000253	0.978723	0.92
6	870	1	46	0.000025	0.978261	0.9
7	900	1	45	0.0000247	0.977778	0.88
8	910	1	44	0.000025	0.977273	0.86
9	930	1	43	0.000025	0.976744	0.84
10	940	1	42	0.0000253	0.97619	0.82
11	950	1	41	0.0000257	0.97561	0.8
12	970	1	40	0.0000258	0.975	0.78
13	990	1	39	0.0000259	0.974359	0.76
14	1000	1	38	0.0000263	0.973684	0.74
15	1010	1	37	0.0000268	0.972973	0.72
16	1020	1	36	0.0000272	0.972222	0.7
17	1030	1	35	0.0000277	0.971429	0.68
18	1070	1	34	0.0000275	0.970588	0.66
19	1100	1	33	0.0000275	0.969697	0.64
20	1110	1	32	0.0000282	0.96875	0.62
21	1130	1	31	0.0000285	0.967742	0.6
22	1170	1	30	0.0000285	0.966667	0.58
23	1200	1	29	0.0000287	0.965517	0.56
24	1220	1	28	0.0000293	0.964286	0.54
25	1230	1	27	0.0000301	0.962963	0.52
26	1250	1	26	0.0000308	0.961538	0.5
27	1270	1	25	0.0000315	0.96	0.48
28	1290	1	24	0.0000323	0.958333	0.46
29	1320	1	23	0.0000329	0.956522	0.44
30	1340	1	22	0.0000339	0.954545	0.42
31	1370	1	21	0.0000348	0.952381	0.4
32	1400	1	20	0.0000357	0.95	0.38
33	1420	1	19	0.0000371	0.947368	0.36
34	1430	1	18	0.0000389	0.944444	0.34
35	1450	1	17	0.0000406	0.941176	0.32
36	1470	1	16	0.0000425	0.9375	0.3
37	1510	1	15	0.0000442	0.933333	0.28
38	1530	1	14	0.0000467	0.928571	0.26
39	1550	1	13	0.0000496	0.923077	0.24
40	1580	1	12	0.0000527	0.916667	0.22
41	1600	1	11	0.0000568	0.909091	0.2
42	1620	1	10	0.0000617	0.9	0.18
43	1640	1	9	0.0000678	0.888889	0.16
44	1650	1	8	0.0000758	0.875	0.14
45	1660	1	7	0.0000861	0.857143	0.12
46	1670	1	6	0.0000998	0.833333	0.1
47	1690	1	5	0.000118	0.8	0.08
48	1700	1	4	0.000147	0.75	0.06
49	1720	1	3	0.000194	0.666667	0.04
50	1740	1	2	0.000287	0.5	0.02
51	1770	1	1	0.000565	0	0

Table A3
Reliability estimates based on simple actuarial method.

S. No	Start time	End time	Midpoint of TI	No. of units failed	No. of units survived	Failure rate	1-(r_j / n_j)	Π (1-(r_j / n_j))
1	0	100	50	0	50	0	1	1
2	100	200	150	0	50	0	1	1
3	200	300	250	0	50	0	1	1
4	300	400	350	0	50	0	1	1
5	400	500	450	0	50	0	1	1
6	500	600	550	0	50	0	1	1
7	600	700	650	0	50	0	1	1
8	700	800	750	1	50	0.0004	0.98	0.98
9	800	900	850	4	49	0.0016	0.9184	0.9
10	900	1000	950	6	45	0.0027	0.8667	0.78
11	1000	1100	1050	3	39	0.0015	0.9231	0.72
12	1100	1200	1150	7	36	0.0039	0.8056	0.58
13	1200	1300	1250	6	29	0.0041	0.7931	0.46
14	1300	1400	1350	8	23	0.007	0.6522	0.3
15	1400	1500	1450	3	15	0.004	0.8	0.24
16	1500	1600	1550	5	12	0.0083	0.5833	0.14
17	1600	1700	1650	7	7	0.02	0	0

Table A4
Median ranks and log normal failure hours.

Sample	Hour	Rank	Median rank	1/(1-Median rank)	Ln[ln(1/(1-Median rank))]	Ln (failure hours)
1	800	1	0.013888889	1.01408451	–4.269681149	6.684612
2	810	2	0.033730159	1.0349076	–3.372255906	6.697034
3	830	3	0.053571429	1.05660377	–2.899335826	6.721426
4	840	4	0.073412698	1.07922912	–2.573777072	6.733402
5	870	5	0.093253968	1.10284464	–2.323881488	6.768493
6	900	6	0.113095238	1.12751678	–2.120116268	6.802395
7	910	7	0.132936508	1.15331808	–1.947409762	6.813445
8	930	8	0.152777778	1.18032787	–1.797019751	6.835185
9	940	9	0.172619048	1.20863309	–1.663418782	6.84588
10	950	10	0.192460317	1.23832924	–1.542886968	6.856462
11	970	11	0.212301587	1.26952141	–1.432799192	6.877296
12	990	12	0.232142857	1.30232558	–1.331232193	6.897705
13	1000	13	0.251984127	1.33687003	–1.23673335	6.907755
14	1010	14	0.271825397	1.373297	–1.14817733	6.917706
15	1020	15	0.291666667	1.41176471	–1.064673327	6.927558
16	1030	16	0.311507937	1.45244957	–0.985502856	6.937314
17	1070	17	0.331349206	1.49554896	–0.910076735	6.975414
18	1100	18	0.351190476	1.5412844	–0.837904556	7.003065
19	1110	19	0.371031746	1.58990536	–0.768572494	7.012115
20	1130	20	0.390873016	1.64169381	–0.70172684	7.029973
21	1170	21	0.410714286	1.6969697	–0.637061542	7.064759
22	1200	22	0.430555556	1.75609756	–0.574308609	7.090077
23	1220	23	0.450396825	1.81949459	–0.513230577	7.106606
24	1230	24	0.470238095	1.88764045	–0.453614492	7.114769
25	1250	25	0.490079365	1.96108949	–0.395267011	7.130899
26	1270	26	0.509920635	2.04048583	–0.338010315	7.146772
27	1290	27	0.529761905	2.12658228	–0.281678627	7.162397
28	1320	28	0.549603175	2.22026432	–0.226115149	7.185387
29	1340	29	0.569444444	2.32258065	–0.171169278	7.200425
30	1370	30	0.589285714	2.43478261	–0.11669397	7.222566
31	1400	31	0.609126984	2.55837564	–0.062543138	7.244228
32	1420	32	0.628968254	2.69518717	–0.008568958	7.258412
33	1430	33	0.648809524	2.84745763	0.04538106	7.26543
34	1450	34	0.668650794	3.01796407	0.099467395	7.279319
35	1470	35	0.688492063	3.21019108	0.153862463	7.293018
36	1510	36	0.708333333	3.42857143	0.208755483	7.319865
37	1530	37	0.728174603	3.67883212	0.264358691	7.333023
38	1550	38	0.748015873	3.96850394	0.320915558	7.34601
39	1580	39	0.767857143	4.30769231	0.378711968	7.36518
40	1600	40	0.787698413	4.71028037	0.438091972	7.377759
41	1620	41	0.807539683	5.19587629	0.499480686	7.390181
42	1640	42	0.827380952	5.79310345	0.563418918	7.402452
43	1650	43	0.847222222	6.54545455	0.630617758	7.408531
44	1660	44	0.867063492	7.52238806	0.702049264	7.414573
45	1670	45	0.886904762	8.84210526	0.779106963	7.420579
46	1690	46	0.906746032	10.7234043	0.863914184	7.432484
47	1700	47	0.926587302	13.6216216	0.959985405	7.438384
48	1720	48	0.946428571	18.6666667	1.073888971	7.45008
49	1740	49	0.966269841	29.6470588	1.220641976	7.46164
50	1770	50	0.986111111	72	1.453173762	7.478735

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