Advances in Reliability, Safety and Security, Part 3 – Kołowrocki, Dąbrowska (eds.)
© 2024 Polish Safety and Reliability Association, Gdynia, ISBN 978-83-68136-15-9 (printed), ISBN 978-83-68136-02-9 (electronic)

Advances in Reliability, Safety and Security

ESREL 2024
Monograph Book Series

Predictive Reliability Modelling Based On Combination Of DoE And ALT

Fatima-Ezahra Indmeskine, Laurent Saintis, Abdessamad Kobi, Mihaela Barreau

Université d'Angers, LARIS, SFR MATHSTIC, F-49000 Angers, France

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Abstract

Crossed array design is a method in the design of experiments used to study the effects of controllable and noise factors on the response of a system. This approach is not commonly used in accelerated life testing for the study of the reliability of electronic components. However, it can enhance predictive reliability modeling. This article presents a methodology for applying the approach to surface-mount ceramic capacitors. It defines a predictive reliability model based on state-of-the-art techniques and estimates parameters using MATLAB. The analysis of the results shows that calculating the signal-to-noise ratio is a useful strategy for understanding the impact of technological factors on the lifetime of ceramic capacitors.

Keywords: design of experiments, accelerated life test, crossed array design, reliability

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1. Introduction

The extensive scope of electronic component applications has necessitated exceptional standards of quality and reliability, particularly for crucial applications such as active implantable medical devices (AIMDs) (Indmeskine, Saintis, and Kobi, 2022). The continuous introduction of novel materials and technologies has led experts in reliability to comprehend electronic components' failure physics and adapt the underlying reliability tests to the application's mission profile. Accelerated life tests are commonly conducted on components to achieve the desired reliability metrics (Elsayed, 2021), and designs of experiments are implemented to ensure component robustness against various factors (Montgomery, 2013). However, there is a noticeable gap in the literature regarding an efficient combination of these two approaches, especially concerning electronic components (Indmeskine, Saintis, and Kobi, 2023). With the aim of modeling the reliability of a component as a function of its design characteristics, this paper showcases a methodology that combines accelerated life testing and design of experiments to obtain relevant results, proposes analytical methods for these results, and applies them to ceramic capacitors. The article is structured as follows: Section 2 summarizes the main elements of the theory related to the design of experiments and accelerated life testing and introduces the methodology for crossed array design. Section 3 presents an example of the application of this methodology to ceramic capacitors, defining a model of reliability and analyzing the results. Finally, Section 4 concludes with objectives and perspectives.

2. Theory

In this section, the methods of Design of Experiments (DoE) and Accelerated Life Testing (ALT) will be briefly reviewed as an introduction to the combination of these approaches through a crossed array design.

2.1. Design of Experiments (DoE)

Design of Experiments are methods, generally used in robustness studies, that enable to effectively design experiments while minimizing the use of time and resources, while using statistical techniques to investigate the effects of factors of interest on the outcome of the system. The main aim is to optimize the outcome and improve the system. Particularly, Taguchi factorial designs (Montgomery, 2013) are one of the interesting designs that are used to make the system insensitive to variability and noise.

Another type of design commonly used is Latin Hypercube Design (LHD). A Latin hypercube for an experiment of n runs and k factors is $n \times k$ matrix where each column is a random permutation of the levels 1, 2, …, n (Montgomery, 2013, 524-25). Zhu and Elsayed (2013) demonstrated the optimality of using a LHD for designing ALT plans that involve multiple stresses. This is in terms of reducing test time, sample units, and improving parameter estimation.

2.2. Accelerated Life Testing (ALT)

Accelerated Life Testing is a widely utilized testing method in the field of reliability, employed for various purposes (Indmeskine, Saintis, and Kobi, 2023; Yang, 2007). ALT involves accelerating the failure of the component under study via established mathematical models that describe the physics of failure of the component. By subjecting the component to increased environmental stress levels (such as temperature, humidity, and voltage) beyond their nominal conditions, potential failure mechanisms during the component's usage phase can be observed. Through analyzing the probability distribution of the component's lifetime, one can estimate the parameters associated with the predictive reliability model of the component.

2.3. Crossed Array Design

Crossed array design is a method of DoE proposed by Taguchi (Pillet, 1997) which involves crossing two experimental designs in the form of an inner array crossed with an outer array (see Fig. 1). The inner array explores controllable factors (framed in red in Fig. 1) that are assumed to be independent, while the outer array analyses uncontrollable factors, considered to be noise (framed in blue in Fig. 1). An accelerated life test will be conducted for each combination of the two arrays. Ultimately, the objective is to employ statistical techniques to examine the impact of different factors on the outcome.

Despite the numerous advantages offered by the combination of ALT approaches and DoE approaches, there remains an insufficient application of these methods. DoE approaches have primarily been used to determine optimal design parameters for ensuring product or system robustness, or to design cost-effective reliability experiments without sacrificing information. However, these approaches have often neglected to consider the value of studying the impact of design parameters on the response and the value of crossing reliability and design of experiments respective methods. The reader can refer to the authors' previous work (Indmeskine, Saintis, and Kobi, 2023) for a review of these methods, of examples of their combination, as well as of predictive reliability models for qualification of electronic components.

In fact, to study the reliability of a given electronic component within the context of predictive reliability, accelerated life tests can be constructed in such a way that control variables are the technological characteristics of the electronic component defined in the inner array, noise variables are environmental stresses accelerated defined in the outer array, and the response variable is the time of failure.

To analyze the crossed array design, the focus lies in modelling the mean and variance of the response variable separately. Generally, the designer is interested in maximizing the mean of the response variable (location effect) while minimizing the variance (dispersion effect), in the form of a dual response system.

Another approach is to calculate the signal-to-noise ratio which includes both location and dispersion effects. The formula depends on whether the optimum response is the maximum, the minimum, or equal to a targeted value.

This design is used to conduct the experiments in a way that provides sufficient information about the interaction between controllable factors and noise factors, and allows the relationship between these factors and the reliability metric to be established. Further details of the design and its analysis are given in the next section.

3. Application on ceramic capacitors

In this section, the methods described previously will be applied to ceramic capacitors. The aim is to build a reliability model based on the design parameters of a component. To do this, a test model is used to generate failure times based on this model. Then, independently, an estimation of the original model parameters using DoE statistical approaches will validate the proposed approach. The proposed procedure is the following:

1. Define a reliability model for ceramic capacitors with parameters fixed from the state of the art and/or predictive reliability guide FIDES ('Guide FIDES 2022 Edition A | FIDES', 2022),
2. Generate failure times for ceramic capacitors based on the model described below, for each component of the designs produced,
3. Estimate initial parameters,
4. Analyze the crossed array design.

The following hypotheses are assumed:

- times of failure follow a Weibull distribution;
- one failure mode dominates (short circuit due to thermo-electrical stresses (Wang and Blaabjerg, 2014)), and the others are neglected;
- failure characterized by the failure mode is modelized by Weibull law with $(\theta;\beta)$ as scale and shape parameters respectively;
- to simplify the reliability model, humidity will not be considered.

Concerning the crossed array design:

- inner array - full factional design is chosen as a DoE approach for the controllable factors: A. Dielectric (with 2 levels), B. Termination with 2 levels, C. Packaging size (with 3 levels), and D. *Capacitance*Voltage* (with 3 levels). This results in a total of 36 combinations (framed in red in Fig. 1);
- outer array - ceramic capacitors can fail due to voltage, humidity, and temperature. These factors are considered here noise variables and are organized in a LHD with 5 levels each, as they are the main accelerators of failure. This results in a total of 5 combinations (framed in blue in Fig. 1).

Failure time is generated for every point of the crossed array design, for 24 components (a random probability of failure is assigned to each component).

3.1. Model for failure time generation

Based on the above assumptions, component reliability can be written as:

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

Where the scale parameter θ is associated with the short circuit failure mode caused by thermos-electrical stresses through an acceleration factor AF_{th-el} as follows:

$$\theta = e^{\lambda_0}.\mathrm{AF}_{th-el}$$

Where λ_0 depends on the technological factors, and the acceleration factor (Arrhenius law for temperature and Inverse Power law for voltage (Nelson, 2004)) is:

$$AF_{th-el} = \left(\frac{1}{S_{ref}}.\frac{V_{app}}{V_0}\right)^{p_{th-el}}.e^{\frac{E_a}{K_B}.\left(\frac{1}{T_0}-\frac{1}{T_{amb}}\right)},$$

where:

- S_{ref} – reference level for the electrical stress;
- V_{app} – voltage applied on the component;
- V_0 – rated voltage;
- p_{th-el} – a model parameter (accelerating power for the electrical stress);
- E_a – activation energy which depends on the technology considered;
- K_B – Boltzmann constant (~8.617×10−5 eV/°C);
- T_{amb} – applied ambient temperature;
- T_0 – nominal ambient temperature.

Therefore, the scale parameter depends on the stresses through the log-linear relationship:

$$\ln(\theta) = \lambda_0 + p_{th-el}.\ln\left(\frac{1}{S_{ref}}.\frac{V_{app}}{V_0}\right) + \frac{E_a}{K_B}.\left(\frac{1}{T_0} - \frac{1}{T_{amb}}\right),$$

where $\ln\left(\frac{1}{S_{ref}}.\frac{V_{app}}{V_0}\right)$ and $\left(\frac{1}{T_0} - \frac{1}{T_{amb}}\right)$ are the transformed variables of voltage and temperature.

The parameter λ_0 is calculated from a regression model on the technological factors of the components by representing the levels of each factor by a binary variable as follows:

Table 1. Regression model of parameter λ_0.

Factor	Factor level	Binary variable	Variable coefficient
Dielectric	X7R	A1 (δ_1)	γ_1
	C0G	A2	γ_2
Termination	Rigid	B1	γ_3
	Flex	B2	γ_4
	0603	C4	γ_5
	0805	C5	γ_6
	1206	C6	γ_7
CV (capacitance*voltage)	Cat1	D1	γ_8
	Cat2	D2	γ_9
	Cat3	D3 (δ_{13})	γ_{10}

Intrinsic contribution of technological factors

$$\lambda_0 = \gamma_0 + \sum_{i=1}^{10} \gamma_i \delta_i \tag{1}$$

Hypotheses

Factors are mutually independent.

3.2. Analysis of crossed array design

In this example, the response of interest is the failure time of the ceramic capacitors, and the objective is to find the levels of the technological factors that maximize time-to-failure and minimize the variance.

The variances are calculated over the mean of failure times for every combination of the ALT since the interest lies in the variability over the controllable variables.

In this case, the signal-to-noise ratio is calculated through the formula (Pillet, 1997, 134):

$$\nu_i = -10 \log \left[\frac{1}{n} \sum_{j=1}^{5} \left(\frac{1}{FT_{ij}^2} \right) \right], \tag{2}$$

where

- ν_i – signal-to-noise (S/N) for the DoE combination No. i;
- n – number of DoE combinations;
- FT_{ij} – the failure time of the DoE combination i for the ALT combination j.

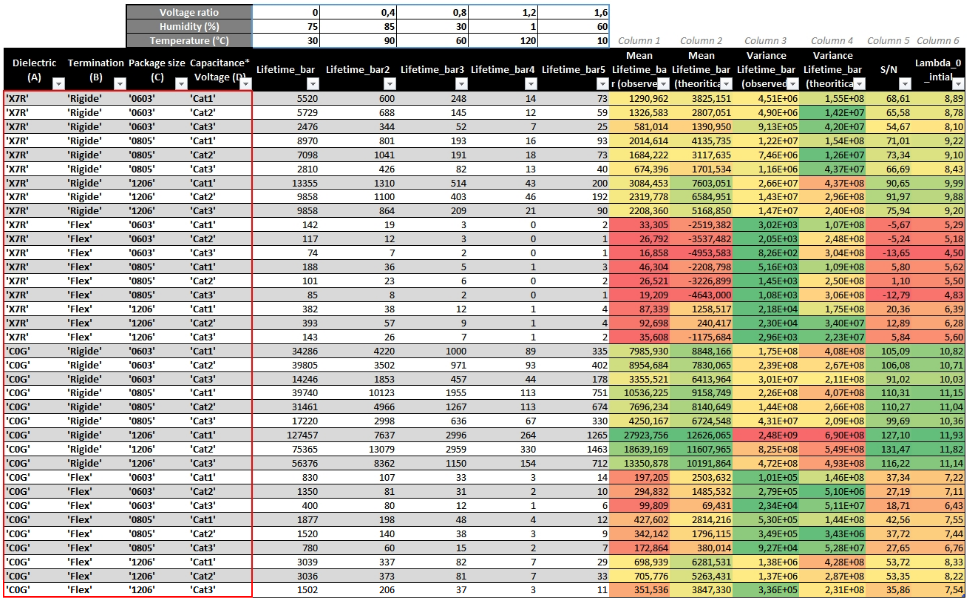
For each point of the crossed array design, failure times were generated for each component then averaged to arrive at the ***Lifetime_bar*** values in Fig. 1. The mean of these values is calculated for every combination of DoE over the ALT combinations (Column 1 in Fig. 1), as well as variance (Column 3 in Fig. 1). The corresponding theoretical values (Column 2 and Column 4 in Fig. 1) are calculated through the model:

$$Y\sim = M + [E_{A1}\ E_{A2}][A] + [E_{B1}\ E_{B2}][B] + [E_{C1}\ E_{C2}\ E_{C3}][C] + [E_{D1}\ E_{D2}\ E_{D3}][D],$$

where

- Y – response under study (mean or variance of Lifetime_bar);
- M – total mean of the responses;
- E_{A1} – effect of level 1 of factor A on the response;
- $[A]$ – levels of factor A (e.g., if factor A is at level 1, $[A] = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$.

The model's initial λ_0 (Column 6 in Fig. 1) is compared to S/N (Column 5 in Fig. 1, calculated via Equation (2) in the last column. The results indicate that S/N is most compatible with λ_0, while mean and variance calculations are not quite compatible. This suggests that S/N more accurately describes the effects of factors on the response.



			Voltage ratio	0	0,4	0,8	1,2	1,6						
			Humidity (%)	75	85	30	1	60						
			Temperature (°C)	30	90	60	120	10	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Dielectric (A)	Termination (B)	Package size (C)	Capacitance* Voltage (D)	Lifetime_bar	Lifetime_bar2	Lifetime_bar3	Lifetime_bar4	Lifetime_bar5	Mean Lifetime_bar (observe	Mean Lifetime_bar (theoritica	Variance Lifetime_bar (observed	Variance Lifetime_bar (theoritica	S/N	Lambda_0 _intial
'X7R'	'Rigide'	'0603'	'Cat1'	5520	600	248	14	73	1290,962	3825,151	4,51E+06	1,55E+08	68,61	8,89
'X7R'	'Rigide'	'0603'	'Cat2'	5729	688	145	12	59	1326,583	2807,051	4,90E+06	1,42E+07	65,58	8,78
'X7R'	'Rigide'	'0603'	'Cat3'	2476	344	52	7	25	581,014	1390,950	9,13E+05	4,20E+07	54,67	8,10
'X7R'	'Rigide'	'0805'	'Cat1'	8970	801	193	16	93	2014,614	4135,735	1,22E+07	1,54E+08	71,01	9,22
'X7R'	'Rigide'	'0805'	'Cat2'	7098	1041	191	18	73	1684,222	3117,635	7,46E+06	1,26E+07	73,34	9,10
'X7R'	'Rigide'	'0805'	'Cat3'	2810	426	82	13	40	674,396	1701,534	1,16E+06	4,37E+07	66,69	8,43
'X7R'	'Rigide'	'1206'	'Cat1'	13355	1310	514	43	200	3084,453	7603,051	2,66E+07	4,37E+08	90,65	9,99
'X7R'	'Rigide'	'1206'	'Cat2'	9858	1100	403	46	192	2319,778	6584,951	1,43E+07	2,96E+08	91,97	9,88
'X7R'	'Rigide'	'1206'	'Cat3'	9858	864	209	21	90	2208,360	5168,850	1,47E+07	2,40E+08	75,94	9,20
'X7R'	'Flex'	'0603'	'Cat1'	142	19	3	0	2	33,305	-2519,382	3,02E+03	1,07E+08	-5,67	5,29
'X7R'	'Flex'	'0603'	'Cat2'	117	12	3	0	1	26,792	-3537,482	2,05E+03	2,48E+08	-5,24	5,18
'X7R'	'Flex'	'0603'	'Cat3'	74	7	2	0	1	16,858	-4953,583	8,26E+02	3,04E+08	-13,65	4,50
'X7R'	'Flex'	'0805'	'Cat1'	188	36	5	1	3	46,304	-2208,798	5,16E+03	1,09E+08	5,80	5,62
'X7R'	'Flex'	'0805'	'Cat2'	101	23	6	0	2	26,521	-3226,899	1,45E+03	2,50E+08	1,10	5,50
'X7R'	'Flex'	'0805'	'Cat3'	85	8	2	0	1	19,209	-4643,000	1,08E+03	3,06E+08	-12,79	4,83
'X7R'	'Flex'	'1206'	'Cat1'	382	38	12	1	4	87,339	1258,517	2,18E+04	1,75E+08	20,36	6,39
'X7R'	'Flex'	'1206'	'Cat2'	393	57	9	1	4	92,698	240,417	2,30E+04	3,40E+07	12,89	6,28
'X7R'	'Flex'	'1206'	'Cat3'	143	26	7	1	2	35,608	-1175,684	2,96E+03	2,23E+07	5,84	5,60
'C0G'	'Rigide'	'0603'	'Cat1'	34286	4220	1000	89	335	7985,930	8848,166	1,75E+08	4,08E+08	105,09	10,82
'C0G'	'Rigide'	'0603'	'Cat2'	39805	3502	971	93	402	8954,684	7830,065	2,39E+08	2,67E+08	106,08	10,71
'C0G'	'Rigide'	'0603'	'Cat3'	14246	1853	457	44	178	3355,521	6413,964	3,01E+07	2,11E+08	91,02	10,03
'C0G'	'Rigide'	'0805'	'Cat1'	39740	10123	1955	113	751	10536,225	9158,749	2,26E+08	4,07E+08	110,31	11,15
'C0G'	'Rigide'	'0805'	'Cat2'	31461	4966	1267	113	674	7696,234	8140,649	1,44E+08	2,66E+08	110,27	11,04
'C0G'	'Rigide'	'0805'	'Cat3'	17220	2998	636	67	330	4250,167	6724,548	4,31E+07	2,09E+08	99,69	10,36
'C0G'	'Rigide'	'1206'	'Cat1'	127457	7637	2996	264	1265	27923,756	12626,065	2,48E+09	6,90E+08	127,10	11,93
'C0G'	'Rigide'	'1206'	'Cat2'	75365	13079	2959	330	1463	18639,169	11607,965	8,25E+08	5,49E+08	131,47	11,82
'C0G'	'Rigide'	'1206'	'Cat3'	56376	8362	1150	154	712	13350,878	10191,864	4,72E+08	4,93E+08	116,22	11,14
'C0G'	'Flex'	'0603'	'Cat1'	830	107	33	3	14	197,205	2503,632	1,01E+05	1,46E+08	37,34	7,22
'C0G'	'Flex'	'0603'	'Cat2'	1350	81	31	2	10	294,832	1485,532	2,79E+05	5,10E+06	27,19	7,11
'C0G'	'Flex'	'0603'	'Cat3'	400	80	12	1	6	99,809	69,431	2,34E+04	5,11E+07	18,71	6,43
'C0G'	'Flex'	'0805'	'Cat1'	1877	198	48	4	12	427,602	2814,216	5,30E+05	1,44E+08	42,56	7,55
'C0G'	'Flex'	'0805'	'Cat2'	1520	140	38	3	9	342,142	1796,115	3,49E+05	3,43E+06	37,72	7,44
'C0G'	'Flex'	'0805'	'Cat3'	780	60	15	2	7	172,864	380,014	9,27E+04	5,28E+07	27,65	6,76
'C0G'	'Flex'	'1206'	'Cat1'	3039	337	82	7	29	698,939	6281,531	1,38E+06	4,28E+08	53,72	8,33
'C0G'	'Flex'	'1206'	'Cat2'	3036	373	81	7	33	705,776	5263,431	1,37E+06	2,87E+08	53,35	8,22
'C0G'	'Flex'	'1206'	'Cat3'	1502	206	37	3	11	351,536	3847,330	3,36E+05	2,31E+08	35,86	7,54

Lifetime_bar *is the mean of lifetimes over all components.*

Mean Lifetime_bar *is the mean of Lifetime_bar over the ALT combinations.*

Fig. 1. Results of data generation and crossed array design analysis.

3.3. Estimation of the parameters of reliability model

The parameters described previously are to be estimated for every combination of the DoE following the procedure (schematized in Fig. 2):

1. Estimate the four parameters (p_{th-el}, E_a, λ_0, β) by maximizing the likelihood function using the function “fmincon” of MATLAB.
2. Choose randomly a parameter, say p_{th-el}, on which analysis of variance (ANOVA) is performed using the “anova” built-in function of MATLAB. If there is a statistical difference between the estimated values of the parameter for every combination, fix the parameter at these values respect, if not, fix the parameter at the mean of the estimated values after removing outliners (using “rmoutliers” built-in function of MATLAB). The factors are considered to have statistical effects on the parameters if the corresponding *pValue* is lower than the level of significance ***a*** (fixed at 1%).
3. Estimate the other non-fixed parameters.
4. Repeat steps 2. And 3. for every other parameter.
5. Estimate the vector γ to find the linear regression relationship between λ_0 and the levels of the technological factors.

This procedure is run for the initial values of the parameters of ($p_{th-el} = 3$, $E_a = 0.2$, $\boldsymbol{\delta}' = (0|0.93|2.86|3.87|0.27|0.69|1.02|1.79|3.40|3.29|2.61)$, $\beta = 1$). Results of this procedure are shown in Fig. 3.

In Column 1, 2, 3, and 4 are shown the estimated parameters. In Column 5, parameter $\widehat{\lambda_0}$ (*Lambda_0_hat*) is calculated through the estimated coefficients of the regression model in Equation 1. The estimation results match the initial values, validating the methodology.

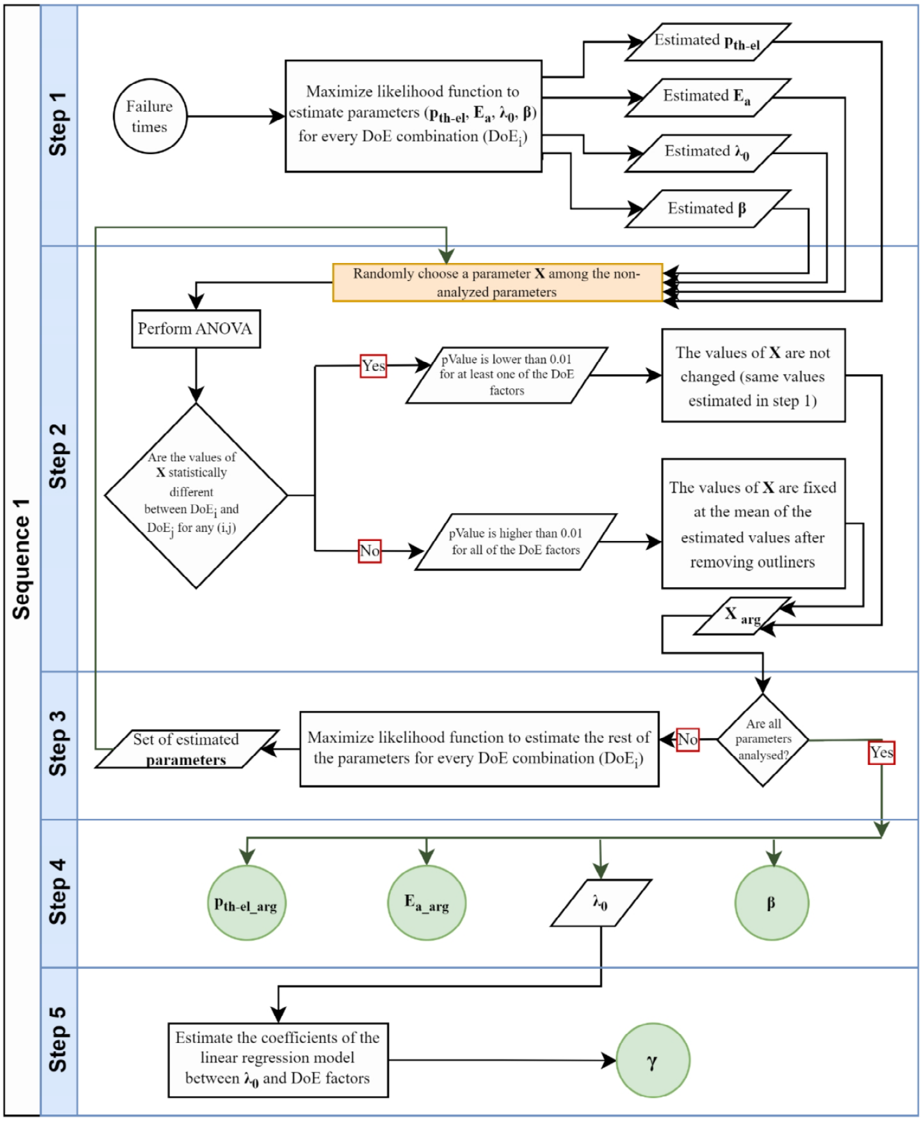
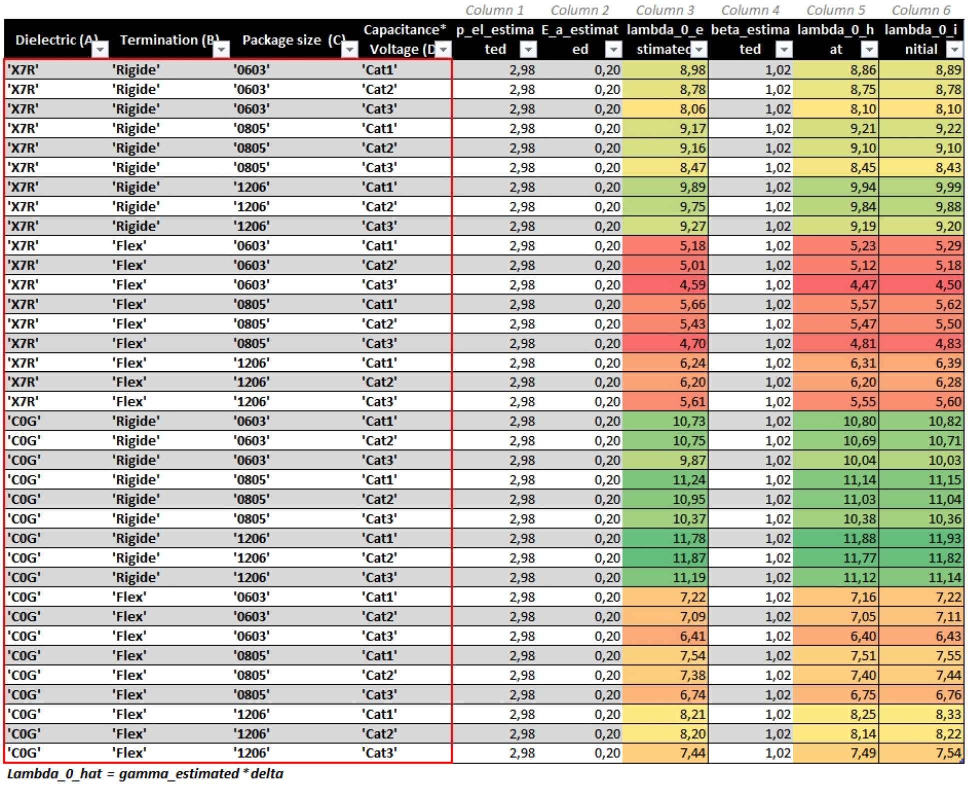


Fig. 2. Procedure for estimation of reliability model parameters.



				Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Dielectric (A)	Termination (B)	Package size (C)	Capacitance* Voltage (D	p_el_estimated	E_a_estimated	lambda_0_estimated	beta_estimated	lambda_0_hat	lambda_0_initial
'X7R'	'Rigide'	'0603'	'Cat1'	2,98	0,20	8,98	1,02	8,86	8,89
'X7R'	'Rigide'	'0603'	'Cat2'	2,98	0,20	8,78	1,02	8,75	8,78
'X7R'	'Rigide'	'0603'	'Cat3'	2,98	0,20	8,06	1,02	8,10	8,10
'X7R'	'Rigide'	'0805'	'Cat1'	2,98	0,20	9,17	1,02	9,21	9,22
'X7R'	'Rigide'	'0805'	'Cat2'	2,98	0,20	9,16	1,02	9,10	9,10
'X7R'	'Rigide'	'0805'	'Cat3'	2,98	0,20	8,47	1,02	8,45	8,43
'X7R'	'Rigide'	'1206'	'Cat1'	2,98	0,20	9,89	1,02	9,94	9,99
'X7R'	'Rigide'	'1206'	'Cat2'	2,98	0,20	9,75	1,02	9,84	9,88
'X7R'	'Rigide'	'1206'	'Cat3'	2,98	0,20	9,27	1,02	9,19	9,20
'X7R'	'Flex'	'0603'	'Cat1'	2,98	0,20	5,18	1,02	5,23	5,29
'X7R'	'Flex'	'0603'	'Cat2'	2,98	0,20	5,01	1,02	5,12	5,18
'X7R'	'Flex'	'0603'	'Cat3'	2,98	0,20	4,59	1,02	4,47	4,50
'X7R'	'Flex'	'0805'	'Cat1'	2,98	0,20	5,66	1,02	5,57	5,62
'X7R'	'Flex'	'0805'	'Cat2'	2,98	0,20	5,43	1,02	5,47	5,50
'X7R'	'Flex'	'0805'	'Cat3'	2,98	0,20	4,70	1,02	4,81	4,83
'X7R'	'Flex'	'1206'	'Cat1'	2,98	0,20	6,24	1,02	6,31	6,39
'X7R'	'Flex'	'1206'	'Cat2'	2,98	0,20	6,20	1,02	6,20	6,28
'X7R'	'Flex'	'1206'	'Cat3'	2,98	0,20	5,61	1,02	5,55	5,60
'C0G'	'Rigide'	'0603'	'Cat1'	2,98	0,20	10,73	1,02	10,80	10,82
'C0G'	'Rigide'	'0603'	'Cat2'	2,98	0,20	10,75	1,02	10,69	10,71
'C0G'	'Rigide'	'0603'	'Cat3'	2,98	0,20	9,87	1,02	10,04	10,03
'C0G'	'Rigide'	'0805'	'Cat1'	2,98	0,20	11,24	1,02	11,14	11,15
'C0G'	'Rigide'	'0805'	'Cat2'	2,98	0,20	10,95	1,02	11,03	11,04
'C0G'	'Rigide'	'0805'	'Cat3'	2,98	0,20	10,37	1,02	10,38	10,36
'C0G'	'Rigide'	'1206'	'Cat1'	2,98	0,20	11,78	1,02	11,88	11,93
'C0G'	'Rigide'	'1206'	'Cat2'	2,98	0,20	11,87	1,02	11,77	11,82
'C0G'	'Rigide'	'1206'	'Cat3'	2,98	0,20	11,19	1,02	11,12	11,14
'C0G'	'Flex'	'0603'	'Cat1'	2,98	0,20	7,22	1,02	7,16	7,22
'C0G'	'Flex'	'0603'	'Cat2'	2,98	0,20	7,09	1,02	7,05	7,11
'C0G'	'Flex'	'0603'	'Cat3'	2,98	0,20	6,41	1,02	6,40	6,43
'C0G'	'Flex'	'0805'	'Cat1'	2,98	0,20	7,54	1,02	7,51	7,55
'C0G'	'Flex'	'0805'	'Cat2'	2,98	0,20	7,38	1,02	7,40	7,44
'C0G'	'Flex'	'0805'	'Cat3'	2,98	0,20	6,74	1,02	6,75	6,76
'C0G'	'Flex'	'1206'	'Cat1'	2,98	0,20	8,21	1,02	8,25	8,33
'C0G'	'Flex'	'1206'	'Cat2'	2,98	0,20	8,20	1,02	8,14	8,22
'C0G'	'Flex'	'1206'	'Cat3'	2,98	0,20	7,44	1,02	7,49	7,54

*Lambda_0_hat = gamma_estimated *delta*

Fig. 3. Results of parameters estimation and regression.

4. Conclusion

In conclusion, this article aims to advance the understanding of reliability modeling through a methodology that combines Design of Experiments (DoE) and Accelerated Life Testing (ALT) approaches. The methodology is demonstrated through a case study involving ceramic capacitors. Failure times were systematically generated and subsequently analyzed using robust statistical methods in MATLAB. The article explores the estimation parameters of reliability model and examines different approaches for analyzing the impact of various technological and environmental factors through the crossed array design. In particular, the calculation of the signal-to-noise ratio of the lifetimes allowed a more accurate representation of the effects of controllable factors on the lifetimes. This methodology can be extended to more failure modes and more technological factors.

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