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Título del Proyecto de Investigación a que corresponde el Reporte Técnico:

Análisis de confiabilidad para motores de Corriente Directa bajo un escenario de voltaje On/Off

Tipo de financiamiento

Sin financiamiento

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Coordinación General de Investigación y Posgrado
UACJ-Investigación

Análisis de confiabilidad para motores de Corriente Directa bajo un escenario de voltaje On/Off

Resumen del reporte técnico en español

En el análisis de confiabilidad, se utilizan diferentes técnicas de estrés para conocer la vida útil y el rendimiento de los dispositivos eléctricos mediante Prueba de vida acelerada. Una de estas técnicas de estrés es el estrés escalonado, que combina las pruebas de confiabilidad tradicionales y pruebas de sobrecarga; con este método, es fácil obtener el tiempo de falla en poco tiempo. No obstante, el análisis del estrés escalonado. Los datos pueden ser difíciles y el especialista generalmente tiene que confiar en atajos o estimaciones para obtener información confiable. A partir de datos de estrés escalonado. En este trabajo se propone un modelo basado en la distribución de Weibull, la ley de potencia inversa, el modelo de daño acumulativo y la técnica de tensión escalonada para analizar el comportamiento de dispositivos electrónicos en un escenario de tensión escalonada. Los parámetros del modelo se analizaron mediante una máxima verosimilitud. Se presenta un caso de estudio basado en motores de CC. Los resultados obtenidos en este trabajo ayudaron al departamento de diseño con el fin de mejorar la vida útil y el rendimiento del dispositivo bajo análisis

Resumen del reporte técnico en inglés

In reliability analysis, different stress techniques are used to know the lifetime and performance of electrical devices via accelerated life testing. One of these stress techniques is the step stress, which combines the traditional reliability testing and

over-stress testing: with this method, it is easy to obtain the failure time in a short time. Nonetheless, the analysis of step-stress data can be difficult, and the specialist has usually had to trust shortcuts or estimations to obtain reliability information from step-stress data. In this paper, a model based on Weibull distribution, inverse power law, cumulative damage model, and step-tress technique is proposed to analyze the behavior of electronic devices under a voltage step-stress scenario. The parameters of the model were analyzed via a maximum likelihood. A case study is based on DC motors is presented in this paper. The results obtained in this paper helped to design department to improve the lifetime and performance of the device under analysis

keywords:

Reliability · Step-stress · Weibull distribution · Inverse power law · DC motor

Potential users:

Since the results of this project were published in a JCR journal with an impact factor, the users are the international scientific community.

1. Introduction

In reliability analysis, different stress techniques are used to know the lifetime and performance of electrical devices via accelerated life testing. One of these stress techniques is the step stress, which combines the traditional reliability testing and over-stress testing: with this method, it is easy to obtain the failure time in a short time. Nonetheless, the analysis of step-stress data can be difficult, and the specialist has usually had to trust shortcuts or estimations to obtain reliability information from step-stress data. In this paper, a model based on Weibull distribution, inverse power law, cumulative damage model, and step-tress technique is proposed to analyze the behavior of electronic devices under a voltage step-stress scenario. The parameters of the model were analyzed via a maximum likelihood. A case study is based on DC motors is presented in this paper. The results obtained in this paper helped to design department to improve the lifetime and performance of the device under analysis

2. Problem statement

Today electrical devices (ED) can be analyzed under reliability techniques to obtain the behavior when a stress is applied. Nevertheless, in reliability analysis exists different test plans to know the lifetime and performance of devices via accelerated life testing (ALT). Typically, ALT plans are based on constant stress; since most of the reliability models are formulated with this kind of stress, most of the applications used constant stress when it is full operation. Notwithstanding, an ALT for ED with a Weibull distribution behavior (WED), the test time and the number of pieces under experiment can be limited due to the manufacturing cost and just in time policy. In those situations, an ALT with constant stress for ED with WED cannot be a good choice due to the test consume considerable time and a large number of pieces to obtain data to feed reliability model and make the inference of performance. An alternative for this problem is to use a step-stress accelerated life testing (SSALT), and this type of ALT applies stress to devices in the way that stress level will be changed at a pre-specified time [1]. SSALT with WED has been studied by much research in reliability. For example, Khamis [2] made a comparison between constant ALT and SSALT and shows the benefit of SSALT in reliability analysis. Nelson [3] proposed the bases for SSALT, method of estimation based on maximum likelihood estimation (MLE) and test plans for ED underWED and inverse power law (IPL). Miller and Nelson [4] present the optimum test plan for SSALT; the objective of this test plan is to minimize the asymptotic variance of ALT and the mean life at design stress induced byWED and MLE. The proposed studied is based on the cumulative exposure model (CEM). Meanwhile, Bai et al. [5] and Bai and Chun [6] extended the results of Miller and Nelson [4] and present a SSALT with a WED model with a closed form for censoring schemes. Further authors have proposed other methodologies based on SSALT and WED; for example, Zhao and Elsayed [7] present a general approach for SSALT based on the acceleration factors. Alhadeed and Yang [8] proposed an SSALT with Khamis–Higgins model, which is an alternative of SSALT Weibull model. This model provides formula a reasonable approximation to the actual optimal times of changing stress levels within a specific range of values of the stress levels and model parameters. Benavides [9] defines an SSALT via retaining the leading term from a series expansion of a general cumulative hazard function and WED. Other applications of SSALT and WED distribution in reliability can be found in Kateri and Balakrishnan [10], EL-Sagheer et al. [11], Hirose et al. [12], Yuan et al. [13], Tang et al. [14], Rackauskas et al. [15]. Li et al. [16], Ling [1], Samanta et al. [17] and Han [18].

Based on the background and literature review, in this project, an SSALT analysis via cumulative damage model (CDM) is proposed. The goal of this paper to estimate the lifetime and performance of DC motors under a voltage step-stress scheme. The data obtained from the experiment were without censoring and assuming a Weibull distribution. The estimation of the parameters for the reliability model will be obtained via maximum likelihood estimation (MLE).

3. Metodology

3.1 Preliminary Notation.

In step-stress testing, units are subjected to a stress level held constant for a specified period of time, at the end of which, if some units survive, the stress level is increased and held constant for another specified period. This process is continued until a predetermined number of units fail or until a predetermined test time is reached. This kind of test requires special reliability models to support the analysis. One of these models is the CDM, which according to Nelson [3] needs to follow these assumptions:

1. The life of the product under test depends only on the current accumulated fraction.

2. If the current stress is maintained in the test, the pieces that are under this stress will fail according to the CDF of that stress, but from the previously accumulated fraction.

Based on the assumptions of the model, let F be a function of a nonnegative random variable with a stress variable V and with Vth as threshold which denotes the maximum level of the stress in the piece; the distribution function D of a random variable T for the failure time and by denoting V_1 the stress that the product is under test in an interval of time $(t_1 , t]$, the distribution can be defined for the first step $t0 \leq t \leq t1$ as:

$$D(t) = \begin{cases} F(t - t_0; V_1) & (V_1 > V_{\mathrm{th}}) \\ 0 & (V_1 \leq V_{\mathrm{th}}) \end{cases} \tag{1}$$

For the next step, $t1 \leq t \leq t2$, from Eq. (1), can be expressed as:

$$D(t) = \begin{cases} F(t - t_1 + s_1; V_2) & (V_2 > V_{\text{th}}) \\ F(s_1; V_2) & (V_2 \leq V_i) \end{cases} \tag{2}$$

A graphical representation of Eq. (2) is presented in Fig. 1. In the following section, we use the CDM described in Eq. (2), the IPL and WED in order to describe the behavior of DC motors under SSALT.

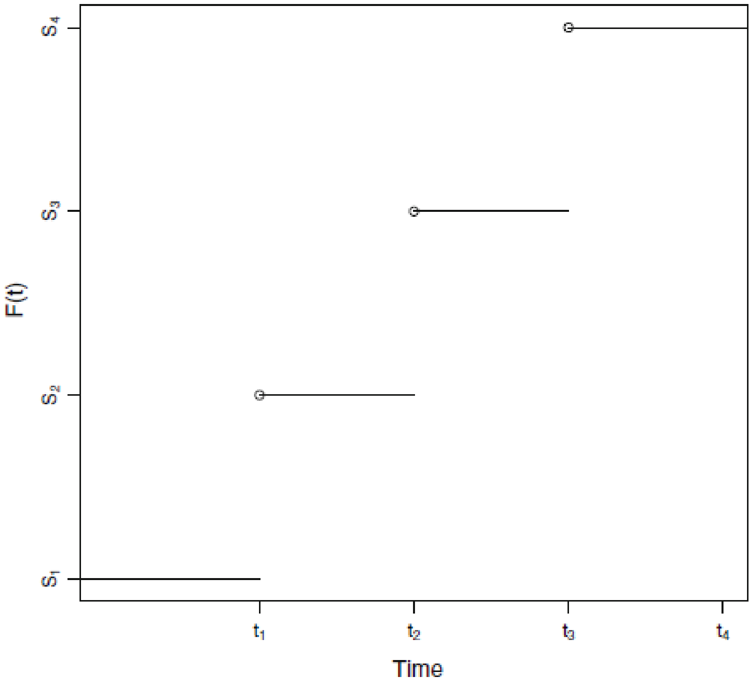


Fig. 1 Representation of reliability step-stress profile (SSP)

3.2 Reliability Model

In reliability, to describe the behavior and performance of ED under a voltage profile scenario, the IPL model is used. The IPL model is written as follows:

$$\lambda = \frac{1}{kV^n} \tag{3}$$

where k > 0 is a characteristic parameter and depends on material properties, product design and other factors in the product under analysis. Parameter n > 0 measures the effect of the stress on the device’s life. Parameter V > 0 represents the voltage stress level applied in the piece. But, for the CDM case Eq. (2) is written as:

$$\lambda = \left[\frac{\alpha}{x(t)}\right]^{n} \tag{4}$$

Now based on the WED, Eqs. (2) and (4), the PDF of the model step-stress Weibull-inverse power law (SSWIPL) is written as:

$$\begin{aligned} f\,(t, x(t)) \\ = \left\{\beta\left[\frac{x(t)}{\alpha}\right]^{n}\left[\int_0^t\left[\frac{x(y)}{\alpha}\right]^{n}\mathrm{d}y\right]^{\beta-1}\right\}\cdot e^{-\left[\int_0^t\left[\frac{x(y)}{\alpha}\right]^{n}\mathrm{d}y\right]^{\beta}} \end{aligned} \tag{5}$$

4. RESULTADOS

In this section, the model established in Eq. (5) is used to estimate the lifetime of DC motors via SSALT. The SSALT was performed with the following parameters considerations:

– 16 DC motors were under SSALT analysis.
– The setup of the SSALT was defined and is given in table 1
– The ambient temperature of the experiment was set to 22 ◦C.

Table 1. Test Setup.

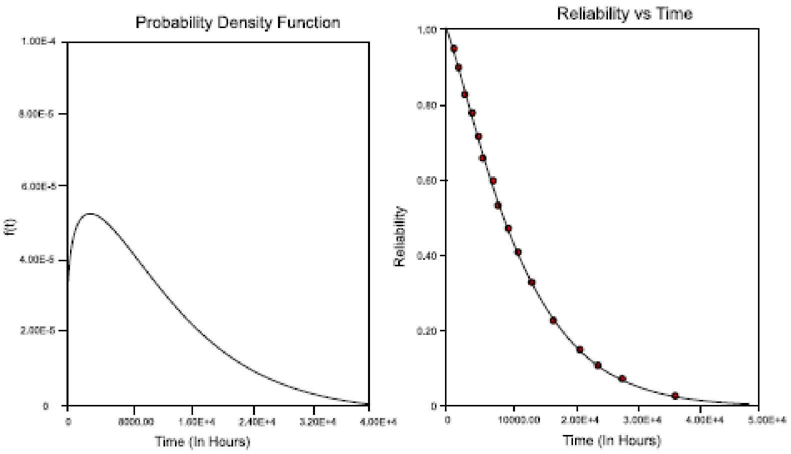
Stress level	Exposed time (in h)
15	$0 < t \leq 250$
18	$250 < t \leq 550$
21	$550 < t \leq 790$
24	$790 < t \leq 910$
27	$910 < t \leq 1120$
30	$1120 < t \leq +\infty$

The parameter estimation using MLE in Eq. (5) were presented in table 2:

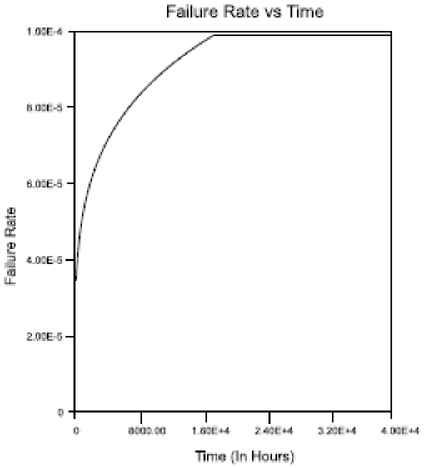
Table 2. Parameter results.

Parameter	Estimation
β	1.319
α	442.801
n	2.406

The graphs of the behavior of the DC motors can be shown in figure 2.



(a) PDF **(b)** Reliability



(c) Hazard function

5. CONCLUSIONES

The presented paper shows a reliability model based on SSALT which analyze the performance of ED under aWED and CDM. Reliability models based on SSALT and CDM can be useful to get more quality information such as the behavior of internal components and how these wears out. On the other hand, reliability models under SSALT and CDM can reduce the experimentation time and simplify the statistical analysis. The practical case presented in Sect. 5 shows the behavior of a DC motor under an SSALT. For this case of study, an MLE was used to know the values of parameters established in Eq. (5). With these parameters, reliability graphs shown in Fig. 2 can be used for the quality department to increase the reliability of the product when a specific condition in the product reaches.

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ANEXOS

Productos generados

Articulo en revista JCR, en Méndez-González, L.C., Rodríguez-Picón, L.A., Pérez Olguin, I.J.C. et al. Reliability analysis for DC motors under voltage step-stress scenario. Electr Eng 102, 1433–1440 (2020). https://doi.org/10.1007/s00202-020-00966-z

Se anexa primera hoja del artículo publicado.

Electrical Engineering
https://doi.org/10.1007/s00202-020-00966-z

ORIGINAL PAPER

Reliability analysis for DC motors under voltage step-stress scenario

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Received: 13 October 2019 / Accepted: 25 February 2020

Abstract

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