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Reliability Prediction of 0.22µf Electrolytic Capacitor Using Fuzzy Logic

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Abstract

Electronic industry is accelerating towards low speed and high-speed processing devices. While achieving the objectives of the modern age, the reliability and life of the components become a major challenge. Most of the electronic equipment and gadgets use the passive components such as capacitor, resistor, inductor etc., which has the failure issue. With the integration of thousand components on a single chip, the probability of component failure enhances. The residual lifetime of an electrolytic capacitor is targeted in this research article. using statistical and fuzzy logic. Fuzzy Inference System (FIS) has been proven as the most accurate component with accuracy rate of 88.9%

Keywords–*Fuzzy Inference System, Reliability analysis, Residual Life Estimation, Electrolytic Capacitor*

1. Introduction

From the advancement of integration level from SSI to ULSI, thousands and millions of electronic components are integrated on a single device. While integrating the higher density on a small space, the reliability becomes a challenging issue. As more and more components are compacting, it will affect on other components and reliability becomes a major issue[1]. When a component is manufactured or designed, it is tested under various parameters and then a minimum-maximum limit is set. Bur when the component is released in the real time, it is affected through other parameters also such as vibration, shock etc., in that case, it would create untimely failure of the component. In the case of electrolytic capacitor, as the temperature increases, it will create leakage in electrolyte and further it will accelerate the failure of the electrolytic capacitor and subsequently, the whole device will be failed[2].

2. Electrolytic Capacitor

The structure of an electrolytic capacitor structure is shown in Figure (1). The electrolytic capacitor consists of a anode foil covered by a dielectric layer, a cathode and the electrolyte liquid[3]. Temperature rise decreases the viscosity of dielectric substrate and decrease the equivalent series resistance (ESR)[4].

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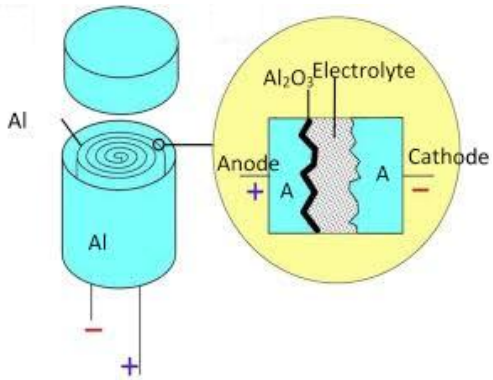


Fig.1 Construction of Aluminum Electrolytic Capacitor

The electrolyte's boiling point restricts the self-heating caused by the internal oscillating current and applied temperature. The self-heating increase electrolyte losses and degrades the lifetime of electrolytic capacitors.

3. Methods and Materials

The life of electrolytic capacitoris estimated by the formula given below:

$$\boldsymbol{Lp = Lx \times 2y} \qquad \textbf{(1)}$$

Where, y = (Tm-Ta-ΔT)/10
ΔT = I^2*ESR/ (B*A)
Lp = Predicted life of electrolytic capacitor
Lx = Load life of electrolytic capacitor
Tm = Maximum temperature rating
Ta = Ambient temperature
ΔT = Temperature rise due to ripple current
I = Ripple current applied to capacitor
B = Thermal constant of capacitor
A = Surface area of capacitor

For Electrolytic capacitor 224SML050MD4, If I = 2mA, Tm = 85°C, Ta = 4, applied voltage = 14v, Load Life = 2000 hours then, the predicted life, Lp = 250378 hours.

3.1 Selection of factors for estimation

Residual life will be estimated by selecting the independent variable that affects the performance of electrolytic capacitor[5]. Specifications of electrolytic capacitor 224SML050MD4 used for the experiment are given in Table 1. In this voltage, Temperature, Ripple current, Frequency and Dissipation factor are the selected factors for progress of a mathematical model.

Table 1. Specifications of Electrolytic capacitor 224SML050MD4

Parameters	Value
Load Life	2000 Hours

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Rated Voltage	50V
D*L	4*5.4
Capacitance	0.22µF

4. Statistical and Artificial Intelligence Techniques for expert system for Life Prediction

4.1 Using Regression Analysis

Regression technique is used to estimate the relationship of a independent variable to a set of predicted variables. This regression approach is used to obtain model for estimation of the life of a capacitor[6]. The relationship between the independent factors (voltage, current, dissipation factor and temperature) and life is expressed by the mathematical equation given below,

$$L(Life) = C\,(V(w)*C(x)*\,DF(y)*T(z) \quad (2)$$

Where, L is the life, V, C, D.F, T represents the values of the process parameters, C is a regression cofficient and w, x, y, z are regression parameter obtained by the regression operation[7].

4.2 Fuzzy Inference System

Fuzzy logic is one of the types of artificial intelligence techniques[8]. The conversion of crisp value to fuzzy value is known as fuzzification and reverse is known as de-fuzzification. The membership functions are selected and designed as per application specification, using MATLAB 2017b[9]

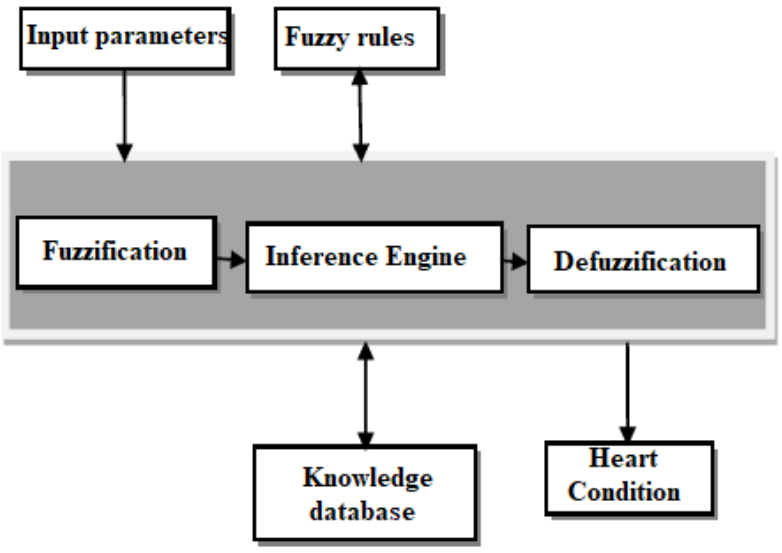


Figure 2. Internal architecture of fuzzy logic system

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The fuzzy rules are regulated which predicts the output response. The internal working flow of fuzzy logic-based approach is depicted in figure 2. Here, input parameters are fuzzified and after inferencing, the output response is predicted which is defuzzied again[10].

5. Results and Discussion

This section discusses the results obtained from the regression model, neural network model and Fuzzy InferenceSystem (FIS) model.

5.1 Determination of cofficients for Regression system

This model will obtain a relation between independent and dependent variables of a system. For this purpose a mathematical model is developed using regression. The regression metjod is applied on the collected data. Here, the linear regression is used to form regression system[11].

$$\mathbf{Life(L)=695218.124+6.399\ ln\ T+0.279\ ln\ RC-0.786\ ln\ V-5.634\ ln\ DF+186.65\ ln\ F} \quad \mathbf{(3)}$$

The equation obtained by linear regression for the selected aspects is given in equation (3). SPSS software is used to obtain the regression coefficients for formation of the system. The values of the regression coefficient shows the how the dependent variable rely on independent variables.

Predicted life using regression coefficents for V=14v, RC=2mA, T=4°C, F=50 and D.F% = 10% will be will be 278965.11 Hours. The above equation says that dissipation factor will have significant effect on residual life[12].

5.2 Estimated Life using Fuzzy Inference System (FIS)

Using Mamdani approach, fuzzy inference system is constructed and membership values are selected to predict the residual lifetime of the 0.22µf electrolytic capacitor. Figure 3., shows the fuzzy inference system of electrolytic capacitor, having various membership function[13].

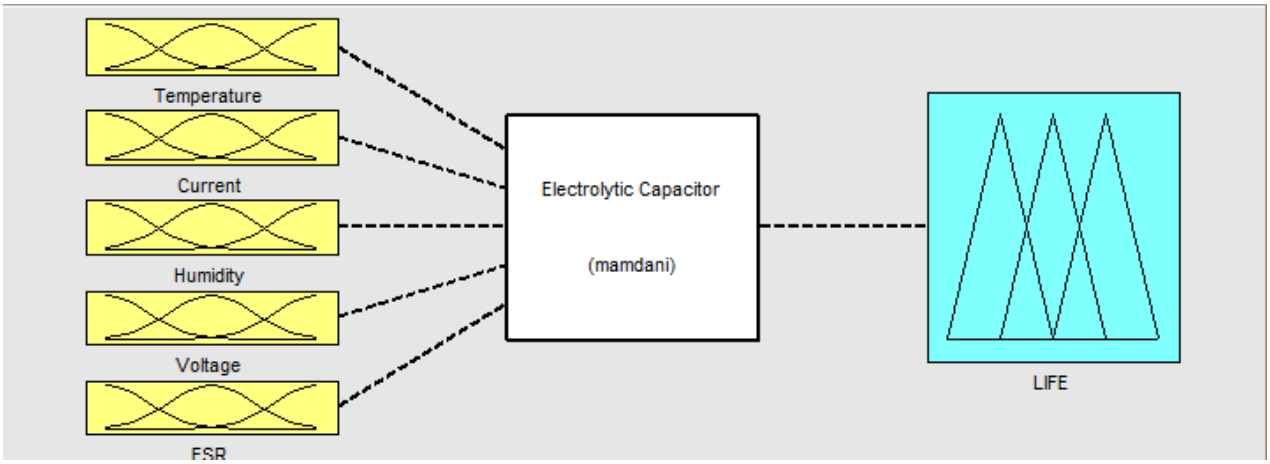


Figure 3. Fuzzy Inference System for Electrolytic Capacitor

The results are obtained in form of predicted life [14]and error rate is obtained for every input from low to high values and the output estimated life is 71719.21 hours whereas measured life using formula is 79611hours. The error rate is 11.003%.

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7. Conclusion.

The residual lifetime analysis is the most prominent factor, while calculating the reliability of the entire device or gadget. It is deduced that temperature can be considered as one of the most prominent factors which can cause device failure but for more accuracy, more physical, environmental or electrical parameters can be taken. In developing Fuzzy Inference System (FIS) Model, an efficient accuracy of 88.9% is achieved and hence it can be selected as a technique to develop Intelligent Model, which predicts the Remaining Useful Life (RUL) of the 0.22µf electrolytic capacitor under various electrical parameters and environmental conditions.

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