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PHYSICS OF FAILURE: AN INTRODUCTION

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ABSTRACT

The physics of failure (POF) is an approach to designing reliable products to avoid failure, based on the knowledge of root cause failure mechanisms. It is based on failure reliability technology that studies the failure regularities from the failure reasons and failure mechanisms of the products. A clear understanding of the physics-of-failure is necessary in applications that afford little opportunity for testing. The purpose of this paper is to present POF as a reliability analysis or science which studies failure mechanisms.
Key words*: physics of failure, reliability physics*

1.0 INTRODUCTION

The traditional approach to reliability assessment is based on empirical models fitted to field data. This approach uses modeling and simulation to identify failure mechanisms prior to physical testing. The three traditional approaches are [1]: (1) using standard handbooks, (2) statistical analysis of data, and (3) performing life testing experiments. The traditional approach may be inappropriate and misleading when designing a new product or a product with new technologies [2]. Also, the science behind base failure rate and other modifying factors is not clear. It has been shown that the standard handbooks (such as Mil-HDBK-217) and related handbook methods, such as Telcordia, PRISM, FIDES, and 217-PLUS are flawed [3].

The physics-of-failure (POF) approach, also known as reliability physics, provides the insight into life and reliability aspects of the component and addresses the root causes of failure such as fatigue, fracture, wear, and corrosion. It is an up-front approach to reliability in that it focuses on preventing failures through robust design and manufacturing practices. This can significantly impact the reliability and life-cycle costs of a system.

2.0 MOTIVATON

A product can be stressed during manufacturing, shipment, storage, handling, operating and non-operating conditions. An object or product fails when stress exceeds its strength. A major measure of the reliability parameter is the failure rate, which is related to the number of failures that occur over a large number of trials.

The principal motivation for POF approach came from military services. The major driver for the implementation of POF was the poor performance of military electronic systems during the Second World War. This led the US Department of Defense to invest heavily on improving the reliability of electronic systems. It also motivated the reliability physics community to initiate POF investigations into degradation mechanisms. Thus, the concept of POF was introduced in 1962 by the Rome Air Development Center, now known as the Air Force Research Laboratory. In the past, industries relied on military standardization when acquiring systems. These design and reliability practices were often not firmly based on physics or engineering science.

3.0 POF MODELS

Deterministic and statistical models play a critical role in the prediction of the reliability. Researchers have developed a wide variety of models for predicting the life span of materials and components [2,4,5]. There are three types of degradation models [4]: physics-statistics-based models, parametric statistics-based models, and nonparametric statistics-based models. It is generally accepted that the physics-based models provide more accurate estimate of reliability than the statistics-based models. In this paper, we present the failure degradation model as a typical example. The degradation value at time t is given by [4]

$$D(t) = D(0) - t\beta \exp(-E/T)$$

Where *D(0)* is the initial degradation value, β is the characteristic of the product or material properties, E is the activation energy, and T is the temperature in Kelvin.

3.1 POF TOOLS

There are two major tools for POF modeling and simulation. They are Computer-Aided Design of Microelectronic Package (CADMP-2) and Computer-Aided Life-Cycle Engineering (CALCE). Both were developed at the University of Maryland. CADMP-2 addresses the reliability of electronics at the package level, while CALCE assesses the reliability at the printed wiring board level [1]. Their overviews are shown in Figures 1 and 2. The CADMP-2 software is used to assess reliability of electronic packages subjected to different constraints. The CALCE software is helpful in designing multilayer printed wiring boards.

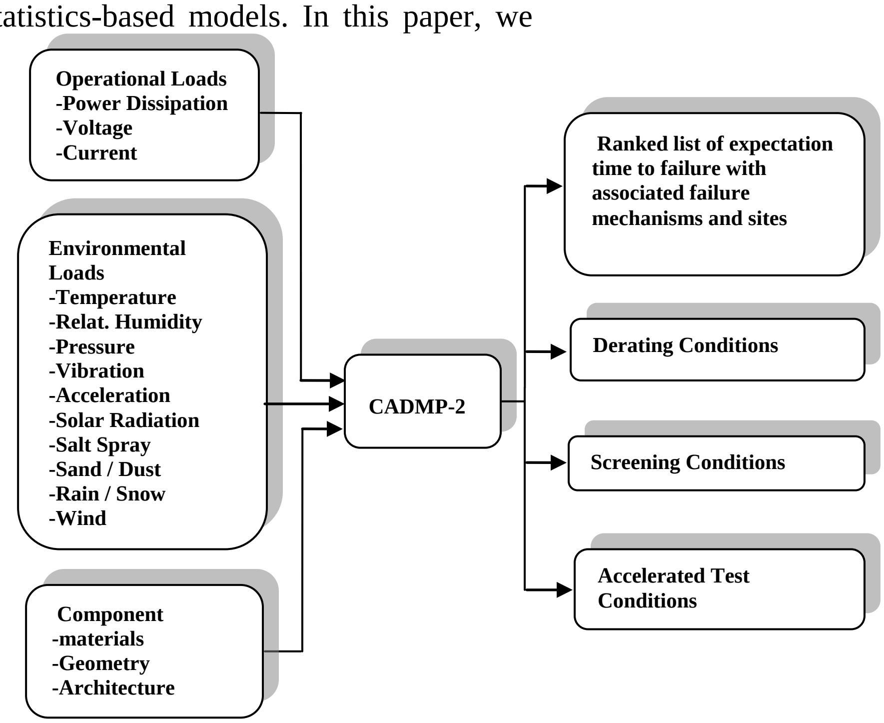

Figure 1 Inputs and outputs for CADMP-2 [1].

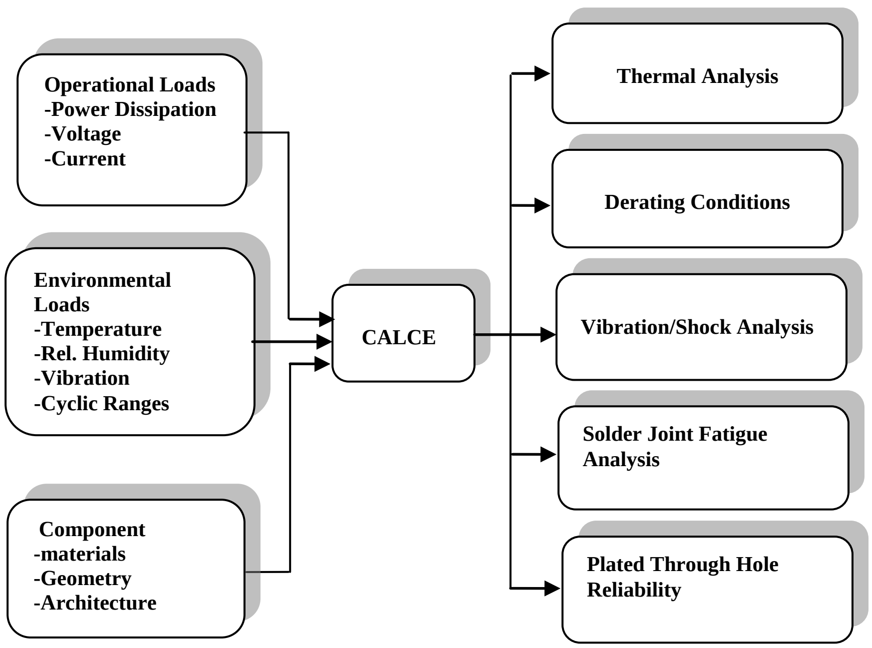

Figure 2 Inputs and outputs for CALCE [1].

4.0 CONCLUSIONS

Reliability assessments based on POF approaches incorporate reliability into the design process to prevent parts from failing in service. POF may be regarded as a methodology that enhances reliability by addressing the root cause mechanisms responsible for component or equipment failures. With the dramatic increase in equipment complexity and applications of new technologies, reliability has become one of the important design features. Physics of failure constitutes the basis of reliability engineering. However, POF method has limitations due to the fact that it is essentially a bottom up approach assessing time to failure due to known failure mechanisms.

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