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DESIGN FOR RELIABILITY AND MAINTAINABILITY

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ABSTRACT

Reliability is one of the key quality characteristics of products and it should be considered during the design and the operational phase of the product. This process begins at the component level, followed by subsystems levels and ends with the entire system. At every level, reliability analysis needs to be performed, testing of the unit at that level also needs to be conducted at accelerated conditions and measurements such as degradation or failure time data are obtained in order to determine the reliability growth and estimate reliability at normal operating conditions. This talk will address approaches for considering reliability during the product life cycle, reliability prediction and reliability improvements. Maintenance approaches with emphasis on condition-based maintenance as well as the recent research in degradation modeling and its applications in maintenance will be presented and highlighted.

Keywords: design for reliability, degradation, reliability prediction.

INTRODUCTION AND MODEL DEVELOPMENT

The high rate of technological advances and innovations are stimulating the continuous introduction of new products and services. Moreover, the intensity of the global competition for the development of new products in a short time has motivated the development of new methods such as robust design, just-in time manufacturing, design for manufacturing and assembly and design for reliability (Elsayed 2012). Moreover, the customers have higher expectations of products' reliability, cost and life cycle. Indeed, extended warranties and similar assurances of product reliability have become standard features of the product and serve as implied indicators of the product's reliability.

Design of products (systems) is an interdisciplinary and concurrent process. Once the specific goals of the design are established then specific objectives such as reliability requirements need to be defined. This presentation focuses only on of the objectives; namely design for reliability, and how it is considered in different stages of the product(s) (or systems) design. The first step in the process begins by defining the subsystems and their interactions in terms of functions and integration in the design. This follows by breaking down the subsystems to additional subsystems, if possible. This process continues down to the details of the lowest subsystem level. At this level, design tools are implemented to study potential failure models using Failure Modes and Effects Analysis (FMEA). This will determine the failure modes, effect of the environment and may provide guidance in identifying areas for reliability improvements by either using a more "reliable" components and/or reconfiguring the subsystem to include redundancies. The reliability metrics for the subsystems can then be estimated their integration will result in the overall system reliability metrics.

During the above process, several reliability related steps need to be considered. At the "lowest" subsystem level, one might conduct reliability testing such as Highly Accelerated

Life Testing, Reliability Growth Test and Accelerated Life Testing. In some situations, degradation testing is performed instead when there are degradation indicators that can monitor the performance of the product with time. We describe typical degradation testing and modeling and its applicability in both reliability prediction and maintenance strategies of the product.

Suppose that the system degradation is described as a stochastic process, $\{Y_t, t \geq 0\}$, satisfying the stochastic Ito differential equation

$$\frac{dY_t}{Y_t} = \mu(t)dt + \sigma dB_t \quad \text{and} \quad Y_0 = y_0 \qquad (1)$$

which involves a deterministic drift function $\mu(t)$, a constant diffusion σ, and a standard Wiener process B_t. Solving the differential equation (1) using the Ito's formula, the (log) degradation path is obtained

$$X_t = \log Y_t = x_0 + m(t) + \sigma B_t \qquad (2)$$

where

$$m(t) = \int_0^t \mu(t)dt - \frac{1}{2}\sigma^2 t = \mathrm{M}(t) - \frac{1}{2}\sigma^2 t. \qquad (3)$$

By choosing an appropriate functional form for the drift function $\mu(t)$, the stochastic process shown in (2) is flexible enough to describe a variety of degradation. In a special case when the drift function is a constant, the process $\{Y_t, t \geq 0\}$ is known as the geometric Brownian process. As an illustration, shown in Fig. 1 are five simulated degradation paths assuming $\mu(t) = \beta\alpha^{-\beta}t^{\beta-1}$ with $\alpha = 2$, $\beta = 1.5$ and $\sigma = 0.1$.

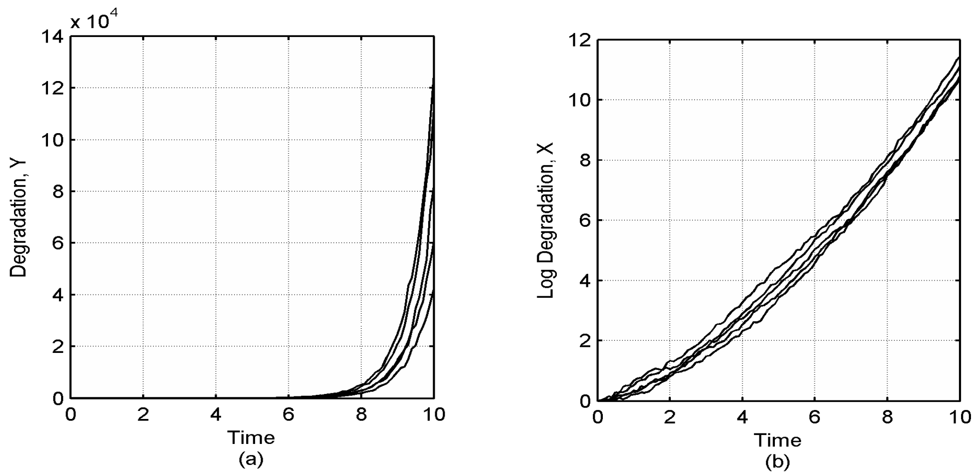

Fig. 1 - An illustration of the degradation process: (a). $\{Y_t, t \geq 0\}$. (b) $\{X_t, t \geq 0\}$

The reliability function and maintenance actions can then be developed for a given failure threshold or maintenance degradation threshold respectively. This can also be used in determining the optimum threshold level that minimizes both the probability of failure and the maintenance cost during the life cycle of the product.

REFERENCES

[1]-Elsayed, E. A., Reliability Engineering, New York: Wiley and Sons, 2012.