A Non-Linear Model for Estimating Reliability in a Degradation Test

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Abstract: Material components follow non-linear degradation because the material loss with time is non-linear; the components present different levels of resistance during a degradation process. Constructing predictions of the component life span and performing reliability analyses regarding degradation is possible by non-linear regression. In this paper, we propose new means for predicting time to failure of the components, using an extrapolation process of a calibration regression method for measuring the error prediction; an accelerated test of a polymeric coating process was performed. Results showed that the proposed model has the ability to estimate component reliability to a certain trust interval and a clear error measurement.

Keywords: Degradation Process, Non-Linear Regression, Calibration Regression, Reliability Analysis

1. Introduction

During accelerated life testing the test units are subjected to more severe stresses than those of the normal operating conditions, thus shortening the testing times and provoking more failures. Estimating the normal stress levels of the process factors, based on the accelerated life testing data, is performed by an extrapolation process (Nelson, 1990). The process of wearing-off material is known as degradation process. Degradation is the reduction in the reliability of a component, until it experiences partial or total failure. Estimating a component’s remaining life is crucial for preservation and maintenance of concrete installations; modeling degradation behavior to predict component’s life span is then of special interest.

Material components follow non-linear degradation because the material loss with time is not proportional to elapsed time; following a natural process. The mechanisms of the specific application must be fully understood, enabling the correct extrapolation model to be completely specified, otherwise results could be biased (Qiu et al., 2000). Using non-linear models by themselves is possible; however, those include unhandled uncertainty because the information related to the failure of a component is obtained by means of extrapolation processes, thus estimated instead of observed, therefore requiring calibration regression. The calibration problem consists on using the observed data as well as the relationship between a dependent variable with an independent variable, for estimating other values of the independent variable from new observations of the dependent variable (Hardin, 2003). Our proposed approach finds its grounds on work from others. Sudret (2007), who focused on the prediction of the initiation time for corrosion and/or the estimation of the residual strength of structures, pointing out the necessity of modeling the spatial variability of the model parameters in order to be able to characterize, not only the probability of degradation, but also the extent of damage. Marano et al. (2008), who proposed a reliability of reinforced concrete structures where an efficient alternative approach was made by considering fuzzy time-dependent reliability analysis. Karbhari et al. (2007) used the Arrhenius method and the procedure developed by Phani and Bose (1987) for modeling mechanisms and processes of deterioration, also for estimating their rates. Tanaka and Lee (1999) made an exponential possibility regression analysis by an identification method. In our model, the parameters are estimates based on a finite sample, so there is some uncertainty in the values. This uncertainty is quantified by the confidence limits and the standard error; hence, the prediction has an associated uncertainty (expressed as a confidence interval). We propose the use a non-linear regression (section 3) to model the degradation behavior, and a calibration regression method (section 4) to perform the extrapolation process including the uncertainty in the estimated times to failure of an analyzed component. The method developed was tested (section 5) on a coating process and data collected from it. The primary aim of this paper is showing the feasibility of an accelerated life test analysis including uncertainty by means of a calibration method.