Optimal Design of Accelerated Degradation Tests Based on Exponential-Dispersion Degradation Model

Ming-Yung Lee

Providence University

Abstract

For highly reliable products, accelerated degradation tests (ADTs) are often used to obtain data to estimate their lifetime distributions for reliability in a timely manner. The step-stress ADT (SSADT) and parallel constant-stress ADT (PCSADT) are two commonly used tests. However, there is seldom study on whether these two types of ADT will remain optimal within a wider class of ADTs with an arbitrary stress function. Furthermore, when experimental cost is considered, certain lifetime estimates may not be sufficiently precise. For the Exponential-Dispersion (ED) degradation model, Tseng and Lee (2016) show the optimal PCSADT design uses two stress levels, or (in some cases) a third accelerated stress level with a small sample is necessary. They also obtain optimal resource allocation rule when the stress levels are prefixed.

Based on Wiener process, Lee (2022) shows that, for any ADT with an arbitrary stress function, there exist statistically equivalent PCSADT and SSADT with the same Fisher information matrix of parameter estimates and hence, the same values for the four commonly used optimality criteria considered in a reliability study. Additionally, he shows that the optimal PCSADT and SSADT are simple ADTs using only the minimum and maximum available stress levels. With these results, he then proposes a two-stage procedure for developing optimal ADTs that takes the estimation precision as well as the experimental cost into account when estimating the Mean-Time-to-Failure (MTTF) and p-th percentile (t_p) of the lifetime distribution. In the first stage, he obtains statistically optimal simple ADT designs by controlling the margin of errors (precisions) of the lifetime estimates and, in the second stage, he determines the minimum experimental resource and its optimal allocation under a cost consideration.

This paper will extend the results to the class of ED models. Finally, we use the light emitting diode (LED) data, stress relaxation data (Yang 2007), and device B data (Meeker and Escobar 1998) to illustrate our method.

Keywords: Reliability, Optimal Accelerated Degradation Test, ED Model, Statistically Equivalent Designs, Fisher Information Matrix, Estimation Accuracy, Margin of Error, Experiment Cost.