Estimating Reliability Performance with Accelerated Life Testing

Steven Wachs
Principal Statistician
Integral Concepts, Inc.

Most manufacturers today recognize the criticality of developing products that will perform reliably during the useful life of the product. Inferior reliability performance alienates customers and significantly impairs brand and company reputations. While product development actions related to ensuring reliability targets are met have increased substantially in recent years, several challenges remain. They include:

- Short product development timeframes
- Difficulty in observing product failures (needed for reliability estimation) in available testing timeframe
- Small sample sizes available for reliability testing

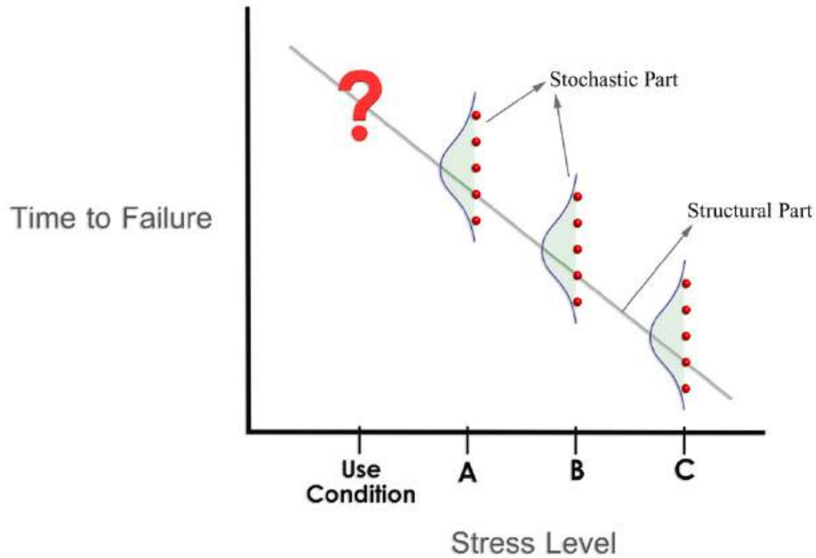
Accelerated Life Testing (ALT) methods may be utilized to overcome many of the challenges in standard reliability testing. *Quantitative* Accelerated Life Testing involves identifying stress conditions that will accelerate the failure mode(s) so that failures may be observed in a shorter time period. Common stress factors include: temperature, pressure, voltage, load, speed, thermal cycling, etc. and more than one stress may be utilized. Various methods of stressing the units during testing include constant stress, step stress, progressive stress, etc.

Many companies perform various types of accelerated tests in order to simply identify potential failure modes or satisfy design verification requirements. However, these tests are typically not designed with the goal of estimating reliability at normal use conditions. Testing resulting in quantitative reliability estimates requires some careful upfront planning including determining adequate sample sizes, stress levels, and allocation of units to the various stress levels.

Reliability predictions using standard methods typically utilize a probability distribution (e.g. Weibull) to describe the time to failure of a material, component, or system. Once one (or more) adequate distributions are identified from the data observed, reliability may be estimated as a function of time. In ALT, we develop a model that describes how this (time-to-failure) distribution is shifted by the various stress conditions. By modeling how the failure time distribution changes as the stress level changes, we can extrapolate and make predictions at *normal use* conditions.

PO Box 251652 • West Bloomfield, MI 48325 • Tel. 248-421-7590 • Fax. 248-539-3858 • www.integral-concepts.com

The graphic to the right illustrates both the stochastic model (e.g. Weibull) and the structural model (life-stress relationship) that comprise an Accelerated Life Test model. The goal is to estimate reliability characteristics at normal use conditions.



The structural model which describes the life-stress relationship may be determined empirically from the data, but knowledge of the *physics of failure* and underlying failure mechanisms is desired. This knowledge helps to justify the use of a specific model form and extrapolation to normal use conditions (as extrapolation always introduces risk into predictions).

Caution must be exercised when using ALT. For one, it is extremely important to ensure that the stress conditions selected simply accelerate failure modes that will likely occur eventually at normal use conditions rather than introduce new failure modes that will not occur at normal use conditions. It is also imperative that the prediction uncertainty be quantified through the use of confidence intervals. Adequate up-front test planning and determining appropriate sample sizes can help to ensure that estimates with adequate precision will be obtained from the test data.

The predictions made using ALT models should be correlated with test results from testing at normal use conditions (or field data, when it becomes available). Such correlations allow the utility of the ALT approach and model to be adequately verified. Additionally, correlating the ALT model predictions with actual data allows the model to be refined for use in future ALT applications.

Accelerated Life Testing is an effective methodology for estimating and improving product reliability given the time and cost constraints manufacturers face today.

PO Box 251652 • West Bloomfield, MI 48325 • Tel. 248-421-7590 • Fax. 248-539-3858 • www.integral-concepts.com