Accelerated Life Testing

Accelerated Life Testing

- Discuss the advantages and assumptions of accelerated testing.
- Identify appropriate methods and useful models that can be used in accelerated life tests.
- Design an accelerated life test.

Definitions

- An *accelerated test* stresses the unit to hasten degradation toward failure.
- An *acceleration factor* measures how much faster the degradation occurs under a given level of stress.
- An *acceleration relationship* models the rate of degradation as a function of the stress level.
- An *accelerated life test* (ALT) will extrapolate the reliability from the test conditions to the actual use level of the stress variable.

Assumptions

- The increase in the stress equally accelerates all of the degradation processes.
- The increase in stress does not alter the degradation process or introduce new ones.
- Stress affects the location of the reliability distribution, but not the scale.
- The selected life distribution and acceleration relationship for the model are suitable.

Stress Forms

- High usage rate
- Faster running rate
- Reduced down time
- Overstress
  - elevated storage temperature of the books, for example

Stress Factors

- Temperature
- Humidity
- Light
- Chemicals
- pH
- Oxygen
- Radiation
- Voltage
- Current

Stress Loading

- Constant
- Step
- Ramp
- Sinusoidal
- Piecewise

Accelerated Life Test Variables

- Exposure time
- Stress
- Other factors
  - Covariates or design factors

Acceleration Factor

- An acceleration factor is a numerical estimate of the change in the degradation rate between the stress and the real use conditions.
- It is a ratio of the degradation rates at different levels of stress.

Acceleration Relationship

- Acceleration relates reliability to the level of the stress.
- The relationship comes from theory of the degradation process for a particular failure mode.
  - For example, the Arrhenius relationship is often used for acceleration by temperature.
- The relationship linearizes the dependence of the life distribution model parameters on the stress variable.

Fit Life by X Transformations

These transformations are available in the platform:

- Arrhenius (°F, °C, °K), $\mu = \beta_0 + \beta_1 \frac{11605}{X}$
- Voltage, $\mu = \beta_0 + \beta_1 Log(X)$
- Linear, $\mu = \beta_0 + \beta_1 X$
- Log, $\mu = \beta_0 + \beta_1 Log(X)$
- Logit, $\mu = \beta_0 + \beta_1 Log\left(\frac{X}{1-X}\right)$
- Reciprocal, $\mu = \beta_0 + \frac{\beta_1}{X}$
- Square Root, $\mu = \beta_0 + \beta_1 \sqrt{X}$
- Box-Cox, $\mu = \beta_0 + \beta_1 BoxCox(X)$
- Location, μ different for each level of X
- Location and scale, μ, σ different for each level of X

Arrhenius Relationship

- The relationship is nonlinear in the model parameters.
- *K* is the degradation rate constant.
- *A* is specific for each specimen, stress, and failure mode.
- *E* is the energy of activation for the degradation process.
- *k* is the Boltzmann constant, 8.617343×10^{-5} eV*K^{-1}
- *T* is temperature (degrees Kelvin).

$$K(T) = Ae^{\frac{-E}{kT}}$$

time to failure = $A * \exp(E/kT)$

Arrhenius Assumptions

- Degradation is first-order.
- Degradation is irreversible.

Arrhenius Acceleration Factor

$$\lambda\left(T,T_r\right)=\frac{K\left(T\right)}{K\left(T_r\right)}=\frac{Ae^{\frac{-E}{kT}}}{Ae^{\frac{-E}{kT_r}}}=e^{\frac{-E}{kT}}e^{\frac{E}{kT_r}}=e^{\frac{E}{k}\left(\frac{1}{T_r}-\frac{1}{T}\right)}$$

DOE for ALT

- Torque as accelerating factor
- Have a good guess what failure data might look like
- Create priors
- Have 100 units at 5,000 cycles for 3 levels of stress from 50 to 100 nm
- Want to predict out to 10,000 cycles

Accelerated Life Test Plan

Factors

Factor Name	Number of Levels	Factor Transformation	Low Usage Condition	High Usage Condition	Low Test Condition	High Test Condition
torque	3	Log	35	35	50	100

Prior Specification

Distribution Choice

- ○ LogNormal
- ◉ Weibull

Prior Mean

- ◉ Specify Intercept
- ○ Specify Quantile

Effect	Prior Mean
Intercept	15.8800
Power (torque)	-1.8600
1/β	0.05000

☑ Specify prior uncertainty.

Prior Uncertainty

Effect	Prior Std Error	Prior Correlations torque	1/β
Intercept	0.21	-0.9975	-0.0600
Power (torque)	0.05		0.04000
1/β	0.01		

Candidate Runs

torque	Minimum Units	Maximum Units
50	0	100
75	0	100
100	0	100

Diagnostic Choices

Probability of interest 0.1

Design Choices

Monitoring Type

- ◉ Continuous Monitoring
- ○ Monitoring at Intervals

Total number of units under test 100

Length of test 5000

DOE for ALT

ALT Data
Fit Life by X

Columns (3/0)
- torque
- Censored
- Failure Time

	torque	Censored	Failure Time
1	50	•	•
2	50	•	•
3	50	•	•
4	50	•	•
5	50	•	•
6	50	•	•
7	50	•	•
8	50	•	•
9	50	•	•
10	50	•	•
11	50	•	•
12	50	•	•

Design Diagnostics

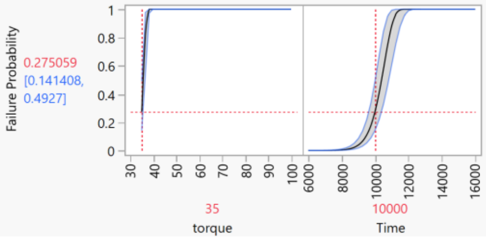
Optimality Criteria

Quantile Estimate Optimal Design

D Criterion	-28.54
Quantile Criterion	0.0004
Probability Criterion	.

Failure probability at use conditions too small for variance estimation.

Distribution Profiler



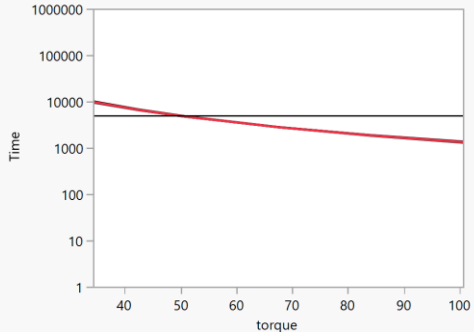
Simulator

Number of Simulations	100
Simulation Probability of Interest	0.1
Simulation Usage for torque:	35

Run Simulations

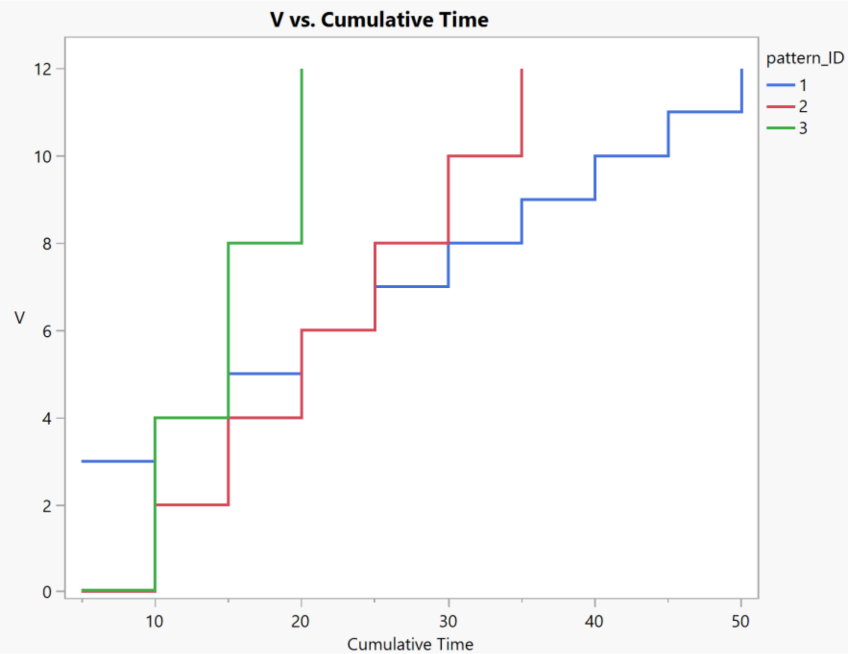
	Average	SD
0.1 Log Quantile	9.156	0.025
R Precision	1.047	0.007
Intercept	15.88	0.15
torque	-1.86	0.034
1/β	0.049	0.006

Simulated Model Fits



Step Stress

- Get results quicker.
- Run test at same stress level for specified duration then proceed to a higher level of stress
- Cumulative Damage platform



Demonstration

Questions?