ACCELERATED TESTING

Description

Accelerated testing is an evaluation performed at a faster cyclical rate, where applicable, and with higher levels of environmental and operating stresses than those that are seen under normal operating conditions. Because of accepted models such as Arrhenius, Eyring, and others, environmental stresses can be elevated above and/or below their normal field use for extended periods to reduce the amount of testing time needed to evaluate the reliability and performance characteristics of the device under test. Some methods of accelerated testing, such as Highly Accelerated Life Test (HALT), apply environmental stresses that exceed the design operational limits and are used to design in reliability; they do not necessarily measure reliability. See also HALT and Highly Accelerated Stress Screening (HASS).

Environmental Stress		Operating Stress	Cyclic Rate
Mechanical	**Climatic**		
Shock, vibration, collision, acceleration, dust and gravel	Temperature, humidity, salt spray, rain, wind, atmospheric pressure, splash, pressure, solar radiation	Voltage, air pressure, fluid pressures, weight, electrical transients	Temperature transition cycles, mechanical applications, i.e., switch activations or lever movements, flexures, engine RPMs, vehicle mileage

Table 1.1. Examples of Factors Used in Accelerated Testing

Purpose

Accelerated testing is used primarily to estimate the reliability characteristics of a product under normal use. Other uses include developing baselines for environmental stress screenings used in the manufacturing process and product reliability enhancement.

Benefits

- Testing time is shortened and the cost of product development is reduced.
- Life distributions, reliability determination, and failure modes can be obtained in a rapid manner before the product release.
- Due to the shortened test time, multiple tests may be performed to make product improvements before the design release.
- Rapid comparisons can be made between different designs.
- Field issues that develop over the life of the product can be evaluated faster.

- In the post-launch and monitoring phase, design changes can be evaluated in an expedient manner for quick implementation.
- Efficient product monitoring can be performed to ensure that the original reliability target is being maintained.
- Defects that would have occurred in the field can be eliminated before the product is released.

Implementation

The initial step in using accelerated testing is to select the stress factors to be applied to the product. Stress factors are the environmental parameters that the product would see during normal use. They include factors such as temperature, vibration, humidity, voltage, and mechanical operation but may incorporate other factors encountered in normal usage. See Table 1.

All of the environmental and operational stresses must be included in testing for reliability purposes. The product can be tested to the stress factors separately; however, combining stress factors is considered to be a more effective means of testing. The level of stress and duration of the test factors can be estimated by theoretical calculations. They can also be correlated from data based on past product similarity and the relationship between stress and the useful life using warranty and historical data.

Optimal stress factor data is obtained from monitoring the stresses on the product in the intended application. This typically takes a significant amount of time, effort, and multiple samples to cover the full breadth of a product's use. In most instances, there are SAE or Military Standard specifications that can be used as guidelines.

Here are some of the limitations in implementing accelerated testing:

- Determination of the acceleration factors may be difficult.
- There may be a lack of a reasonable correlation between the accelerated testing and normal use. This is especially true for an initial release of a new product line where failure modes have not been established.
- Excessive stresses may induce a physical change that is unrealistic.
- The initial investment in equipment for testing is often very costly.
- Failure modes not indicative of normal usage may be induced.

Process Flow

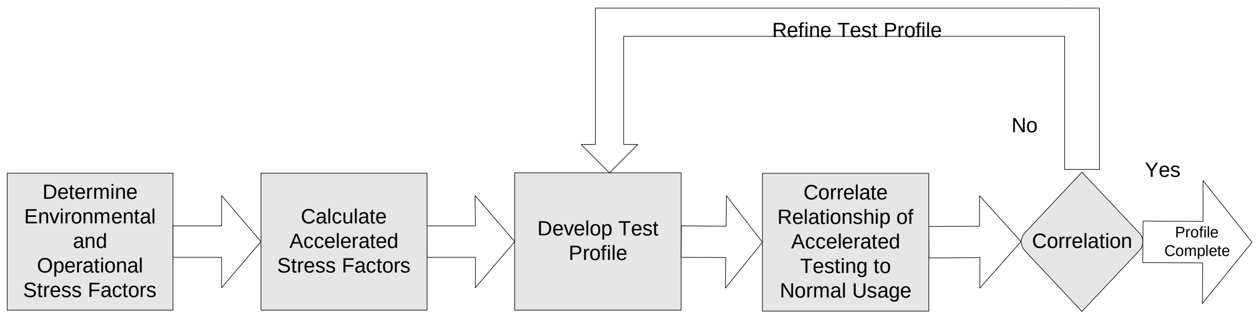


Figure 1.1. Test Profile Development Flow Chart

Examples

Example 1

In a simple one-factor test, it is estimated that a certain dash switch would be used, worst case, 10 times a day. Assuming worst-case conditions, if the vehicle were in use 365 days of the year over a 10-year design life period, the switch would need to be tested to 36,500 applications.

Given that one on-off application can be performed in 10 seconds, the total 36,500 applications can be completed in 101.4 hours, or fewer than 5 days.

Example 2

In this multiple environmental/operational stress example, an Electrical Control Unit (ECU) mounted in the cab of a vehicle is intended for linehaul vehicle use and could be activated several times during the day. Based on past experience and analysis of warranty units of a similar type of ECU, it is known that 100 thermal cycles have proven to be effective in achieving the desired reliability rate. Vibration data taken from the mounting location of the device while driven over multiple rough road surfaces at a test track reveals an average of .73 $g_{rms.}$ Acceleration factors applied to the initial test data compress the 39,000 hours of operation of normal driving time to 5.3 g_{rms} at 12hrs. Key-on activations and daily functional use are estimated or taken from monitored data of the intended target vehicle.

Heavy Truck Linehaul Vocation Vehicle for an Electrical ECU:

- 195,000 Miles / Year @ 95^{th} Percentile

- 195,000 Miles / 50 MPH = 3,900 Hours of Operation / Year
- 10 Years of Operation = 39,000 Hours of Operation
- Temperature Operational Design Limits per SAE J1455 -40C° to +85C°
- Voltage Design Limits 9.0V – 16V per SAE J1455 (Nominal 13.8V)
- Estimated Key On-Off Cycles = 18,250 (3,650 days X 5/Day)
- Functional activations = 43,800 (3,650 days X 12/day).
- Thermal Cycles = 100 Cycles @ -40C° to +85C°, dwell time is 2 hours, 30-minute transitions
- Humidity = 90 % @ Temperatures > 38C°
- Accelerated Vibration Equivalent = 5.3 g_{rms} at 12hrs per axis
- Key On-Off Cycles per hour = 36.5 per hour.
- Functional activations = 87.6 per hour
- Electrical power = 16V, maximum voltage per SAE J1455.

The test is to be run in a combined environment chamber with temperature cycle, vibration, and humidity.

The unit is to be functionally activated and powered on and off at the required rate listed above.

The unit is to be functionally tested when the unit is powered.

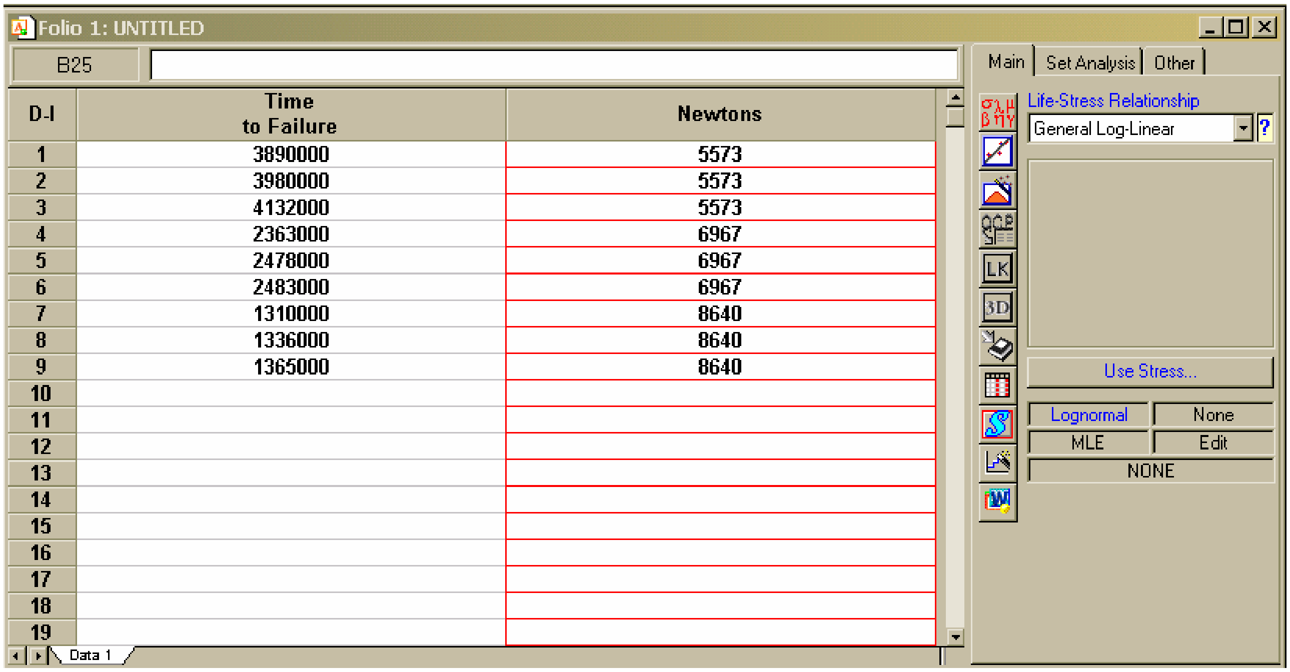
Total test time would be 20.8 days.

In this particular example, combined environmental testing is being performed to be more representative of real-world testing. Individual testing could be performed but would decrease the effectiveness of the testing. Conservative estimates of the use of the test item should be maintained to represent the worst case usage.

Example 3

A certain automotive component was used in an effort to determine whether or not an existing test could be revised to assist in shortening the design development cycle. The test was set up to review impact at three (3) stress levels and run to failure.

(1) Run test at levels defined to failure. The following was obtained for the assumed Log-Linear life stress relationship.



D-I	Time to Failure	Newtons
1	3890000	5573
2	3980000	5573
3	4132000	5573
4	2363000	6967
5	2478000	6967
6	2483000	6967
7	1310000	8640
8	1336000	8640
9	1365000	8640
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Figure 1.2. Stress Test Data

(2) The model was validated for a Log-Normal distribution. The Power model of the Cumulative Damage Relation was assumed. The logarithmic power stress relationship was assumed.

(3) The analysis was initiated. A parameter test of significance was conducted that noted that the estimates for the three (3) stress states did not differ significantly at the 1% level. The plot is shown in Figure 1.3.

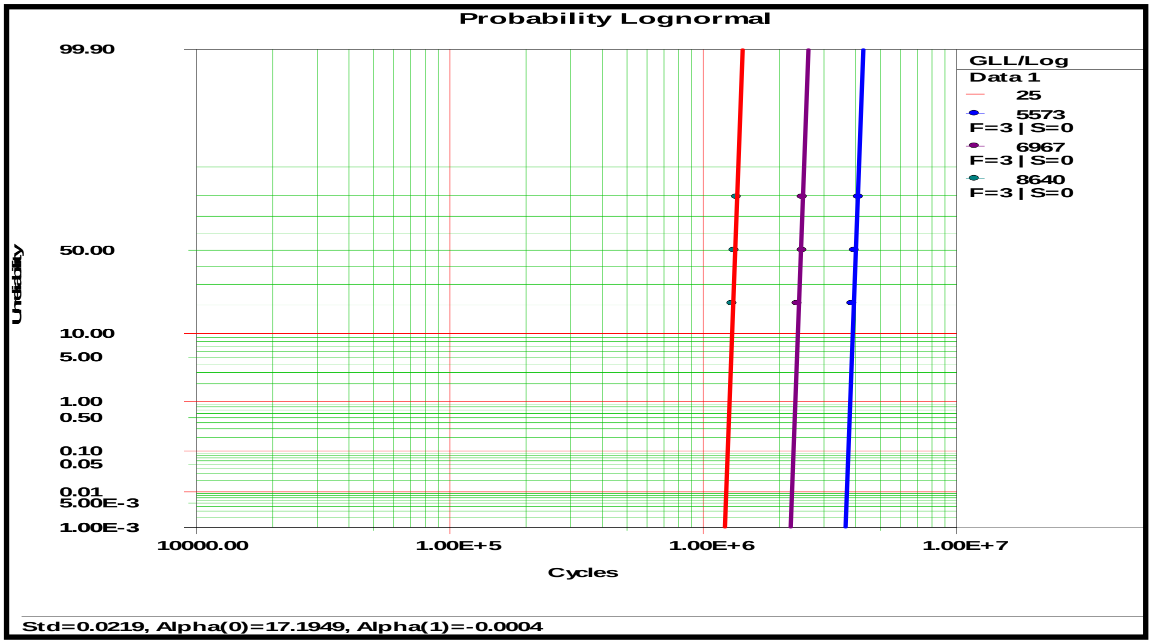
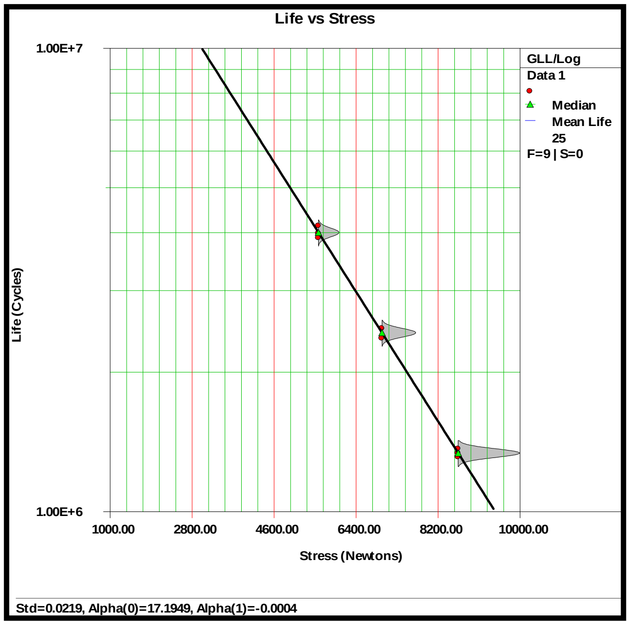


Figure 1.3. Probability Log Normal

(4) The Life Cycle vs. Stress as well as the Acceleration Factor vs. Stress plots were produced.



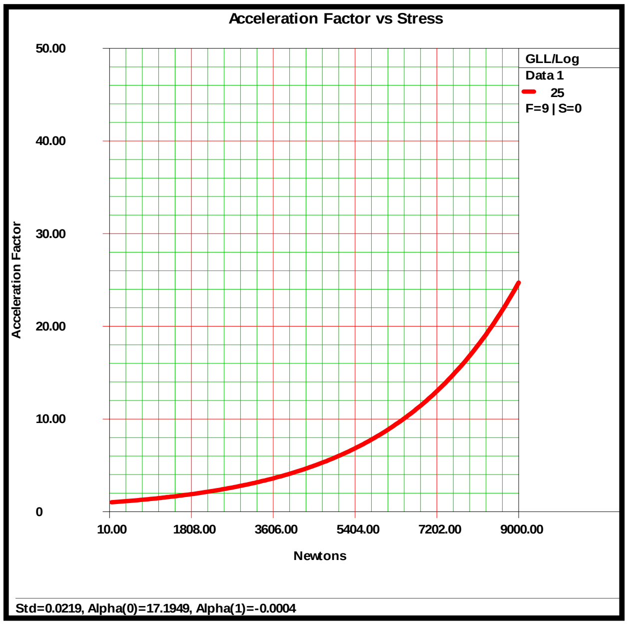
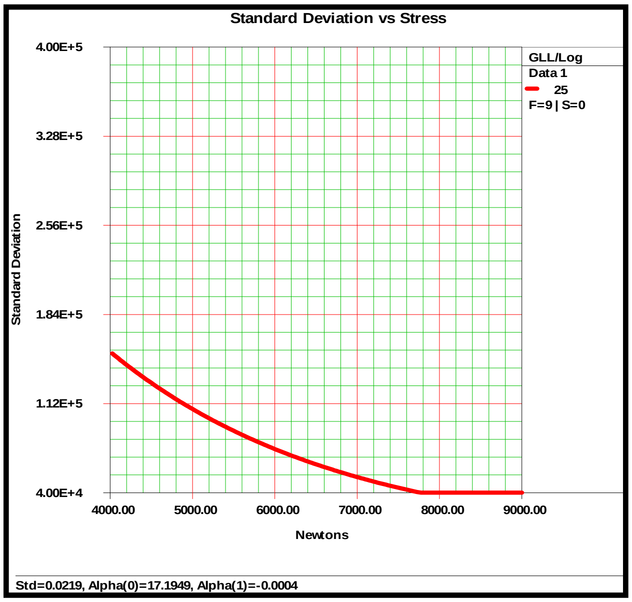


Figure 1.4. Life vs. Stress

Figure 1.5. Acceleration Factor vs. Stress

The standard deviation vs. stress was verified to be directionally correct (the higher the stress, the smaller the deviation). The standardized vs. fitted residuals plot was also used. In a Residual vs. Fitted Value plot, the standardized residuals are plotted versus the scale parameter of the underlying life distribution (which is a function of stress) on log-linear paper (linear on the Y-axis). It is used to detect behavior not modeled in the underlying relationship.



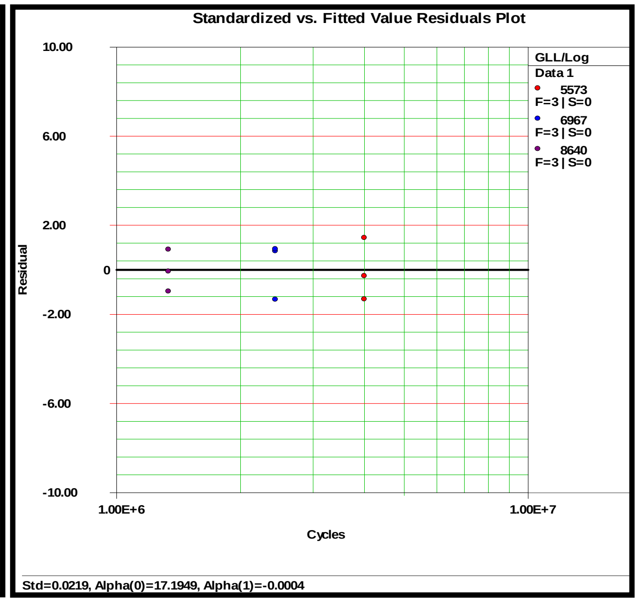


Figure1. 6. Standard Deviation vs. Stress

Figure 1.7. Standardized vs. Fitted Value Residuals

(6) Reviewing the existing test requirements and customer duty cycle, revisions were made to the test that afforded a 38% reduction in overall time. Furthermore, a HASS was developed from this, which generated further test and program timing reductions.

General Comments

Products are expected to last for many years; however, allowable product development time and cost continue to decline. Accelerated testing can reduce testing time substantially. While reliability estimates can be made using models for the individual components, overall reliability, interactions, untried components, or a new environment can only be obtained by testing. This is especially true for complex products. Without accelerated testing, it is difficult to determine reliability rates with any amount of certainty given the short design cycles and higher reliability requirements.

References

Chelsea, D. Stewart and Trapp, PhD., O.D._*Accelerated Handbook.* Portola Valley, CA, Technology Associates, 1990.

Nelson, Wayne. *Accelerated Testing Statistical Models, Test Plans, and Data Analyses.*, A Wiley-Interscience Publication. 1990