# An Accelerated Lifetime Model With Combined Stress Factors for Reliability Evaluation of Automotive Sensors

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## Abstract

- The evaluation of sensors life time and reliability is a key topic in the automotive industry.
- There is a need for invention and creation of customized models for life time acceleration.
- Using JMP "reliability" module, a two stress parameters accelerated lifetime model is built and used to evaluate reliability of parts whose environmental conditions exhibit high temperature and vibrations.
- Another part of the study is focused on the evaluation of confidence intervals of failure occurrence in conditions where the sampling ratio is high compared to total population.

## Objectives

- Building 2 stress parameters models with JMP "reliability" module
- Correcting the confidence intervals calculated by classic inference statistics and build related JMP tools

## Conclusions

- Degradation studies are really useful when no failure are expected during the time of the trials
- Our modified confidence interval provides to the customers an accurate estimation when the sampling rate is low

## Building a 2 stress parameters accelerated model with JMP

### METHOD

- Acceleration factor are used to generate failure. There are some cases however where it is no possible to generate failures during the time of the trials .
- **Innovation1: use of degradation models**, where the response is no more a failure time but a parameter of interested related to the failure mode.
  - The theory of ALT tests can be used : no failure are observed but by extrapolating the parameter measured and using a specification limit, it is possible to generate "pseudo failures" that are then analyzed with a Weibull or another survival distribution.
- **Innovation2: use of 2 acceleration factors**. This is especially useful to get a good representation of the failure modes on sensors.
  - JMP software and the degradation platform have been very useful and easy to use.
  - an EYRING model with temperature and vibrations factors is considered. EYRING equation:

Path Definition

$$\text{Degra} = \text{Beta0} + \text{Beta1} * \text{Exp}\left[\frac{-\text{Beta2}}{(\text{Celsius} + 273.15)} - \text{Beta3} * \text{Voltage} - \text{Beta4} * \left(\frac{\text{Voltage}}{(\text{Celsius} + 273.15)}\right)\right] * \text{time} = e$$

Parameter of interest — Temperature — Vibration

### RESULTS (Figure 1)

- Degradation of the response of an Automotive sensor as a function of stress is simulated
- The JMP platform is used to evaluate MTTF results

## Real product life in the field: confidence intervals of failure occurrence

### METHOD

- Assume that a sample of size n is drawn from a population of size N, and the proportion of defects $p$ is estimated from that sample. A confidence interval can be drawn for the unknown proportion P of defects using the standard formulae proposed by Agresti.
- These formulas apply when the sampling rate n/N is low, typically lower then 10%. When the sampling rate is higher than 10%, we propose a correction that takes into account the sampling rate, to have a better estimate of the variance of $p$ . The proposed corrected 95% confidence interval is:

$$\left[p - 2\sqrt{\frac{p(1-p)}{n} \times (1 - n/N)}\ ;\ p + 2\sqrt{\frac{p(1-p)}{n} \times (1 - n/N)}\right]$$

### RESULTS (Figure 2)

- An application case of field return is simulated
- The JMP platform is used to make risk assessment

## References

- Nelson, Accelerated Testing, Wiley
- Boulanger & Escobar, Experimental Design for a Class of Accelerated Degradation Tests, Technometrics
- Agresti, Coull, Approximate Is Better than "Exact" for Interval Estimation of Binomial Proportions. The American Statistician

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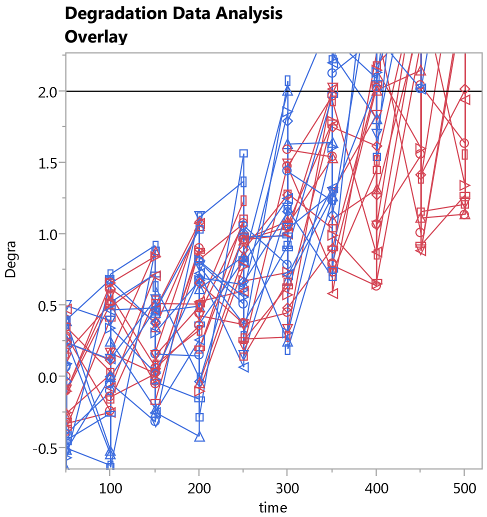
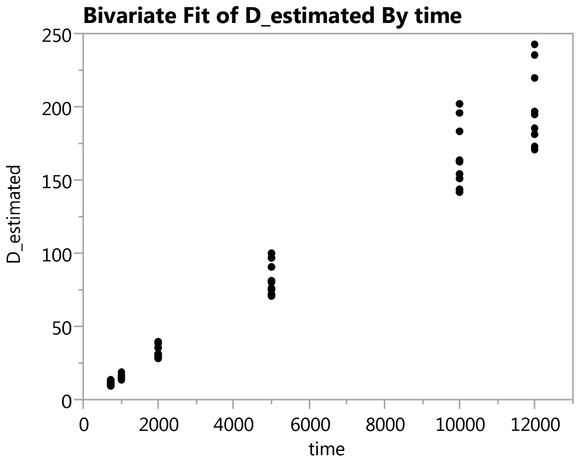
## Figure 1

Simulation database for acceleration life test: 3 levels for T, 2 levels for vib




**USL = 2% => MTTF = 794 time units**

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## Figure 2

Simulation example: 1400 parts delivered (N), 300 analysed sample size (n) with potential failure

| sample size n | population size N | observed proportion p | 95% CI lower bound | 95% CI upper bound | 95% CI CORRECTED lower bound | 95% CI CORRECTED upper bound |
|---|---|---|---|---|---|---|
| 300 | 1400 | 0.05 | 0.025 | 0.075 | 0.028 | 0.072 |
| 300 | 1400 | 0.1 | 0.065 | 0.135 | 0.069 | 0.131 |
| 300 | 1400 | 0.2 | 0.154 | 0.246 | 0.159 | 0.241 |
| 300 | 1400 | 0.3 | 0.247 | 0.353 | 0.253 | 0.347 |
| 300 | 1400 | 0.5 | 0.442 | 0.558 | 0.449 | 0.551 |

For an observed proportion of 50%, the modified bounds for failure occurrence at 95% Confidence Index are now:

*[44.9% to 55.1%]*

Whereas classical formula gives

*[44.2% to 55.8%]*

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