Reliability Engineering: The Flip Side of Failure Analysis

Lance R Curtis
Reliability Engineer, General Electric
21 April 2011

29 Oct 2013 edition containing minor editorial changes

Disclaimer

This presentation contains no information proprietary to the General Electric Company. No General Electric documents, information, or other resources were used in the preparation of this presentation. All of the information in this presentation was obtained from either public domain sources or respected third-party (i.e. non-GE) sources. A list of references appears at the end of this presentation.

So what is reliability?

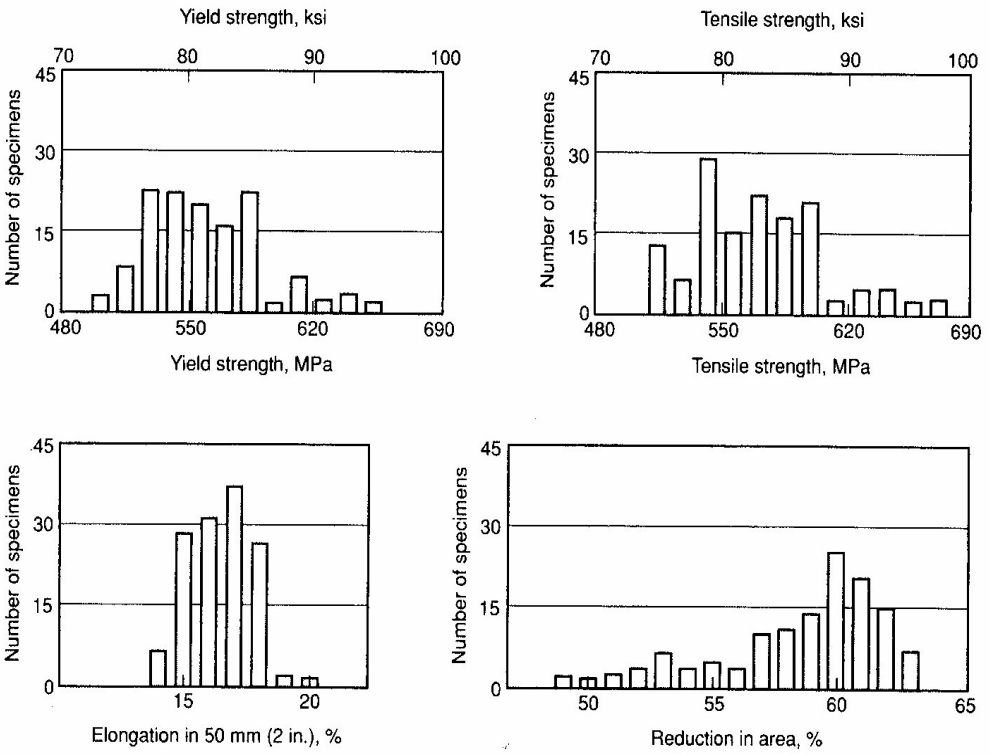
- Reliability means different things to different people.
- For most engineering applications, reliability is the probability that a functional unit will perform its required function for a specified interval under stated conditions.
- Probability means that performance is measured according to a statistical distribution!

Why a branch of engineering around reliability?

- First and foremost, cost savings!
- Second, the market demands it.
  - Customers want worry-free operation.
  - Competitors are doing it, so we must also.
- Because reliability involves statistical distributions, engineering judgment is needed to separate what belongs in the distribution from what doesn't!

Real Engineering is All About Statistics

- Most engineering parameters are really distributions (stress and strength, for example)



There's no school like the old school – Deterministic Design

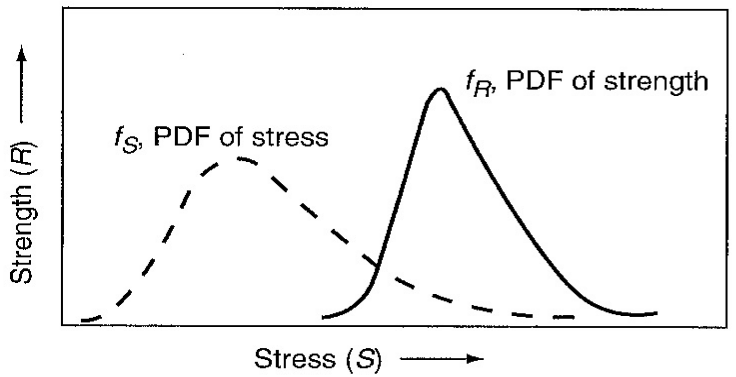
- Notwithstanding that most engineering parameters are really statistical distributions, using them in hand calculations requires considerable time and resources.
- Factors of safety, still taught in many engineering schools today, are the deterministic equivalent to including probabilistic analysis in design.
- Use of factors of safety led to bulkier designs that require more materials.

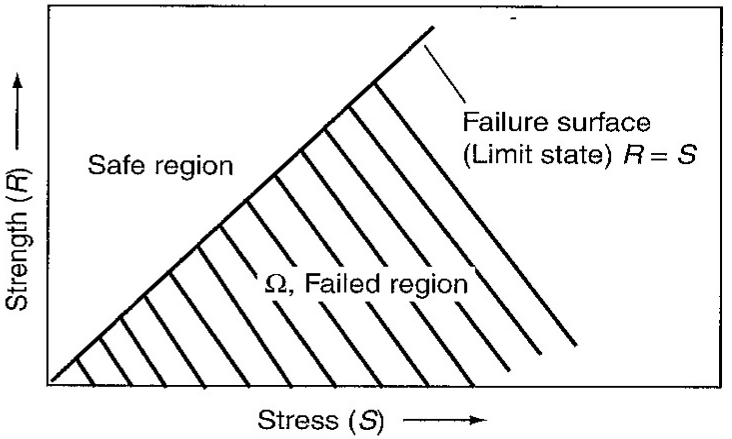
Enter the Age of the Modern Computer

- To respond to the changing times, products needed to be lighter, faster, cheaper, etc. This led to decreased factors of safety, which increased the probability of failure.
- Modern computers make it easy to perform the complex and time-consuming calcula-tions required to design according to distriu-tions of parameters.
- Now it is easier to design probabilistically!

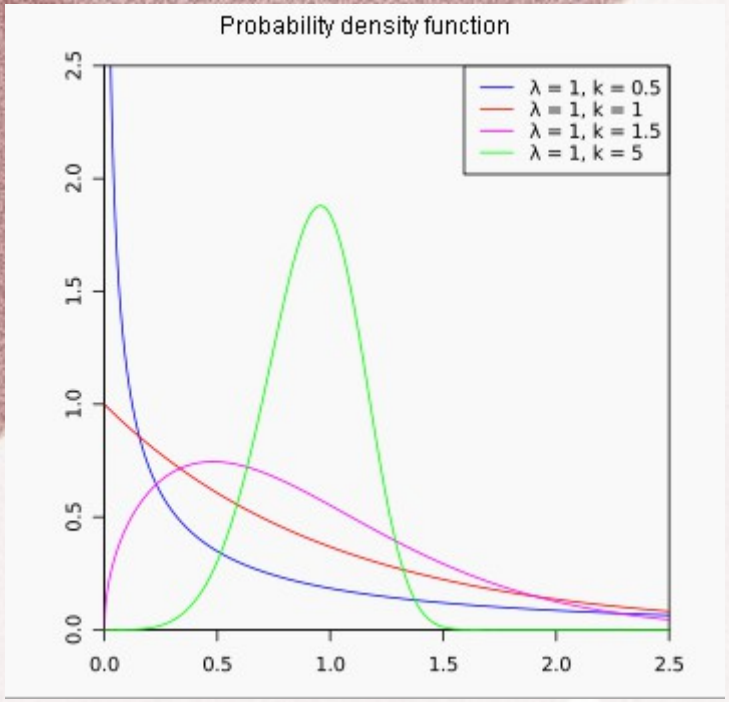
Failure is really a distribution!

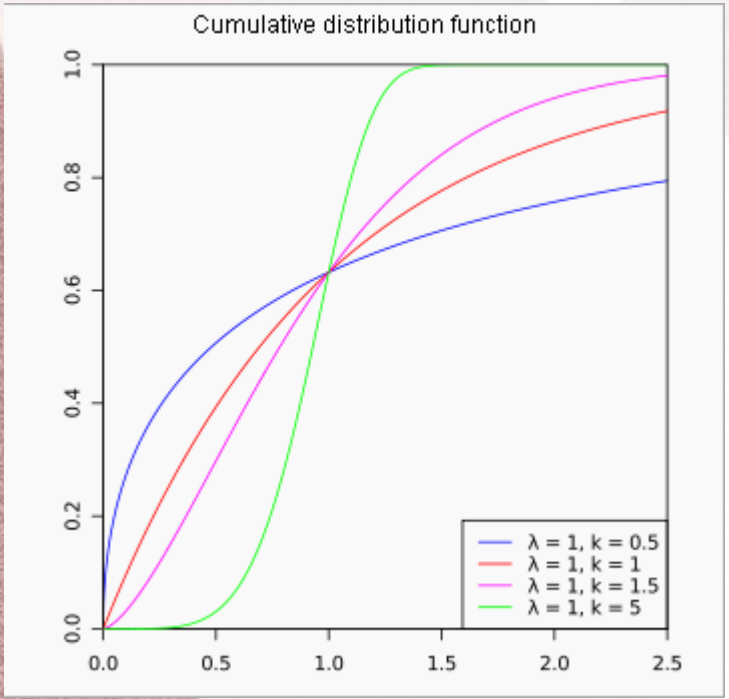
- It's not just engineering parameters that are distributions!
- Stress/strength overlap is the classic failure distribution example.





Enter Reliability Modeling





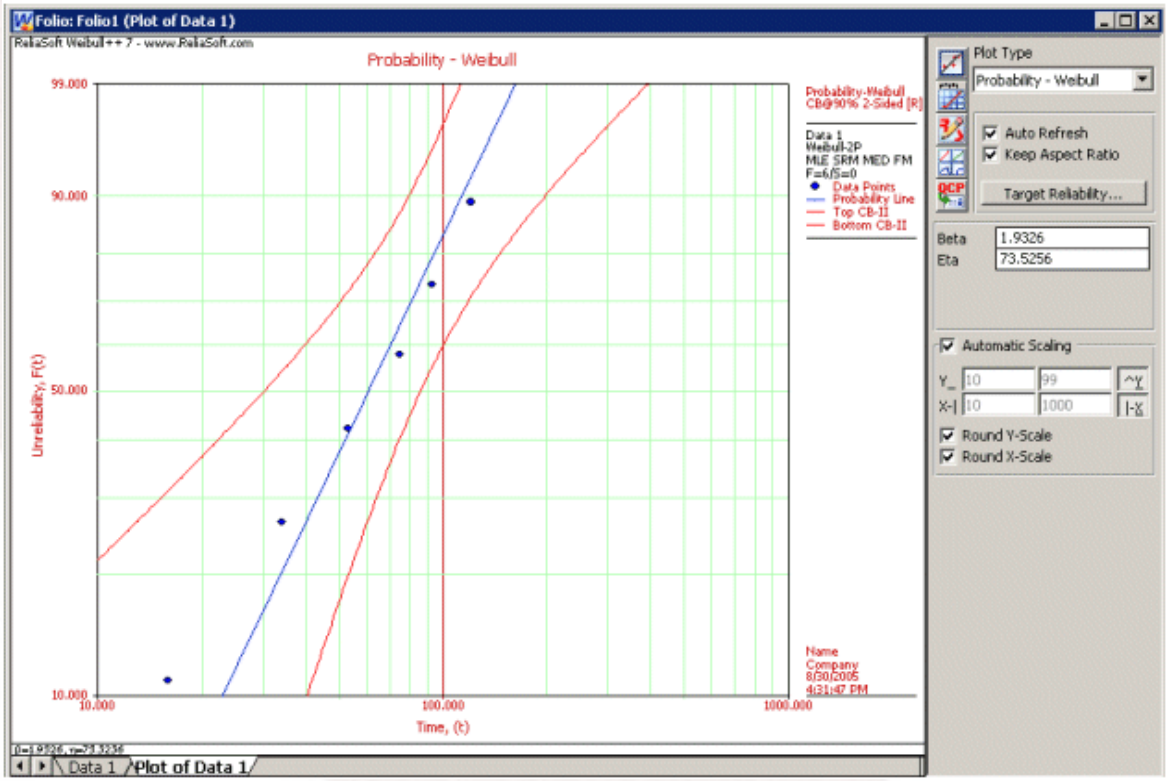
- Because failure is a distribution, we can model it the same way we model any statistical distribution.
- We only need to know which distribution to fit the data to.

E pluribus unum - "Out of many, one"

- Many different types of distributions
  - Normal
  - Lognormal
  - Extreme value
  - Weibull
  - Exponential
  - Beta
  - Uniform
  - Poisson
- Weibull is the distribution of choice because its parameters can be changed to mimic several other common distributions used in engineering.

If you got the data, honey, I got the risk prediction!

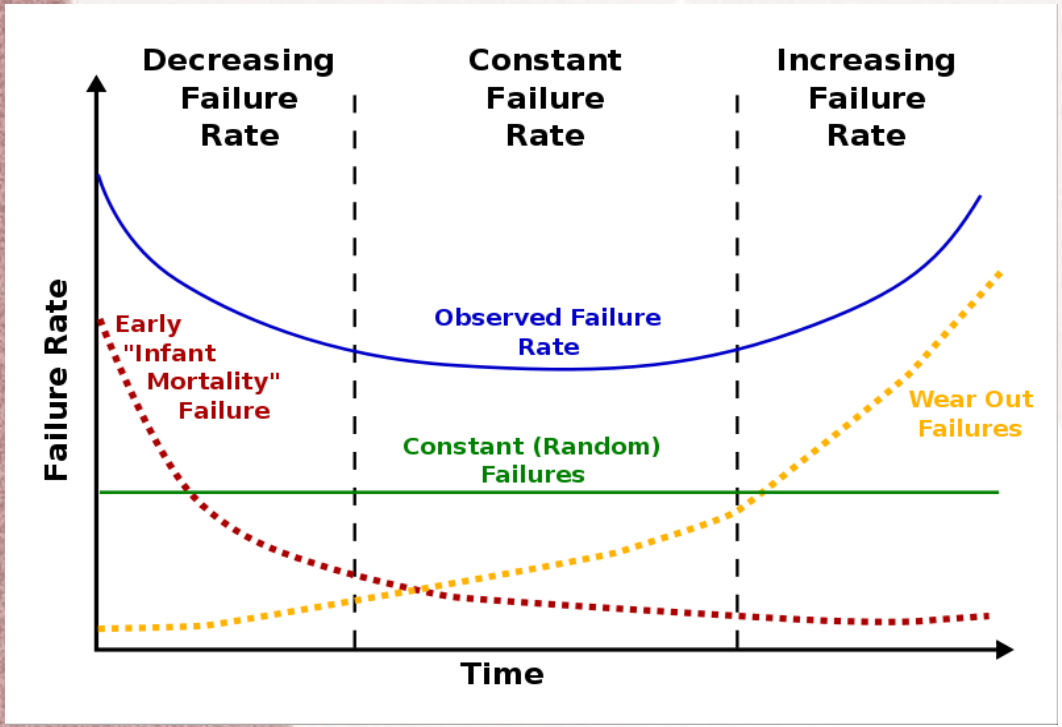
- Weibull modeling provides lots of information and utility.
  - Predict risk
  - See trending
  - Set inspections
  - Warranties
  - Part inventories
  - Process control
  - Failure analysis



- Weibulls are robust models but limited to a single part-failure-mode combination.

The Bathtub Curve

- Weibull models tell you about the failure mode if you understand the shape factor (S.F.) and the bathtub curve.
  - S.F. is the slope of the line in your model plot.



  - S.F. < 1 → Infant mortality
  - S.F. = 1 → Random
  - 1 < S.F. < 4 → Early Wearout
  - S.F. > 4 → "Old but quick" Wearout

Lance R Curtis / ASM Old South Chapter

Garbage in, garbage out – Limitations of getting good models

- No model can make good predictions if the data that feeds the model is bad.
- Better data → better predictions
- Getting good data is the hard part
- Reality = your data sets are often dirty and incomplete
- Engineering judgment plays a huge role in deciding what data is used and what data is not!

How much do you like to play poker?

- Reliability models provide a risk prediction as a probability. This prediction is a technical assessment only.
- Reliability modeling does NOT provide levels of acceptance (i.e. whether a certain risk is excessive). This determination is strictly a business decision!
- Marrying risk predictions to cost make them more intelligible to decision makers.
- Decision makers must also weigh intangible costs in the balance also.

Failure analysis & Reliability Engineering – Two sides of the same coin

Failure Analysis

- Micro view
- Past focus
- Typically one event
- Feeds reliability analysis

Reliability Engineering

- Macro view
- Future focus
- Any number of events
- Feeds failure analysis efforts

So much more in the magician's hat!

- There are MANY more reliability tools, including these:
  - System Reliability Modeling
  - Design for Reliability (DFR)
  - Accelerated Life Testing
  - Monte Carlo Simulation
- Find more at online
  - weibull.com
  - barringer1.com

Thanks for your time!

Questions?

References

- Slide 3 - http://en.wikipedia.org/wiki/Reliability_engineering
- Slide 5 - Harry R. Millwater & Paul H. Wirsching, "Analysis Methods for Probabilistic Life Assessment", ASM Handbook Volume 11: Failure Analysis and Prevention, 2002, p. 251.
- Slide 8 - Harry R. Millwater & Paul H. Wirsching, "Analysis Methods for Probabilistic Life Assessment", ASM Handbook Volume 11: Failure Analysis and Prevention, 2002, p. 255.
- Slide 9 - http://en.wikipedia.org/wiki/Weibull_distribution
- Slide 11 - http://www.weibull.com/LifeDataWeb/estimation_of_the_weibull_parameter.htm#mle
- Slide 12 - http://en.wikipedia.org/wiki/File:Bathtub_curve.svg; Paul Barringer, Reliability Engineering Principles, 2003, 3-Slides 17-20.
- Slide 13 - Paul Barringer, Reliability Engineering Principles, 2003, 23 (all slides).
- Slide 16 - Harry R. Millwater & Paul H. Wirsching, "Analysis Methods for Probabilistic Life Assessment", ASM Handbook Volume 11: Failure Analysis and Prevention, 2002, p. 259-63; http://www.reliasoft.com/newsletter/v8i2/reliability.htm; http://www.weibull.com/acceltestwebcontents.htm.