44 WEIBULL ANALYSIS

Description

Weibull Analysis plots product failures and suspensions by rank order on the ordinate versus product life on the abscissa. This plot is used to define the failure rate or reliability for a population of product for a range of lifetimes.

Purpose

Weibull analysis is best used to determine the failure rate of reliability for a particular failure mode of an individual component. It can define the nature of the failure mode, that is, whether it is infant mortality, random, or wear-out. It can be used to predict the financial impact of the failure for decision-making purposes. It can be used to make comparative decisions for various design alternatives. It can be used to compare the actual performance of a product versus its design goals.

Benefits

- Weibull analysis, using widely available software, is an easy-to-use tool to evaluate product reliability.
- In conjunction with Logistics Support Analysis, Weibull analysis can be used to determine field service strategy.
- When kept in a database, Weibull analysis can be used to compare reliability of various design alternative concepts. Combining Weibull analyses can also be used to model total reliability of components and entire systems.
- Weibull analysis provides visual failure statistics and potential liability at the end of the warranty period.

Implementation

Weibull plots are most effective when the specific failure mode and population base are carefully selected and discussed before analysis. The population base and failure modes should be specifically annotated on the plot.

Weibull analysis can be used for a data population consisting only of failures and for a mixture of failures and suspensions.

Weibull is best used for a single failure mode on a single component. Mixing modes and components muddles the information extracted and may underestimate the risk of failure. Limiting to a specific mode allows better characterization of that mode.

Data sets comprising failed and suspended units (censoring) require the use of Weibull analysis as a first step in the analysis process. Software currently does not exist to enable the application of numerous other probability models directly.

Goodness of fit should be calculated to make sure that the Weibull line fits the data and the correct distribution has been selected. Rank regression and maximum likelihood estimation are two of the most widely used.

Special care need be taken for small samples. The risk of error is significant.

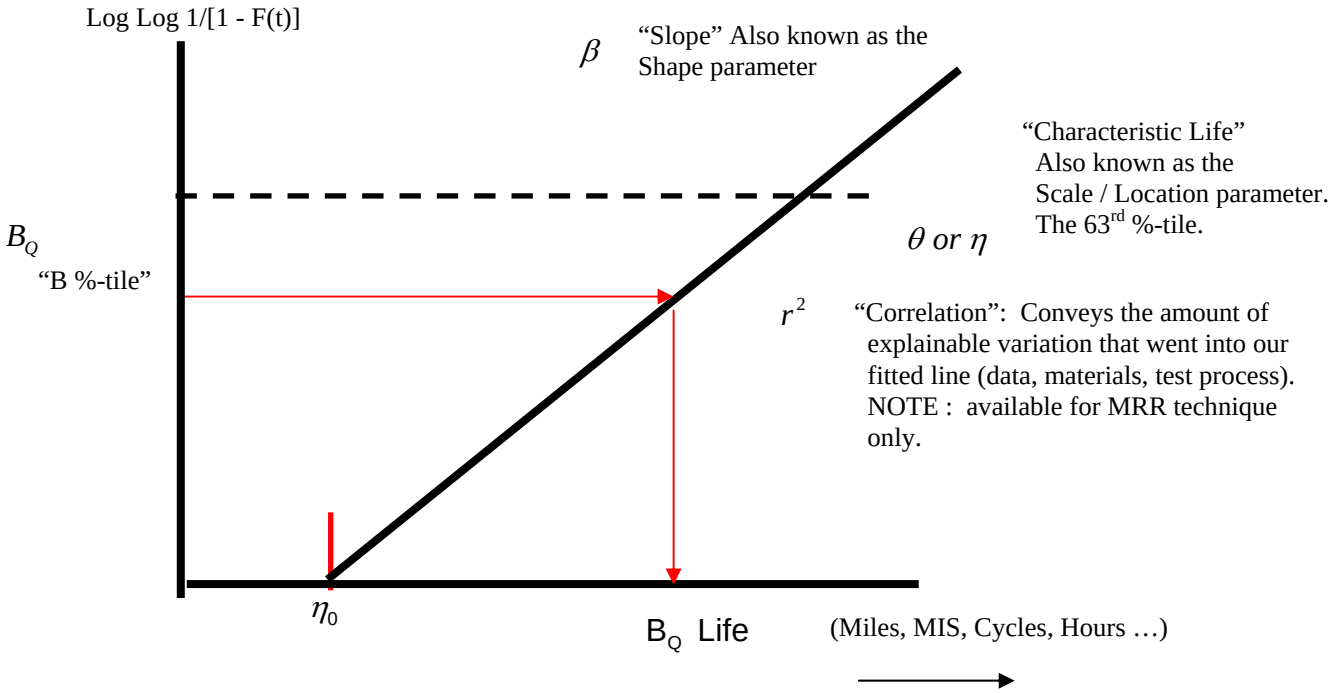
When dealing with no failures, Weibayes analysis is typically used. Care must be taken NOT to apply the technique blindly. The technique is based on an assumed Weibull slope. Instead, this assumption should be based on historical data.

Process Flow

1. Determine the product and process goals and performance requirements.
2. Determine the boundaries and level of complexity for system or component to be analyzed.
3. Finalize the analysis approach and report format to be used.
4. Initiate the test or data extraction.
5. Obtain failure and suspension cycles, mileage, or time in service.
6. Conduct the Weibull Analysis.
7. Obtain parameter estimates. These are most likely the Weibull slope and characteristic life.
8. From analysis, perform goodness of fit to potential candidate probability distributions.
9. Perform a Monte Carlo simulation (optional).
10. Finalize the selection for best probability distribution.
11. Use the analysis results to compare to reliability goals and generate a financial risk analysis.

Example

Basic Weibull Plot Interpretation



"Minimum Life"
Another Scale / Location parameter:
If applicable, the point on the time scale where failures initiate; prior to that, point failures cannot happen.

Figure 44.1. Basic Weibull Format

Further comments on Shape parameter (the "fingerprint").

$\beta < 1 \Rightarrow DHR$

$\beta = 1 \Rightarrow CHR$

$\beta > 1 \Rightarrow IHR$

where

DHR = Decreasing hazard rate. Infant Mortality failures.
CHR = Constant hazard rate. Random/Chance failures.
IHR = Increasing hazard rate. Durability / Wear-out failures.

Reference the following figure (42.2), which conveys the hazard rate configuration over the life cycle of a product (the “bathtub” curve).

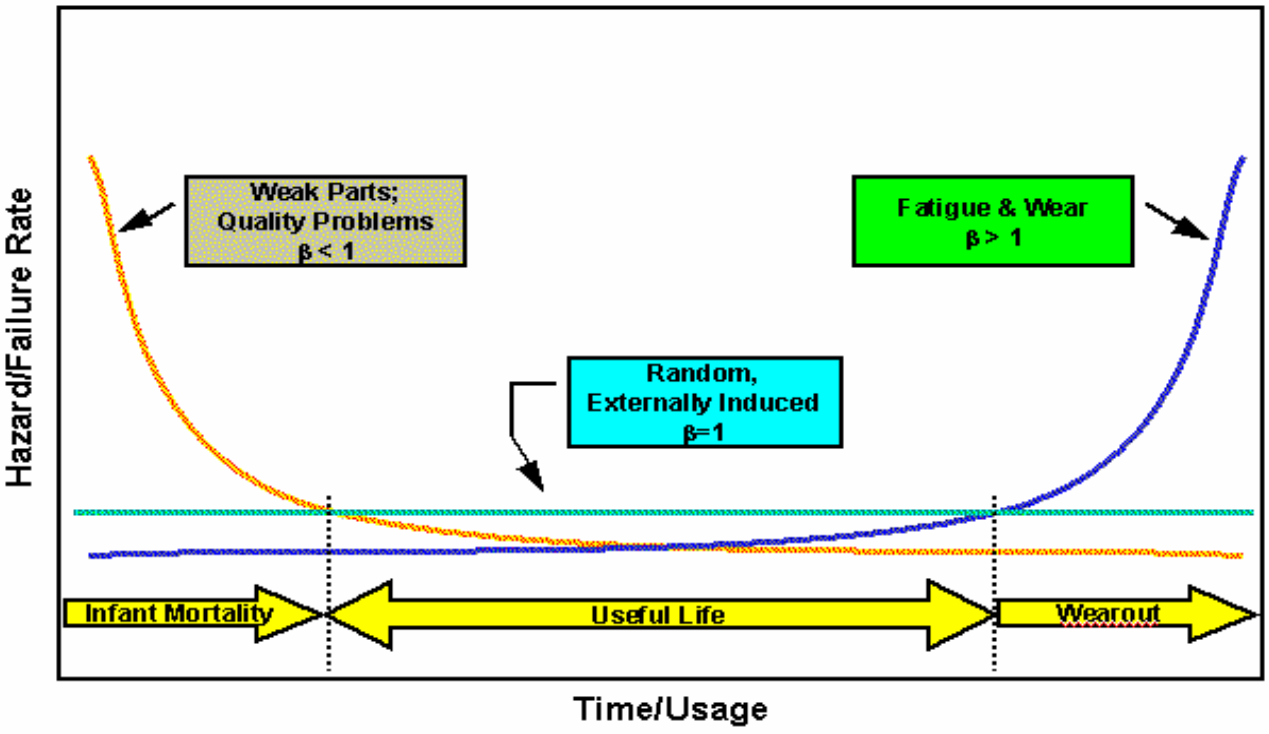


Figure 42.2. Classic Bathtub Curve

The shape parameter (Figure X) also provides an indication of the form of the underlying probability density function.

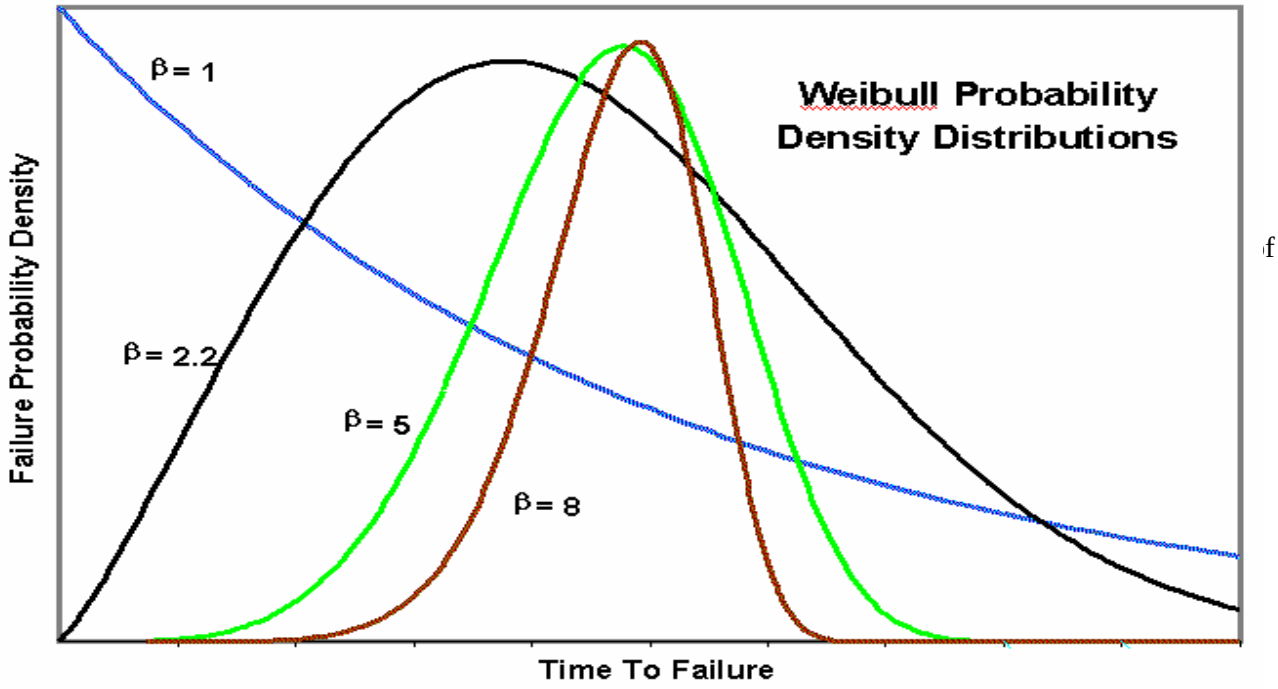


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Figure 44.3. Weibull Probability Density Distributions

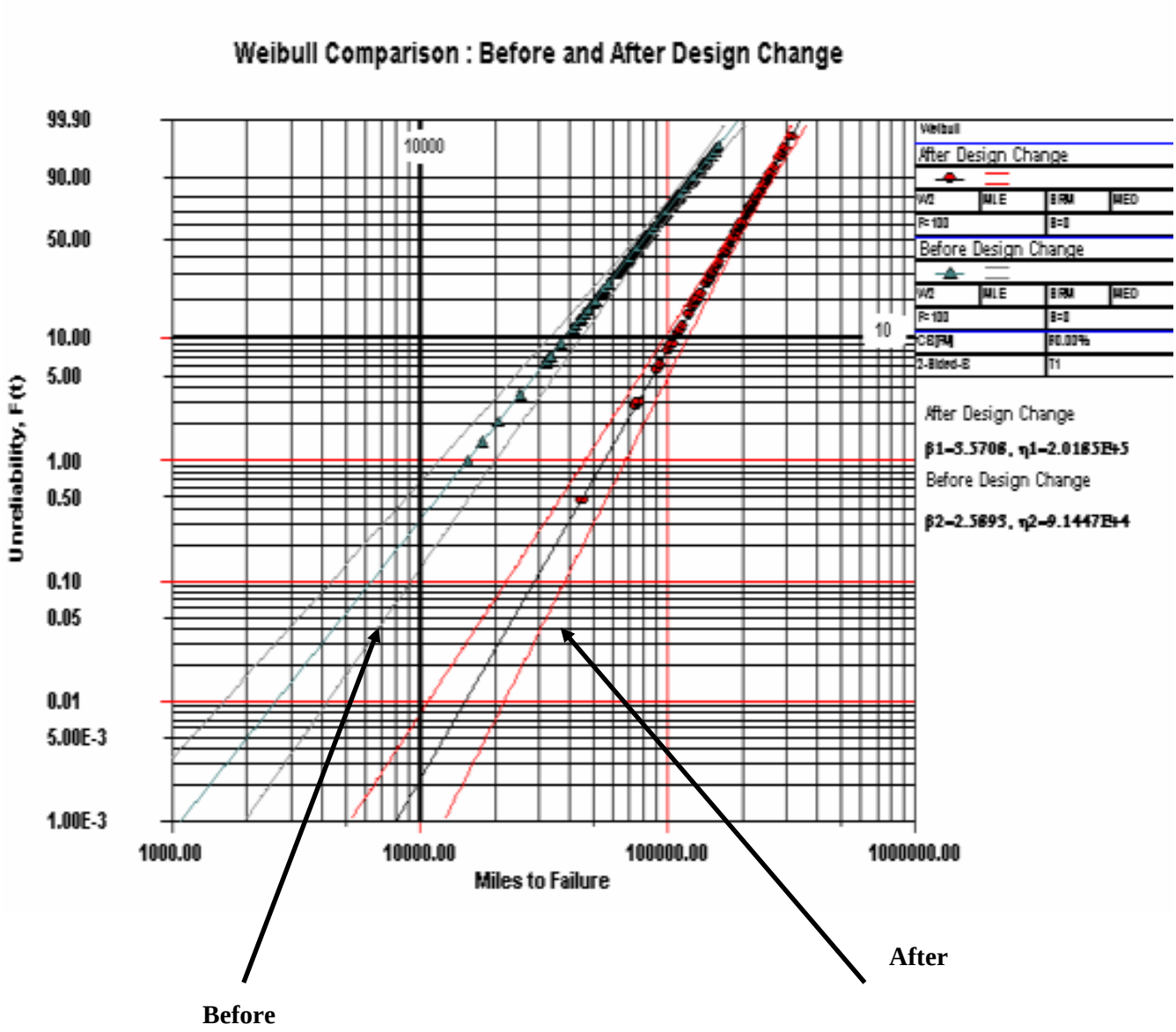

Figure 44.4. Weibull Plots Before and After Design Change

Conclusion

The new high-temperature material application has a demonstrated B10 range of 100,000 to 130,000 miles. At the 99.9percent failure point, prior design indicates failure by 200,000 miles. After design change we net 370,000 miles. The net result is a definite improvement in the life of the product.

General Comments

Because of the easy-to-use software available today, Weibull analysis is one of the premier tools used for life data analysis. Its usage ranges from a standalone application or as a lead-in to obtaining the true nature of the underlying distribution of times to failure. With the availability of Monte Carlo simulation features in the existing software, simulated data sets can be developed and used in other software analysis programs that did not and do not have the capability of analyzing both failure and censored data sets.

Weibull and life data analysis are used primarily in the Product and Process Validation phase to assess whether required goals have been met. A library of historical Weibull analyses can be helpful in reliability planning as well.

References

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