ReliaRisk
可靠性工程解决方案

您的可靠性专业帮手

Reliability Advisor Working For Your Business

Julio E. Pulido博士

Dec. 2016

维 修
测 试
数据分析
可靠性
可维护性

成功企业的高效解决方案

EFFECTIVE SOLUTIONS FOR BUSINESS SUCCESS

ReliaRisk有限责任公司是一个可靠性工程顾问集团，帮助企业通过**降低产品开发失误和降低保修成本**，来增加盈利能力。ReliaRisk专注于整合可靠性的方法和六西格玛设计工具，并将这些方法和工具融合到贵公司的产品质量计划中去。

ReliaRisk LLC is a reliability engineering consulting group that helps business-to-business organizations grow profitability by **reducing product development escapes and warranty costs**. ReliaRisk concentrates on integrating **D**esign **f**or **R**eliability methodologies and **D**esign for **S**ix **S**igma tools into your company's **A**dvanced **P**roduct **Q**uality **P**lanning and **R**eliability based **M**aintainability **P**rogram.

ReliaRisk
可靠性工程解决方案

我们的目标
Our Mission

客户的满意是我们的目标。
YOUR CUSTOMER'S SATISFACTION IS OUR GOAL

ReliaRisk为客户提供最好的可靠性和维修性工程和项目管理方法和工具，以最大程度地降低和优化项目和运营成本。

ReliaRisk provides customers with the best methods and tools for reliability and maintainability engineering and program management, minimizing project costs while optimizing your operations.

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我们的价值
Our Value

可靠性专业支持与服务

PROFESSIONAL RELIABILITY SUPPORT AND SERVICE

我们的可靠性咨询团队结合了在可靠性和质量工程各领域的专业知识，产品范围涉及到 - 暖通空调系统，微电子及机电设备，以及先进的飞机系统和海洋钻井设备等。

Our reliability consulting team has combined expertise in all areas of reliability and quality engineering for a broad spectrum of products – from HVAC systems, microelectronics and electromechanical appliances to advanced aircraft systems and offshore drilling equipment.

ReliaRisk 可靠性工程解决方案

拥有20 年

可靠性工程经验

Reliability Engineer Experience

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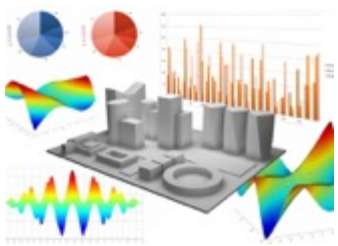
我们的服务
Our Service

数据分析

- 寿命数据和保修分析
- 基于可靠性的资产管理
- 生命周期成本分析
- 预测健康管理
- 实时监控设备管理
- 实验设计
- 可靠性框图
- 故障树分析
- 可靠性增长分析



加速寿命试验

- 振动
- 湿度测试
- 电子失效机理
- 高温和低温的影响
- 热循环
- 温度 - 湿度的关系
- 阿累尼乌斯关系
- 艾瑞关系
- 寿命分布
- 可靠性/不可靠性图

计划管理

- 寿命数据和保修分析
- 可靠性组织发展
- 可靠性流程和程序
- 失效模式与影响分析
- 可靠性为中心的维修
- 可靠性资产管理
- 生命周期成本分析
- 设备健康预测管理
- 设备运行状态管理
- 实验

可维护性

- 仿真系统可用性分析
- 系统和寿命的可靠性
- 生命周期成本分析
- 可靠性增长分析（Duane 和
- Crow模型）
- 组织机构发展
- 预防性维护优化
- 备件管理

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与ReliaRisk合作，我们将帮助您成功。

PARTNER WITH RELIARISK. WE WILL HELP YOU SUCCEED.

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作者简介
About the Author

- **Dr. Julio Pulido** is a Principal Reliability Engineer at ReliaRisk LLC. His responsibility is to drive the capability development of Design for Reliability program for ReliaRisk Customers with emphasis in Reliability and structural and fluid dynamic interaction.
- Has **20+ years of experience** as an engineering executive in **Product Design and Design Assurance Organizations** in medical, automotive, aerospace, HVAC and nuclear industries. He has published over 50 peer reviewed Journal and Conference papers.
- **His specialty** is in the area of **Structural Analysis**, **Design for Vibration**, **Fatigue analysis**, **Structural Reliability**, and **Accelerated Testing Techniques**.

Education

- BS from the Federal University of Bahia, Brazil;
- MS from the Federal University of Rio Grande do Sul, Brazil;
- PhD from the Federal University of Rio de Janeiro, Brazil;
- PhD Research at Duke University;
- MBA from Xavier University
- Certificate in Information Technology Management from the University of Chicago.

Working Experience

USA	**China**
Emerson Electric	Bosh Electronics (Shanghai)
Siemens Medical	BYD Automotive
Ingersoll Rand	Hong Kong Productivity Council
ReliaSoft	
Nortek	

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作者简介
About the Author

- **Julio Pulido博士**是ReliaRisk LLC的首席顾问。他立志于帮助客户提高可靠性计划设计的能力，侧重于培养可靠性和结构和流体动力学相互作用的设计能力。
- 拥有超过**20年多年**的可靠性工程的工作经验，他与可靠性咨询团队结合了在可靠性和质量工程各领域的专业知识，产品范围涉及到 – 暖通空调系统，微电子及机电设备，以及先进的飞机系统和海洋钻井设备等。 **Julio Pulido博士**在美国国家和国际研讨会上发表超过**50篇以上的学术论文**（RAMS and ARS）。
- **论文范围包含**：产品的可靠性，可靠性管理程序，加速测试，振动测试，寿命预测和测试技术等方面。
- **专业领域**：**结构分析，振动设计，疲劳分析，结构可靠性和加速测试技术**。

Education

- 博士学位后|结构可靠性专业|美国杜克大学（北卡州杜兰）|美国
- 博士|结构工程专业|巴西COPPE联邦大学|巴西
- 硕士|工商管理专业|美国泽维尔大学（俄亥俄州）|美国
- 硕士|信息技术的战略应用专业|美国芝加哥大学|美国
- 硕士|结构工程专业|巴西联邦大(里约热内卢）|巴西
- 学士|土木工程专业|巴西巴伊亚联邦大|巴西

Working Experience

美　国

谷轮公司-艾默生电气
西门子-医疗系统/西门子-能源与自动化比
英格索兰公司－气温控制部
美国ReliaSoft 软件公司
NORTEK空调有限公司

中　国

博世电子（上海）
亚迪汽车
香港生产力促进局

ReliaRisk 可靠性工程解决方案

数据分析

统计学在工程中的应用-第一部分

Data Analysis

Statistics For Engineers – Part I

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RELIABILITY ENGINEERING SOLUTIONS

概率分布函数
Probability Distribution Function(PDF)

Data Analysis
Statistics For Engineers - PDF

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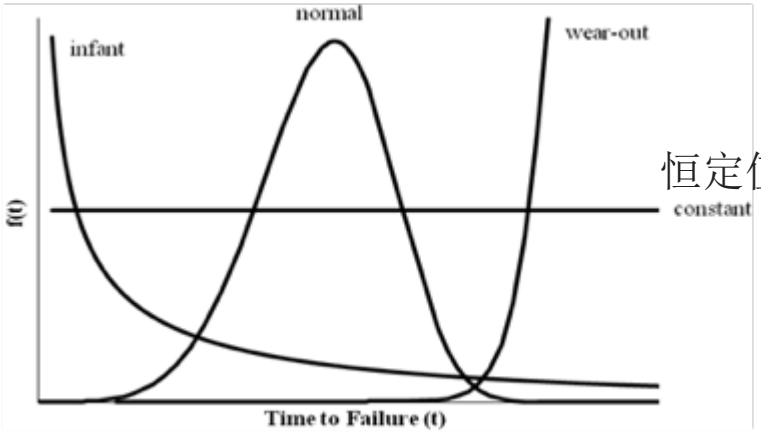
RELIABILITY ENGINEERING SOLUTIONS

概率分布函数
Probability Distribution Function(PDF)

- 概率密度函数（PDF）f（t）用于描述随机变量t的统计分布。PDF可以用于确定变量t在t1到t2的范围内的概率。
- 这给出以下等式：

- The probability density function (PDF), f(t), is used to describe the statistical distribution of a random variable, t.
- The PDF can be used to determine the probability a variable t, lies within a range of t1 to t2.
- This gives the following equation:

产品早期　　产品正常使用　　产品损耗



恒定值

故障时间

$$P(t_1 < t < t_2) = \int_{t_1}^{t_2} f(t)dt$$

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概率分布
Probability Distribution

- 换句话说，t在t1到t2的区间中的概率是从t1到t2的概率密度函数曲线下的面积。
- 注意，PDF下的总面积总是等于1，因为t位于数据集中的概率是100％。数学上，它写成：
- In other words, the probability that t lies in the in the interval of t1 to t2 is the area under the probability density function curve from t1 to t2.
- It is noted that the total area under the PDF is always equal to 1 because the probability that t lies in the data set is 100 percent. Mathematically, it is written as:

$$\int_0^{\infty} f(t)dt = 1$$

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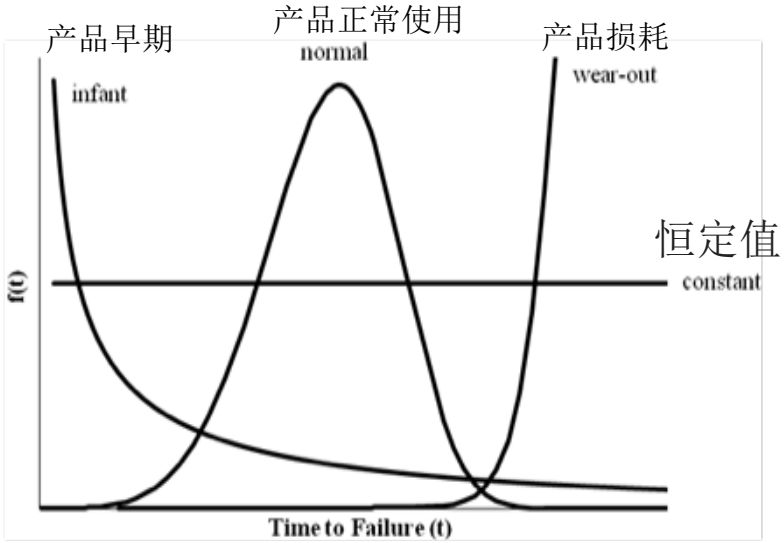
概率分布函数
Probability Distribution Function(PDF)



- 左图是概率密度函数（PDF）的图示，其显示了婴儿死亡率，常数，库存和正常的不同故障。
- x轴表示故障时间，而y轴是从0到100％的概率。
- 从PDF，现在可以派生以下功能：
  - 累积分布函数（CDF）：F（t）
  - 危害功能：h（t）
  - 可靠性函数：R（t）

- The figure is an illustration of the probability density function (PDF) showing the different failures of infant mortality, constant, ware-out and normal.
- The x-axis represents the time to failure while the y-axis is the probability from 0 to 100 percent.
- From the PDF, the following functions can now be derived:
  - Cumulative Distribution Function (CDF): F(t)
  - Hazard Function: h(t)
  - Reliability Function: R(t)

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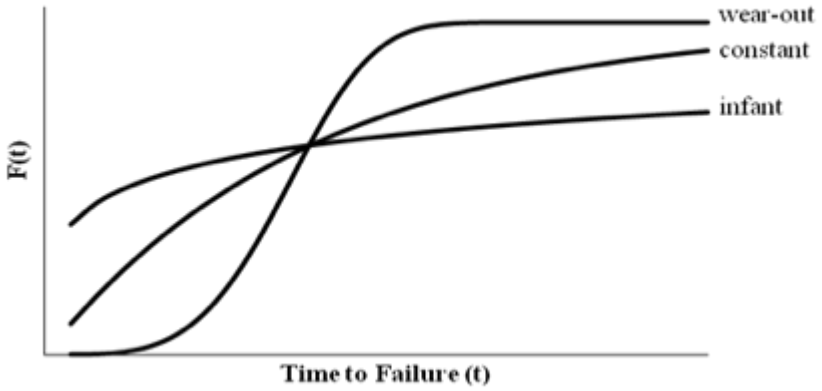
累积分布函数
Cumulative Distribution Function

- 累积分布函数（CDF）F（t）是变量t不大于t1的特定值的概率。
- The cumulative distribution function (CDF), F(t), is the probability that the variable, t, is not greater than the specific value of t1.



$$P(0 \le t \le t_1) = \int_0^{t_1} f(t)dt$$

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累积分布函数
Cumulative Distribution Function

- 累积分布函数F（t）如下导出：
- The cumulative distribution function F(t) is derived as so:

$$F(t) = \int_0^t f(t)dt$$

在故障时刻t1，CDF的值是直到t1的概率密度函数下的面积

At the time to failure t1, the value of the CDF is the area under the probability density function up to t1

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一些分布类型
Some Distributions Types

- 让我们回顾一些概率分布函数的一般基础知识。
- We will review some probability distribution function as general basic knowledge.

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正态分布
Normal Distribution

正态分布
Normal Distribution

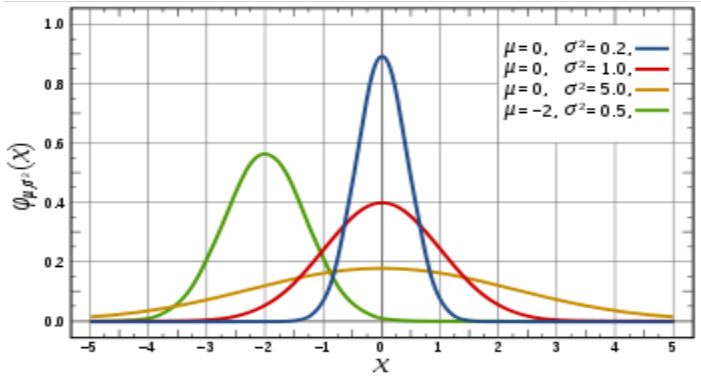
$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}},$$

累积分布函数（cdf）描述了随机变量落在形式（-∞，x）的间隔中的概率。标准正态分布的cdf用大写希腊字母Φ（phi）表示，并且可以计算为概率密度函数的积分

The cumulative distribution function (cdf) describes probabilities for a random variable to fall in the intervals of the form (−∞, x].

The cdf of the standard normal distribution is denoted with the capital Greek letter Φ (phi), and can be computed as an integral of the probability density function

$$F(x;\, \mu, \sigma^2) = \Phi\left(\frac{x-\mu}{\sigma}\right) = \frac{1}{2}\left[1 + \operatorname{erf}\left(\frac{x-\mu}{\sigma\sqrt{2}}\right)\right], \quad x \in \mathbb{R}.$$



- 在概率理论中，正态（或高斯）分布是连续的概率分布，其通常用作第一近似来描述倾向于聚集在单个平均值周围的实值随机变量。
- 相关联的概率密度函数的图形是“钟”形，并且被称为高斯函数或钟形曲线。
- 参数μ是平均值（峰的位置）和σ2
- 是方差（分布宽度的度量）。
- μ= 0和σ2= 1的分布称为标准正态分布。
- 正态分布被认为是统计中最突出的概率分布。
- 这有几个原因：
  - 首先，正态分布很容易解析，也就是说，涉及这种分布的大量结果可以以明确的形式得出。
  - 第二，正态分布作为中心极限定理的结果出现，其表明在温和条件下，大量随机变量的和近似正态分布。
  - 最后，正态分布的“钟”形状使其成为在实践中遇到的大量随机变量的建模的方便的选择。
- 因此，正态分布通常在实践中遇到，并且在统计学，自然科学和社会科学中被用作复杂现象的简单模型。

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对数正态分布
Lognormal Distribution

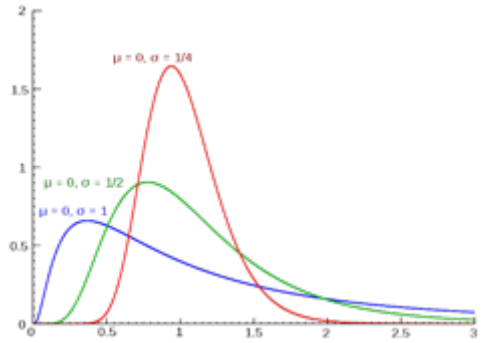
对数正态分布的概率密度函数为：
The probability density function of a log-normal distribution is:

$$f_X(x;\mu,\sigma) = \frac{1}{x\sigma\sqrt{2\pi}}\, e^{-\frac{(\ln x-\mu)^2}{2\sigma^2}}, \quad x>0$$

累积分布函数
Cumulative distribution function

$$F_X(x;\mu,\sigma) = \frac{1}{2}\operatorname{erfc}\left[-\frac{\ln x-\mu}{\sigma\sqrt{2}}\right] = \Phi\left(\frac{\ln x-\mu}{\sigma}\right),$$

其中erfc是互补误差函数，Φ是标准正态cdf
where erfc is the complementary error function, and Φ is the standard normal cdf



- 在对数正态分布中，表示为μ和σ的参数分别是变量的自然对数的平均值和标准偏差（根据定义，变量的对数是正态分布的）。
- 在非对数标度上，μ和σ可以分别称为位置参数和尺度参数。
- 相反，非对数样本值的平均值和标准偏差在本文中表示为m和s和d

- In a log-normal distribution, the parameters denoted μ and σ, are the mean and standard deviation, respectively, of the variable's natural logarithm (by definition, the variable's logarithm is normally distributed).
- On a non-logarithmized scale, μ and σ can be called the location parameter and the scale parameter, respectively.
- In contrast, the mean and standard deviation of the non-logarithmized sample values are denoted m and s and d in this article

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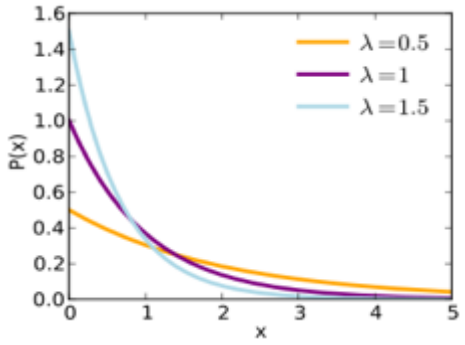
指数分布
Exponential Distribution

指数分布的概率密度函数（pdf）是
The probability density function (pdf) of an exponential distribution is

$$f(x;\lambda) = \begin{cases} \lambda e^{-\lambda x}, & x \geq 0, \\ 0, & x < 0. \end{cases}$$

这里λ> 0是分布的参数，通常称为速率参数。
分布在间隔[0，∞）上受支持。
如果随机变量X具有这种分布，则写入X～Exp（λ）。
Here λ > 0 is the parameter of the distribution, often called the rate parameter.
The distribution is supported on the interval [0, ∞).
If a random variable X has this distribution, we write X ~ Exp(λ).
累积分布函数给出下式
The cumulative distribution function is given by

$$F(x;\lambda) = \begin{cases} 1 - e^{-\lambda x}, & x \geq 0, \\ 0, & x < 0. \end{cases}$$



- 在概率论和统计学中，指数分布（也称为负指数分布）是一系列连续概率分布。
- 它描述了泊松过程中的事件之间的时间，即其中事件以恒定的平均速率连续且独立地发生的过程。
- 注意，指数分布与分布的指数族的类别不同，其是包括指数分布作为其成员之一的概率分布的大类，而且还包括正态分布，二项分布，伽马分布，泊松，和许多其他。

- In probability theory and statistics, the exponential distribution (a.k.a. negative exponential distribution) is a family of continuous probability distributions.
- It describes the time between events in a Poisson process, i.e. a process in which events occur continuously and independently at a constant average rate.
- Note that the exponential distribution is not the same as the class of exponential families of distributions, which is a large class of probability distributions that includes the exponential distribution as one of its members, but also includes the normal distribution, binomial distribution, gamma distribution, Poisson, and many others.

威布尔分布
Weibull Distribution

- 威布尔分布以瑞典教授Waloddi Weibull命名
- 威布尔概率分布定义为：
- The weibull distribution is named for the Swedish professor Waloddi Weibull
- The weibull probability distribution is defined as:

$$f(t) = \frac{\beta(t-\delta)^{\beta-1}}{\theta^{\beta}} \exp[-(\frac{t-\delta}{\theta})^{\beta}] \qquad t \geq \delta$$

β (beta) = the shape parameter
θ (theta) = the scale parameter
δ (delta) = the location parameter

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威布尔
Weibull

- β，θ，δ是连续的
- Theta经常采取离散值，如周期。
- Theta只有当幅度足够大，使数据表现得好像是连续的，才可以接受。
- 以下是可接受的范围

- β,θ,δ are continuous
- Theta often takes on discrete values such as cycles.
- Theta is only acceptable when the magnitude is large enough so that the data behaves as if it is continuous.
- Following are the acceptable ranges

$$0 < \beta < \infty$$
$$0 < \theta < \infty$$
$$-\infty < \delta < \infty$$

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威布尔（两参数）
Weibull (Two Parameter)

- 对于两参数威布尔分布（δ= 0），θ被称为特征寿命。
- 63.2%的人口失去特征生命点，而不管β的值。
- For the two parameter weibull distribution (δ=0), θ is known as the characteristic life.
- 63.2% of the population fails by the characteristic life point regardless of the value of β.

$$f(t) = \frac{\beta(t-\delta)^{\beta-1}}{\theta^{\beta}} \exp[-(\frac{t-\delta}{\theta})^{\beta}]$$

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威布尔（三参数）
Weibull (Three Parameter)

- 对于三参数威布尔分布，特征寿命为（δ+β）
- 虽然δ可以取负值，但这是不寻常的。
- δ的负值表示在时间= 0之前存在故障
- 例如保质期故障 - 在使用前的存储期间出现故障的项目。
- For the three parameter weibull distribution, the characteristic life is (δ+β)
- Although δ can take negative values, it is unusual.
- Negative value of δ indicates there are failures before time = 0
    - An example is shelf life failures – items that fail during a storage period before being used.

$$f(t) = \frac{\beta(t-\delta)^{\beta-1}}{\theta^{\beta}} \exp[-(\frac{t-\delta}{\theta})^{\beta}]$$

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威布尔
Weibull

$$f(t) = \frac{\beta(t-\delta)^{\beta-1}}{\theta^{\beta}} \exp[-(\frac{t-\delta}{\theta})^{\beta}]$$

- 威布尔分布可以在各种各样的情况下使用，并且取决于β的值，等于或可以近似几个其他分布
- The weibull distribution can be used in a wide variety of situations and, dependent on the value of β, is equal to or can approximate several other distributions

$\beta = 1$

威布尔分布与指数分布相同

The weibull distribution is identical to the exponential distribution

$\beta = 2$

威布尔分布与Rayleigh分布相同

The Weibull distribution is identical to the Rayleigh distribution

$\beta = 2.5$

威布尔分布近似对数正态分布

The weibull distribution approximates the lognormal distribution

$\beta = 3.6$

威尔布分布近似正态分布

The weibull distribution approximates the normal distribution

$\beta = 5$

威布尔分布近似于峰值正态分布

The weibull distribution approximates the peaked normal distribution

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什么是“可靠性”?

涉及内容
Topics

- 可靠性的定义
- 可靠性条款
- 浴缸曲线
- 可靠性规格
- 分销基础
- 置信区间

- Definition of Reliability
- Reliability Terms
- Bathtub Curve
- Reliability Specifications
- Distribution Basics
- Confidence Intervals

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可靠性工程解决方案

字面定义
Dictionary Definition

- 可靠的（形容词）
  - 能够依赖;可靠的：可靠的助手;可靠的车。
  - 在不同的临床实验或统计学试验中产生相同或相容的结果。
- 可靠性（名词）
  - 始终生成的任何系统的属性
  - 相同的结果，优选满足或超过其
  - 规格
  - 摘自www.dictionary.com
- re·li·a·ble (adj.)
  - Capable of being relied on; dependable: a reliable assistant; a reliable car.
  - Yielding the same or compatible results in different clinical experiments or statistical trials.
- reliability (n.)
  - An attribute of any system that consistently produces the same results, preferably meeting or exceeding its specifications
  - from www.dictionary.com

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实用定义
Practical Definition

- 随着时间的推移研究系统能力以满足给定的规格
- 成功的可能性
- 自然的数学表示

- The study of a systems capability to meet a given specification over time
- The likelihood of success
- A mathematical representation of nature

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可靠性与质量
Reliability Vs. Quality

- 质量 - 产品满足规格的能力。
- 可靠性 - 产品满足规格随时间变化的能力。

- Quality – is the ability of a product to meet a specification.
- Reliability – is the ability of a product to meet a specification over time.

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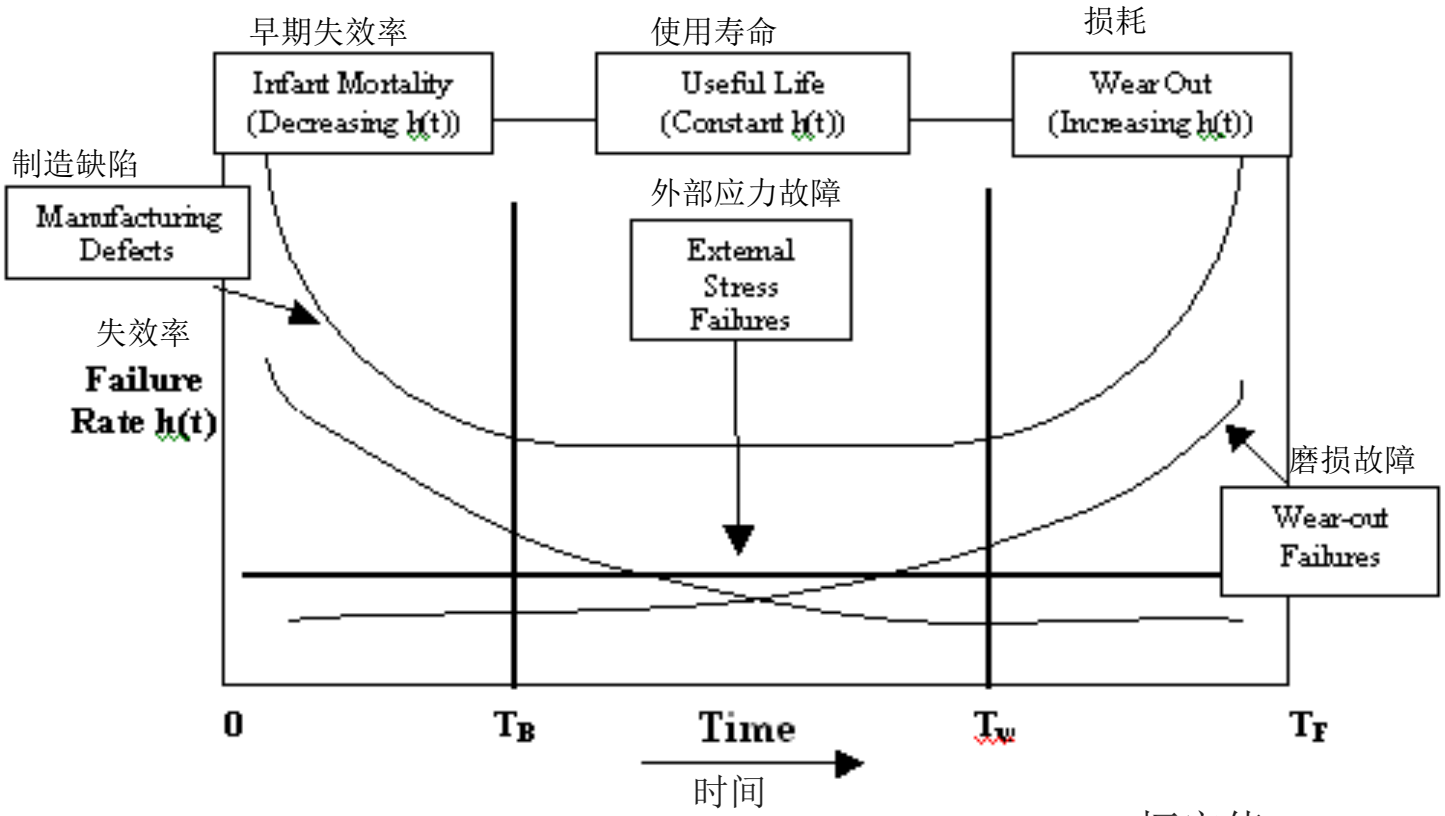
浴缸模式
Bath Tub



浴缸曲线
Bathtub

- 浴缸曲线用于说明整个群体随时间的故障率，而不是单个产品的故障率。
- 由于故障率随时间的形状，该图被称为“浴盆曲线”。
- 对于各种各样的机械和电子部件和系统，当经验人口故障率作为单位随时间推移而老化时，浴盆曲线已被重复地绘制和计算。
- 浴缸曲线分为三个区域：早期失效，使用寿命和磨损。

- The bathtub curve is used to illustrate the failure rate of an entire population over time and not the failure rate of a single product.
- The plot is termed the “bathtub curve” due to the shape of the failure rate over time.
- For a wide variety of mechanical and electronic components and systems, the bathtub curve has been repeatedly graphed and calculated when the empirical population failure rates as units age over time.
- The bathtub curve is divided into three regions: infant mortality, useful life and wear-out.

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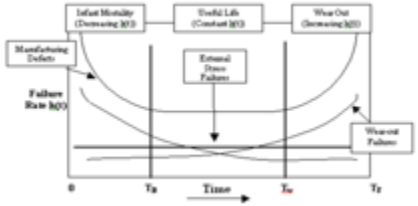
浴缸曲线
Bathtub



- 时间零点和结核病之间的第一个区域称为早期失效率。虽然故障率开始非常高，但随着时间接近时间TB迅速降低。
- 在TB和TW之间的下一个区域期间，故障率稳定并变得恒定。这个区域被称为使用寿命期或内在故障期。这个时期被称为使用寿命，因为大多数人口的大部分时间都在浴盆曲线的恒定时期。
- 如果产品寿命足够长，它将经过最终区域，磨损失效期。在该区域中，当材料磨损并且劣化故障以增加的速率发生时，故障率迅速增加。

- The first region between time zero and TB is known as the infant mortality period. Although the failure rate starts very high, it promptly decreases as time approaches time TB.
- During the next region between TB and TW, the failure rate levels off and becomes constant. This region is known as the useful life period or the intrinsic failure period. This period is termed useful life because the majority of population spends most of their lifetimes in the constant period of the bathtub curve.
- If the product survives long enough, it will go through the final region, the wear-out failure period. In this region, the failure rate increases rapidly as materials wear out and degradation failure occur at an increasing rate.

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相关术语
Terms

- **故障** - 设备无法按规定运行
- **索赔** - 保修索赔
- **检查员/暂停** - 一个正常（无故障）单位
- **生存概率** - 一个单位在给定时间没有失败的可能性，或者在给定时间可能不会发生故障的人口部分
- **故障率** - 故障的瞬时概率。可以随时间改变！
- PDF - 概率密度函数
- CDF - 累积分布函数
- **可靠性函数** - 1-CDF
- **危险功能** - 瞬时故障率
- **Failure** – the units inability to function as specified
- **Claim** – warranty claim
- **Censor/Suspension** – a functioning (non-failed) unit
- **Survival Probability** – the likelihood a unit is has not had a failure at a given time, or the portion of a population likely not to have had a failure at given time
- **Failure rate** – the instantaneous probability of failure. Can change with time!
- **PDF** – Probability Density Function
- **CDF** – Cumulative Distribution Function
- **Reliability Function** – 1-CDF
- **Hazard Function** – Instantaneous failure rate

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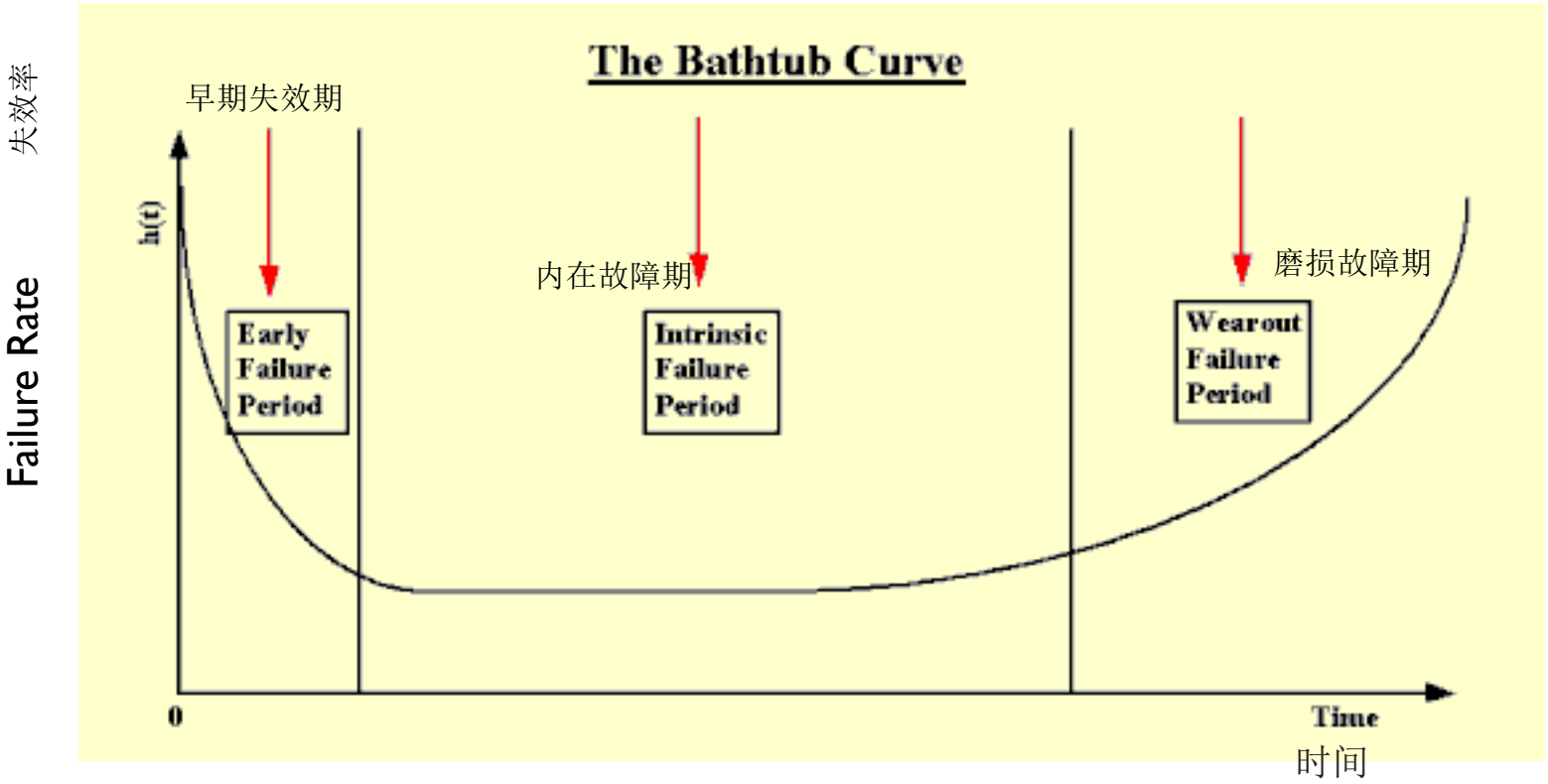
浴缸曲线
Bathtub Curve



可靠性规范
Reliability Specifications

4组件：

1. 所需的可靠性@特定时间
2. 置信度
3. 环境
4. 故障定义

4 Components:

1. Required Reliability @ specific time
2. Confidence
3. Environment
4. Failure Definition

99.7%的存活，在暴露于80℃和80%湿度的90%置信度。失败被认为是输出信号的任何损失。

99.7% survival at 4000 hours of operation, at 90% confidence exposed to 80C and 80% humidity. A failure is considered any loss of output signal.

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待续
To Be Continued

- 更多内容请关注： http://www.reliariskllc.com/reliability-engineering-documents/
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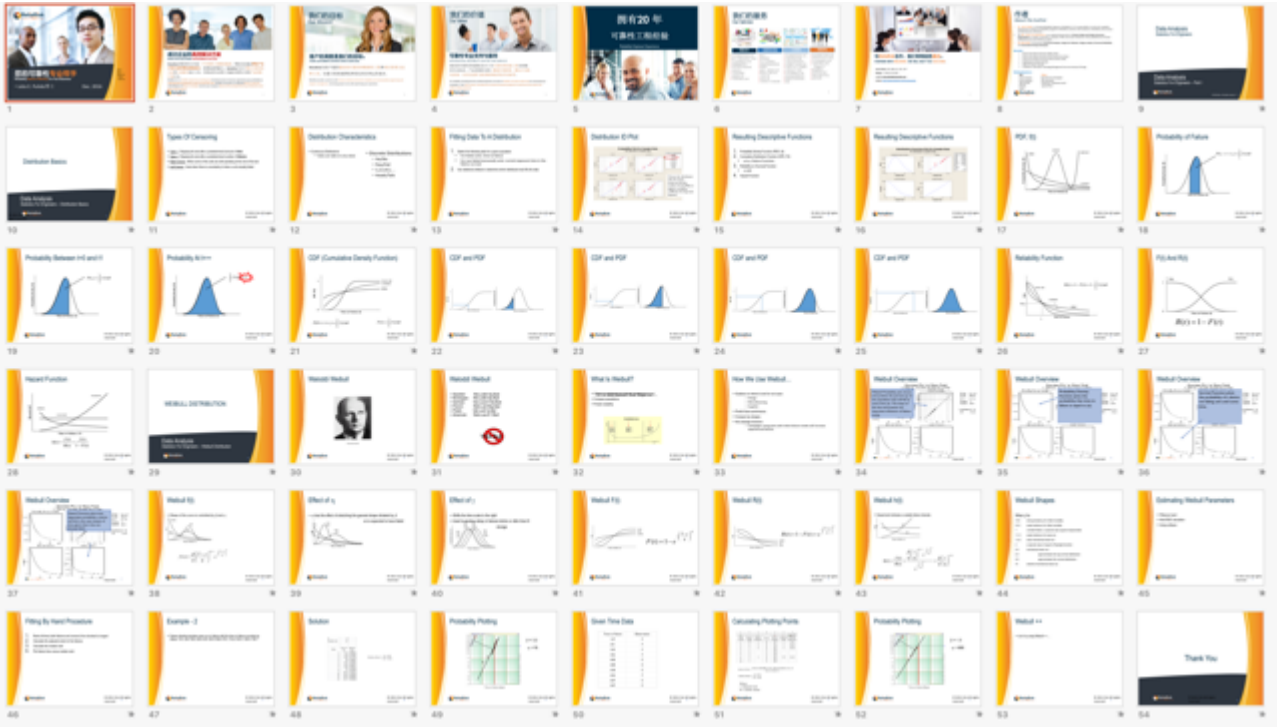

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谢　谢！

Thank You！

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RELIABILITY ENGINEERING SOLUTIONS

