DAE Mobile Training Team

RANDOM FAILURE
(Weibull's Distribution)

TEST & TUTORIAL

As of 5th Feb 2021

แบบทดสอบ RANDOM FAILURES (Weibull’ Distribution)

แบบทดสอบ RANDOM FAILURE (WEIBULL’S DISTRIBUTION)

1. According to reliability engineers, which of the following is true ?

a. Weibull analysis is the implied assumption that the future is the same as the past.

b. As soon as design, maintenance or operating policies and practices change, the prior failure history becomes unrepresentative of the future.

c. Weibull Analysis requires complete and accurate failure data over a period of stable practices.

d. All of the above a, b and c are true.

2. According to Weibull data, which of the following is NOT true ?

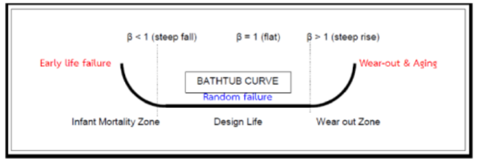
a. Complete data is the practitioner is aware of the exact time-to-failure for a sample of the product.

b. Right Censored data is that all population failed at exact time.

c. Left Censored data is that the failures are between 0 and 50 hours.

d. All of the above a, b and c are not true.

3. Use the Bathtub Curve to choose the correct answer.



Infant mortality zone is the zone with shape parameter (β) < 1.0; what is the probable cause of infant mortality ?

a. Inadequate burn in (run in).

b. Misassemble.

c. Some quality problems.

d. All of the above a, b and c are correct.

4. Useful life or design life zone is the zone with shape parameter (β) = 1.0; called for random failures; what is the probable cause of random failures ?

a. Maintenance errors.

b. Operating errors.

c. Failures due to nature (FOD, Lightening Strike, …..).

d. All of the above a, b and c are correct.

5. Early wear-out zone is the zone with shape parameter $1.0 < \beta < 4.0$; what is the probable cause of early wear out ?

a. Many mechanical failure modes.

b. Roller and / or Bearing failures.

c. V – Belt failures.

d. All of the above a, b and c are correct.

6. Old age or rapid wear-out zone is the zone with shape parameter $\beta > 4.0$; what is the probable cause of early wear out ?

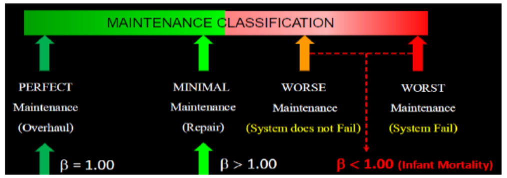
a. Stress corrosion.

b. LCF (Low Cycle Fatigue), HCF (High Cycle Fatigue, TMF (Thermal Fatigue).

c. Erosion.

d. All of the above a, b and c are correct.

7. From the maintenance classification figure below, what is the cause of “Worst Maintenance” causing infant mortality ($\beta < 1.0$) ?



a. Bad maintenance.

b. Hidden faults.

c. Human errors and / or use of faulty parts.

d. All of the above a, b and c are correct.

8. When β = 1.0, the part implies random failure; overhaul the part is not appropriate for random failure due to independent of time. What type of maintenance is the most effective for parts which have random failures characteristic ?

a. On Condition (OC)

b. Condition Monitoring (CM)

c. System Rate Monitoring (SRM)

d. Component Reliability Monitoring (CRM)

9. Any Time Change Item (TCI) has its failure rate (λ) = 1 / TBO (Time Between Overhaul). If part “A” has TBO = 2,500 flying hours, what is the failure rate (λ) of part “A” ?

a. λ_A = 0.0002 (1/5,000)

b. λ_A = 0.00025 (1/4,000)

c. λ_A = 0.0004 (1/2,500)

d. λ_A = 0.0005 (1/2,000)

แบบทดสอบ RANDOM FAILURES (Weibull' Distribution) Cont.

10. Any Time Change Item (TCI) has its failure rate (λ) = 1 / TBO (Time Between Overhaul).
Given the design reliability of any part is derived from the formula $R(t) = e^{-(\lambda * t)}$; t = time.
Then, the design reliability of any TCI at the expired date (t = TBO) shall be
$R(t)_{TCI\ expired\ date} = e^{-(1/TBO * TBO)} = e^{-(1)}$. If e = the base for natural logarithms = 2.718281828... .
What is the reliability of any TCI at its expired date ?

a. 1/2.718281828 = 0.37

b. (1 - 1/2.718281828) = 0.63

c. (1/2.718281828) * 2 = 0.74

d. (1/2.718281828) * 1.5 = 0.56

11.

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.989493892							
R Square	0.979098162							
Adjusted R Square	0.978377409							
Standard Error	0.176250682							
Observations	31							

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	42.19892237	42.19892237	1358.437773	6.5157E-26
Residual	29	0.900864782	0.031064303		
Total	30	43.09978715			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-9.483433725	0.244340074	-38.81243704	1.49764E-26	-9.983165286	-8.983702164	-9.983165286	-8.983702164
X Variable 1	1.214831206	0.032960673	36.85699083	6.5157E-26	1.147419062	1.282243351	1.147419062	1.282243351
Beta (or Shape Parameter) =	1.214831206							
Alpha (or Characteristic Life) =	2456.222177							

By using Weibull distribution from the figure above, we obtain the value of Shape Parameter (β) = 1.2148 and the value of Characteristic Life (α) = 2,456 flying hours. Which of the following statement is true ?

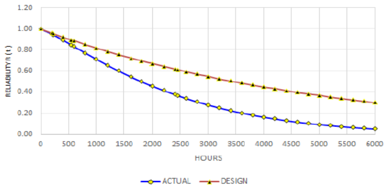
a. The part is normal early wear out ($1.0 < \beta < 4.0$). At 2,456 flying hours, 63 % of the part would be failed and 37 % would be good.

b. The part is normal early wear out ($1.0 < \beta < 4.0$). At 2,456 flying hours, 37 % of the part would be failed and 63 % would be good.

c. The part is old age wear out (β =1.2148). At 2,456 flying hours, 63 % of the part would be failed and 37 % would be good.

d. The part is old age wear out (β =1.2148). At 2,456 flying hours, 37 % of the part would be failed and 63 % would be good.

12.



A Time Change Item (TCI) part has its design reliability (orange line) and actual reliability (blue line) as shown in the figure above. The overhaul interval of this TCI part is 5,000 flying hours. What is the reliability of this TCI at 5,000 flying hours expired ?

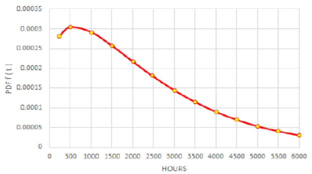
a. 0.74

b. 0.37

c. 0.63

d. 0.56

13. PDF f(t) or Population Density Function of a part has its maximum value at 500 flying hours which has reliability = 0.000304 as shown in the figure below. Which of the following statement is correct ?



a. The part would mostly failed at 500 flying hours.

b. At 500 flying hours, 37 % of the part would be failed and 63 % would be good.

c. At 500 flying hours, 63 % of the part would be failed and 37 % would be good.

d. The part would need to be overhauled at 500 flying hours.

14. What shall we do with parts which have been verified as "Infant Mortality ($\beta < 1.0$)" ?

a. Inform MRO provider or MRO supplier of the situation to find root cause(s).

b. Inform MRO's Thai Agent of the situation.

c. Supply Division and Technical Division record and continue to monitor the situation.

d. All of the above a, b and c are correct.

15. Ideally, how many data points are required regarding Weibull distribution in order to ensure a robust analysis ?

a. 5 or more data points.

b. 10 or less data points.

c. 10 or more data points.

d. 5 or less data points.

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b. As soon as design, maintenance or operating policies and practices change, the prior failure history becomes unrepresentative of the future.

c. Weibull Analysis requires complete and accurate failure data over a period of stable practices.

d. All of the above a, b and c are true.

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Weibull Concept

- Weibull analysis is the implied assumption that the future is the same as the past.
- As soon as design, maintenance or operating policies and practices change, the prior failure history becomes unrepresentative of the future.
- An analysis using the old data would produce poor decisions in that case.
- Weibull Analysis requires complete and accurate failure data over a period of stable practices, along with an analyst who has thorough understanding of the effects of past and current maintenance and operating policies and practices.

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2. According to Weibull data, which of the following is NOT true ?

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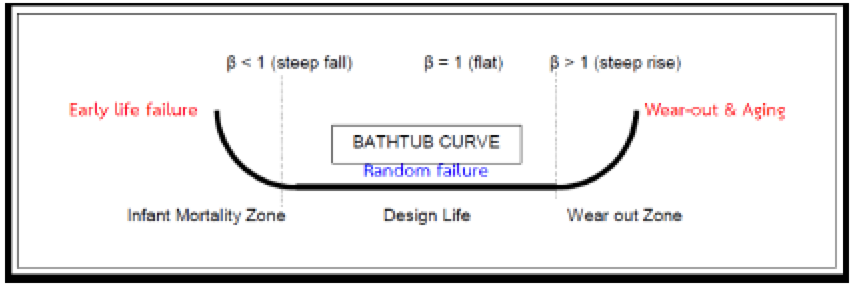
Weibull 3 Types of Data

1.Complete data: With Complete data, the practitioner is aware of the exact time-to-failure for a sample of the product. An example would be that the product failed at 15,000 cycles.

2. Right Censored data: With Right Censored data, the practitioner successfully tests the product or component for a pre-determined or known period of time, number of cycles, etc. An example would be that the component operated successfully for 20,000 cycles. The product or component may have continued to perform within acceptable parameters for an unknown period.

3. Interval data and Left Censored data: With these data types, the exact time-to-failure is unknown but it falls within a known time range. An interval is a defined length of time between two known points. Therefore, component failures between 10 and 50 hours of use represent interval data. If the component failures are between 0 and 50 hours, the data is considered left censored.

3. Use the Bathtub Curve to choose the correct answer.



Infant mortality zone is the zone with shape parameter (β) < 1.0; what is the probable cause of infant mortality ?

a. Inadequate burn in (run in).

b. Misassemble.

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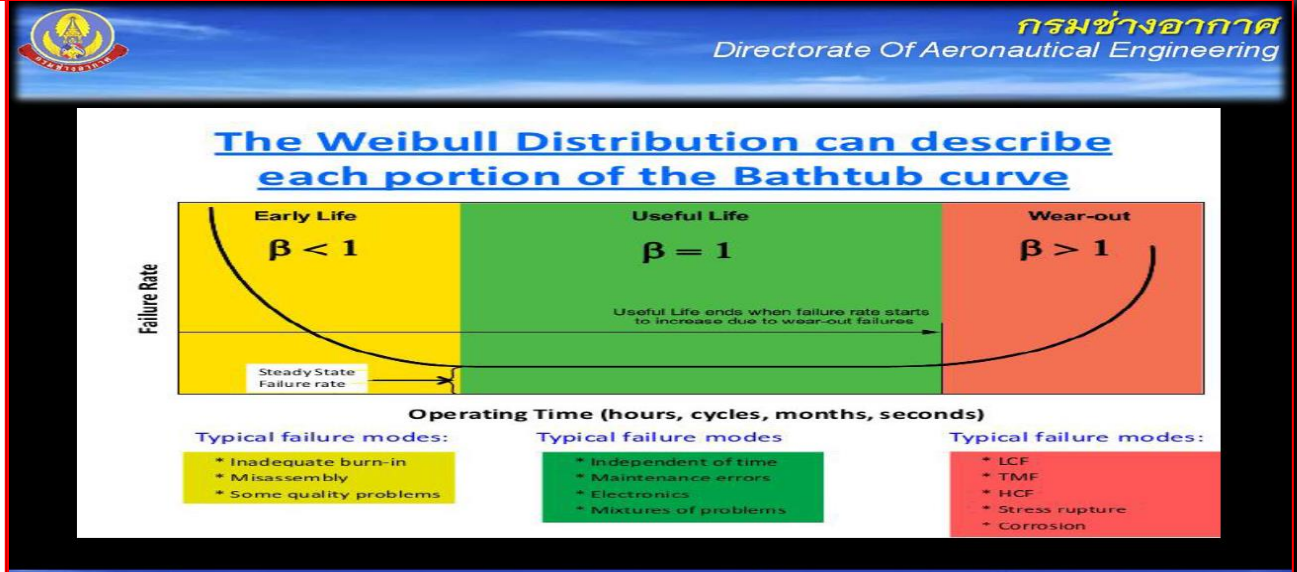

β - Shape Parameters Interpretation

$\beta < 1.0$	Infant Mortality	Inadequate burn-in (run-in) time to stress test, production problems, misassemble, poor QC, overhaul problems, solid state electronic failed
$\beta = 1.0$	Random Failures	Maintenance Errors, Human Errors, Abusive Events, FOD, Lightening Strike, Failures due to nature,
$1.0 < \beta < 4.0$	Early Wear Out	Many mechanical failure modes. β= 1.5: Roller Bearing Failure β = 2.0: Ball Bearing Failure β= 2.0 – 3.5: Corrosion or Erosion β= 2.5: V – Belt Failure β= 2.5 – 4.0: LCF (Low Cycle Fatigue)
$\beta > 4.0$	Old Age (Rapid) Wear Out	$\beta >$ 5.0: Stress Corrosion Material Properties, Brittle materials like ceramics, some form of erosion.

4. Useful life or design life zone is the zone with shape parameter (β) = 1.0; called for random failures; what is the probable cause of random failures ?

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β > 4 = Wear-out (End of life failures)

- β > 4 are wear-out or end of life failures.
- They should not appear in the design life.
- Age related failures include stress corrosion cracking, creep, high cycle fatigue (HCF), and erosion.
- Appropriate maintenance is often renewal of the item with new or send the item to overhaul.

β - Shape Parameters Interpretation

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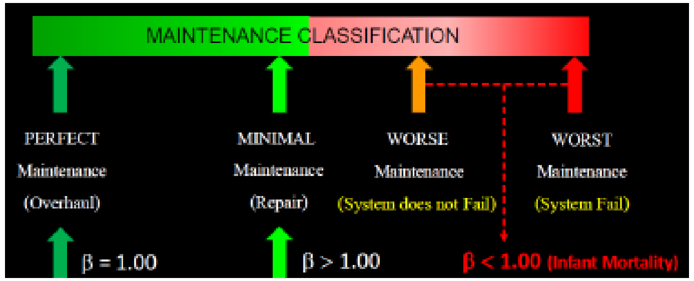

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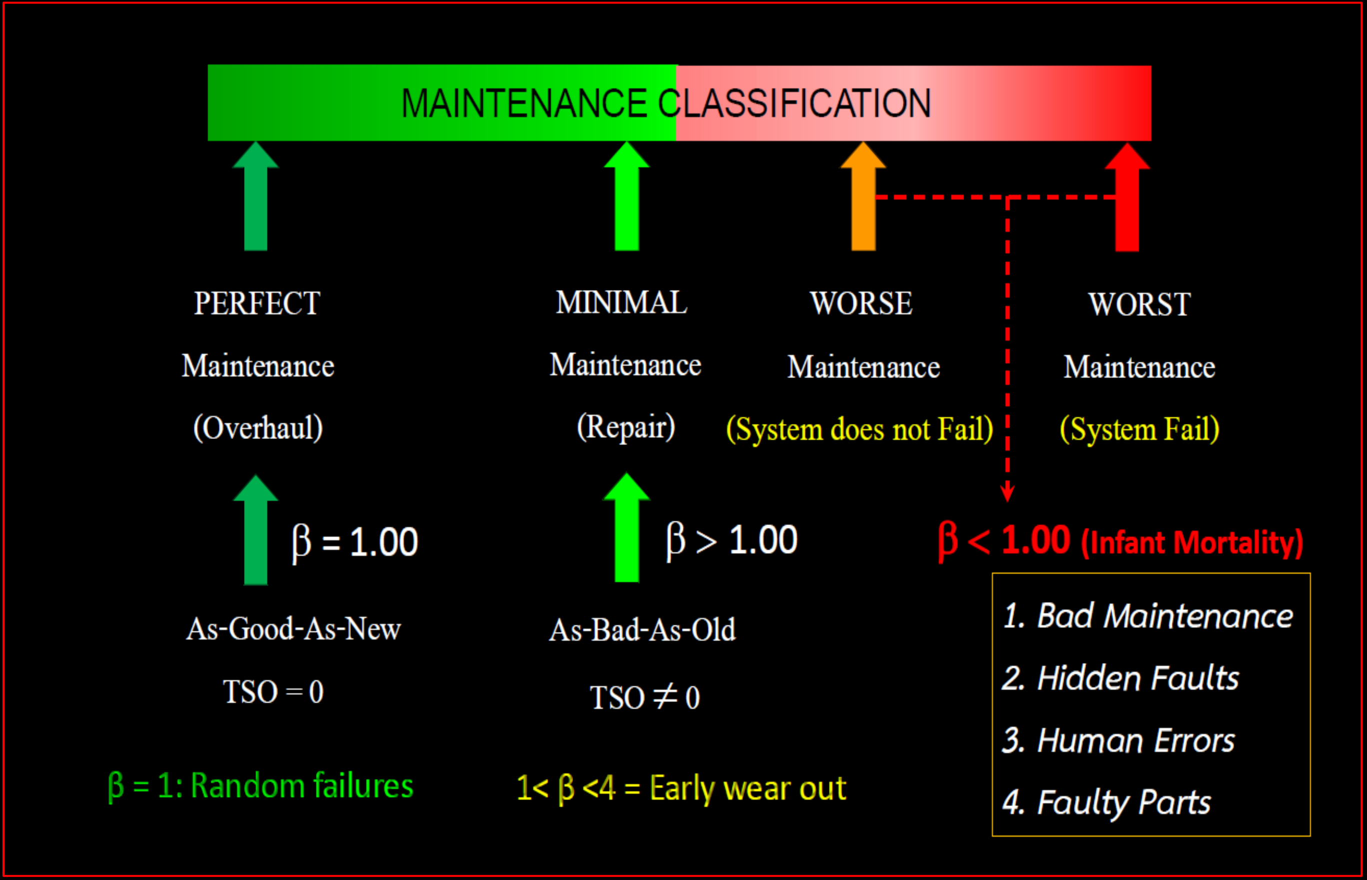

8. When β = 1.0, the part implies random failure; overhaul the part is not appropriate for random failure due to independent of time. What type of maintenance is the most effective for parts which have random failures characteristic ?

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β = 1: Random failures

- ♦ β = 1 implies random failures.
- ♦ These failures are independent of time where an old part is "As good as a New part".
- ♦ Maintenance overhauls are not appropriate for random failures.
- ♦ Condition monitoring (CM) and inspection are strategies used to detect the onset of failure, and reduce the consequences of failure.
- ♦ This zone is affected by random incidents and accidents.
- ♦ It reflects poor operating procedures, poor risk management and poor materials selection at design.

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9. Any Time Change Item (TCI) has its failure rate (λ) = 1 / TBO (Time Between Overhaul). If part "A" has TBO = 2,500 flying hours, what is the failure rate (λ) of part "A" ?

a. λ_A = 0.0002 (1/5,000)

b. λ_A = 0.00025 (1/4,000)

c. λ_A = 0.0004 (1/2,500)

d. λ_A = 0.0005 (1/2,000)

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แนวทางดำเนินการ (Solution)

1. จากค่าอัตราการชำรุดของพัสดุ หรือ Failure Rate (λ) ที่ได้รับทราบแล้วว่าคือ "อัตราส่วนของจำนวนพัสดุที่ชำรุดในห้วงเวลาหนึ่ง" โดยที่ค่า Failure Rate (λ) มีค่าคงที่ (λ = Constant)
2. ตัวอย่างของ λ = Constant คือพัสดุประเภท TCI (Time Change Item)
3. F100-PW-220/E Core Module เป็นพัสดุ TCI ที่ต้องถอดเปลี่ยนทุก ๆ 4,000 Cycles นั่นคือ OEM กำหนดอายุใช้งานก่อนซ่อมใหญ่ที่ 4,000 Cycles
4. Core Module จึงมีค่า Constant Failure Rate (λ) = 1 / 4,000 = 0.00025
5. เราเรียกว่าเป็นค่าของ "Design Reliability" ของ Core Module ซึ่งคำนวณได้จากสูตร Design Reliability R(t) = e ^ - (λ * t)

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Then, the design reliability of any TCI at the expired date (t = TBO) shall be
$R(t)_{TCI\ expired\ date} = e^{-(1/TBO * TBO)} = e^{-(1)}$. If e = the base for natural logarithms = 2.718281828... .
What is the reliability of any TCI at its expired date ?

a. 1/2.718281828 = 0.37

b. (1 - 1/2.718281828) = 0.63

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e^{-1} = 1/e = 1/2.718281828

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1 < β < 4 = Early wear out

- 1 < β < 4 implies early wear out.
- You would not expect this type of failure within the design life.
- Failure mechanisms such as corrosion, erosion, low cycle fatigue (LCF) and bearing failures fall in this range.
- Maintenance often involves a periodic rework, modification, retrofit or life extension task.
- The shape can be altered by better materials selection, by degradation management and by good control of operating practices.

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ความหมายของ β และ α

***β* = SHAPE PARAMETER**

β < 1.00 แสดงว่าเป็นการชำรุดแบบก่อนกำหนด (Infant Mortality)
β = 1.00 แสดงว่ามีอัตราการชำรุดที่คงที่ (Constant Failure Rate หรือ λ = 1 / MTBF)
β > 1.00 แสดงว่าเป็นการชำรุดที่เกิดจากการเสื่อมสภาพจากการใช้งานตามปกติ

***α* = CHARACTERISTIC LIFE**

α คือตัวเลขที่บอกถึงอายุใช้งานที่พัสดุจะมีการชำรุด (Failed) = 63.2 % และจะยังมีสภาพใช้งานได้ (Serviceable) = 36.8 % หรือกล่าวอีกนัยหนึ่ง α ก็คือ "อายุใช้งานของพัสดุหลังจากผ่าน Burn-In Period ไปแล้ว จะชำรุดที่อายุเท่าใดนั้นเอง"

เป็นองค์กรที่มุ่งเน้นการพัฒนาระบบการซ่อมสร้างอากาศยาน ให้มีความปลอดภัยและเป็นมาตรฐานสากล

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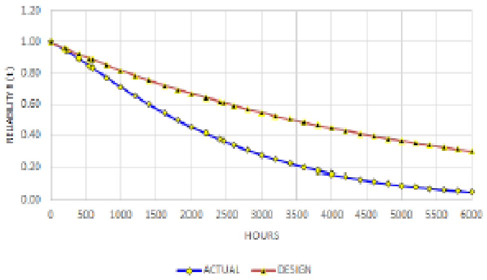
12.



A Time Change Item (TCI) part has its design reliability (orange line) and actual reliability (blue line) as shown in the figure above. The overhaul interval of this TCI part is 5,000 flying hours. What is the reliability of this TCI at 5,000 flying hours expired ?

a. 0.74

b. 0.37

c. 0.63

d. 0.56

11.1 Design VS Actual Reliability

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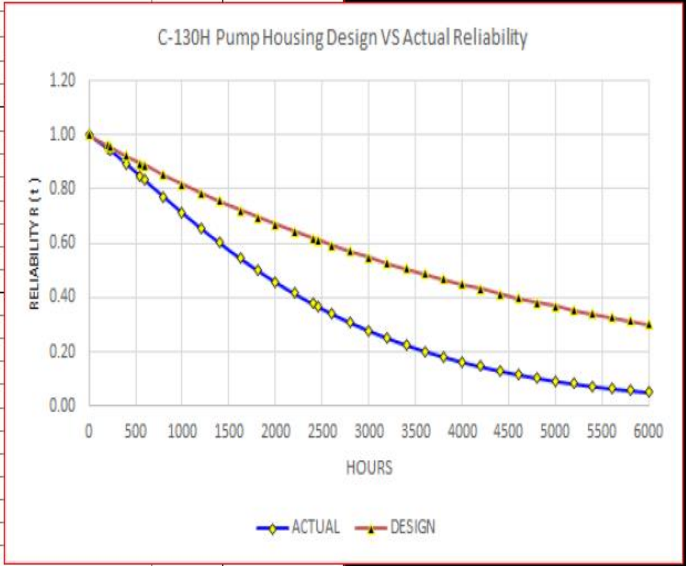
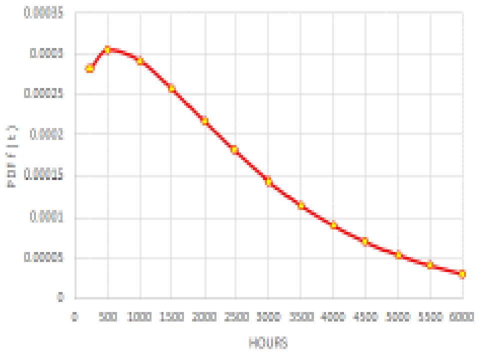
HOURS	ACTUAL RELIABILITY	DESIGN RELIABILITY		Beta (or Shape Parameter) =	1.214831	TBO
	ACTUAL R = e ^ - ((t / α) ^ β)	R (t) = e ^ - (λ * t)		Alpha (or Characteristic Life) =	2456.222	Failure Rate (λ)
0	1.00000	1.00000				
200	0.95360	0.96079				
230	0.95	0.95504	WARRANTY			
400	0.89559	0.92312				
550	0.85014	0.89583				
600	0.83489	0.88692				
800	0.77418	0.85214				
1000	0.71487	0.81873				
1200	0.65779	0.78663				
1400	0.60342	0.75578				
1626	0.54561	0.72238				
1816.53	0.50000	0.69537	MEDIAN			
2000	0.45882	0.67032				
2200	0.41697	0.64404				
2400	0.37823	0.61878				
2456.22	0.36788	0.61186	ALPHA (α)			
2600	0.34248	0.59452				
2800	0.30959	0.57121				
3000	0.27943	0.54881				
3200	0.25183	0.52729				
3400	0.22664	0.50662				
3600	0.20370	0.48675				
3800	0.18284	0.46767				
4000	0.16392	0.44933				
4200	0.14678	0.43171				
4400	0.13129	0.41478				
4600	0.11730	0.39852				
4800	0.10469	0.38289				
5000	0.09334	0.36788				
5200	0.08314	0.35345				
5400	0.07398	0.33960				
5600	0.06577	0.32628				
5800	0.05842	0.31349				
6000	0.05185	0.30119				



13. PDF f(t) or Population Density Function of a part has its maximum value at 500 flying hours which has reliability = 0.000304 as shown in the figure below. Which of the following statement is correct ?



a. The part would mostly failed at 500 flying hours.

b. At 500 flying hours, 37 % of the part would be failed and 63 % would be good.

c. At 500 flying hours, 63 % of the part would be failed and 37 % would be good.

d. The part would need to be overhauled at 500 flying hours.

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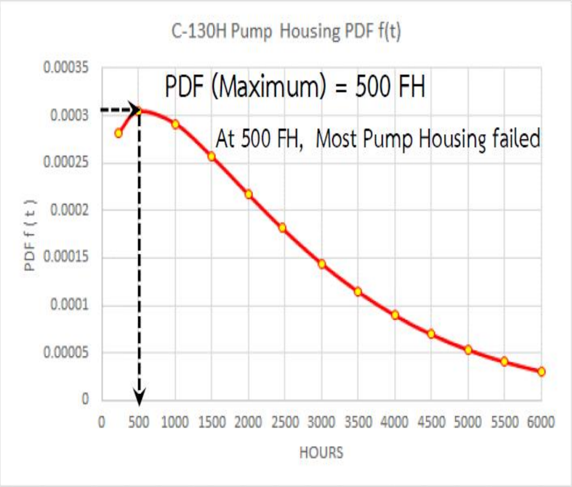
11.3 PDF (Population Density Function) Directorate Of Aeronautical Engineering

HOURS	PDF: POPULATION DENSITY FUNCTION: f (t)
	PDF: $f(t) = (\beta / t) * (t / \alpha)^\beta * ((e^{-(t/\alpha)^\beta}))$
230	0.000281084
500	0.000304043
1000	0.000291497
1500	0.000256849
2000	0.00021713
2456.22	0.000181951
3000	0.000144271
3500	0.000114689
4000	9.00272E-05
4500	6.99116E-05
5000	5.37826E-05
5500	4.10304E-05
6000	3.10669E-05



14. What shall we do with parts which have been verified as "Infant Mortality ($\beta < 1.0$)" ?

a. Inform MRO provider or MRO supplier of the situation to find root cause(s).

b. Inform MRO's Thai Agent of the situation.

c. Supply Division and Technical Division record and continue to monitor the situation.

d. All of the above a, b and c are correct.

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4.1 Weibull เป็นการคำนวณหา Characteristic Life (α) ของโครงสร้าง อ., เครื่องยนต์ และบริภัณฑ์ ที่เกิดการชำรุดแบบสุ่ม (Random Failure) มีประโยชน์อย่างยิ่ง เพราะทำให้เราทราบถึงลักษณะของการชำรุด (β Shape Parameter) ว่าเป็น Infant Mortality หรือเป็น Normal Wear Out ทำให้ทราบค่า Burn-In Period และทราบอายุใช้งานหลัง Burn-In ว่าเป็นเท่าใด

4.2 กรณีที่พบว่าเป็น Infant Mortality จะได้สืบหาสาเหตุที่เป็น Root Cause เช่น คุณภาพของแหล่งซ่อม, คุณภาพของวัสดุที่ใช้ในการซ่อม เป็นต้น

4.3 ขั้นตอนในการดำเนินการไม่ยุ่งยากซับซ้อนอย่างที่คิด ที่สำคัญคือจะต้องทดลองฝึกปฏิบัติบ่อย ๆ จึงจะเกิดความชำนาญ และเป็นการยกระดับขีดความสามารถของหน่วยซ่อมในการคำนวณตามทฤษฎีความเชื่อถือได้ทางวิศวกรรม (Reliability Engineering)

15. Ideally, how many data points are required regarding Weibull distribution in order to ensure a robust analysis ?

a. 5 or more data points.

b. 10 or less data points.

c. 10 or more data points.

d. 5 or less data points.

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Weibull Concept

- Many organizations have kept records of failures manually or in computer systems, but not used the data in any useful way.
- Failure data is the best source of reliability information available.
- By transforming maintenance and parts history into useful data used to make failure forecasts, it models the benefits of alternative strategies, or analyses the reliability of current systems and their capacity to meet operating needs.
- Ideally about 10 data points are required for each failure mode to ensure a robust analysis. Too few points causes uncertainty & interpretation from the curves cannot be trusted.

เป็นองค์กรที่มุ่งเน้นการพัฒนาระบบการซ่อมสร้างอากาศยาน ให้มีความปลอดภัยและเป็นมาตรฐานสากล

DAE Mobile Training Team

RANDOM FAILURE
(Weibull’s Distribution)

TEST & TUTORIAL

As of 5th Feb 2021