King Saud University
Department of Industrial Engineering
IE-434 Reliability and Maintenance Engineering
First Midterm Exam - Duration 90 min
Sun 20rd of Nov, 2011; 24th of Thul-Hijjah, 1432

Student Name :...
Student Number :...

Question 1 (5 Points)

A ball bearing at the end of its running life has failure pattern with threshold time of 200,000 running hours. A previous study shows that the characteristic life of this type of ball bearing is 75,000 running hours. The shape factor may take one of the following values depending on the stage of failure rate (.75, 1.0, and 2.0) Find the following:

1. What is the probability that this ball bearing will survive for 300,000 running hours but not more than 350,000 running hours? **(2 Points)**
2. What is failure rate at 375,000 running hours? **(1 Point)**

Another ball bearing was in its useful running period with MTTF estimated to be 65,000 running hours:

3. What is the probability that the ball bearing would fail at 120,000 running hours? **(1 Point)**
4. Explain the importance of Weibull distribution in describing components reliability. **(1 Point)**

For Weibull distribution, the threshold time t_0 = 200000; characteristic life η =75000 and shape factor at the end of running life > 1 in this question = 2

1) Survival probability = $P(t) = e^{-\left[\frac{t-t_0}{\eta}\right]^{\beta}}$

$$P(300000)\text{-}P(350000) = e^{-\left[\frac{300000-200000}{75000}\right]^2} - e^{-\left[\frac{350000-200000}{75000}\right]^2}$$

=0.169 – 0.0183 = .1507 = 15.07 %

2) Failure rate $\lambda(t) = \frac{\beta}{\eta^{\beta}}(t - t_0)^{\beta - 1}$ = $\lambda(375000) = \frac{2}{75000^2}(375000 - 200000)^1$

= 0.0000622 failure/hour

3) Useful running period is exponential distribution

Probability that the ball bearing fails is $F(t) = 1 - R(t) = 1 - e^{(-\lambda t)}$

$\lambda = \frac{1}{MTTF} = \frac{1}{65000} = 0.00001538$

$F(120000) = 1 - e^{(-\lambda t)} = 1 - e^{(-0.00001538)(120000)} = 0.842 = 84.2\ \%$

4) With Weibull distribution many different failure behaviors can be described (all three stages in the bathtub curve)

Question 2 (6 Points)

A system consists of 3 subsystems A, B and C as shown in Fig. 1, each of which has a constant failure rate as follows

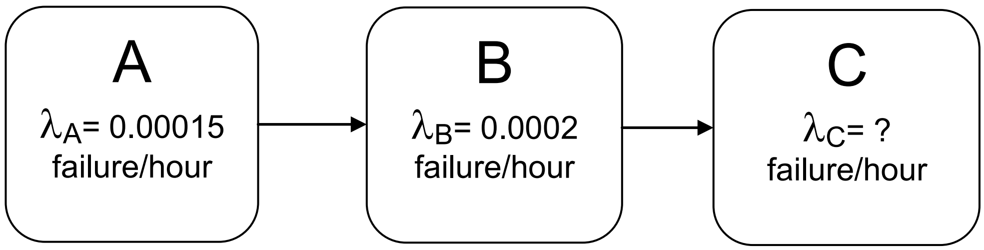


Fig. 1

1. If the system reliability at 1500 hour is 15%, find λ_c **(2 Points)**
2. Find the failure probability of the system at 1000 hours of running time **(1 Points)**

If the maintenance engineer proposes to improve the system reliability by replacing subsystem C with two identical subsystem C1 and C2, both of constant failure rate where the whole system fails if either C1 or C2 fails. With the proposed improvement in place, the system reliability at 1500 hour increases to 20%

3. Calculate the failure rate of the new subsystem C1 and C2 (2 **Points)**
4. Calculate the mean time to failure of the system with the proposed change **(1 Points)**

1) In a system with series-connected components

   Rs = R1. R2. R3 ...... Rn

   For exponentially distributed times to failure the measures are .15= $R_s(t) = e^{\left(-\sum_{i=1}^{n} \lambda_i t\right)}$

   $.15 = e^{\left(-\sum_{i=1}^{n} \lambda_i t\right)}$; $\ln(.15) = -\sum_{i=1}^{n} \lambda_i t = -1.897 = -1500(0.00015+0.0002+\lambda_c)$

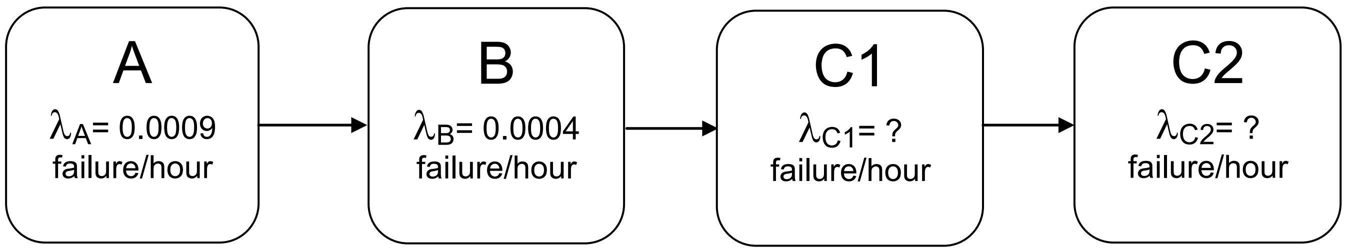
   $\lambda_c = 0.000914$

2) $R_s(t) = e^{\left(-\sum_{i=1}^{n} \lambda_i t\right)}$

   $R_s(1000) = e^{-(1000)(0.00015+0.0002+0.000914)} = .282 = \%\ 28.2$

   Failure probability $F_s(1000) = 1 - R_s(1000) =$ % 71.7

3)



Rs = R1. R2. R3 ...... Rn

$$.2 = e^{\left(-\sum_{i=1}^{n}\lambda_i t\right)}$$; ln(.2) = $-\sum_{i=1}^{n}\lambda_i t$ = -1.609= -1500(0.00015+0.0002+ λ_{c1}+ λ_{c2})

$\lambda_{c1} = \lambda_{c2}$ =0.000361

4) The mean time to failure = $\dfrac{1}{\sum_{i=1}^{n}\lambda_i}$

$$= \frac{1}{0.00015 + 0.0002 + .000361 + .000361}$$

= 932.0 hours

Question 3 (4 Points)

A spot welding machine consists of three subsystems is running in a three shift body fabrication plant for automotive application producing 175 parts every shift. The maximum allowed maintenance time is 45 min which is the time between two shifts. Each subsystem in the spot welding machine has its own failure rate and repair time as follows:

Subsystem	Failure Rate (failure/hour)	Repair Time
Subsystem 1	0.0025	25 min
Subsystem 2	0.005	15 min
Subsystem 3	0.004	10 min

1. What is the MTTR of the spot welding machine? **(1 Points)**
2. What is the probability that a repair of the spot welding machine will be performed within 45 min. **(2 Points)**
3. What is the MMD of the spot welding machine if the paper work processing time of the maintenance request is 15 min and the time to get the required spare parts from the warehouse is 25 min. **(1 Points)**

1) $MTTR = \frac{\left(\sum_{i=1}^{n} \lambda_i CMT_i\right)}{\sum_{i=1}^{n} \lambda_i} = \frac{0.0025(25/60) + 0.005(15/60) + 0.004(10/60)}{0.0025 + .005 + .004} = 0.257 hours = 15.43 \min$

2) The maintainability function = $1 - e^{(\frac{-t}{MTTR})}$

$= 1 - e^{[-(45/60)/(.257)]} = .946 =$ 94.6 %

3) Mean Maintenance Downtime: MMD = MAMT + LDT + ADT

= .257+ (15/60) + (25/60) = .924 hours = 55.4 min