INTERRELATIONSHIP OF BURN-IN CRITERIA

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Abstract: Burn-in is a quality control process that is used to minimize the warranty cost of a product by screening out of the defective products through prior operation for a period of time before sale. However, the burn-in process also has a cost associated with it and uses some portion of the life of the product. In the literature, minimization of the total expected cost and maximization of the reliability of the product are two criteria that are used for the calculation of the optimal burn-in time. In this paper the interrelationship of burn-in criteria is investigated and an example is provided.

Keywords: *Optimal Burn-in Time, Expected Cost, Mean Residual Life, Delivered Reliability*

1. Introduction

Burn-in is a quality control process that is used to minimize the warranty cost of a product by screening out of the defective products through prior operation for a period of time before sale. During this period, refereed to as *burn-in time*, the failure of the product can be dealt with in a far less costly manner. However, the burn-in process also has a cost associated with it and uses some portion of the life of the product. In the literature, minimization of the total expected cost and maximization of the reliability of the product are two criteria that are used for the calculation of the optimal burn-in time.

A balk of the literature on burn-in uses minimization of the total expected cost as a criterion. Some examples of such literature are Genadis (1996), Mi (1996), Mi (1997), Perlstein, Jarvis, and Mazzuchi (2001), and Yun, Lee, and Ferreira (2002). Reliability criterion is represented in two ways, maximization of the mean residual life (MRL) and maximization of the delivered reliability. Some examples of the literature that uses maximization of the reliability as the criterion are Whitbeck and Leemis (1989), Launer (1993) and Mi (1994).

2. The Interrelationship of Burn-in Criteria

Interrelationship of burn-in criteria is defined using delivered reliability. Delivered reliability is the conditional reliability of a product for a mission time given that the product survived the burn-in. Letting T be the lifetime of the product, Θ be the parameter vector of the lifetime distribution, t_m be the mission time, and $R(t \mid \Theta)$ be the reliability function of the product, delivered reliability is calculated as

$$R^{(D)}(t_m \mid t_b, \Theta) = P(T > t_m + t_b \mid T > t_b) = \frac{P(T > t_m + t_b)}{P(T > t_b)} = \frac{R(t_m + t_b \mid \Theta)}{R(t_b \mid \Theta)} \tag{2.1}$$

Given the mission time and the parameter vector, delivered reliability is a function of burn-in time t_b.

When a mission time is not specified for a product, MRL is used as the reliability criterion. MRL of a product is the expected lifetime of the product given that it survives the burn-in. MRL is calculated as

$$MRL = E[T - t_b \mid T > t_b, \Theta] = \frac{\int_{t_b}^{\infty} R(t \mid \Theta)dt}{R(t_b \mid \Theta)} = \int_0^{\infty} P\{T - t_b > t \mid T, t\}dt = \int_0^{\infty} R^{(D)}(t \mid t_b, \Theta)dt, \tag{2.1}$$

Last two equality in (2.1) is written by noting that (T- t_b|$T > t_b$) is a positive random variable and $R^{(D)}(t_m|t_b, \Theta)$ is the reliability function of this random variable. Maximizing (2.1) over possible values of burn-in time results the optimal burn-in time for MRL criterion.

Depending on the warranty contract and treatment of failed products, there are several cost functions for burn-in process. In this paper the cost function of Perlstein, Jarvis and Mazzuchi (2001) is used. According to this cost function products in a batch of size N are burned-in simultaneously. Products that are failed during burn-in and during warranty time are scrapped. Failures of the products are assumed to be conditionally independent. Letting C_0 be the fixed set up cost of burn-in, C_1 be the per product per unit time cost of burn-in, C_2 be the scrap cost of a product that is failed during burn-in, and C_3 be the field replacement cost of a product that is failed during warranty time, the expected cost function is given as

$$E[Cost(t_b \mid \Theta)] = C_0 + C_1 N t_b + C_2 N F(t_b \mid \Theta) + C_3 N[F(t_b + t_m \mid \Theta) - F(t_b \mid \Theta)], \qquad (2.3)$$

where $F(t|\Theta)$ is the cumulative distribution function (CDF) of the product. $NF(t_b|\Theta)$ denotes the expected number of products which fail during burn-in and $N[F(t_b + t_m|\Theta) - F(t_b|\Theta)]$ is the expected number of products which fail during warranty period. Using the facts $R(t_m + t_b|\Theta) = R^{(D)}(t_m|t_b, \Theta)\, R(t_b|\Theta)$ and $F(t|\Theta) = 1 - R(t_b|\Theta)$, (2.3) can be written as

$$E[Cost(t_b \mid \Theta)] = C_0 + C_2 N + C_1 N t_b + NR(t_b \mid \Theta)[C_3 - C_2 - C_3 R^{(D)}(t_m \mid t_b, \Theta)]. \qquad (2.4)$$

In (2.4) last two terms are functions of burn-in time. As $R^{(D)}(t_m|t_b, \Theta)$ increases expected cost decreases and when $[C_3 - C_2 - C_3 R^{(D)}(t_m|t_b, \Theta)]$ is negative as $R(t_b|\Theta)$increases expected cost decreases.

3. Example

It is known from the previous life tests that a product has a mixed Weibull lifetime distribution with parameters $\pi = 0.2$, $\beta_w = 1.2$, $\beta_s = 1.5$, $\theta_w = 25$, $\theta_s = 1450$. Mixture lifetime distributions are utilized when the population of products is composed of sub-populations of defected (weak) products and non-defected (strong) products where defects cause the early failures. This notion of a mixture of weak and strong products was made popular by Jensen and Petersen (1982).

The mission time and cost parameters for above product are specified as t_m=100 time units, C_0 = \$15, C_1 = \$3, C_2 = \$300 and C_3 = \$1500. Products are burned-in simultaneously in a batch of size 50. Figure 1 illustrates the MRL, delivered reliability and expected total cost as a function of burn-in time. Optimal burn-in times are calculated as 66 time units for MRL criterion, 95 time units for delivered reliability criterion, and 31 time units for cost criterion.

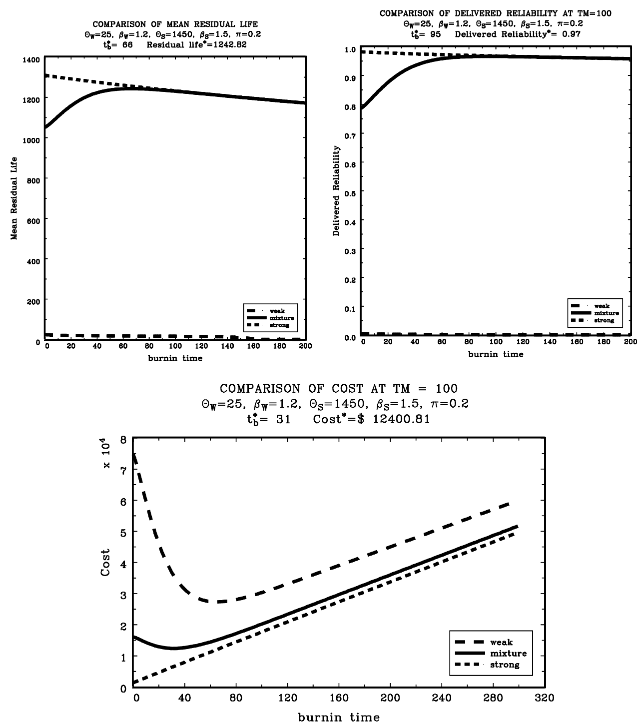

Figure 1.Burn-in criteria as a function of burn-in time

The values of criteria for different optimal burn-in times are given in Table 1. The burn-in time that minimizes the total expected cost is much less than the burn-in times that maximizes the delivered reliability and MRL. Even though burn-in criteria related to each other by (3.1) and (3.2), each criterion results a different optimal burn-in time. The percent changes in the values of criteria under the optimal burn-in time of other criteria are given in Table 2. If the cost optimum burn-in time is used, MRL and delivered reliability decreases by % 3.38 and % 6.19 respectively from their optimal values.

Table 1.Values of burn-in criteria for optimal burn-in times

	MLR opt. tb 66	$R^{(D)}$ opt. tb 95	Cost opt. tb 31
MRL	1242.821	1232.991	1200.766
$R^{(D)}$	0.96	0.97	0.91
E[Cost]	15216.26	19437.8	12400.81

Table 2.Percent change in values of burn-in criteria

	MLR opt. tb = 66	$R^{(D)}$ opt. tb = 95	Cost opt. tb = 31
% decrease in MRL		0.79	3.38
% decrease in Rd	1.03		6.19
% increase in E[Cost]	22.70	56.75	

4. Conclusion

Optimal burn-in time of a criterion is not optimal for the other criteria. Since the optimal burn-in time of cost criterion is much less than the optimal burn-in times of the other criteria manufacturer has to decide how much she/he is willing to pay to increase the delivered reliability.

As a future work reasons for the difference in the optimal burn-in times will be investigated.

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