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Study on special type double sampling plan based on truncated Life-test for assuring percentile lifetime using exponentiated generalized FRECHET distribution

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Abstract

In the industrial sector, statistical quality control plays a major role in monitoring and maintaining the standard quality of products. Acceptance sampling plans are one of the traditional methods of Statistical Quality control, and sampling inspections help prevent the production or purchase of bad products. The decision is made regarding whether to accept or reject the corresponding lot based on the observed lifetimes of the test items or the number of failures during a predetermined testing period of time, taking into account both the producer's and consumer's risks is known as Reliability Acceptance Sampling plan. This paper deals with a Special Type Double Sampling Plan based on Truncated Lifetest for percentile using Exponentiated Generalized Frechet Distribution. The minimum sample size is essential to ensure the specified lifetime is provided at the consumer's risk. The Operating Characteristic values, Operating Characteristic Curve of the sampling plan as well as minimum ratio of producer's risk are computed. Tables and results are explained with appropriate examples.

Keywords: Exponentiated generalized frechet distribution, special type double sampling plan, producer's risk, consumer's risk, lifetime.

1. Introduction

In modern technological world, customers are more expertise in the reliable quality products. Assume that a producer sends a consumer a shipment of components known as a lot. The inspection samples have been taken from the lot, and the number of defective items will be counted. The selection of the sample size 'n' and acceptance number 'c' are the basic criterion of acceptance sampling plan. If number of defectives less than or equal to acceptance number, the entire lot will be accepted. If the number of defectives greater than acceptance number, the lot will be rejected. In some situations, the experimenters might take a time while before recording the necessary number of failures. As a result, sampling plan use time-truncated life tests to make decisions quickly. Time-truncated life tests have a defined number of failures and experiment duration. This approach is excellent for reducing the cost and time of a submitted lot's inspection. In acceptance sampling based on truncated life tests have the following assumptions: (i) the units are destructible or are degraded after the life test, and (ii) there are several distributions that model the product life reasonably well. The main problem in acceptance sampling plan is finding the minimum sample size, Operating Characteristic function and producer's risk exceeds the specified and true lifetime of product. In this paper focuses Special Type Double sampling plan based on truncated life test using Exponentiated Generalized Frechet Distribution. Special Type Double sampling plan is a special cases of Double sampling plan. Schilling and Neubauer proposed a concept of Single Sampling Plan with a zero acceptance number is extremely helpful in the field of compliance and safety-related testing. A lot by lot special type double sampling strategy is employed as an alternative to the Single Sampling Plan in order to avoid the problems with smaller acceptance numbers. Special type double sampling plan based on truncated lifetest approach will be more efficient and save time and cost.

In Reliability Acceptance Sampling Plan based on truncated life test using various distribution of review of literature given below: Epstein (1954) ^[5] has developed truncate life test in the Exponential cases. Gupta and Groll (1961) ^[6] has developed Sampling Plans Based on the Gamma Distribution. Rao *et al.* (2010) ^[10] has designed the life test sampling plans for log- logistic Distributions. Kantam and Rosaiah (2005) ^[11] has progressed an acceptance sampling based on the Inverse Rayleigh Distribution. Rosaiah. *et al.* (2006) ^[12] has described the source of reliability of test plans for Exponentiated Log-Logistic Distribution. Balakrishnan *et al.* (2007) ^[3] has designed an acceptance sampling plan from truncated life tests based on the Generalized Birnbaum-Saunders Distribution. Aslam, *et al.* (2010) ^[2] has designed acceptance sampling plan using generalized exponential Distribution. Pradeepa Veerakumari, *et al.* (2016) ^[9] has developed for Exponentiated Rayleigh Distribution. Kaviyarasu *et al.* (2017) ^[8] has developed for Weibull-Poisson Distribution.

Dodge and Romig (1959) ^[4] have studied the use of DSP (0,1) plan to product characteristics involving costly and destructive testing. Sudamani Ramaswamy and Sowmya (2016) ^[13] discussed time truncated special purpose double sampling DSP (0, 1) for compound Rayleigh distribution. Jayalakshmi, *et al.* (2022) ^[7] has developed a Special Type Double Sampling Plan for Life Tests Based on Percentiles Using Gompertz Frechet distribution. Abd-Elfattah (2016) ^[1] has developed Exponentiated Generalized Frechet Distribution. The Exponentiated Generalized family of densities, denoted as $f(x)$, offers enhanced adaptability in its tail regions and finds widespread applications across engineering and biological fields.

2. Exponentiated Generalized Frechet Distribution

The Cumulative Distribution Function of Exponentiated Generalized Frechet distribution is

$$F(x) = \left[1 - \left(1 - \exp - \left\{ \left(\frac{\sigma}{x} \right)^\lambda \right\} \right)^\alpha \right]^\beta \quad (1)$$

The Probability density function of Exponentiated Generalized Frechet distribution is

$$f(x) = \alpha \beta \lambda \sigma^\lambda x^{-(\lambda-1)} \exp \left[- \left(\frac{\sigma}{x} \right)^\lambda \right] \left\{ 1 - \exp \left[- \left(\frac{\sigma}{x} \right)^\lambda \right] \right\}^{\alpha-1} \left\{ 1 - \left[1 - \exp \left(- \left(\frac{\sigma}{x} \right)^\lambda \right) \right]^\alpha \right\}^{\beta-1}$$

Where, α, β, λ are Shape parameters and σ be a Scale parameter. (2)

Survival Function of Exponentiated Generalized Frechet distribution is

$$S(x) = 1 - \left[1 - \left(1 - \exp - \left\{ \left(\frac{\sigma}{x} \right)^\lambda \right\} \right)^\alpha \right]^\beta \quad (3)$$

Hazard Function of Exponentiated Generalized Frechet distribution is

$$h(x) = \beta \lambda \sigma^\lambda x^{-(\lambda-1)} \left[\frac{\left\{ 1 - \exp \left[- \left(\frac{\sigma}{x} \right)^\lambda \right] \right\}^{\alpha-1} \left\{ 1 - \left[1 - \exp \left(- \left(\frac{\sigma}{x} \right)^\lambda \right) \right]^\alpha \right\}^{\beta-1} \exp \left[- \left(\frac{\sigma}{x} \right)^\lambda \right]}{1 - \left[1 - \left(1 - \exp - \left\{ \left(\frac{\sigma}{x} \right)^\lambda \right\} \right)^\alpha \right]^\beta} \right] \quad (4)$$

Quantile Function of Exponentiated Generalized Frechet distribution is

$$Q(u) = \sigma \left[-\ln \left(1 - \left(1 - (1-u)^{\frac{1}{\beta}} \right)^{\frac{1}{\alpha}} \right) \right]^{-\frac{1}{\lambda}} \quad (5)$$

2.1 Percentile Estimator of Exponentiated Generalized Frechet Distribution

The q^{th} percentile function of the any distribution is given below,

$$\Pr(T \leq t_q) = q$$

$$t_q = \sigma \left[-\ln \left(1 - \left(1 - (1-u)^{\frac{1}{\beta}} \right)^{\frac{1}{\alpha}} \right) \right]^{-\frac{1}{\lambda}} \quad (6)$$

$$\varphi_q = \left[-\ln \left(1 - \left(1 - (1-u)^{\frac{1}{\beta}} \right)^{\frac{1}{\alpha}} \right) \right]^{-\frac{1}{\lambda}} \quad (7)$$

Replacing the scale parameter σ in equation (1) then we get Cumulative Distribution function for Exponentiated Generalized Frechet distribution is

$$F(x) = \left[1 - \left(1 - \exp - \left\{ \left(\frac{\sigma}{\varphi_q \delta_q} \right)^\lambda \right\} \right)^\alpha \right]^\beta \quad (8)$$

Taking a first derivative of partial differentiation with respect to δ , we get

$$\frac{\partial F(t, \delta)}{\partial \delta_q} = \frac{e^{-\frac{1}{\varphi_q \delta_q}}}{\varphi_q \delta_q^2} \beta \left[1 - \left(1 - \exp - \left\{ \left(\frac{1}{\varphi_q \delta_q} \right)^\lambda \right\} \right)^\alpha \right]^{\beta-1} \cdot -\alpha \left[1 - \exp - \left\{ \left(\frac{1}{\varphi_q \delta_q} \right)^\lambda \right\} \right]^{\alpha-1} \cdot -\lambda \exp - \left\{ \left(\frac{1}{\varphi_q \delta_q} \right)^\lambda \right\}. \quad (10)$$

$\frac{\partial F(t, \delta)}{\partial \delta_q} > 0$. The cumulative distribution function $F(t, \delta)$ is a non- decreasing function of δ .

2.2 Special type double sampling plan based on truncated life test using Exponentiated generalized Frechet distribution

In Special Type Double Sampling plan is characterized by $\left(n_1, n_2, c_1, c_2, \frac{t}{t_q} \right)$. The proposed sampling plan the probability of acceptance is given by,

$$L(p) = (1 - p)^{n_1 + n_2} \left[1 + \frac{n_2 p}{(1 - p)} \right] \quad (11)$$

The operating procedure of special double sampling plan for the truncated life test consists of the following steps:

- Draw a random sample of size n_1 from the lot and put on test for pre-assigned experimental time to and observe the number of defectives d_1 . If $d_1 \geq 1$ reject the lot.
- If $d_1 = 0$, draw a second random sample of size n_2 and put on test for time t_0 and observe the number of defectives d_2 .
- If $d_2 \leq 1$ accept the lot, otherwise reject the lot.

2.3 Minimum Sample Size

The life test terminates at the predetermined period t_0 , and the number of failures that occurred between $[0, t]$ is noted. If and only if the total number of failures at the decision about the termination time does not exceed the acceptance numbers c_1 and c_2 , the lot is decided to be accepted. The theory of binomial distribution can be used because the lot size is supposed to be infinitely large. The probability of acceptance must satisfy the conditions,

$$(1 - p)^{n_1 + n_2} \left[1 + \frac{n_2 p}{(1 - p)} \right] \leq 1 - P^* \quad (12)$$

Where, $n = n_1 + n_2$, p is the probability that items fails before t_0 .

$$P = \left[1 - \left(1 - \exp - \left\{ \left(\frac{\sigma}{\varphi_q \delta_q} \right)^\lambda \right\} \right)^\alpha \right]^\beta$$

The minimum sample sizes are satisfying the conditions of Search procedure. To determine the minimum sample size of Special Type Double Sampling plan reduces to

$$\text{Minimize ASN} = n_1 + n_2(1 - p)^n$$

$$\text{Subject to } (1 - p)^{n_1 + n_2} \left[1 + \frac{n_2 p}{(1 - p)} \right] \leq 1 - P^*$$

n_1 and n_2 are integers

2.4 Operating Characteristic Function

The operating characteristic curve plots between the probability of acceptance and specified lifetime of product. The operating characteristic function of the Special Type Double sampling plan must satisfying the following equation,

$$L(p) = (1 - p)^{n_1 + n_2} \left[1 + \frac{n_2 p}{(1 - p)} \right] \quad (13)$$

Where, $p = F(t, \delta)$ and δ can be indicated as a function of $\delta = t/t_q$

$$p = F\left(\frac{t}{t_q}, \frac{1}{d_q}\right)$$

Where $d_q = t_q/t_q^0$

In the minimum sample size and operating Characteristic values of 25th percentile using Exponentiated Generalized Frechet Distribution given in Table 1.

Table 1: Minimum sample sizes and operating characteristic values for special type double sampling plan ($n_1, n_2, c_1=0, c_2=1, t/t_{0.25}$) for a given p^* under Exponentiated Generalized Frechet distribution.

P*	n ₁	n ₂	ASN	$\frac{t}{t_q}$	t_q/t_q^0									
					1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.9	2	3
0.75	3	3	3	0.8	0.0228	0.116	0.3108	0.5467	0.7427	0.8698	0.9398	0.9895	0.996	0.9999
	2	2	3	0.85	0.0323	0.1212	0.288	0.4948	0.6834	0.8215	0.9076	0.9798	0.9913	0.9999
	2	2	3	0.9	0.1453	0.2878	0.4596	0.6262	0.7622	0.8595	0.9222	0.9798	0.9904	0.9999
	2	2	3	0.95	0.0865	0.1924	0.3405	0.5055	0.6579	0.7802	0.8676	0.9593	0.979	0.9999
	2	2	3	1	0.0495	0.1229	0.2405	0.3896	0.5456	0.6851	0.7955	0.9269	0.9593	0.9997
	2	2	3	1.1	0.0288	0.069	0.1384	0.2388	0.363	0.497	0.6252	0.8233	0.8872	0.9982
	2	2	3	1.2	0.0489	0.0941	0.1611	0.2496	0.3545	0.4676	0.5794	0.7687	0.8384	0.9947
	2	2	3	1.25	0.0352	0.0698	0.1234	0.1976	0.29	0.3948	0.5039	0.704	0.784	0.9295
0.9	5	3	6	0.8	0.0848	0.2403	0.4558	0.6623	0.8145	0.9076	0.9576	0.9926	0.9972	0.9999
	3	3	5	0.85	0.1215	0.2796	0.4772	0.662	0.8018	0.8928	0.9459	0.9884	0.995	0.9999
	3	2	5	0.9	0.1069	0.2441	0.4244	0.605	0.7522	0.8557	0.921	0.9797	0.9904	0.9999
	3	2	5	0.95	0.0865	0.1924	0.3405	0.5053	0.6579	0.7802	0.8676	0.9593	0.979	0.9999
	2	2	4	1	0.1178	0.2284	0.3702	0.5218	0.6608	0.7737	0.857	0.9505	0.9726	0.9998
	2	2	4	1.1	0.0488	0.1098	0.2053	0.3295	0.4671	0.6003	0.7158	0.8749	0.9219	0.9988
	2	2	4	1.2	0.0192	0.0488	0.1034	0.1871	0.2965	0.4208	0.5463	0.757	0.8324	0.9947
	2	2	4	1.25	0.0119	0.032	0.0715	0.1366	0.2282	0.3402	0.4615	0.6857	0.7737	0.9283
0.95	7	3	9	0.8	0.1619	0.3526	0.5657	0.7431	0.863	0.9076	0.9695	0.9947	0.998	0.9999
	4	3	6	0.85	0.1889	0.3693	0.5646	0.7294	0.8457	0.8928	0.959	0.9913	0.9962	0.9999
	3	3	5	0.9	0.1453	0.2878	0.4596	0.6262	0.7622	0.8552	0.9222	0.9798	0.9904	0.9999
	3	2	5	0.95	0.0865	0.1924	0.3405	0.5053	0.6579	0.7802	0.8676	0.9593	0.979	0.9999
	2	2	4	1	0.1178	0.2282	0.3702	0.5218	0.6608	0.7737	0.857	0.9505	0.9726	0.9998
	2	2	4	1.1	0.0488	0.1098	0.2053	0.3295	0.4671	0.6003	0.7158	0.8749	0.9219	0.9988
	2	2	4	1.2	0.0192	0.0488	0.1034	0.1871	0.2965	0.4208	0.5463	0.757	0.8324	0.9947
	2	2	4	1.25	0.0119	0.032	0.0715	0.1366	0.2282	0.3402	0.4615	0.6857	0.7737	0.9283
0.99	10	5	14	0.8	0.3088	0.5173	0.7021	0.8338	0.9145	0.959	0.9815	0.9968	0.9988	1
	7	3	9	0.85	0.3613	0.5391	0.6971	0.8165	0.8965	0.9452	0.9726	0.9942	0.9975	0.9999
	3	2	4	0.9	0.2577	0.4208	0.5862	0.7272	0.8324	0.9033	0.9472	0.9865	0.9936	0.9999
	3	2	4	0.95	0.1769	0.3154	0.4743	0.6264	0.7524	0.8458	0.909	0.9726	0.9859	0.9999
	3	2	4	1	0.1178	0.2282	0.3702	0.5218	0.6608	0.7737	0.857	0.9505	0.9726	0.9998
	3	1	4	1.1	0.0488	0.1098	0.2053	0.3295	0.4671	0.6003	0.7158	0.8749	0.9219	0.9988
	2	1	3	1.2	0.0192	0.0488	0.1034	0.1871	0.2965	0.4208	0.5463	0.757	0.8324	0.9947
	2	1	3	1.25	0.0119	0.032	0.0715	0.1366	0.2282	0.3402	0.4615	0.6857	0.7737	0.9283

2.5 Minimum ratio of Producer's risk

The producer's Risk is described as the probability of rejecting a lot $t_q > t_q^0$. For a given value of the producer's risk, say α and satisfying the following equation.

$$(1-p)^{n_1+n_2} \left[1 + \frac{n_2 p}{(1-p)} \right] > 1 - \alpha \quad (14)$$

Where $\alpha = 0.05$,

$$p = F\left(\frac{t}{t_q} \cdot \frac{1}{d_q}\right)$$

Table 1: Minimum Ratio of Producer's risk of 0.05 for Special Type Double Sampling Plan for Exponentiated Generalized Frechet distribution

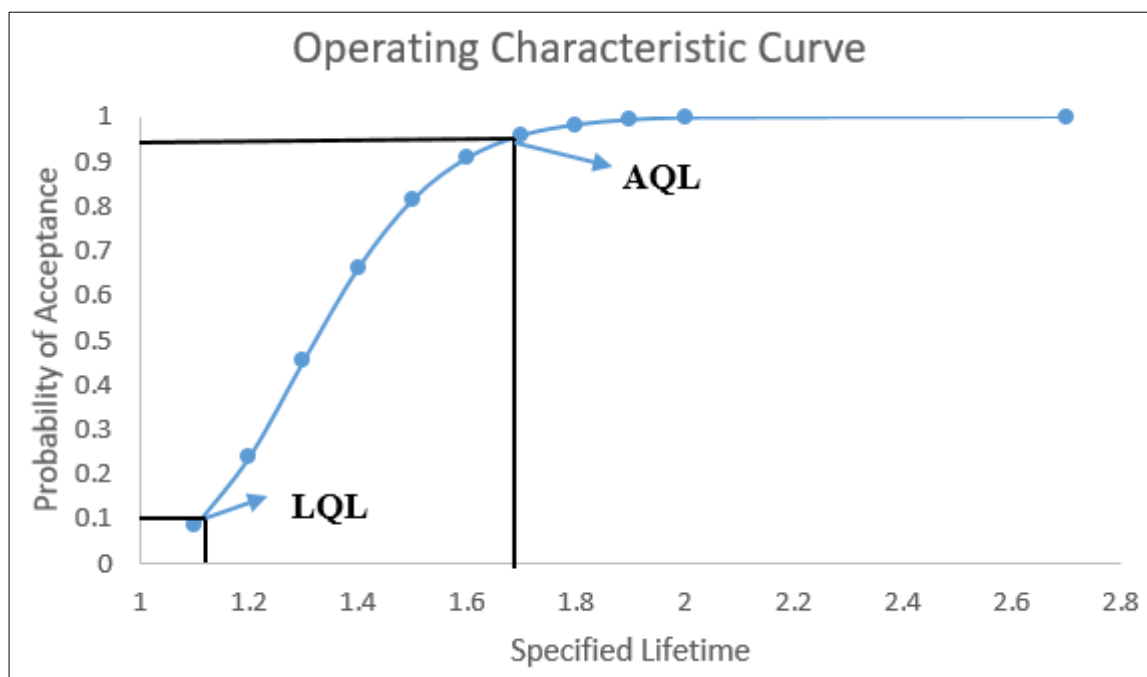
$\frac{t}{t_q}$ p^*	0.8	0.85	0.9	0.95	1	1.1	1.2	1.25
0.75	1.3317	1.3405	1.4187	1.4977	1.5764	1.7340	1.8911	1.9706
0.9	1.5441	1.5695	1.6583	1.7498	1.7702	1.9479	2.1243	2.2130
0.95	1.6805	1.7098	1.7688	1.8668	1.8979	2.0869	2.2768	2.3695
0.99	1.9030	1.9813	1.9835	2.0911	2.2030	2.4306	2.5781	2.6828

2.6 Numerical Illustration

Assume that an Inspector conducts an experiment on lifetime of juice mixer, when he interests with use to Exponentiated Generalized Frechet Distribution with fixed shape parameter $\alpha = 3, \beta = 2, \gamma = 3$. Figure 1 represents the images of juice mixer. The investigator wants to run the experiment for 320 hours, but the laboratory has testers to true percentile life time is 400 hours, $c_1=0, c_2=1, \alpha=0.05, \beta=0.10$, then, $\varphi_{0.25} = 0.1173$ is computed from the equation get under the percentile estimator and the minimum ratio and the minimum sample size is $n_1 = 5, n_2 = 3$ get the information from the table 1. The probability of acceptance is given by $(n_1, n_2, c_1, c_2, t/t_{0.25}) = (5, 3, 0, 1, 0.8)$ with $p^* = 0.95$ under the Exponentiated Generalized Frechet distribution. Table 5.3.2 represents the Operating Characteristic values with $p^* = 0.95$ under Exponentiated Generalized Frechet Distribution. Figure 5.3.3 represents the Operating Characteristic curve for truncated life test using Exponentiated Generalized Frechet distribution.

**Fig 1:** Juice Mixer**Table 3:** $(n_1, n_2, c_1, c_2, t/t_{0.25}) = (7, 3, 0, 1, 0.8)$ with $p^* = 0.95$ under the Exponentiated Generalized Frechet distribution

d_q	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.7
L(P)	0.0848	0.2403	0.4558	0.6623	0.8145	0.9076	0.9576	0.9818	0.9926	0.9972	0.9999

**Fig 2:** Operating characteristic curve for special type double sampling plan using 25th percentile of exponentiated generalized frechet distribution

It reveals that if the true 25th percentile is almost equal to the true 10th percentile ($t_q/t_q^0 = 0.8$) the producer's risk nearly 0.9152 ($1 - 0.0848$). The producer's risk is almost nearly equal to Zero whenever the actual 25th percentile is greater than or equal to 1.6 times the specified 25th percentile. The numerical illustration reveals that minimum sample size is $n_1 = 5$ and $n_2 = 3$ and the minimum producer's risk is 1.7 times of specified lifetime.

2.7 Construction of tables

Step 1: Find the value of φ_q based on various percentile lifetime for fixing the values of parameters are $\alpha = 3, \beta = 2, \lambda = 3$ and $q = 0.10, 0.25$ and 0.50 . Set the evaluated $\varphi_q = 1.1173, c_1 = 0, c_2 = 1$ and $t/t_q = 0.8, 0.85, 0.9, 0.95, 1, 1.1, 1.2$ and 1.25 .

Step 2: Find the minimum value of n satisfying

$$(1 - p)^{n_1 + n_2} \left[1 + \frac{n_2 p}{(1 - p)} \right] \leq 1 - P^*$$

Step 3: Find the operating characteristic function of the Special Type Double sampling plan must satisfy,

$$L(p) = (1 - p)^{n_1 + n_2} \left[1 + \frac{n_2 p}{(1 - p)} \right]$$

Where, $p = F(t, \delta)$ and δ can be indicated as a function of $\delta = t/t_q \therefore p = F\left(\frac{t}{t_q} \cdot \frac{1}{d_q}\right)$

Where $d_q = t_q/t_q^0$. Set the evaluated

$$d_q = t_q/t_q^0 = 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.9, 2 \text{ and } 2.7.$$

Step 4: Find the minimum ratio for the acceptability of a lot with producer's risk must satisfy the condition is,

$$(1 - p)^{n_1 + n_2} \left[1 + \frac{n_2 p}{(1 - p)} \right] > 1 - \alpha$$

$$\text{Where, } p = F\left(\frac{t}{t_q} \cdot \frac{1}{d_q}\right)$$

3. Conclusion

In this paper deals with the Special Type double sampling based on truncated life test using Exponentiated Generalized Frechet Distribution. Special Type Double Sampling Plan is also called as Zero-one Double Sampling plan. In this paper mainly concentrates minimize the producer's risk and also satisfy the consumer expectations. So, we used the truncated life test approach because it very useful to save inspection time and cost. The probability of acceptance is given by $(n_1, n_2, c_1, c_2, t/t_{0.25}) = (7, 3, 0, 1, 0.8)$ with $p^* = 0.95$ under the Exponentiated Generalized Frechet distribution. The table values are used for suitable applications of the product. So, it is strongly recommended that industrial practitioners can use the proposed plan for the testing of electronic products.

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