SELECTION PROCEDURE FOR SKIP LOT SAMPLING PLAN OF TYPE SKSP-R BASED ON PERCENTILES OF EXPONENTIATED RAYLEIGH DISTRIBUTION

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Abstract

In this study, acceptance sampling techniques are effective for reducing the cost and time of the submitted lots. In this hectic environment, a high level of product reliability and quality assurance is expected. Use the abbreviated life tests in the acceptance sampling plan as a result. To make a choice on the product, sampling plans with time-truncated life tests are used. This study uses percentiles under the exponentiated Rayleigh distribution to build a skip lot sampling plan of the SkSP-R type for a life test. A truncated life test may be carried out to determine the minimum sample size to guarantee a specific percentage life time of products. In particular, this paper highlights the construction of the Skip lot Sampling Plan of the type SkSP-R by considering the Singe Sampling Plan (SSP) and Double Sampling plan(DSP) as reference plans for life tests based on percentiles of Exponentiated Rayleigh Distribution (ERD). Calculations are made for various quality levels to determine the minimum sample size, prescribed ratio, and operational characteristic values. The proposed sampling plan, which is appropriate for the manufacturing industries for the selection of samples, is also analyzed in terms of its parameters and metrics. Illustrations are provided to help you comprehend the plan. In addition, it addresses the feasibility of the new strategy.

Keywords: Exponentiated Rayleigh Distribution, Percentiles, Life tests, Single Sampling Plan, SkSP –R.

I. Introduction

The term used to define the collection of statistical instruments used by quality engineering professionals is Statistical Quality Control (SQC). Acceptance sampling is one of the main fields of statistical quality control. Acceptance sampling is a technique that deals with the procedures by which the acceptance or rejection decision is based on sample inspection. Between no inspection and 100% inspection, acceptance sampling is the "middle of the road" method. Two key classifications of acceptance plans are available: by attributes and variables. There is a possibility, therefore, of rejecting a good lot (the risk of the producer) and accepting a poor lot (the risk of the consumer). Skip-lot sampling proposals are intended to decrease the cost of inspection.

Samples can be drawn from just a fraction of the submitted lots under the skip-lot sampling inspection. The main aim of the skip-lot sampling plan is to reduce the pace of inspection of samples, thus reducing the overall cost of inspection. Dodge [6] initially suggested the Skip-lot sampling plan, requiring a single decision or review to assess the acceptability or non-acceptability of the lot. These plans are called Skip-lot sampling plans of type SkSP-1. The time-truncated acceptance sample technique has fascinated enormous writers such as Epstein [7], Sobel and Tischendr [16], Goode and Kao [8], Gupta and Groll [9], Kantam et al. [10,11], Baklizi [3], Tsai and Wu [18], Balakrishnan et al . [4], Aslam and Shahbaz [2], Rao et.al. [15], Aslam et al. [1], Pradeepa Veerakumari and Ponneeswari [13], Pradeepa Veerakumari et.al [14], Suganya and Pradeepa Veerakumari [17].

Balamurali et.al., [5] introduce new skip-lot sampling plan of resampling, it is named as SkSP-R. The SkSP-R plan is a sampling technique based on the concept of the continuous sampling procedure and the resampling scheme for continuous bulk product flow consistency inspection. As a percentile-based comparative plan with Exponential Rayleigh Distribution, the paper focuses on developing a SkSP-R life-test plan with a single sampling plan. Rayleigh Exponential Distribution is an important distribution and reliability study of life studies. It has some of the basic structural properties and exhibits great consistency in mathematics Most properties of the distribution of Exponentiated Rayleigh are similar to those of gamma, Weibull and exponential distribution. The functions of ERD for distribution and density are in comparable forms. This is easily applied to the truncated plans as a consequence. The ERD distribution's cumulative function is given by,

$$F(t;\tau,\theta) = \left[1 - e^{-1/2(t/\tau)^2}\right]^{\theta},\ t>0,\ 1/\tau>0,\ \theta>0 \quad (1)$$

Where, τ and θ are the scale and shape parameters respectively. Its probability density function is the first derivative of any cumulative distribution function. The likelihood density function of ERD can therefore be written as,

$$f(t;\tau,\theta) = \theta\left[1 - e^{-1/2(t/\tau)^2}\right]^{\theta-1}\left[\frac{t}{\tau^2} e^{-1/2(t/\tau)^2}\right] \quad (2)$$

SSP were suggested by Pradeepa Veerakumari and Ponneeswari [13] for life research based on the ERD percentiles. Subsequently, Skip-lot sampling plans for life testing based on the percentiles of ERD were developed by Pradeepa Veerakumari et.al [14].

II. Skip-lot Sampling Plan SkSP-R

When opposed to a single sampling plan, the skip-lot sampling plan (SkSP) offers a smaller sample size during the inspection. To minimise the inspection cost, skip-lot sampling plans have been commonly used in industries. In order to establish the sampling plan that is designated as

SkSP-R, the lot resubmission considered under the resampling method was introduced. In circumstances where resampling is allowed on lots not approved during the original inspection, the desired sampling plan may be used. Therefore, if the idea of the resampling concept is implemented, a skip-lot sampling strategy is supposed to be more successful. In order to decide the optimal parameters of the sampling plan, the optimum combination of plan parameters was derived to protect both the manufacturer and the user. With the aid of the reference attribute sampling method, the Skip-lot Sampling Plan-R demonstrates that it is similar to the SkSP-2 plan developed by Perry [12].

III. Operating procedure for SkSP-R

i. Use the reference plan to start a standard inspection. During the usual inspection, the lots are inspected in the order of application, one by one.

ii. On normal inspection, discontinue normal inspection when 'i' consecutive lots are admitted, and turn to skipping inspection.

iii. Inspect just a fraction of 'f' of the randomly picked lots during skipping inspection. Until a sampled lot is refused, the skipping inspection is continued.
iv. If a lot is rejected after 'k' has been approved consecutively by sampled lots, then go to the immediate next lot for the resampling procedure as in step (5) below.
v. Carry out the inspection using the reference plan during the resampling process. If the lot is approved, then proceed to skip the inspection. Resampling is performed on non-acceptance of the lot for 'm' times and the lot is rejected. If, it has not been approved on resubmission (m-1).
vi. If a lot is rejected in a resampling system, then return to regular inspection in phase (1) immediately.
vii. Replace or correct all non-conforming units discovered in the rejected lots with conforming units.

The proposed plan was developed with a reference plan and defined by four parameters, namely $'f'$ - the fraction of lots inspected in the skipping inspection mode, $'i'$ - the usual inspection clearance number, $'k'$ - the sampling inspection clearance number, and $'m'$ - the number of times the lots are submitted for resampling.

IV. Operating procedure of SkSP-R with SSP as a reference plan based on percentiles of ERD

Step 1: A random sample of size n is drawn and a random sample of size is drawn and positioned on a time test.

Step 2: The number of defects d is counted and the approval number c is compared.

i. If d>c , then the lot is refused.
ii. If d≤c, then the lot is approved.

Step 3: If d>c, terminate the test and reject the lot if it is obtained before the stated time.

V. Operating characteristic function for SkSP-R using Single Sampling Plan

The OC function is the most commonly used tool for calculating the effectiveness of the sampling plan and from which the likelihood of acceptance is extracted. It provides the likelihood that it is possible to accept the lot. SSP OC feature for life tests based on the ERD percentiles is as follows,

$$L(p) = \sum_{i=0}^{c} \binom{n}{i} p^i (1-p)^{n-i} \qquad (3)$$

Where $P = F(t, \delta_0)$ represents the failure probability at time t given a determined 100q^th^ percentile of the lifetime t_q^0 and p depends only on $\delta_0 = t/t_q^0$. In Table 3, Pradeepa Veerakumari (2016), the OC values are tabulated.

For the lot value p, the OC function of SkSP-R is given by,

The operating feature function for the SkSP-R plan is given as per Balamurali.et.al (2014),

$$P_a(p) \frac{fP+(1-f)P^i+fP^k(P^i - P^k)(1-Q^m)}{f(1-P^i)(1-P^k(1-Q^m)+P^i\,(1+fQP^k)} \qquad (4)$$

Then, the Average Sample number is

$$ASN\ (p) = ASN\ (R)F \qquad (5)$$

Where, R- represents the Average Sample number of the reference plan, P represents the probability of acceptance of the reference plan.

5.1 Illustration

Suppose that the life time of the electric goods follows ERD. Skip lot sampling plan of type SkSP-3 with SSP as reference plan based on 50th percentile is applied for testing. The parameters for the life testing is as follows: θ=2, t=40hrs, $t_{0.50}$=20hrs, c=0, α=0.05 and β=0.05 then η = 1.56712 from the equation and the ratio is found to be $t/t_{0.50}$ =2.00 by applying the minimum sample size according to the requirements is $n=5$ and the corresponding OC values L(p) for the Single Sampling plan for the life tests based on percentiles of ERD (n,c, $t/t_{0.50}$ = 5,2,1.22) with $P^* = 0.95$. $L(p)$ is the P value for SkSP-R with SSP for life tests based on the percentiles of ERD as reference plan. For $i=1, k=3$ and $f=1/3$; the probability of acceptance $L(p)$ values of SkSP-R with SSP for life tests based on percentiles of ERD are found from eqn. 4 as,

$t / t^0_{0.50}$	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
$L(p)$	0.0237	0.4685	0.8460	0.9552	0.9864	0.9957	0.9985	0.9995	0.9998

From the illustrations, it is indicated that the actual 50th percentile is almost equal to the required 50th percentile ($t/ t_{0.50}$=1.00) the producer's risk is approximately 0.9808 (1-0.0192). Also the producer's risk is nearly equal to 0.05 or less and the actual producer risk is large or nearly equal to 2.15 times of the required percentile. For the purpose of convenience OC values of the table are constructed and tabulated with parameters $i=1$, $k=3$, $f=1/3$ and $c=2$ in Table 1.1.

Table 1.1 : *Gives the OC values for sampling plan (n,c = 2, t/$t_{0.50}$) for a given P^* under ERD when θ=2*

P^*	$t / t^0_{0.50}$	$t / t^0_{0.50}$								
		0.7	**0.9**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**
0.75	0.7	0.4655	0.8770	0.9711	0.9928	0.9981	0.9994	0.9998	0.9999	1.0000
0.75	0.9	0.4864	0.8696	0.9664	0.9909	0.9974	0.9992	0.9997	0.9999	1.0000
0.75	1	0.4710	0.8570	0.9612	0.9891	0.9968	0.9990	0.9997	0.9999	1.0000
0.9	0.7	0.2283	0.7741	0.9437	0.9851	0.9958	0.9988	0.9996	0.9999	0.9999
0.9	0.9	0.1618	0.6956	0.9151	0.9751	0.9924	0.9976	0.9992	0.9997	0.9999
0.9	1	0.3376	0.8004	0.9443	0.9837	0.9950	0.9983	0.9993	0.9997	1.0000
0.95	0.7	0.1276	0.6919	0.9206	0.9782	0.9938	0.9981	0.9994	0.9998	0.9999
0.95	0.9	0.1155	0.6446	0.8987	0.9698	0.9907	0.9970	0.9990	0.9996	0.9999
0.95	1	0.0921	0.5938	0.8770	0.9615	0.9876	0.9958	0.9985	0.9995	0.9998
0.99	0.7	0.0237	0.4685	0.8460	0.9552	0.9864	0.9957	0.9985	0.9995	0.9998
0.99	0.9	0.0259	0.4366	0.8198	0.9437	0.9817	0.9938	0.9978	0.9992	0.9997
0.99	1	0.0110	0.3168	0.7495	0.9173	0.9715	0.9899	0.9963	0.9986	0.9994

Table 1.2 : *Minimum sample size for the 50th percentile of ERD to exceed the given value* $t_{0.50}$

P^*	c	$t / t_{0.50}$								
		0.7	**0.9**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**
0.75	**0**	4	3	3	2	2	1	1	1	1
0.75	**1**	9	6	4	2	2	2	2	2	2
0.75	**2**	14	7	5	3	3	3	3	3	3
0.75	**3**	19	9	6	5	4	4	4	4	4
0.9	**0**	10	5	3	1	1	1	1	1	1
0.9	**1**	17	8	6	3	3	2	2	2	2
0.9	**2**	23	11	9	4	4	4	3	3	3
0.9	**3**	30	14	11	5	5	4	4	4	4
0.9	**10**	71	35	28	14	12	12	11	11	11
0.95	**0**	13	6	4	2	2	1	1	1	1
0.95	**1**	21	9	8	3	3	2	2	2	2
0.95	**2**	28	14	11	6	5	4	3	3	3
0.95	**3**	36	17	13	6	4	4	4	4	4
0.99	**0**	20	10	6	3	3	2	1	1	1
0.99	**1**	29	13	10	4	3	3	2	2	2
0.99	**2**	39	17	14	6	4	4	3	3	3
0.99	**3**	45	21	17	7	5	5	4	4	4

Table 1.3 : *Gives the ratio $d_{0.50}$ for accepting the lot with the procedure's risk of 0.05 when θ=2*

P^*	c	$t / t_{0.50}$								
		0.7	**0.9**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**
0.75	**0**	0.4411	0.4412	0.4421	0.4935	0.6021	0.6021	0.6021	0.6021	0.6021
0.75	**1**	0.5022	0.5691	0.6538	0.8637	0.8637	0.8637	0.8637	0.8637	0.8637
0.75	**2**	0.5426	0.6816	0.7764	0.8178	1.0061	1.0061	1.0061	1.0061	1.0061
0.75	**3**	0.5640	0.7283	0.8644	0.9499	1.1016	1.1016	1.1016	1.1016	1.1016
0.9	**0**	0.3185	0.3838	0.4411	0.6039	0.6021	0.6021	0.6021	0.6021	0.6021
0.9	**1**	0.4242	0.5415	0.5692	0.7241	0.7242	0.8637	0.8637	0.8637	0.8637
0.9	**2**	0.4656	0.5842	0.6492	0.8570	0.8573	1.0061	1.0061	1.0061	1.0061
0.9	**3**	0.4898	0.6229	0.6761	0.9499	0.9500	1.1016	1.1016	1.1016	1.1016
0.95	**0**	0.2977	0.3654	0.4080	0.6039	0.4935	0.6022	0.6021	0.6021	0.6021
0.95	**1**	0.3998	0.5023	0.5204	0.7230	0.7230	0.8637	0.8655	0.8637	0.8637
0.95	**2**	0.4402	0.5537	0.6029	0.7224	0.7762	1.0061	1.0061	1.0061	1.0061
0.95	**3**	0.4689	0.5845	0.6564	0.9519	1.1017	1.1016	1.1016	1.1016	1.1016
0.99	**0**	0.2675	0.3280	0.3653	0.4421	0.4408	0.4935	0.6022	0.6022	0.6022
0.99	**1**	0.3600	0.4508	0.4866	0.6539	0.7264	0.7242	0.8637	0.8637	0.8637
0.99	**2**	0.4038	0.5095	0.5536	0.7766	1.0089	0.8573	1.0060	1.0060	1.0060
0.99	**3**	0.4356	0.5467	0.5949	0.8644	0.9494	0.9499	1.1017	1.1017	1.1017

VI. Operating procedure of SkSP-R with DSP as a reference plan based on percentiles of ERD

The modus operandi of SkSP-R with DSP as a reference plan based on percentiles of ERD are as follows:

Step 1: A random sample of size n_1 is drawn and put on a life test.

Step 2: The number of defectives $d_1$is counted and a comparison is made with the acceptance number c.

i. If $d_1>c_1$, then reject the lot.

ii. If $d_1\leq c_1$, then accept the lot.

Step 3: If $d_1<c_2$, is obtained before the specified time t_0, terminate the test, and reject the lot.

Step 4: If $c_1< d_1 \leq r_1$, take a second sample of size n_2 from the remaining lot and put them on test for time $t_0$and count the number of non-conformities (d_2).

Step 5:

If $d_1+d_2 \leq r_1$, accept the lot.

If $d_1+d_2 > r_1$, reject the lot.

VII. Operating characteristic function for SkSP-R using Double Sampling Plan

OC function is the most applied technique to measure the efficiency of the sampling plan and from where the probability of acceptance is derived. It provides the probability that the lot can be accepted. The OC function of DSP for life tests based on the percentiles of ERD is as follows,

$$L(p) = \sum_{d_1}^{c_1} \binom{n_1}{d_1} p^{d_1}(1-p)^{n_1-d_1}. \sum_{d_1+c_{1+1}}^{c_2} \binom{n_1}{d_1} p^{d_1}(1-p)^{n_1-d_1} . \sum_{d_2=0}^{c_2-d_2} \binom{n_2}{d_2} p^{d_2}(1-p)^{n_2-d_2} \quad (6)$$

Where $P = F(t, \delta_0)$ represents the failure probability at time t given a determined 100q[th] percentile of the lifetime t_q^0 and p depends only on $\delta_0 = t/t_q^0$. The ASN Value of DSP is calculated from the equation,

$$ASN = n_1 p_1 + (n_1+n_2)(1-p_1) = n_1 + n_2(1-p_1) \quad (7)$$

The OC function of SkSP-R for the lot quality p is given by,

$$P_a(p) \frac{fP+(1-f)P^i+fP^k(P^i- P^k)(1-Q^m)}{f(1-P^i)(1-P^k(1-Q^m)+P^i\,(1+fQP^k)} \quad (8)$$

Then, the Average Sample number is

$$ASN\,(p) = ASN\,(R)F \quad (9)$$

Where ASN (R) represents the Average Sample number of the reference plan; P represents the probability of acceptance of the reference plan.

7.1 Illustration

Presume that the lifetime of the electric goods follows ERD. Skip lot sampling plan of type SkSP-R with DSP as a reference plan based on the 10[th] percentile is applied for testing. The parameters for the life testing is as follows: θ=2, t=40hrs, $t_{0.50}$=20hrs, c_1=0,c_2=1, α=0.01 and β=0.05 then η = 0.871929 from the equation and the ratio is found to be $t/t_{0.50}$ =2.00 by applying the minimum sample size according to the requirements is n_1=9,n_2=11 and the corresponding OC values $L(p)$ for the Double Sampling plan for the life tests based on percentiles of ERD $n_1, n_2, c_1, c_2, {}^{t}/_{t_{0.1}}$ = (9,11,0,1,0.9379) with P* = 0.99. *L (p)* is the *P* value for SkSP-R with DSP for life tests as a reference plan defined on the percentiles of ERD. For *i=1,k=3,* and *f=1/5;* the probability that SkSP-R with DSP will consider *L(p)* values for life tests based on percentiles of ERD is found from Equation 8 For,

$t/t^0_{0.1}$	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
$L(p)$	0.0398	0.3764	0.6235	0.9123	0.9668	0.9978	0.9993	0.9997	0.9999

From the illustrations, it is indicated that the actual 10th percentile is almost equal to the required 10th percentile $t/t^0_{0.1}$ the producer's risk is approximately 0.9602 (1-0.0398). Moreover, the producer's risk is closely equal to 0.05 or less and the actual producer risk is large or nearly equal to 2 times the required percentile. For the purpose of convenience OC values of the table are constructed and tabulated with parameters *i=1,k=3, f=1/5* and $c_1=0, c_2=1$ in Table 2.

Table 2: *Gives the OC values for Sampling Plan* $(n_1, n_2, c_1, c_2, {}^{t}/_{t_{0.1}} = (9,11,0,1,0.9379)$ *for a given P* under ERD when θ=2*

P*	$t\,/\,t^0_{0.50}$	$t_{0.1}/t^0_{0.1}$								
		1	**1.25**	**1.5**	**1.75**	**2**	**2.25**	**2.5**	**2.75**	**3**
0.75	0.7	0.5839	0.8364	0.7766	0.9265	0.9736	0.9897	0.9957	0.9980	0.9990
0.75	0.9	0.4318	0.8912	0.7603	0.9209	0.9715	0.9888	0.9953	0.9978	0.9996
0.75	1	0.4797	0.8460	0.7440	0.9153	0.9694	0.9880	0.9949	0.9976	0.9995
0.9	0.7	0.2276	0.6008	0.7277	0.9097	0.9673	0.9872	0.9946	0.9975	0.9992
0.9	0.9	0.2755	0.6557	0.7114	0.9042	0.9652	0.9863	0.9942	0.9973	0.9991
0.9	1	0.2234	0.6105	0.6951	0.8986	0.9631	0.9855	0.9938	0.9971	0.9990
0.95	0.7	0.3713	0.0653	0.6788	0.8930	0.9610	0.9846	0.9935	0.9969	0.9999
0.95	0.9	0.1191	0.6201	0.6625	0.8874	0.9589	0.9838	0.9931	0.9968	0.9998
0.95	1	0.1670	0.5250	0.6462	0.8819	0.9569	0.9829	0.9928	0.9966	0.9997
0.99	0.7	0.0149	0.4702	0.6299	0.8763	0.9548	0.9821	0.9924	0.9964	0.9997
0.99	0.9	0.0628	0.3154	0.6136	0.8707	0.9527	0.9813	0.9920	0.9963	0.9996
0.99	1	0.0107	0.3605	0.5973	0.8651	0.9506	0.9804	0.9917	0.9961	0.9996

VIII. Conclusion

In this study, life testing plans based on percentiles of ERD for Skip-lot Sampling plan of type-R with Single Sampling Plan and Double Sampling Plan as reference plan are developed. Skip-lot Sampling plan of type-R with SSP and DSP as reference plan requires minimum sample size and also has better operating characteristics values. Thus, results in reduction of inspection cost and better efficient. The proposed plan can be further extended to other sampling plans for instance SkSP and other probability distribution.

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