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RESEARCH ARTICLE

DESIGNING OF SKIP-LOT SAMPLING PLAN OF TYPE SKSP-R WITH MULTIPLE DEFERRED STATE MDS(0,2) SAMPLING PLAN AS REFERENCE PLAN

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ABSTRACT

This paper proposes a new procedure for designing of Skip-lot Sampling Plan of type SkSP-R with Multiple Deferred Sampling Plan as reference plan indexed through acceptable and limiting quality levels. The proposed plan is economically more advantageous to make decision on the submitted lot and also inspection of product producing in continuous stream towards resampling techniques. The illustrations are provided for various combinations of parameters involved in SkSP-R with MDS (0,2) as reference plan.

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INTRODUCTION

Statistical quality control is a simple tool for statistical method to determining the level of quality goals which are being met without necessarily checking every item produced and for indicating whether or not the variations which occur one exceeding normal expectations. Acceptance sampling is the procedure of randomly inspecting a sample of goods and making decision whether to accept or reject the entire lot based on the sample results. Skip-lot sampling plans are widely used in industries in order to reduce sampling costs and inspection efforts when products have good quality history. The skip-lot sampling plan is economically advantageous and useful to minimize the cost of the inspection particularly with costly and destructive testing. This scheme is shown to be more efficient than the single sampling plan. Dodge (1955) introduced the concept of skip-lot sampling, by applying the principle of continuous sampling plan of type CSP-1 to a series of lots or batches of material. This plan is designated as SkSP-1 plan and is especially applicable for bulk materials or products produced in successive lots. Perry (1973) formalized the application of skip-lot sampling to the situation in which each lot to be inspected and sampled according to lot inspection plan, called the reference plan.

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This plan is designated as the SkSP-2 plan. Vijayaraghavan (2000) introduced designing and evaluation method of skip-lot sampling plan of type SkSP-3 plan and the operating characteristic function is derived using the markov chain approach. Recently Balamurali and Chi-Hyuck Jun (2006) have developed SkSP-V plan based on the principles of CSP-V plan. Aslam *et al*. (2010) have established the designing methodology to determine the parameters for system of skip-lot sampling plan with corresponding to two points on the operating characteristic curve. Balamurali and Subramani (2012) developed Optimal designing of Skip-lot Sampling plan of type SkSP-2 with Double Sampling plan as the reference plan. Further Kavithamani (2014) has studied SkSP-V with various attribute reference plans towards acceptable and limiting quality levels of inspection lots. Recently, a new type of skip-lot sampling plan called SkSP-R was developed by Balamurali.et.al (2014) based on the principle of continuous sampling procedure and resampling scheme for the quality inspection of continuous flow of bulk products.

Execution of SkSP-R Plan

The SkSP-R plan is a new system of sampling procedure which is based on the principle of continuous sampling procedure and resampling scheme for the quality inspection of continuous flow of bulk products. The SkSP –R plan uses the reference plan which is similar to the SkSP-2 plan of Perry

(1973). The operating procedure of SkSP – R plan is as follows.

Operating procedure for SkSP-R plan

The operating procedures of SkSP-R are as follows

- Begin the procedure with normal inspection by applying specified reference plan (for instance MDS (0,2)). During normal inspection, lots are inspected one by one in order of being submitted.
- When i consecutive lots are accepted based on the reference plan under normal inspection, discontinue the normal inspection and switch to skipping inspection.
- During the skipping inspection, inspect only a fraction f of lots selected at random by applying reference plan. The skipping inspection is continued until a sampled lot is rejected.
- When a lot is rejected, after *s* consecutively sampled lot have been accepted, then go for re-inspection procedure for the immediate next lot as in step (5) given below.
- During re-inspection procedure, perform the inspection using the reference plan. If the lot is accepted, then continue the skipping inspection. On non-acceptance of the lot, re-inspection is done m times and the lot is rejected if it has been accepted on $(m-1)^{st}$ resubmission.
- If a lot is rejected on the re-inspection scheme, then we immediately revert to normal inspection.
- Replace or correct all non-conforming units found with conforming units in the rejected lots.

The proposed plan involves the reference plan with parameters, namely f, ($0<f<1$), the fraction of lots inspected in skipping inspection mode, i, the clearance number of normal inspection, s, the clearance number for re-inspection procedure and m, the number of time the lots are submitted for re-inspection. In general, i, s and m are positive integers. So, the plan is designated as SkSP-R (i, f, s, m).

Operating procedure for MDS(r, b) plan

- For each lot select a sample of n units and test each unit for conformance to specified requirements
- Accept the lot if d (the observed number of observation of defectives) is less than or equal to r, reject the lot if d greater than or equal to r+b.
- If $r+1 \le d \le r+b$, accept the lot if the forthcoming m lots in succession are all accepted.

Operating Procedure for MDS (0,2)

A multiple deferred State sampling plan of Wortham and Baker (1976) with r=0 and b=2 is operated as follows:

- From each lot, take a random sample of n units and observe the non-conforming units d.

If d=0, accept the lot; if d>2, reject the lot. If d=2, accept the lot, provided the forthcoming m lots in succession are all accepted (previous m lots in case of multiple dependent state sampling)

The probability of acceptance based on Poisson model is

$$P = e^{-np} + npe^{-np}e^{-npm_2} + \frac{np^2}{2}e^{-np(1+m_2)} \quad (2.1.1)$$

It is noted that $P_a(f, i)$ is a function of 'i' clearing interval; 'f' sampling fraction.

The operating characteristic function for MDS (r, b) is as follows

$$P = P_a(p) = P_{a,r}(p) + [P_{a,r+b}(p) - P_{a,r(}(p)][P_a(p)]^m \quad (2.1.2)$$

When the parameter r=0 and b=2. The probability of acceptance will be

$$P = e^{-np} + npe^{-np}e^{-npm_2} + \frac{np^2}{2}e^{-np(1+m_2)} \quad (2.1.3)$$

Operating procedure for SkSP-R with Multiple Deferred Sampling plan MDS(0,2) as reference plan

Step 1: Begin the procedure with normal inspection following the procedure of Multiple Deferred State Sampling plan MDS (0, 2) as the reference plan. During normal inspection, lots are inspected one by one in order of being submitted satisfying the conditions of MDS (0, 2).
Step 2: From each lot submitted for inspection, take a random sample of size n and measure the number of defectives d. If d=0, accept the lot; if d>2, reject the lot. If d=2, accept the lot, provided the forthcoming m lots in succession are all accepted (previous m lots in case of multiple dependent state sampling).
Step 3: When i consecutive lots are accepted based on the reference plan under normal inspection, discontinue the normal inspection and switch to skipping inspection. During the skipping inspection, inspect only a fraction f of lots selected at random by applying Multiple Deferred Sampling plan MDS (0, 2) as the reference plan. The skipping inspection is continued until a sampled lot is rejected.
Step 4: When a lot is rejected, after s consecutively sampled lot have been accepted, then go for re-inspection procedure for the immediate next lot as in step (5) given below.
Step 5: During re-inspection procedure, perform the inspection using the reference plan. If the lot is accepted, then continue the skipping inspection. On non-acceptance of the lot, re-inspection is done m times and the lot is rejected if it has been accepted on $(m-1)^{st}$ resubmission. If a lot is rejected on the re-inspection scheme, then we immediately revert to normal inspection. Replace or correct all non-conforming units found with conforming units in the rejected lots.

Designing of SkSP-R with MDS (0,2) for given n, i ,f ,s ,k, m_1 and m_2

The procedure for designing SkSP-R with MDS (0, 2) as reference plan indexed through Acceptable and Limiting Quality Level is drawn and Tables are simulated for various combinations of parameter values n, i, s, f, m_1, m_2 and k using MS- Excel Software.

Construction of tables

The operating characteristic function $P_a(p)$ to SkSP-R sampling plan with Multiple Deferred Sampling plan as reference plan [MDS (0, 2)] as reference plan is given as:

$$P_a(p) = \frac{fP + (1-f)P^i + (P^i - P)(1-Q^{m_1})}{f(1-p^i)[1 - P^s(1-Q^{m_1}) + P^i(1 + fPQ^s)]}$$

Here $P = e^{-np} + npe^{-np}e^{-npm_2} + \frac{np^2}{2}e^{-np(1+m_2)}$

Designing plans for given AQL, LQL, α and β

- Specify p_1 = Acceptable Quality Level at α = 0.05 or 0.01.
- Specify p_2 = Limiting Quality Level at β = 0.10 or 0.05.
- Obtain the corresponding ratio OR = p_2 / p_1 at different combination of α and β.
- 4. Choose a plan having the parameters i and m with nearest OR in the corresponding table.
- The actual np_1 and np_2 values corresponding to the OR value has been noted.
- Determine the sample size n= np_1 / p_1 Round up the value for determining the sample size.
- Thus the plan consists of the parameter n, i, f, k, m_1 and m_2 and s.

Illustration

For given, at α = 0.05, p_1=0.005672 and β = 0.05, p_2=0.0408 .Then the Operating Ratio OR= p_2/p_1 = 7.1932. And np_1 value is selected from table 1 as 0.5672 and the corresponding sample size n is computed as n = np_1/p_1 = 0.5672/0.005672, n = 100. Hence the parameters of SkSP-R with Multiple Deferred Sampling Plan indexed through Acceptable and Limiting Quality Levels is n=100, i=3, k=1 m_1 =1 and m_2=1.

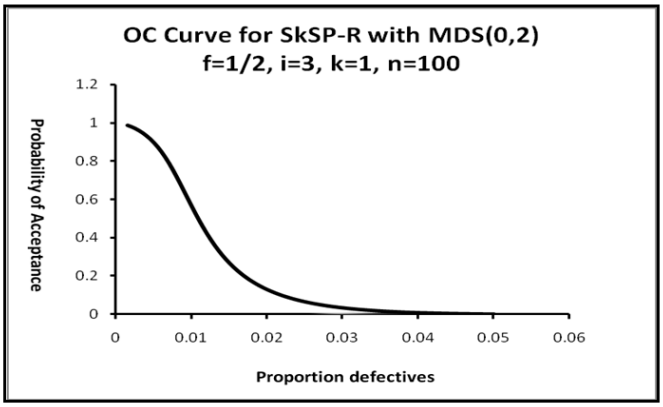

Fig. 1. Operating Charateristic Curve for SkSP-R Sampling Plan with MDS (0,2) through specified parametric values

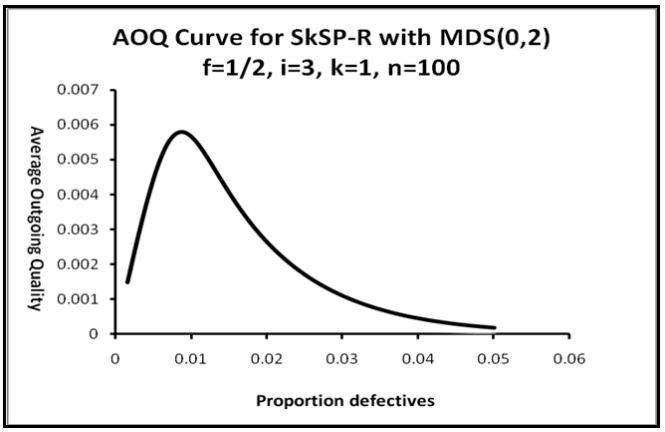

Fig. 2. Average Outgoing Quality Curve for SkSP-R Sampling Plan with MDS (0,2) through specified parametric values

Table 1. Table for Unity values and Operating Ratio for SKSP-R with MDS (0, 2) as the Reference Plan

f	i	k	m_1	m_2	0.99	0.95	0.9	0.5	0.1	0.05	0.01	OR(0.99,0.01)	OR(0.95,0.05)
1/3	1	1	1	1	0.1875	0.4383	0.6429	1.5798	3.0420	3.6411	5.045	26.9051	8.30729
1/5					0.2510	0.5672	0.8157	1.8728	3.4534	4.0809	5.529	22.0277	7.19446
1/7					0.2991	0.6747	0.9447	2.0816	3.7349	4.3788	5.8524	19.5667	6.48972
2/5					0.1710	0.3987	0.5882	1.4816	2.9005	3.4883	4.8746	28.5064	8.74924
2/7					0.2068	0.4742	0.6921	1.6636	3.1639	3.7721	5.1900	25.0908	7.95429
3/5	1	2	P1	1	0.1310	0.3232	0.4749	1.2309	2.5609	3.1348	4.4947	34.3109	9.70055
	2				0.1310	0.3193	0.4605	1.0829	2.2159	2.7579	4.0399	30.8390	8.63747
	3				0.1310	0.3173	0.4484	1.0081	2.1525	2.713	4.0272	30.7420	8.55121
	4				0.1310	0.3117	0.4378	0.9608	2.1384	2.7084	4.0272	30.7420	8.68922
	5				0.1310	0.3113	0.4286	0.9282	2.1355	2.7080	4.0272	30.7423	8.69799
¼	3	1	1	1	0.2255	0.4795	0.6425	1.2168	2.2340	2.7584	4.0369	17.9028	5.75293
		2			0.2129	0.4638	0.6115	1.1650	2.1921	2.7286	4.0273	18.9139	5.88288
		3			0.2122	0.4535	0.5941	1.1433	2.1849	2.7259	4.0272	18.9776	6.01026
		4			0.2115	0.4460	0.5811	1.1327	2.1836	2.7256	4.0272	19.0374	6.11187
		5			0.2109	0.4401	0.5724	1.1276	2.1834	2.7256	4.0272	19.0932	6.19332
2/4	3	2	1	1	0.1522	0.3457	0.4816	1.0391	2.1596	2.7153	4.0272	26.4621	7.85454
			2		0.1540	0.3651	0.5285	1.1272	2.2122	2.7515	4.0368	26.2092	7.53658
			3		0.1541	0.3685	0.5409	1.1835	2.2617	2.7837	4.0464	26.2662	7.55452
			4		0.1541	0.3689	0.5437	1.2194	2.3034	2.7994	4.1222	26.7580	7.58936
			5		0.1541	0.3689	0.5442	1.2421	2.3392	2.8268	4.0616	26.3646	7.66274
2/7	4	2	1	1	0.2054	0.4277	0.5574	1.0549	2.146	2.7096	4.0271	19.6083	6.33508
				2	0.1448	0.313	0.4131	0.8123	1.8144	2.3974	3.9021	26.9474	7.65939
				3	0.1190	0.2628	0.3508	0.7164	1.7429	2.3588	3.8952	32.7250	8.97529
				4	0.0999	0.2338	0.3151	0.6683	1.7278	2.3549	3.8949	38.9876	10.0718
				5	0.0888	0.2145	0.2903	0.6432	1.7246	2.3545	3.8948	43.8606	10.976

Conclusion

Acceptance sampling plan have been widely used in industry to determine whether the manufactured item satisfy the pre-specified quality levels or not. At this point, an enterprise must have to take a decision for accepting or rejecting the lots in accordance with randomly chosen units. This paper provide a new procedure has been evolved involving two methodologies namely Skip-lot Sampling Plan of type SkSP-R and Multiple Deferred Sampling plan MDS (0,2) as reference plan. This plan evolves the Acceptable Quality Level (AQL), Limiting Quality Level (LQL) and Operating Ratio has been studied. Under Skip-lot sampling inspection, samples may be drawn from only a fraction of the submitted lots. The main purpose for Skip-lot sampling is to decrease the frequency of sampling inspection and reduce the total inspection costs.

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