A STUDY ON COMPARISON OF VARIOUS CONTINUOUS SAMPLING AND SKIP-LOT SAMPLING PLAN PROCEDURES

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Abstract

This paper explains the brief review of skip-lot sampling plan procedures followed by continuous sampling plan procedures. Also, various types of skip-lot sampling plans are compared with continuous sampling plans. The efficiency of SkSP-T is tested on comparison with various skip-lot sampling plans using Single Sampling Plan. A new system of skip-lot sampling plan of type SkSP-T is compared with other skip-lot sampling plans. Different types of skip-lot sampling plans namely SkSP-2, SkSP-3, SkSP-V and SkSP-R. The tables are constructed for various combinations of various parameters using various numerical methods.

Keywords: Continuous Sampling Plan, Skip Lot Sampling Plan, Skip-lot Sampling Plan of Type SkSP-T, Single Sampling Plan.

I. Introduction

Acceptance sampling is a major tool in statistical quality control. Various Attributes Acceptance sampling procedures has been developed by several authors since 1940. Acceptance sampling plan has four broad categorized. It includes Continuous sampling plans, special purpose plans. Special purpose plan includes skip lot sampling procedure. In this paper explains the brief review of continuous sampling plan procedures and skip-lot sampling plan procedures.

II. Comparison of CSP-1 and SkSP-1

Continuous sampling plan of type CSP-1 is introduced by [5]. CSP-1 plan is a continuous flow of discrete products. The operating procedure of CSP-1 is executed in two stages of inspections namely 100% inspection and sampling inspection. These two types of inspection are controlled by the parameters i (clearance interval used for 100% inspection) and f (sampling frequency used for sampling inspection). CSP's intended for applied only individual units. The average number of total production Pa (p) accepted are passed on a sampling basis is given by

$$P_a(p) = \frac{q^i}{f+(1-f)q^i} \quad (1)$$

Where f is the Sampling Frequency ($0<f<1$), i is the Clearance Interval on 100% inspection. The first skip-lot sampling plan of type SkSP-1 is introduced by [8] it is based on the concept of continuous sampling plan of type CSP-1. Skip-lot sampling plan is a bulk materials or products produced in successive lots. The SkSP-1 sampling plan was proposed without considering the concept of reference plan. Skip-lot sampling plan of type SkSP-1 is followed by continuous sampling plan of type CSP-1. SkSP-1 is implemented by the following procedures are developed by [8]:

a) "Units" are be transformed into "lots" (clubbing of units).
b) After the inspection processes lots are conforming or non-conforming. Suppose accepting a non-conforming lot and rejecting a conforming lot in this situation used AOQL (Average Outgoing Quality Limit).
c) Using 2% AOQL table. If AOQL=2% then the standard plan parameter values are fixed. Since *f=1/2*, *i=14* and *f=1/2*, *i=15*.

Operating Procedure for SkSP-1

a) Each nonconforming lots corrected or replaced by a conforming lot.

When *i=14*, *f=1/2*.

b) Each nonconforming lots rejected and not replaced by a conforming lot.

When *i=15*, *f=1/2*.

Under the plan is executed individually to each characteristic under inspection. During some specific characteristics are elaborated, try to analyze partially single characteristic within per lot.

Step1: Necessarily to test each lot, 15 lots are received and successive lots are found to be conforming.

Step2: During 15 successive lots are found conforming, the lots are selected at randomly and to test half of a lots. In this case accepted lots are not tested.

Step3: During a lot is rejected, go back to step-2.

III. Comparison of CSP-2 and SkSP-2

CSP-2 is proposed by [6] it is a reconstruction of CSP-1 plan. Continuous sampling plan of type CSP-2 is different from CSP-1 plan. In this new plan once the sampling inspection is initiate, stop to 100% inspection. When defect is found in sampling inspection it will use only the sampling frequency (*f*) of a succeeding of two defects occurs in the other *k* (successive sampling units) or less sample units. Suppose two defects occurs in *k* successive sampling units or less sampling units then the system immediately go to 100% inspection otherwise sampling inspection is ongoing. CSP-2 plan is maintained with three parameters *i*, *f* and *k*. The average number of total production Pa(p) accepted are passed on a sampling basis is given by

$$P_a(p) = \frac{q^i(2-q^k)}{f(1-q^k)(1-q^i)+q^i(2-q^k)} \quad (2)$$

Where *f*- Sampling Frequency, *i*- Clearance Interval on 100% inspection and *k*- Clearance Interval on sampling inspection. Skip-lot Sampling Plan of type SkSP-2 is developed by [7]. It is an extension of skip-lot sampling plan of type SkSP-1 and based on the origin of continuous sampling plan of CSP-1. In [15] has provided some operating characteristic of SkSP-2 plan using markov chain techniques. Skip-lot plan of type SkSP-2 is used an attribute inspection plan it is called as "reference plan". The reference plan comprises certain rules, based on the record of lot acceptance or rejections, for switching back and forth between 'normal' and 'skipping' inspection. Every lot has received on the normal inspection and skipping inspection randomly selected fraction *f* of the lots and skipped lots are automatically accepted. Probability of acceptance under SkSP-2 plan is

$$P_a(p) = \frac{fP+(1-f)P^i}{f+(1-f)P^i} \quad (3)$$

Where *f*- Sampling frequency, *i*- clearance interval and P- Probability of acceptance under the reference plans.

IV. Comparison of CSP-3 and SkSP-3

The new concept of continuous sampling plan of type CSP-3 is designed by [6]. It is also moderation of CSP-1 and CSP-2 plans. CSP-3 is filtration of CSP-2 plan to provide additional production against highly defective quality. Four defects occur in k successive sampling units or less sampling units

then the system immediately go to 100% inspection otherwise sampling inspection is ongoing. It supplies additional manufacture on "Spotty quality". The average fraction of total production accepted on a sampling basis is

$$P_a(p) = \frac{q^i[1+q^4(1-q^k)}{f(1-q^{k+4})(1-q^i)+q\left(1+q^{4i}(1-q^k)\right)+4fpq^i} \quad (4)$$

Where *f*- Sampling Frequency, *i*- Clearance Interval on 100% inspection and *k*- Clearance Interval on sampling inspection. Skip-lot sampling plan of type SkSP-3 is developed by [17] using markov chain technique. It is a basic concept of continuous sampling plans and skip-lot sampling plans. Probability of acceptance under SkSP-3 plan is

$$P_a(p) = \frac{fP(1-P^i)(1-P^k)+(1-f)P^i(2-P^k)+fP^{i+1}(2-P^k)}{f(1-P^i)(1-P^k)+P^i(2-P^k)} \quad (5)$$

Where *f*- Sampling Frequency, *i*- Clearance Interval on normal inspection and *k*- Clearance Interval on skipping inspection.

V. Comparison of CSP-V and SkSP-V

Exceptional study of continuous sampling plan of type CSP-V introduced by [2]. In CSP-V plan *f* (sampling frequency) is never control to minimizing; using a smaller clearance interval to reducing inspection. CSP-V plan clearance number *x* (<*i*) can be used when 100% inspection only. And another clearance number *i* can be used in both 100% inspection and sampling inspection. The average fraction of total production accepted on a sampling basis (the operating characteristic function) is

$$P_a(p) = \frac{q^i}{q^i+f[1-q^i+q^k(q^i-q^x)]} \quad (6)$$

Where *f*- Sampling Frequency, *i*- Clearance Interval on 100% inspection, *k*- Clearance Interval on sampling inspection and *x*-Reduced clearance interval for 100% inspection. A new system of skip-lot sampling plan of type SkSP-V is introduced by [14]. The important feature of SkSP-V is the lot is rejected on skipping inspection then the system go to normal inspection with reduced clearance number. The probability of acceptance under the SkSP-V plan is

$$P_a(p) = \frac{fP+(1-f)P^i+fP^{k+1}(P^i-P^x)}{(1+P^{i+k}-P^{2k})+(1-f)P^i} \quad (7)$$

Where, *f*- frequency, *i*- clearance interval, *k*- number of lots that consecutively were accepted under skip-lot inspection, *x*- number of reduced lots that were accepted under normal inspection

VI. Comparison of CSP-R and SkSP-R

CSP-R plan which introduced by [12] the normal-tightened-reduced inspection concept of MIL-STD-105D [13], the US standards for attributes sampling. Monograph for the selection of CSP-R plan is developed by [1]. Skip-lot sampling plan of type Resampling SkSP-R is introduced by [18]. In resampling plan, the producer maintains the quality of product. In SkSP-R sampling plan, m number of time the lots are submitted for resampling. The probability of acceptance under the SkSP-R plan is

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

Where *Q = 1-P*, *P* is the probability of acceptance of a single lot under the reference plan, *f*-the fraction of lots inspected in skipping inspection mode, *i*-clearance number of normal inspection, *k*-the clearance number of sampling inspection, *m*-the number of times the lots are submitted for resampling.

VII. Brief explanation of SkSP-T and compared with CSP-T

The three-level continuous sampling plan assign as CSP-T (T-tightened) is designed by [9]. CSP-T is

derived an Average Outgoing Quality (AOQ) and Average Fraction Inspection (AFI) functions for continuous sampling plan of type CSP-T plan using Markov Chain Techniques. In this sampling plan is modified form of [10] and [4] following the methodology of as a multilevel plan CSP-T allows a reduction in sampling frequency (*f*) as quality improves, reducing the amount of sampling necessary. The sampling frequency is cut in every level then the quality is improved. Many authors study the properties and designing methodologies of continuous sampling plans of type CSP-T. Markov Chain model of CSP-T plan developed by [11], and Modified Tightened three level continuous sampling plan id derived by [3].

Skip-lot sampling plan of type SkSP-T (T-tightened) is introduced by [16]. It is based on the concept of continuous sampling plan of type CSP-T, continuous sampling plan of type CSP-M, modified tightened three level continuous sampling plan and skip-lot sampling plan of type SkSP-2. Sampling level is fixed by using CSP-M procedure; sampling fractions are taken from the CSP-T procedure and other concepts are taken by modified CSP-T and SkSP-2 procedures. The main advantage of skip lot sampling plan of type SkSP-T sampling plan is that the process moves from one level of skipping inspection to another without going back to normal inspection and various references plan are adopted for running normal and skipping inspections. In SkSP-T sampling plan the sampling frequency (*f*) is minimized by every skipping inspection level. This procedure may face the challenges of producer and consumer in terms of risks experienced by them during product and process control. SkSP-T plan contains two inspections, namely normal and skipping inspection. Skip-lot sapling plan is starts with normal inspection using various reference plans. In skipping inspection entire lots in the structure of construction and the skipping inspections are continued. The number of consecutive conforming lots or batches reaches some pre-specified clearance number *i* continue to normal inspection. If *i* consecutive lots are cleared with normal inspection, using skipping inspection with fraction f appear; if another *i* consecutive conforming lots are passed under fractional inspection, the fraction (*f*) is bisecting to *f*/2, and then to *f*/4 provided no non-conforming is found. Then the non-conforming is found in skipping inspection the system goes to normal inspection. SkSP-T plan based on Burr type XII distribution and SkSP-T based on fuzzy logic techniques are developed [19,20].

Operating Procedure for SkSP-T

Step 1: Start with the normal inspection using reference plans.

Step 2: When *i* consecutive lots are accepted on normal inspection, discontinue the normal inspection and started as skipping inspection.

Step 3: Under skipping inspection mode, inspect only fraction *f* of the lots selected randomly, mention first level.

Step 4: After *i* lots in succession have been found without a non-conforming at first level, the system then switches to skipping inspection with a fraction of *f*/2, mention second level.

Step 5: After *i* lots in succession have been found without a non-conforming at second level, the system then switches to skipping inspection with a fraction of *f*/4, called third level.

Step 6: If a non-conforming lot is found on either skipping level, the system reverts to normal inspection.

Step 7: Exchange all non-conforming lots with conforming ones.

The probability of acceptance under SkSP-T plan is

$$\text{Pa (p)} = \frac{P^i(f_2f_3(1-P^i)+f_1f_3P^i(1-P^i)+f_1f_2P^{2i})}{f_1f_2f_3(1-P^i)+P^i(f_2f_3(1-P^i)+f_1f_3P^i(1-P^i)+f_1f_2P^{2i})} \quad (9)$$

Where, P = Probability of Acceptance, *f* is the sampling frequency and *i* is the clearance number.

VIII. Designing plans for given AQL, LQL, α and β

1. Specify p_1 = Acceptable Quality Level at α = 0.05 or 0.01.
2. Specify p_2 = Limiting Quality Level at β = 0.10 or 0.05.

3. Obtain the corresponding ratio $OR = p_2 / p_1$ at different combination of α and β.
4. The actual np_1 and np_2 values corresponding to the OR value has been noted.
5. 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_1, f_2, f_3, and c.

Table 1: *Comparison of Operating Characteristics Values*

P	CSP-2	SkSP-2	CSP-3	SkSP-3	CSP-V	SkSP-V	CSP-T	SkSP-T
0.001	0.9930	0.9976	0.9944	0.9999	0.9965	0.9999	0.9997	0.9999
0.002	0.9748	0.9911	0.9937	0.9996	0.9960	0.9996	0.9987	0.9997
0.003	0.9484	0.9811	0.9921	0.9986	0.9951	0.9990	0.9980	0.9992
0.004	0.9158	0.9682	0.9896	0.9963	0.9934	0.9983	0.9974	0.9990
0.005	0.8784	0.9527	0.9860	0.9921	0.9909	0.9974	0.9967	0.9987
0.006	0.8375	0.9350	0.9810	0.9859	0.9870	0.9962	0.9960	0.9985
0.007	0.7940	0.9155	0.9742	0.9773	0.9813	0.9949	0.9953	0.9982
0.008	0.7488	0.8942	0.9650	0.9663	0.9727	0.9934	0.9946	0.9979
0.009	0.7027	0.8716	0.9528	0.9529	0.9601	0.9916	0.9939	0.9977
0.01	0.6562	0.8477	0.9367	0.9372	0.9418	0.9897	0.9931	0.9974

IX. Comparative study

In nature skip-lot sampling plans are followed by continuous sampling plans. Continuous sampling plan is a series of lots or batches of materials. Skip-lot sampling plan is a bulk materials or products produced in successive lots. In this paper, various types of skip-lot sampling plans (SkSP) are compared with continuous sampling plans (CSP). Skip-lot sampling plan of types SkSP-2, SkSP-3, SkSP-V and SkSP-T using Single Sampling plan as reference plan. Compared to other skip-lot and continuous sampling plans, SkSP-T has more parameters.

From table 1 compared with probability of acceptance (Pa (p)) values of continuous sampling plans and skip-lot sampling plans for using various parameters and its values. It concludes that skip-lot sampling plan has high probability of acceptance (Pa (p)) compared with continuous sampling plans. Hence Skip-lot sampling plans have more efficient than continuous sampling plans. It concludes that SkSP-T is superior to other skip-lot and continuous sampling plans.

X. Conclusion

In this paper, various types of skip-lot sampling plans are compared to Continuous sampling plans. In general skip lot sampling plans are reducing the frequency of sampling inspection and overall inspection cost. Comparison of continuous sampling plans and skip-lot sampling plans the new plan of skip-lot sampling plan of type SkSP-T has high probability of acceptance and good quality level. The new proposed plan of skip-lot sampling plan of type SkSP-T is better protection to the producer and the consumer. The main advantage of skip lot sampling plan of type SkSP-T sampling plan is that the process moves from one level of skipping inspection to another without going back to normal inspection.

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