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DESIGNING OF THREE STAGE CHAIN SAMPLING PLAN WITH MINIMIZATION APPROACH

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Abstract : Acceptance Sampling plans are the practical tools for quality assurance applications involving product quality control. Using Trigonometric ratio, one can get a better plan which has an OC curve similar to ideal OC curve. The approach of minimum angle method by considering the tangent of the angle between the lines joining the points (AQL, 1-α) (LQL,β). This paper introduces a procedure and tables for the selection of Three Stage Chain Sampling Plan (0, 2, 3) Through Minimum Angle Criteria, involving producers and Consumers quality levels. A table and methods are given for the construction of plans indexed by minimum angle method.

Keywords: Statistical quality control, Chain sampling plan, Minimum angle method, Trigonometric ratio, Minimization Approach

I. INTRODUCTION

Acceptance sampling is a statistical tool used to make decisions concerning whether or not a lot of products should be released for consumer use. An acceptance sampling plan is a statement regarding the required sample size for product inspection and the associated acceptance or rejection criteria for sentencing individual lots. The criteria used for measuring the performance of an acceptance sampling plan, is usually based on the operating characteristic (OC) curve which quantifies the risks for producers and consumers. The OC curve plots the probability of accepting the lot versus the lot fraction nonconforming, which displays the discriminatory power of the sampling plan. The basic acceptance sampling plan called the single-sampling plan is widely used in industry to inspect items due to its easiness of implementation. A single sampling attribute inspection plan calls for acceptance of a lot under consideration .If the number of nonconforming units found in a random sample of size n is less than or equal to the acceptance number Ac. Whenever a sampling plan for costly or destructive testing is required, it is common to force the OC curve to pass through a point, say,(LQL,β). Unfortunately, the AC=0 plan has the following disadvantages.

1. The OC curve of the AC=0 plan has no point of inflection and hence it starts to drop rapidly even for the smallest increases in the fraction nonconforming p.
2. The producer dislikes an AC=0 plan since a single occasional nonconformity will call for the rejection of the lot.

The chain sampling plan Chsp-1 by Dodge is an answer to the question of whether anything can be done to improve the pathological shape of the OC curve of a zero-acceptance –number plan.

II. REVIEW OF LITERATURE

Dodge (1955) treats this problem using a procedure, called chain sampling plan (ChSP – 1). These plans make use of the cumulative inspection results from several results, from one or more samples along with the results from the current sample, in making a decision regarding acceptance or rejection of the current lot. The chain sampling plans are applicable for both small and large samples. Dodge and Stephens (1966) extended the concept of chain sampling plans and presented a set of two stage chain sampling plans based on the concept of ChSP – 1 developed by Dodge (1955). They presented expressions for OC curves of certain two – stage chain sampling plans and made comparison with single and double sampling attributes inspection plans. The three-stage chain sampling plan of type ChSP (0,1,2) developed by Soundararajan and Raju (1984) is a generalization of Dodge (1955) chain sampling plan ChSP–1 and Dodge and Stephens (1966) chain sampling plan ChSP–(0,1). Soundararajan and Raju (1984) gives the structure and operating procedure of generalized three – stage chain sampling plan and expressions for OC curve of certain three – stage plans are also given. ChSP (0,1,2) can be used for both small and large samples, but it is particularly useful when samples must necessarily be small (eg., when tests are costlier). The greater generality in the choice of parameters in the ChSP – (0,1,2) plan allows for greater flexibility in matching these plans to other plans and allows for improved discrimination between good and bad quality. A more complete discussion of chain sampling plan can be found in Schilling (1982).

III. OPERATING PROCEDURE FOR THREE STAGE CHAIN SAMPLING PLAN

Step 1: At the outset, select a random sample of n units from the lot and from each succeeding lot.

Step 2: Record the number of defectives d, in each sample and sum the number of defectives, D, in all samples from the first up to and including in the current sample.

Step 3: Accept the lot associated with each new sample during the cumulation as long as $D_i \leq c_1;\ 1 \leq i \leq k_1$.

Step 4: When k1 consecutive samples have all resulted in acceptance continue to sum the defectives in the k_1 samples plus additional samples up to not more than k_2 samples.

Step 5: Accept the lot associated with each new sample during cumulation as long as $D_i \leq c_2;\ k_1 \leq i \leq k_2$.

Step 6: When k_2 consecutive samples have all resulted in acceptance continue to sum the defectives in the k_2 samples plus additional samples up to not more than $k_3$samples.

Step 7: Accept the lot associated with each new sample during cumulation as long as $D_i \leq c_3;\ k_2 \leq i \leq k_3$.

Step 8: When the third stage of the restart period has been successfully completed (i.e., k_3 consecutive samples have been resulted in acceptance),start cumulation of defectives as moving total over k_3 samples by adding the current sample result while dropping from the sum, the sample result of the k_3th preceding sample. Continue this procedure as long as $D_i \leq c_3$ and in each instance accept the lot.

Step 9: If for any sample at any stage of the above procedure, D_i is greater than the corresponding c, reject the lot.

Step 10: When a lot is rejected return to step-1 and fresh restart of the cumulation procedure.

The three-stage chain sampling plan has 7 parameters which are defined below:

n = sample size

k_1= The maximum number of samples over which the cumulation of the defectives take place in the first stage of procedure.

k_2 = The maximum number of samples over which the cumulation of the defectives take place in the second stage of procedure.

k_3= The maximum number of samples over which the cumulation of the defectives take place in the first of procedure.

c_1 = The allowable number of defectives in the cumulative results from $k_1$or fewer sample of n. Thus, c_1 is an acceptance number for cumulative results. It is the cumulative results criterion (CRC) that must be met by cumulative sampling results during the first stage of of the restart period in order to permit acceptance of a lot.

c_2 = The allowable number of defectives in the cumulative results from k_1+ 1 to k_2 sample of n. Thus, c_2 is also an acceptance number for cumulative results and the CRC that must be met by cumulative sampling results during the second stage of the restart period in order to permit acceptance of a lot.

c_3 = The allowable number of defectives in the cumulative results from k_2 + 1 to k_3 sample of n. Thus, c_3 is also an acceptance number for cumulative results and the CRC that must be met by cumulative sampling results during the third stage of the restart period in order to permit acceptance of a lot.

When the sample size is not more than one-tenth of the lot size, and when the quality is measured in terms of defectives, the OC curve can be computed using the binomial model. In addition to the condition of sample size being not more than one-tenth of the lot size, if the lot quality p (measured in terms of defectives) is less than or equal to 0.01, the OC curve can be based on the Poisson model. When the quality is measured in terms of defects, the appropriate model is also the Poisson one. Under the condition for application of the Poisson model the probability of accepting a lot given the proportion nonconforming under the ChSP-(0,2,3) plan with parameters n, k_1, k_2, k_3, c_1, c_2, and $c_3$was derived by Raju (1984) as

$P_a(p)$=

$$\frac{\begin{array}{c} P_0 + (p_1+p_2)p_0^{k_2-1} + (k_2-k_1-1)p_1^2p_0^{k_2-2} + (k_3-k_2-1)p_1(p_1+2p_2)p_0^{k_3-2} + \binom{k_3-k_2-1}{2} \\ p_1^3p_0^{k_3-3} + p_3p_0^{k_3-1} + (p_2+p_1)p_0^{k_1}\left[\frac{1-p_0^{k_2-k_1-1}}{1-p_0}\right] + p_1^2p_0^{k_1}\left[\frac{1-(k_2-k_1-1)p_0^{k_2-k_1-2}}{1-p_0} + \frac{p_0\left(1-p_0^{k_2-k_1-1}\right)}{(1-p_0)^2}\right] \\ p_1(p_1+2p_2) * (k_2-k_1)p_0^{k_2-1} + p_1^3p_0^{k_2}\left[\sum_{j=0}^{k_3-k_2-4}\binom{j+2}{2}p_0^j\right] + p_1(p_1+2p_2)p_0^{k_2} \\ \left[\frac{1-(k_3-k_2-1)p_0^{k_3-k_2-2}}{1-p_0} + \frac{p_0\left(1-p_0^{k_3-k_2-2}\right)}{(1-p_0)^2}\right] + p_1^3p_0^{k_2-2}\binom{k_2-k_1}{2} + p_0^{k_2}p_3\left[\frac{1-p_0^{k_3-k_2-1}}{1-p_0}\right] \end{array}}{\begin{array}{c} 1 + (p_2+p_1)p_0^{k_1}\left[\frac{1-p_0^{k_2-k_1-1}}{1-p_0}\right] + p_1^2p_0^{k_1}\left[\frac{1-(k_2-k_1-1)p_0^{k_2-k_1-2}}{1-p_0} + \frac{p_0\left(1-p_0^{k_2-k_1-1}\right)}{(1-p_0)^2}\right] \\ p_1(p_1+2p_2) * (k_2-k_1)p_0^{k_2-1} + p_1^3p_0^{k_2}\left[\sum_{j=0}^{k_3-k_2-4}\binom{j+2}{2}p_0^j\right] + p_1(p_1+2p_2)p_0^{k_2} \\ \left[\frac{1-(k_3-k_2-1)p_0^{k_3-k_2-2}}{1-p_0} + \frac{p_0\left(1-p_0^{k_3-k_2-2}\right)}{(1-p_0)^2}\right] + p_1^3p_0^{k_2-2}\binom{k_2-k_1}{2} + p_0^{k_2}p_3\left[\frac{1-p_0^{k_3-k_2-1}}{1-p_0}\right] \end{array}}$$

Where,

P_0= Probability of getting exactly zero non- conforming in a sample of size n

P_1= Probability of getting exactly one non- conforming in a sample of size n

P_2= Probability of getting exactly two non- conforming in a sample of size

P_3= Probability of getting exactly three non- conforming in a sample of size n

IV.A REVIEW ON TRIGONOMETRIC RATIO

The practical performance of any sampling plan is generally revealed through its operating characteristic curve. When producer and consumer are negotiating for quality limits and designing sampling plans, it is important especially for the minimize the consumer risk. In order to minimize the consumer's risk, the ideal OC curve could be made to pass as closely through (AQL, 1-α) was proposed by Norman Bush (1953) considering the tangent of the angle between the lines joining the points (AQL, 1-α), (AQL, β). Norman Bush et al. (1953) have considered two points on the OC curve as (AQL, 1-α) and (IOL, 0.50) for minimize the consumer's risk. But Peach and Littauer (1946) have taken two points on the OC curves as (p1,1-α) and (p2,β) for ideal condition to minimize the consumers risks here another approach with minimization of angle between the lines joining the points (AQL,1-α) , (AQL, β) and (AQL, 1- α) , (LQL, β) was proposed by Singaravelu (1993). Applying this method one can get a better plan which has an OC curve approaching to the ideal OC curve. Govindaraju.K (1990), Soundararajan.V (1981) and many others have studied AQL.

The formula for tanθ is given as

$$\tan\theta = \frac{oppositesite}{adjacentside} \qquad \text{----------------(2)}$$

Tangent of angle made by AB and AC is

$$\tan\theta = (P_2\text{-}P_1) / P_a(P_1)\text{-}P_a(P_2) \qquad \text{--------------- (3)}$$

Where P_1= AQL and P_2 = LQL.

This may be expressed as,

$$n\tan\theta = (nP_2\text{-}nP_1) / (1\text{-}\alpha\text{-}\beta) \qquad \text{----------------(4)}$$

The smaller value of this tanθ closer is the angle θ approaching zero, and the chord AB approaching AC, the ideal condition through (AQL, 1-α)

$$\text{Now } \theta = \tan\text{-}1\{(n\tan\theta/n)\} \qquad \text{----------------(5)}$$

Using this formula, the minimum angle θ is obtained, for the given np_1 and np_2 values.

V.EXAMPLE

1. To construct p_1= 0.48 and p_2 = 2.25, then OR = p_2/p_1 = 2.25/0.48 = 5. The associated sets of values corresponding to the computed OR values from Table 2 is, k_1=4, k_2=5, k_3=6, np_1 = 2.4805, np_2 =5.9718 and ntanθ = 48.1499 from the above results, one can find, n = np_1/p_1 = 2.4805/0.48 = 5.167. θ = $\tan^{-1}$\{(48.1499)/ 5.1677\} = 1.000. Now the minimum angle is θ = 0.9999. Hence the selected parameters for the three-stage chain sampling plan of type ChSP (0,2,3) for given p_1= 0.48 and p_2 = 2.25 with minimum angle θ = 0.9999.

2.To construct p_1= 0.67 and p_2 = 0.028, then OR = p_2/p_1 = 0.028/0.67= 24. The associated sets of values corresponding to the computed OR values from Table 2 is, k_1=9, k_2=10, k_3=11, np_1 = 2.4884, np_2 =5.9713 and ntanθ = 47.9903 from the above results, one can find, n = np_1/p_1 = 2.4884/0.67 = 3.714. θ = $\tan^{-1}$\{(47.9903)/ 3.714\} = 0.9989. Now the minimum angle is θ = 0.9989 Hence the selected parameters for the three-stage chain sampling plan of type ChSP (0,2,3) for given p_1= 0.67 and p_2 = 0.028 with minimum angle θ = 0.9989.

VI.CONSTRUCTION OF TABLES

The binomial model for the OC curve will be exact in the case of fraction non-conforming. It can be satisfactorily approximated with the Poisson model where p is small, n is large, and np < 5 when the quality is measured in terms of non-conformities, the Poisson model is the appropriate one. Under the Poisson assumption, the expression for

$$P_0 = e^{-np},\ P_1 = npe^{-np},\ P_2 = ((np))^{2/2})\, e^{-np},\ P_3 = ((np))^{3/2})\, e^{-np} \text{-------------------- (6)}$$

The equation cannot easily solve. The solutions for np for a given Pa have been found by Newton's method of successive approximation and are tabulated in Table 1 for different values of k_1, k_2, k_3.

VII. CONCLUSION: The present development would be a valuable addition to the literature and a useful device to the quality practitioners. Acceptance sampling is the technique which deals with the procedures in which decision either to accept or reject lots or process which are based on the examination of samples. The work presented in this paper relates to the new procedure for the construction and selection of tables for designing sampling inspection plan through Minimum Angle Method. This procedure reduces the cost of inspection for the producer and the consumer, gets good items. In practice it is desirable to design any sampling plan with the associated quality levels which concern to producer and consumer. Tables provided in this paper are tailor – made which are handy and readymade, which are also well considered for comparison purposes. Tables are also useful for developing and under developing countries, which have limited resources to the Industrial shop floor- situations.

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Table 1 Values of operating ratio for constructing ChSP (0,2,3) i=1.

k_1	k_2	k_3	p2/p1 for α = 0.05			p2/p1 for α= 0.01		
			α = 0.05 β = 0.10	α = 0.05 β = 0.05	α =0.05 β =0.01	α =0.01 β =0.10	α = 0.01 β = 0.05	α = 0.01 β =0.01
1	4	5	5.5010	9.2047	9.5483	10.6211	13.9254	19.0273
2	3	4	7.0714	8.3348	9.0952	10.1716	13.5015	21.9788
2	5	10	4.2124	5.4998	8.5111	18.1253	23.6650	36.6220
2	9	10	2.7654	3.6231	5.6591	17.4307	22.8366	35.6700
3	4	5	3.2911	4.2666	6.4483	3.7150	4.8162	7.2789
4	5	6	4.7196	6.1007	9.2601	27.7453	35.8649	54.4383
5	6	7	4.2898	5.5514	8.2792	22.3260	28.8924	43.0890
6	7	8	2.1788	2.7865	4.3083	2.6936	3.4449	5.3264
7	8	9	3.5541	4.2990	5.9187	11.2677	13.6295	18.7643
8	9	10	37.7775	45.8143	63.5241	65.0694	72.1861	77.5695
9	10	11	3.5439	4.2980	5.9617	11.2382	13.6299	18.9055

9	10	20	2.6421	3.2503	4.5612	58.5665	72.0470	101.1057
10	11	12	5.3252	6.4624	9.1963	35.8124	43.4600	61.8459
11	12	13	3.5475	4.2979	6.0275	32.3592	39.2041	54.9805
11	12	19	3.5588	4.2845	6.0578	7.9416	9.5609	13.5181
11	17	20	1.0746	1.3017	1.8314	19.0236	23.0425	32.4193
12	13	14	3.1227	3.6729	4.8556	8.4097	9.8917	13.0769
13	14	15	2.0786	2.4741	3.2940	4.8732	5.8004	7.7225
13	14	19	5.9515	7.0071	9.4257	6.8764	8.0961	10.8906
13	14	22	3.1252	3.6791	4.9648	8.4193	9.9113	13.3752

Table 2 Certain characteristic values for ChSP (0,2,3) through Trigonometric ratio

k_1	k_2	k_3	np_1	**np₂**	$P_a(p_1)$	$P_a(p_2)$	**Ntanθ**
1	4	5	1.9857	5.9923	0.95	0.1	47.51834
2	3	4	1.9559	5.9922	0.95	0.1	48.12046
2	5	10	1.8019	5.9721	0.95	0.10	48.15045
2	9	10	1.7688	5.972	0.95	0.10	48.14964
3	4	5	1.6933	5.9619	0.95	0.10	48.15078
4	5	6	1.6888	5.9538	0.95	0.10	48.14997
5	6	7	1.6378	5.9457	0.95	0.10	48.1511
6	7	8	1.5935	5.9376	0.95	0.10	48.15224
7	8	9	1.5567	5.9295	0.95	0.10	48.15337
8	9	10	1.5201	5.9214	0.95	0.10	48.15451
9	10	11	1.4995	5.9133	0.95	0.10	47.99309
9	10	20	1.4604	5.9052	0.95	0.10	48.15678
10	11	12	1.4028	5.8971	0.95	0.10	48.15792
11	12	13	1.3525	5.889	0.95	0.10	47.75578
11	12	19	1.3012	5.8809	0.95	0.10	48.16019
11	17	20	1.2561	5.8728	0.95	0.10	48.16132
12	13	14	1.2165	5.8647	0.95	0.10	48.16246
13	14	15	1.1808	5.8566	0.95	0.10	48.16359