DESIGN AND TESTING OF A SAMPLING PLAN FOR TWO CONTINUOUS PRODUCTION LINES

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ABSTRACT

This paper presents a plan CSP-1-2L for inspection of two continuous production lines. The plan is defined by 2 numbers i_1 and i_2 (the numbers of consecutive non-defective units that must be produced on lines 1 and 2 during a 100% inspection of the lines) and 2 fractions f_1 and f_2 (the specified sampling frequencies for lines 1 and 2 during a fractional inspection of the lines). CSP-1-2L computes 3 performance measures, average total fraction inspected, average total outgoing quality and average total outgoing quality limit, for given values of incoming fractions of defective units on line 1 (p_1) and on line 2 (p_2).

The validity and accuracy of the performance measure formulas for four inspection patterns have been tested by extensive simulations. Optimal inspection patterns have been found for the sets of p_1, p_2, i_1, i_2, r_1 ($=1/f_1$) and r_2 ($=1/f_2$) values for which the formulas are valid. For low levels of incoming fractions of defectives p_1 and p_2, the formulas for all performance measures are valid for all inspection patterns. However, for higher levels of p_1, p_2, or for large differences between them, the formulas are valid only for a restricted range of i_1, i_2, r_1, r_2 values. Further, if $p_1 < p_2$ then we must use $i_1 \leq i_2$ and $r_1 < r_2$, and if there is a large difference between p_1 and p_2, then there must also be large differences between i_1 and i_2 and between r_1 and r_2.

KEYWORDS: Continuous sampling plan, Continuous production lines.

1. INTRODUCTION

A continuous sampling plan (CSP) is a plan of sampling inspection for a product consisting of individual units (parts, subassemblies, finished articles etc.) that is manufactured in quantity by an essentially continuous process. A CSP is applicable only to units subject to nondestructive inspection on a GO-NOGO basis. It is intended primarily for use in process inspection of parts, or final inspection of finished articles, where it is desired to have assurance that the percentage of defective units in the accepted product will be less than some prescribed low figure. The original continuous sampling plan (CSP-1) has been described by H.F. Dodge [1] and further investigations of the plan have been carried out by many researchers. Reviews of CSPs are now available in textbooks (see, e.g., Duncan [2], Grant [3] and Montgomery [4]).

All of the CSPs discussed in the literature have been restricted to the case of one production line. If the operator inspects two production lines using a one-production line CSP, there will be large errors and the operator cannot calculate the actual performance measures of the plan. The main objective of this paper is to develop a CSP that can be used for two production lines. The paper describes the following:

1) The design of a continuous sampling plan for two production lines called CSP-1-2L.

2) The development of the theory and formulas for important performance measures in CSP-1-2L, such as the average total fraction inspected (ATFI), the average total outgoing quality (ATOQ) and the average total outgoing quality limit (ATOQL).

3) Tests of the validity and accuracy of the formulas for the performance measures by comparison of the values computed from the formulas with values obtained through extensive simulations.

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2. MATERIALS AND METHODS

2.1 The Operating Procedure of CSP-1-2L

The CSP-1-2L uses three different types of inspection scheme for the units being produced on 2 production lines. The schemes contain 4 parameters, namely 2 positive integers i_1 and i_2, and 2 fractions f_1 and f_2, which are defined by:

i_1 A number of consecutive non-defective units that must be produced on line 1 during a 100% inspection of units produced on line 1.

i_2 A number of consecutive non-defective units that must be produced on line 2 during a 100% inspection of units produced on line 2.

f_1 A sampling frequency for a fractional inspection of units produced on line 1.

f_2 A sampling frequency for a fractional inspection of units produced on line 2.

The units sampled during a fractional f_1 or f_2 inspection of a line must be an unbiased sample of units produced on the line. In all inspection schemes any defective unit that is detected will be replaced immediately by a non-defective unit.

The three different types of inspection scheme are as follows, where j = 1 or 2 and k = 1 or 2 and k ≠ j:

All(j)-0(k) 100% of units produced on line j and 0% of units on line k are inspected. The scheme must continue until a total of i_j consecutive non-defective units are produced on line j.

All(j)-F(k) 100% of units produced on line j are inspected and a specified fraction f_k of the units on line k are inspected. The 100% inspection on line j must continue until a total of i_j consecutive non-defective units are produced on line j.

If no defective unit is detected on line k before the 100% inspection on line j is completed, then the f_k inspection continues. However, if a defective unit is detected on line k before the 100% inspection on line j is completed, then the inspection on line k is stopped, i.e., 0% of units on line k are then inspected.

F-F The specified fraction f_1 of the units on line 1 and the specified fraction f_2 of the units on line 2 are inspected. This scheme continues until a defective unit is found on either line.

The operating procedure of CSP-1-2L is as follows:

1. The operator begins by using the inspection scheme All(1)-0(2).
2. The operator then switches to the inspection scheme All(2)-F(1).
3. The operator then begins a sequence of inspection steps using one of the four schemes All(2)-0(1), All(1)-F(2), All(2)-F(1) or F-F above. The selection of the inspection scheme for the new step depends on the results of the preceding step. The selection rules are as follows:
   a) If the preceding step was scheme All(2)-0(1), then the operator selects scheme All(1)-F(2) for the new step.
   b) If the preceding step was scheme All(j)-F(k) which was completed with 100% inspection on line j and f_k inspection on line k, then the operator selects scheme F-F for the new step.
   c) If the preceding step was scheme All(j)-F(k) which was completed with 100% inspection on line j and 0% inspection on line k, then the operator selects scheme All(k)-F(j) for the new step.
   d) If the preceding step was scheme F-F which finished with a defective unit on line j and no defective unit on line k, then the operator selects scheme All(j)-F(k) for the new step.
   e) If the preceding step was scheme F-F which finished with defective units being detected on lines 1 and 2 at the same time, then the operator selects scheme All(2)-0(1) for the new step.

In summary, a 100% inspection on either line must continue until the specified number i_1 or i_2 consecutive non-defective units are produced on the line. A 0% inspection on a line will be followed by a 100% inspection on the line. A successful 100% inspection on a line will be followed by an f_1 or f_2 inspection on the line. An f_1 or f_2 inspection in which a defective unit is detected will be followed by a 100% inspection on the line. An exception is in scheme F-F where detection of defects on the two lines at the same time will be followed by 100% inspection on line 2 and 0% inspection on line 1.

2.2 The Performance Measures used in CSP-1-2L

The performance measures that we define in CSP-1-2L are generalizations of the performance measures AFI (average fraction inspected), AOQ (average outgoing quality) and AOQL (average outgoing quality limit) used in the conventional 1-line CSPs [1]. The measures that we use are as follows:

- The average total fraction inspected (ATFI).
- The average total outgoing quality (ATOQ).
- The average total outgoing quality limit (ATOQL).

We have identified four different types of inspection patterns that can occur in the 2-line inspection process described in section 2.1. For each of the 4 patterns, the three performance measures are defined by:

Average total fraction inspected:

$$ATFI_i = \frac{TATI_i}{ACL_i} \quad ; \; i = 1, 2, 3, 4 . \qquad (1)$$

where

$TATI_i$ = Sum of the average number of units inspected on each line in a cycle of pattern i.

ACL_i = Sum of the average number of units produced on each line in a cycle of pattern i.

Average total outgoing quality:

$$ATOQ_i = \frac{(p_1 + p_2)}{2}(1 - ATFI_i) \quad ; \; i = 1, 2, 3, 4 . \qquad (2)$$

where p_1 and p_2 are the incoming fractions of defective units that are actually produced on lines 1 and 2, respectively.

Average total outgoing quality limit:

$$ATOQL_i = \max_{p_1, p_2} (ATOQ_i) \quad ; \; i = 1, 2, 3, 4 \qquad (3)$$

The values of these measures will depend on the values of the constants i_1, i_2, f_1, f_2 used in the inspection schemes described in section 2.1 and on the incoming fractions of defective units (p_1, p_2) that are actually produced by the two lines.

We have analyzed the cycles in each of the four patterns and derived the following formulas for the $ATFI_i$ as functions of i_1, i_2, f_1, f_2, p_1 and p_2.

$$ATFI_1 = \frac{2u_1 + u_2 + f_1 v_1 + f_2 v_2}{2u_1 + u_2 + v_1 + v_2 + s_2} \qquad (4)$$

$$ATFI_2 = \frac{2u_1 + 2u_2 + f_1 v_1 + f_2 v_2}{2u_1 + 2u_2 + v_1 + v_2 + s_1 + s_2} \qquad (5)$$

$$ATFI_3 = \frac{2u_1 + 2u_2 + 2f_1 v_1 + 2f_2 v_2}{2u_1 + 2u_2 + 2v_1 + 2v_2 + s_1 + s_2} \qquad (6)$$

$$ATFI_4 = \frac{2u_1 + u_2 + 2f_1 v_1 + 2f_2 v_2}{2u_1 + u_2 + 2v_1 + 2v_2 + s_2} \qquad (7)$$

where

$$u_1 = \frac{1-q_1^{i_1}}{p_1 q_1^{i_1}}, \quad u_2 = \frac{1-q_2^{i_2}}{p_2 q_2^{i_2}}, \quad v_1 = \frac{1}{f_1\ p_1}, \quad v_2 = \frac{1}{f_2\ p_2}, \quad s_1 = u_2 = \frac{1-q_2^{i_2}}{p_2 q_2^{i_2}}, \quad s_2 =$$

$$u_1 = \frac{1-q_1^{i_1}}{p_1 q_1^{i_1}}$$

with

q_1 = $1-p_1$ = fraction of non-defective units actually produced on line 1,
q_2 = $1-p_2$ = fraction of non-defective units actually produced on line 2,
u_1 = average number of units produced (or units inspected) on line 1 during a 100% inspection of line 1,
u_2 = average number of units produced (or units inspected) on line 2 during a 100% inspection of line 2,
v_1 = average number of units produced on line 1 during a fractional inspection of line 1,
v_2 = average number of units produced on line 2 during a fractional inspection of line 2,
f_1v_1 = average number of units inspected on line 1 during a fractional inspection of line 1,
f_2v_2 = average number of units inspected on line 2 during a fractional inspection of line 2,
s_1 = average number of units produced on line 1 during 0% inspection of line 1,
s_2 = average number of units produced on line 2 during 0% inspection of line 2.

The formulas for u_1, u_2, v_1, v_2, s_1 and s_2 are complicated and we will not give them here. For details of these formulas, see [5].

2.3 Tests of the Validity and Accuracy of Performance Measures for CSP-1-2L

In order to test the validity and accuracy of the performance measures that we have defined for CSP-1-2L, we have compared the results from our formulas with the values for the performance measures obtained from extensive simulations.

We have examined three different levels for the incoming fractions p_1 and p_2 of defective units produced on the 2 lines.

Level 1: Low level. $p_1, p_2 = 0.003$ or 0.005.
Level 2: Medium level. $p_1, p_2 = 0.01$ or 0.03.
Level 3: High level. $p_1, p_2 = 0.05$ or 0.07.

The values of i_1 and i_2 were selected from the 6 values 10, 15, 20, 30, 40, 50, and the values of $r_1 = 1/f_1$ and $r_2 = 1/f_2$ were selected from the 8 values 2, 3, 4, 5, 7, 10, 15, 25.

We carried out tests using the following procedure. We selected values for p_1 and p_2 and simulated the output of 2 production lines for these values by generating random sequences of defective and non-defective units. We then analyzed these sequences using the CSP-1-2L inspections defined by a selected set of values for i_1, i_2, r_1 and r_2. The simulations were repeated 60 times.

Before carrying out detailed tests of our formulas, we carried out some preliminary experiments to find sets of reasonable values for p_1, p_2, i_1, i_2, r_1 and r_2. We found that if $p_1 < p_2$, then i_1 and i_2 should be selected with $i_1 \le i_2$ and r_1 and r_2 should be selected with $r_1 < r_2$. Similarly, if $p_1 > p_2$, then we should select $i_1 \ge i_2$ and $r_1 > r_2$. For $p_1 \ne p_2$, we then made extensive tests using values of i_1, i_2, r_1, r_2 satisfying these conditions.

We carried out four types of detailed experiments:

Type 1: We selected $p_1 = p_2$, $i_1 = i_2$ and $r_1 = r_2$. Simulations were carried out for the 3 levels of p_1, p_2, the six possible values for i_1 and i_2 and the 8 possible values for r_1 and r_2.
Type 2: We selected $p_1 \ne p_2$ and at the same level.
Type 3: We selected $p_1 \ne p_2$ and at adjoining levels.
Type 4: We selected $p_1 \ne p_2$ with one value being in the low level and one value being in the high level.

For each set of values of the constants i_1, i_2, r_1, r_2, p_1, p_2, we computed the values of ATFI and ATOQ. The average values of ATFI and ATOQ over the 60 simulation runs were then calculated.

These average values were then compared with the values of $ATFI_i$ and $ATOQ_i$ computed from the formulas given in equations (4)-(7) and equation (2).

For each of the four inspection patterns and for each set of p_1, p_2 values, we analyzed our results to test the validity and accuracy of our formulas by comparing the results from the simulations with the results from our formulas. In testing the validity of an $ATFI_i$ formula, we accepted the formula as a valid formula if the difference between the $ATFI_i$ value from the formula and the average ATFI value from the simulations was less than or equal to 0.05. In testing the validity of an $ATOQ_i$ formula, we accepted the formula as a valid formula if the difference between the $ATOQ_i$ value from the formula and the average ATOQ value from the simulations was less than or equal to 0.005.

We then compared the validity of the formulas for each inspection pattern to find optimal inspection patterns for each set of p_1, p_2 values. We defined inspection pattern i to be an optimal pattern if the formulas for $ATFI_i$ and $ATOQ_i$ were valid for at least 98% of the acceptable sets of i_1, i_2, r_1 and r_2 values.

3. RESULTS AND DISCUSSION

From the results of the detailed experiments on CSP-1-2L, we found that the validity and accuracy of the formulas for the performance measures $ATFI_i$ and $ATOQ_i$, and the choices for the optimal patterns depended on the values of $p_1, p_2, i_1, i_2, r_1, r_2$.

In Table 1 we show, for each choice of p_1 and p_2 values, the percentages of experiments for different choices for i_1, i_2, r_1, r_2 for which the formulas in equations (4)-(7) and (2) are valid. In Table 2, we give a list of the optimal inspection patterns for each choice of p_1 and p_2 values and a list of the sets of restrictions on values of i_1, i_2, r_1 and r_2 under which the formulas for the $ATFI_i$ and $ATOQ_i$ for each pattern are valid.

3.1 Equal incoming fractions of defectives ($p_1 = p_2$)

Our simulations indicated that for $p_1 = p_2$ the validity and accuracy of the formulas depends on the level of defectives p_1 and p_2. For the lower levels of defectives ($p_1 = p_2 = 0.003, 0.005, 0.01$) all performance formulas are valid for $i_1 = i_2$ and $r_1 = r_2$ for the sets of i_1 and i_2 values from 10 to 50 and the sets of r_1, r_2 values from 2 to 25 used in our experiments. Further, since all 4 formulas for $ATFI_i$ and $ATOQ_i$ are valid for all i_1, i_2, r_1, r_2 values, they can all be regarded as optimal for these lower levels of defectives. However, for the higher levels of defectives (p_1, $p_2 = 0.03, 0.05, 0.07$), the formulas are valid only for a restricted range of i_1, i_2 and r_1, r_2 values. For $p_1 = p_2 = 0.03$ the formulas are valid for $i_1 = i_2 \leq 40$ and the optimal patterns are 1 and 2, for $p_1 = p_2 = 0.05$ the formulas are valid for $i_1 = i_2 \leq 20$ and the optimal pattern is 2, and for $p_1 = p_2 = 0.07$ the formulas are valid for $i_1 = i_2 \leq 15$ and the optimal pattern is 2.

3.2 Unequal incoming fractions of defectives ($p_1 \neq p_2$)

Our simulations showed that for $p_1 \neq p_2$ the validity and accuracy of the formulas depends on the level of defectives p_1 and p_2, the choices for the i_1 and i_2 values, and the choices for the r_1 and r_2 values. As stated above, our preliminary experiments indicated that if $p_1 > p_2$, then the only reasonable choices are $i_1 \geq i_2$ and $r_1 > r_2$. Similarly, if $p_1 < p_2$, then the only reasonable choices are $i_1 \leq i_2$ and $r_1 < r_2$.

We will discuss the cases for $p_1 < p_2$ only, since the results for $p_1 > p_2$ are similar. The values for p_1 and p_2 can be selected from the same level, or from adjoining levels or from extreme levels. We will discuss each of these cases in turn, starting with p_1, p_2 values chosen from the same level.

3.2.1 Incoming fractions of defectives selected from the same level

From Table 1 and Table 2 it can be seen that for the low level of defective values ($p_1 = 0.003$, $p_2 = 0.005$) all $ATFI_i$ values are valid for all values of $i_1 \leq i_2 \leq 50$ and for all values of $r_1 < r_2 \leq 25$. Therefore, all of the 4 patterns are optimal.

For the medium level of defective values ($p_1 = 0.01$, $p_2 = 0.03$) the $ATFI_1$, $ATFI_2$ and $ATFI_3$ formulas are valid for all tested values $i_1 \leq i_2 \leq 50$ and $r_1 < r_2 \leq 25$. However, the $ATFI_4$

formula is only valid for some of the possible choices for i_1, i_2, r_1, r_2. We therefore accept patterns 1, 2 and 3 as optimal patterns.

For the high level of defective values ($p_1 = 0.05$, $p_2 = 0.07$) the $ATFI_1$ and $ATFI_2$ values are valid for more than 98% of the values for $i_1 \leq i_2 \leq 20$ for all values of r_1 and r_2. The $ATFI_3$ and $ATFI_4$ values are valid for a much smaller percentage of the values for $i_1 \leq i_2 \leq 20$. We therefore accept patterns 1 and 2 as optimal for $i_1 \leq i_2 \leq 20$.

3.2.2 Incoming fractions of defectives selected from adjoining levels

For the value of p_1 selected from the low level ($p_1 = 0.003$ or 0.005) and the value of p_2 selected from the medium level ($p_2 = 0.01$ or 0.03), we see from Table 1 that all $ATFI_i$ formulas are valid for all $i_1 \leq i_2 \leq 50$ values but only for a restricted set of r_1, r_2 values. The main restriction is that r_2 cannot be chosen as a high value when r_1 is chosen as a low value. In the case for higher difference between p_1 and p_2 the restriction is that r_2 cannot be chosen as a low value when r_1 is chosen as a low value. The detailed restrictions are stated in column 4 of Table 2. For these restricted sets of values, the optimal patterns are 1, 2, 3, 4 for $p_2 = 0.01$ and they are 1 and 2 for $p_2 = 0.03$.

For the value of p_1 selected from the medium level ($p_1 = 0.01$ or 0.03) and the value of p_2 selected from the high level ($p_2 = 0.05$ or 0.07), we see from Table 1 that all $ATFI_i$ formulas are valid only for a restricted range of i_1, i_2, r_1, r_2 values. Table 2 shows that the $ATFI_1$ and $ATFI_2$ values are valid for more than 98% of the possible choices for $i_1 \leq i_2 \leq 50$ ($p_1 = 0.01$, $p_2 = 0.05$), for $i_1 \leq i_2 \leq 30$ ($p_1 = 0.03$, $p_2 = 0.05$) and for $i_1 \leq i_2 \leq 20$ ($p_1 = 0.01$ or 0.03, $p_2 = 0.07$) for all choices of values for $r_1 < r_2 \leq 25$. For these restrictions, the optimal patterns are 1 and 2.

3.2.3 Incoming fractions of defectives selected from extreme levels

For the value of p_1 selected from the low level ($p_1 = 0.003$ or 0.005) and the value of p_2 selected from the high level ($p_1 = 0.05$ or 0.07), Table 1 shows that the $ATFI_i$ formulas are valid only for a very restricted range of i_1, i_2, r_1, r_2 values. A detailed analysis of the simulation results then showed that we had to use the values $i_1 = 10$, $i_2 = 20$ or 30 and $r_1 = 2, 4, 7, 10$ and $r_2 = 3(r_1)$ or $4(r_1)$ to obtain an optimal inspection pattern. For these restrictions, the optimal pattern is 2.

Table 1. The percentages of simulations for which our formulas for $ATFI_i$ and $ATOQ_i$ agree with the average ATFI values and average ATOQ values computed from the simulations to tolerances of less than or equal to 0.05 for ATFI and less than or equal to 0.005 for ATOQ.

Incoming fraction of defective units		The percentages of simulations for which the differences between $ATFI_i$ values from formulas and the average ATFI values from simulations ≤ 0.05				The percentages of simulations for which the differences between $ATOQ_i$ values from formulas and the average ATOQ values from simulations ≤ 0.005			
p_1	p_2	$ATFI_1$	$ATFI_2$	$ATFI_3$	$ATFI_4$	$ATOQ_1$	$ATOQ_2$	$ATOQ_3$	$ATOQ_4$
0.003	0.003	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
0.005	0.005	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
0.01	0.01	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
0.03	0.03	96.43	96.43	78.57	75.00	100.00	100.00	100.00	100.00
0.05	0.05	71.43	78.57	85.71	53.57	92.86	100.00	100.00	100.00
0.07	0.07	53.57	50.00	78.57	42.86	64.29	71.43	92.86	89.29
0.003	0.005	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
0.01	0.03	100.00	100.00	98.25	89.47	100.00	100.00	100.00	100.00
0.05	0.07	70.18	66.67	82.46	40.35	78.95	96.49	100.00	84.21
0.003	0.01	97.60	98.40	97.60	97.60	100.00	100.00	100.00	100.00
0.005	0.01	91.20	96.00	85.60	85.60	100.00	100.00	100.00	100.00
0.003	0.03	93.60	95.20	93.60	92.00	100.00	100.00	100.00	100.00
0.005	0.03	100.00	100.00	96.00	91.20	100.00	100.00	100.00	100.00
0.01	0.05	100.00	94.40	85.60	67.20	99.20	100.00	96.00	91.20
0.03	0.05	87.20	88.80	72.80	41.60	100.00	100.00	100.00	98.40
0.01	0.07	83.20	92.00	76.80	60.00	84.00	80.00	68.00	64.00
0.03	0.07	70.40	67.20	81.60	47.20	96.00	100.00	96.80	89.60
0.003	0.05	55.71	72.86	42.86	32.86	68.57	71.43	61.43	58.57
0.005	0.05	74.29	88.57	54.29	28.57	77.14	82.86	71.43	60.00
0.003	0.07	35.71	58.57	27.14	24.29	27.14	22.86	17.14	14.29
0.005	0.07	47.14	64.29	44.29	32.86	40.00	31.43	18.57	15.71

Table 2. The optimal inspection patterns for given values of incoming fractions of defective units (p_1, p_2). (A pattern i is defined to be an optimal inspection pattern if the formulas for $ATFI_i$ and $ATOQ_i$ give valid values for at least 98% of the simulation runs for the restrictions on i_1, i_2, r_1 and r_2 values given in the table.)

p_1	p_2	Restrictions on values of i_1, i_2	Restrictions on values of r_1, r_2	Optimal inspection patterns
0.003	0.003	-	-	1, 2, 3, 4
0.005	0.005	-	-	1, 2, 3, 4
0.01	0.01	-	-	1, 2, 3, 4
0.03	0.03	≤ 40	-	1, 2
0.05	0.05	≤ 20	-	2
0.07	0.07	≤ 15	-	2
0.003	0.005	-	-	1, 2, 3, 4
0.01	0.03	-	-	1, 2, 3
0.05	0.07	≤ 20	-	1, 2
0.003	0.01	-	-	1, 2, 3, 4
0.005	0.01	-	-	1, 2, 3, 4
0.003	0.03	-	-	1, 2
0.005	0.03	-	-	1, 2
0.01	0.05	-	-	1, 2
0.03	0.05	≤ 30	-	1, 2
0.01	0.07	≤ 20	-	1, 2
0.03	0.07	≤ 20	-	1, 2
0.003	0.05	$i_1 = 10$	$r_1 = 2, 4, 7, 10$	2
0.005	0.05	$i_2 = 20, 30$	$r_2 = 3(r_1), 4(r_1)$	
0.003	0.07			
0.005	0.07			

4. CONCLUSIONS

A CSP-1-2L sampling plan has been proposed for inspection of two continuous production lines and the theory and formulas for the performance measures of the plan have been obtained. We have analyzed the validity and accuracy of the formulas for the performance measures of the plan for the case where there is a known incoming fraction of defective units (p_1) on line 1 and a known incoming fraction of defective units (p_2) on line 2. The sampling plan requires the choice of four constants i_1, i_2, f_1 and f_2, where i_1 and i_2 are numbers of consecutive non-defective units that must be produced on lines 1 and 2, respectively, during a 100% inspection of the line, and f_1 and f_2 are specified sampling frequencies on lines 1 and 2, respectively, during a fractional inspection of the line.

The performance measures used in the plan are an average total fraction inspected (ATFI), an average total outgoing quality (ATOQ) and an average total outgoing quality limit (ATOQL). A theory for these performance measures has been developed and formulas for ATFI, ATOQ and ATOQL have been derived for four different patterns of inspection that can occur in the plan. The validity and accuracy of our formulas for ATFI and ATOQ have been tested for each of the 4 patterns by comparing them with average values for ATFI and ATOQ obtained by extensive simulations over a wide range of p_1, p_2, i_1, i_2, r_1 ($=1/f_1$) and r_2 ($=1/f_2$) values. For each set of p_1, p_2 values, the sets of i_1, i_2, r_1 and r_2 values for which the formulas are valid have been determined. Optimal inspection patterns have been found for the sets of p_1, p_2, i_1, i_2, r_1 and r_2 values for which the performance measure formulas are valid.

The simulations show that CSP-1-2L is suitable for inspection of two continuous production lines. For small values of the incoming fractions of defectives (p_1, p_2 = 0.003, 0.005, 0.01) we have found that the formulas for all of our performance measures are valid for each of the four inspection patterns. For higher levels of the incoming fractions of defectives we have found that the formulas for our inspection patterns might be valid only for a restricted range of choices for the i_1, i_2, r_1 and r_2 values. The detailed conditions for the validity and accuracy of our formulas have been determined. As a general rule, the higher the level of the incoming fractions of defectives the more restricted the range of i_1, i_2, r_1 and r_2 values for which the formulas are valid. We have found that if $p_1 < p_2$ then we must also use $i_1 \leq i_2$ and $r_1 < r_2$. Further, if there is a large difference between p_1 and p_2, then there must also be large differences between i_1 and i_2 and r_1 and r_2.

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