Research Field: Industrial Engineering

Study Of Product Quality's Effect Based On Variable Sampling Plan Using Process Capability Indices (PCI) As Trigger Of Maintenance Policy Decision

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Abstract-Interaction between quality and maintenance policy have been known for long ago. Product quality can be affected by the degradation of system which can increase the probability of failure and the number of fraction of nonconforming product. Therefore the role of maintenance activities required to maintain and restore the performance of the production unit. Inference of deterioration based on the quality of products is an alternative that is more effective and efficient than the deterioration inference based on the condition of the equipment (traditional condition-based maintenance). Beside the product quality is directly affected by the degradation process of production, the degradation of product quality provide feedback about the condition of the equipment without having to involve the expensive technology.

This study proposes the interaction between maintenance policy and product quality of production system that depend on the reliability and quality deterioration. Quality control is conducted using a variable sampling plan by PCI as a decision criterion. PM Activities carried out when the number of rejection lot sequentially reaches a specified threshold. Numerical example is conducted to demonstrate the implementation of the proposed interaction model. The behavior of the proposed model for various parameter is examined and discussed.

Keywords-Variable sampling plan, PCI, quality-based maintenance

1. Introduction

For the last three decades,a lot of effort have been made by researchers in studying various interaction between maintenance, quality control and production. [1]It is characterized by many researches who proposed integration model between those three basic functions in the literature.In the literature on integration model, almost all models did not consider the deterioration of the quality and reliability equipment simultaneously.When the two phenomena are observed, Preventive Maintenance (PM) plays a dual role, increase the reliability of production equipmentand restore the product quality at the desired level [2]. Because the deterioration has direct impact on the production system and the output of quality, thus its better to makePM decisions on the actual level of deterioration rather than the equipment age [3]. Then, the inference deterioration based on the products quality becomes more effective and efficient because the degradation of product quality provide the feedback of the equipments's condition without having to involve expensive technologyas incondition-based maintenance.Researchs about the determination of maintenance activity based on feedback of quality information starting to get the attention of the researchers. But, there are very few researchersdiscuss aboutthe use of information from sampling activity for conditioning monitoring and maintenance decision making.Acceptance sampling (AS) is a practical tool in the application of quality assurance and has been widely used in many industries for a long time. [4]. In the manufacturing industry with high technology, where the produced product has very low fraction defective, The measurement of fraction non-conforming by approximation approach is no longer working well because the inspected sample may not contain the defect. PCI is an alternative method that is more effective than traditional method to measure the fraction of non-conforming because it is more accurate and reliable [4].

This research proposes the interaction of maintenance policy and quality control for production system that depend on the reliability and quality deterioration. Quality control conducted using variable sampling plan (VSP) that use PCI as a decision criterion. PM Activities carried out when the number of rejection of lot sequentially reach specified limits. In this paper, we use an effective acceptance sampling for lot sentencing based on the most popular index Cpk.

2. Designing Cpk Acceptance Sampling Plan

Cpk index considered as yield-based index because this index provides a boundary on the process yield for the normal distribution.In practice, the process mean and standard deviation of the process (μ and σ) is unknown, the sample data must be taken to calculate the index Cpk.To estimate the Cpk index,[5]used$\hat{C}$pkinsteador natural estimator. The Natural estimator of $\hat{C}_{pk}$obtained by replacing conventional process mean μ and standard deviationσ by$\bar{x} = \sum_{i=1}^{n} x_i / n$ and S $s = \left[\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{(n-1)}\right]^{1/2}$. The equation of natural estimator $\hat{C}_{pk}$is as follow[4]:

$$\hat{C}_{pk} = \frac{d - |\bar{x} - M|}{3s}$$

Where d=(USL-LSL)/2 is half of the specification interval, M= (USL+LSL)/2 is the mid-point between the lower and the upper specificaton (USL,LSL). Under the assumption the normality, [5] obtain the Cdf of

$\hat{C}pk$which is the miture of chi-square distribution and normal distribution.

The operating procedure of the proposed variablessampling plan based on $\hat{C}_{pk}$index is stated as follows:

Step 1: Determine process capability requirements (i.e. $C_{AQL}$and C_{RQL}) α-riskand the β-risk

Step 2: Check Table 1 to find the critical acceptance value (k) and the required number of product units for inspection (n) based on given values of α-riskand the β-risk, . $C_{AQL}$and C_{RQL}.
Step 3: Calculate the value of$\hat{C}_{pk}$ (sample estimator)from the n inspected sample data.
Step 4: Make a decision to accept the entire products ifthe estimated$\hat{C}_{pk}$value is greater than the critical value k ($\hat{C}pk$>k) Otherwise, we reject the entire products.

From the definition of the Cpk index, it may be rewritten as $C_{pk} = (\frac{d}{\sigma} - |\xi|)/3$, where $\xi = (\mu - M)/\sigma$. Thus, given Cpk=C, b=d/σ can be expressed as $b = 3C + |\xi|$.
Let P(C) be the operating characteristic(OC) function, then:
Pa(Cpk) = P($\hat{C}pk$ ≥k)=1-P($\hat{C}pk$<k)=1-F$\hat{C}pk$ (k)

$$= \int_0^{b\sqrt{n}} G\left(\frac{(n-1)(b\sqrt{n}-t)^2}{9n(C_0)^2}\right)\left(\phi(t+\xi\sqrt{n})+\phi(t-\xi\sqrt{n})\right)dt$$

Considering the probability of acceptance Pa products (Cpk) then the determination of the plan parameters (n, k) based on the index Cpk must fulfill two conditions on the quality level and allowable risk below: Thus, the plan parameters (n, k) can be obtained by completing two parallels of non-linier simultaneously. The equation is as follows:

$$\left[1-\int_0^{b_A\sqrt{n}} G\left(\frac{(n-1)(b_A\sqrt{n}-t)^2}{9n(C_0)^2}\right)\left(\phi(t+\xi\sqrt{n})+\phi(t-\xi\sqrt{n})\right)dt\right] - \alpha \le 0,$$

and

$$\left[1-\int_0^{b_R\sqrt{n}} G\left(\frac{(n-1)(b_R\sqrt{n}-t)^2}{9n(C_0)^2}\right)\left(\phi(t+\xi\sqrt{n})+\phi(t-\xi\sqrt{n})\right)dt\right] - (1-\beta) \ge 0,$$

Two parallels of non-linier above then resolved use matlab software to find solutions of those equation.

3. Interaction of Quality product and PM

In this study, author adopt the concept of tightened-normal-tightened (TNT) sampling plan as a decision criterion or treshold on quality product for making PM decision. The activity of PM decision is conducted when the number of rejection of lot in a row reached to a prescribed treshold. If x is the number of the rejected lot sequentially, so in this research study, the value of X will be set 2 on all inspected lot, where if there were twice rejection sequentially, so the factory will do the PM activity.
In this study, for each of simulation will be conducted about 100 times in in the same number of samples. The simulation will be conducted three times on the same sample number which the simulation will be done in three times to the different value of Caql and Crql. For the first simulation performed on C_{AQL} andC_{RQL} as those conducted in numerical example, the 1:33 and 1:00 with the producer's α-risk = 0.05 and β-consumer's risk = 0:05. Where the number of samples and cititical value (n, k) is n = 80 and k = 1.1669. The second simulation performed on C_{AQL} and C_{RQL}, ie 1:50 and 1:33 with the producer's α-risk = 0.05 and β-consumer's risk = 0:05. Where the number of samples and cititical value (n, k), namely n = 418 and k = 1.4154. While the third simulation conducted on C_{AQL} and C_{RQL}, namely 1.67 and 1:33 with the producer's α-risk = 0.05 and β-consumer's risk = 0:05. Where the number of samples and the critical value (n, k), namely n = 117 and k = 1.5016. Just as in the numerical example, all samples taken at random will be tested for normality and consider as normal distribution. According [6], the adequacy of the normality assumption must be examined before making the decision acceptance of products based on the proposed sampling. If there may be some situations that the product data may not follow a normal distribution, then the transformation techniques (such as Box-Cox tranformation) can be performed using several available computer software (such as Minitab and so on).

4 Analysis and Conclusion

From the result of interaction model, the chart of each simulation show the fluctuatif of process capability indices trend. But, we can know if the process capability indices trend decrease significantly where the rejected lot reach the treshold until PM decision is made, then the deterioration of process could be kown. Deterioration impact directly to the production system avaibility and output quality. Meanwhile, the output quality is very affected directly by deterioration of process production. Then the interaction between quality and maintenance can lead some advantages. First,the inference of deterioration based on product quality is an effective and efficient alternative. Second, the proposed PM quality-based is very usefull for managerial to increase their quality performance.

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