CHAPTER 1 INTRODUCTION

1.1 Problem Statement

Techniques of statistical process control are widely used by the manufacturing industry to detect and eliminate defects during production. The control chart technique may be considered as a graphical expression of statistical hypothesis testing. Statistical Process Control (SPC) use statistical technique for checking, analyzing and finally improving the quality of the processes, reducing their variability. They are not only able to separate types of variation in the process, but also able to analyze and indicate root causes of variations in the process. They also alert process control personnel to halt process of defect analysis and process improvement. The average controls chart by the Shewhart's control charts are likely to be use extensively, but the average control charts (applying Shewhart's method) are convenient for the variability consists of two parts: the common cause and the special cause. The Common causes are inherent part of the procedure, so they cannot be avoided. On the other hand, the existence of the Special causes is not an inherent part of the procedure, and the main objective of the SPC technique is the disaggregating between a common cause and special cause, in order to eliminate the latter one.

Among the univariate procedures, Shewhart's $\overline{X}$ chart supplemented with run rules has been widely used (see Nelson, 1984). Two very effective alternatives to the $\overline{X}$ chart may be used when detection of small sustained shifts is important (see Montgomery, 1991): the two-sided Cumulative Sum (CUSUM) chart and the Exponentially Weighted Moving Average (EWMA) chart. EWMA control chart is used to monitor quality characteristics of raw material or products in a continuous process. It is widely used in continuous flow processes; for example, a chemical plant may collect data periodically on the results of analysis used to determine the percentages of certain chemical constituents. The EWMA utilizes all previous observations get older and older. By varying the parameter of the EWMA statistic, the 'memory' of the EWMA control chart can be influenced. A control chart based on the EWMA was introduced by Roberts (1959). More recent references include Hunter (1986), Crowder (1989), and Lucas and Saccucci (1990).

An alternative technique to detect small shifts is to use the EWMA methodology developed by Roberts (1959). This type has some very attractive properties, in particular:

1. Unlike $\overline{X}-R$ chart and individuals charts, all of the data collected over time may be used to determine the control status of a process.
2. The EWMA is often superior to the CUSUM charting technique for detecting "large" shifts.
3. EWMA schemes may be applied for monitoring standard deviations in addition to the process mean.
4. There exists the ability to use EWMA schemes to forecast values of process mean.
5. The EWMA methodology is not sensitive to normality assumptions.

An important assumption that underpins the use of the EWMA (as well as other control charts) is that the samples obtained over time may be independent. If that assumption is violated, there are two possible scenarios:

1. Positive autocorrelation (e.g. low values tend to be followed by other low values, or high values tend to follow other high values). This can possibly lead to control limits that may be too narrow-positive correlation can increase the frequency of false alarms.
2. Negative autocorrelation (e.g. processes that frequently over-correct) may lead to overly wide control limits; hence special causes of variation that may be present in the process could be missed.

In many applications, the quality of the process is characterized by a single quality characteristic (called random variable), which is usually assumed to follow a normal distribution. However, it is increasingly common today for processes to be characterized by more than one random variable. These random variables are usually correlated, and assumed to follow a multivariate normal distribution. Most of works on control charts in the multivariate case has concentrated on the problem of monitoring the process mean vector. Harold Hotelling established multivariate process control techniques in his 1947 pioneering paper. Hotelling (1974) applied multivariate process control methods in bombsights problem. There are multivariate extensions for all kinds of univariate control chart, such as multivariate Shewhart type control charts, multivariate CUSUM control charts, and multivariate EWMA control charts. In addition, there are unique procedures for the construction of multivariate control charts, based on multivariate statistical.

A multivariate Shewhart type control chart uses the information only from the current sample and they are relative insensitive to small and moderate shifts in the mean vector. Multivariate Cumulative Sum (MCUSUM) and Multivariate Exponentially Weighted Moving Average (MEWMA) control charts are developed to overcome this problem. So there are two groups of SPC, i.e. Univariate Statistical Process Control (USPC) and Multivariate Statistical Process Control (MSPC) which are used for different scenarios. The univariate quality control has only one process output variable or quality characteristic measured and tested. One of the disadvantages of the USPC is that for a single process, there are many variables simultaneously. One of the most popular multivariate control statistics is the MEWMA (Multivariate Exponentially Weighted Moving Average). EWMA control chart provide more sensitivity to small shift in the univariate case, and it can be extended to multivariate quality control problem.

The "Single" charts for variables data were developed like MSE Chart (Lowry, et al., 1992) which use only mean squares of deviations from the target value to plot two non-Crossing measurements on a single chart, *T* chart (Cheng and Li , 1993) which plots the sum of absolute deviations of the extreme data values from the target value on a single chart and SC chart (Chao and Cheng, 1996, 2008) which uses one 2-D chart to control location $\left(\bar{X}\right)$ and spread $\left(\sigma_{n-1}\right)$ simultaneously. Cheng and Mao (2008) proposed a multivariate control chart, A Multivariate Semi-Circle Control Chart for Variable Data, which can be used to control the location shift or/and the variation change of a multivariate process simultaneously.

The MEWMA control chart design methods specify the optimal selection of variable parameters (sample size (n), the interval between sample (h), exponential weight used for each quality characteristic (r), the control limit for the MEWMA process (k) in the chart. These decisions were based on statistical criteria, through restricting the probability of Type I or Type II errors. Using control charts is in fact economically motivated though the selection of design parameters that did not originally use cost information to motivate. The operator can control the cost of running and monitoring a process by ad hoc basis though cost tradeoffs that are not explicitly used to choose chart parameters. So control charts became increasingly popular. The idea of designing charts on the basis of cost tradeoffs, leads to economic design. Using the economic design and statistic criteria minimizes the average cost when a single out-of-control state (assignable cause) occurs. Duncan's cost model includes the cost of sampling and inspection, the cost of defective products, the cost of false alarms, the cost of searching for assignable caused, and the cost of process correction. Benerjee and Rahim (1988) modified Duncan's model. They recommend the use of non-uniform sampling intervals when the time to occurrence of the assignable cause follows a Weibull distribution having increasing hazard rates. The idea of using non-conform sampling scheme was extended by some researchers, for example, Parkhideh and Case (1989); Ohta and Rahim (1997); Rahim and Ben-Daya (1998). The works may be appropriate for some processes which deteriorate over time, but they are very complicated and difficult to implement at the shop level because the sample size, sampling interval, and action limit coefficient decrease slowly with the age of the system. This makes administration of such chart tedious (Costa, 2001).

Loss cost is important in manufacturing. It is major factor of economic model that require the minimize cost. Many researcher uses Taguchi loss function to optimize the loss cost in process.

The objectives are to propose an economic model for EWMA control chart, MEWMA control chart and Semi-Circle MEWMA control chart when all design parameters are variable. The design parameters are allowed to vary in real time design, variable parameters which vary in real time, are based on current sample information. The models are developed, providing a cost function, which represents the cost per time unit or controlling the quality of a process through the EWMA control chart with variable parameters (VP EWMA control chart), MEWMA control chart with variable parameters (VP MEWMA control chart) and extend multivariate Semi-Circle Control to Semi-Circle MEWMA control chart with variable parameters (VPSC MEWMA control chart). As the cost function is a function of the design parameters and economic design of the control charts, it provided a device for optimal selection of design parameters. So, the cost function of VP EWMA control chart, VP MEWMA control chart and VPSC MEWMA control chart having all design parameters variable and economic design were considered. We developed the economic design of VP EWMA control chart, VP MEWMA control chart and VPSC MEWMA control chart to determine the values of the five test variables of the chart (i.e., the sample size (n), the sampling interval (h), the warning limit coefficient (w), the control limit (k) and the exponential weight constant (r). By optimizing these parameters, the total loss cost per hour $(E(L))$ is expectedly minimized.

The rest of this work is organized as follows:

Chapter 2, we discuss the literature reviews and theoretical background.
Chapter 3, the economic analysis of the integrated model is discussed.
Chapter 4, the computational results of total hourly cost optimization by genetic algorithm.
Chapter 5, conclusion and discussion are discussed.

1.2 Objectives of research

1. To develop the economic design EWMA control chart with variable parameters.
2. To extend the cost model of Costa (2001) to the VP MEWMA control chart and VPSC MEWMA control chart and find the minimum total hourly loss cost in process by VP MEWMA and VPSC MEWMA using genetic algorithm.

1.3 Scope of research

Model assumptions

To simplify the mathematical manipulation and analysis, the following assumptions are made:

1. The process characteristic monitored by the EWMA control chart follows a normal distribution with mean (μ) and standard deviation (σ).
2. In the start of the process, the process is assumed to be in the safe state; that is $\mu = \mu_0$.
3. The process mean may be shifted to the out-of-control region; that is, $\mu = \mu_0 + L\sigma$.
4. The process mean may be shifted to the warning region; that is, $\mu = \mu_0 + w\sigma$.
5. If the process is within warning limit, it always goes out-of-control.
6. The p dimensional random vector X, which represents p quality characteristics, is normal characteristics, is normal distributed with the mean vector μ and known covariance matrix Σ_X.
7. The process assumed to start with an in-control state $(\mu = \mu_0)$ but after a random time of in-control operation it will be disturbed by a single assignable cause that causes a fixed shift in the process mean vector $(\mu = \mu_1)$.
8. The process after the shift remains out-of-control until the assignable cause is eliminated (if possible).
9. The inter-arrival time of the assignable cause disturbing the process is assumed following an exponential distribution with a mean $\frac{1}{\lambda}$ hours.
10. The process is stopped if the T^2 (VP MEWMA) or T_p (VPSC MEWMA) value falls outside the action limit, and then a search starts to find the assignable cause and adjust the process.

11. During each sampling interval, there exists at most one assignable cause which makes the process out of control, the assignable cause will not occur at sampling time.

12. All the process costs (including sampling costs, in-control and out-of-control production cost, warning, false alarm and repair costs) are known.

13. $r_1 = r_2 = \ldots = r_p = r$ (Weight past observation similarly for the p quality characteristics).

1.4 Advantages of research

1. By designing parameters and varying variable by EWMA control chart, efficiency can be found in this design.
2. By designing parameters and varying variable by VP MEWMA control chart VPSC MEWMA control chart, efficiency can be found in this design.
3. It can be used to develop other control charts and find minimal hourly loss cost function