Chapter 0

Introduction and Chapter-wise Summary

0.1 Introduction :

Statistical methods and their applications in quality improvement have had a long history. Dr. Walter A. Shewhart of the Bell Telephone Laboratories developed statistical control chart concept in 1924, which was formal beginning of statistical quality control. Towards the end of 1920's Harold F. Dodge and Harry G. Roming both of Bell Telephone Laboratories developed statistical based acceptance sampling as a alternative to 100% inspection. Dr. Juran who worked with Dr. W. A. Shewhart is one of the founding father of Statistical Quality Control. A good account of history of quality methodology along with timeline has been given by Montogomery(1996).

Statistical Quality Control concepts were used in word war II in manufacturing industries. Wartime expenses made it apparent that statistical techniques were necessary to control and improve quality. Since 1980 there has been a profound growth in the use of statistical methods for quality improvement.

Industrial organizations are now using statistical techniques and getting benefit in terms of quality and money. In fact use of statistical techniques for improvement of quality of the product inparticular and quality of the entire system ingeneral has become mandatory on the organizations seeking for ISO certification. In the following we first give definition of quality as given in Montgomery (1996) and then discuss the statistical aspects of quality control.

The traditional definition of quality of products and services is based on the viewpoint that they must meet the requirements of those who use them.

Definition of Quality :

i) "Quality means fitness for use."

This definition is somehow associates quality with conformance of the product. However one can talk about the term quality inspite of meeting the customer's requirement. Motivated with this view another way of defining quality as ;

ii) "Quality is inversely proportional to the variability."

Therefore as per definition (ii) above in order to improve the quality of the product one has to reduce the variability in process and products.

In the following we introduce concept of variation in context of quality control.

The manufacturing process always involves a certain amount of variation in the end product. The concept of variation states that no two items will be perfectly identical even if extreme care is taken to make them identical in some respect. Variation is a fact of nature, which is bound to occur. Therefore two extremely similar things are difficult to obtain. The variability of the measurable quality characteristic should be reduced to improve the quality.

There are two types of causes of variations.

Variations

Chance causes | Assignable causes

In the frame of statistical quality control the natural variability which is beyond the control and which occurs at random is called as *variation due to chance cause*. It is also called *random variation* or *inherent* or *natural variation*. These variations may be due to the inherent characteristic of process or machine, which occurs at random like fluctuation in electric current, error in basic measurement devices etc.

The unnatural variation is known as variation due to *assignable causes*. The variations due to assignable causes are great as compared to variations due to chance causes and it can be controlled. With these two kinds of variations we now introduce the term statistical control of the process.

Statistical Control:

A process that is operating with only chance causes of variations present alone is said to be in *statistical control or in-control.* A process that is operating in presence of assignable causes is said to be *out of control.*

Since the variability can be described in statistical terms, the statistical methods play a central role in quality improvement. We can classify the data on quality characteristic as either attribute data or variable data. Characteristic such as length, voltage, viscosity, weight, diameter, eccentricity, electric resistance, tensile strength etc. are variable data where as characteristic such as number of defects, number of items of products, number of crakes etc. are discrete data.

A value of measurement, that corresponds to the desired value for the quality characteristic is called *nominal* or *target value.*

The ranges or limits usually bound these target values. The largest allowable value for the quality characteristic is called *Upper Specification Limit* (USL) and smallest allowable value for quality characteristic is called *Lower Specification Limit* (LSL). Some quality characteristics have upper or lower specification limit on only one side of the target. For example the compressive strength used in automobile bumper, has a target value and lower specification limit, but no upper specification limit. The elasticity of material like rubber or wire has only upper specification limit but no lower specification limit.

The components or products, which fail to meet one or more specifications, are called *defective* or *non-conforming units*. In such cases, we usually classify each item inspected as either conforming or non-conforming. Such quality characteristics are called *attributes*.

Statistical Process Control (SPC) is a collection of statistical tools, useful in analyzing quality and improving the performance of the production process. A measure objective of SPC is to detect the occurrence of assignable causes of process shift quickly.

Therefore to control quality of the process one has to go back to search the reason for production of defective units and the aim remains to bring the production measure to the target value and no assignable causes of variations should present.

SPC has seven major tools and are known as "the magnificent seven" as:

1. Histogram or Steam and leaf display.
2. Check sheet.
3. Pareto chart.
4. Cause and effect diagram.
5. Defect concentration diagram.

6. Scatter diagram.

7. Control charts.

We note that all the above seven tools are graphical/diagrammatic so that people working on shop floor can understand and use these tools in a better way. The details about these tools can be found in Montgomery (1996).

Among these seven tools '*control chart*' is the most technically sophisticated tool. The present study is related to control charts based on nonparametric statistic. In the following section we take an account of literature on control charts in general and nonparametric control chart inparticular.

0.2 Literature Survey :

Since 1924, There have been number of research papers on the study of control charts, one may refer to Montgomery (1996) for list of references. However emphasis has been given on parametric control charts. If the construction and in-control properties of the control chart depend on the underlying distribution of the process output, we call the control chart to the parametric. However if construction and in-control properties of control chart do not depend on specific distribution then we call the control chart to be nonparametric. A formal definition of nonparametric charts has been given in due course of the discussion.

In literature Bakir and Reynolds(1979), Amin and Searcy (1991), Hackl and Ledolter (1991, 1992), Amin, Reynolds and Bakir (1995) and recently Chakraborti, Loan and Bakir (2001) are the major contributions to the study of nonparametric control charts. In the present study we give emphasis on study of nonparametric control charts based on sign statistic, a well-known distribution free statistic.

In the following we give chapter-wise summary.

0.3 Chapter-wise Summary :

This dissertation is devoted to nonparametric quality control charts based on sign statistic. It consists of four chapters.

In chapter I, we discuss some basic concepts related to parametric control charts. In section 1.1 parametric control charts developed by Dr. W. A. Shewhart are discussed. Further we describe the construction of Shewhart control chart, out of control criteria and types of control charts. Section 1.2 deals with Shewhart control chart for variables namely mean chart, range chart and median chart. In section 1.3 the control chart for attribute based on Binomial distribution is introduced. In section 1.4 equivalence of testing of hypothesis and control charts is discussed and concept of Run Length, Average Run Length (ARL) to measure performance of control chart is introduced. In the last section we give ARL values for mean chart through simulation, when the characteristic under study follows normal, double exponential, gamma, exponential and uniform distribution.

In chapter II, we discuss Nonparametric Quality Control Chart (NQCC) based on sign statistic. In section 2.1 the motivation of NQCC and literature survey of NQCC in detail is given. In section 2.2 we discuss NQCC based on sign statistic for monitoring the shift in process mean (or median) as suggested by Amin, Reynoldsand Bakir (1995). ARL values for one-sided control charts and two-sided control chart based on sign statistic for various process output distributions are simulated. Comparison of nonparametric sign chart and Shewhart mean chart is made using ARL. In section 2.3 control chart based on curtailed sampling plans is introduced. Expected sample size for in-control process is given, for control chart under curtailed sampling plans. Limitations of the control chart based on sign statistic have been given in section 2.4.

In chapter III, control charts with memory viz. Cumulative Sum (CUSUM) Charts and Exponentially Weighted Moving Average (EWMA) control chart have been introduced in section 3.1. A general linear test statistic for control charts is given and particular cases of this general form like Shewhart chart, CUSUM chart, EWMA charts have been discussed. In section 3.2 nonparametric CUSUM chart is studied. In section 3.3 nonparametric EWMA control chart has been given. In this section we study EWMA control chart based on sign statistic and Grouped Signed Ranks

(GSR) as given by Amin and Searcy (1991). ARL values for CUSUM, EWMA and GSR control charts are simulated. In section 3.4 nonparametric control charts with supplementary runs rule is discussed. It is observed that NQCC charts based on sign perform better than Shewhart mean chart for heavy tailed distributions.

In chapter IV, we discuss nonparametric quality control charts to detect increase in variability. In section 4.1 we introduce control chart for variability and in section 4.2 we study NQCC based on signs as suggested by Amin et al. (1995). In section 4.3 nonparametric sign control chart to detect increase in variability based on quantiles have been proposed. The ARL values of proposed chart have been simulated for normal and double exponential distribution and are compared with the corresponding parametric chart. In last section we suggest some problems for future study in the field of nonparametric control charts. The dissertation ends with list of appendix references.