

UNIVERSITI MALAYSIA PAHANG

**BORANG PENGESAHAN STATUS TESIS♦**

JUDUL: **DEVELOPMENT OF STATISTICAL PROCESS CONTROL (SPC)**  
**MATLAB-BASED SOFTWARE FOR AUTOMOTIVE**  
**INDUSTRIES APPLICATION**

SESI PENGAJIAN: 2011/2012

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DEVELOPMENT OF STATISTICAL PROCESS CONTROL (SPC) MATLAB-  
BASED SOFTWARE FOR AUTOMOTIVE INDUSTRIES APPLICATION

SITI HAZLINA BINTI MOKHTAR

A thesis submitted in fulfillment of the requirements  
for the award of the degree of  
Bachelor of Manufacturing Engineering

Faculty of Manufacturing Engineering  
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JUNE 2012

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**Dedicated to my beloved parents**

Mr Mokhtar bin Yusof  
Mrs Rapeah binti Mamat

and

**My fellow friends**

## **ACKNOWLEDGMENTS**

The special thank goes to my supervisor, Mr Nafrizuan bin Mat Yahya. The supervision and support that he gave truly help, tremendous technical guidance, advices, continuous encouragement, constructive criticisms, suggestion throughout this project and administrative support in the progression and smoothness of the project. The cooperation is much indeed appreciated.

Not forget, great appreciation go to the rest of Burnmark Industries Sdn. Bhd. staff that help me from time to time during this project and providing me in acquired data. This project really brought us together to appreciate the true value of friendship and respect of each other.

Last but not least, I would like to thank to my beloved parents for their love, encouragement and support throughout my life. Special thanks should be given to my friends in supporting me in finish up this project. I really appreciate their comments and suggestions, which was crucial for the successful completion of this study.

## **ABSTRACT**

This project is motivated by an interest in promoting the use computer-based statistical process control (SPC) in manufacturing sector specifically for automotive industries in Malaysia. The use of computer-based SPC is essential in quality function. They are capable to perform various operations or tasks very accurately at fast speeds. SPC techniques are simple statistical techniques to help identify process problems and it can be implemented as simple as analyzing data and plotting charts. However, the development of SPC in Malaysian small and medium-sized enterprises (SMEs) is found lacking because they remain to use traditional SPC techniques which the data are calculated and analyzed manually. Consequently, manual work on traditional SPC has focused on particular limitations; with only little quality faults are detectable, time-consuming and burdensome. This paper highlights the results of an effort to design the SPC computer-based system for conducting simple statistical analysis. The system named as MagNa version 1.0 MATLAB-based software, which is able to offer more benefits to the Malaysian SMEs specifically for automotive industries application.



## ABSTRAK

Projek ini adalah di atas dorongan kepentingan dalam menggalakkan penggunaan *Statistical Process Control* (SPC) yang berasaskan komputer dalam sektor pembuatan khususnya untuk industri automotif di Malaysia. Penggunaan komputer berasaskan SPC adalah penting dalam menjalankan fungsi kualiti untuk mencapai piawaian yang ditetapkan. Sistem ini mampu untuk melaksanakan pelbagai operasi atau tugas yang sangat tepat pada kelajuan yang cepat. Teknik SPC merupakan teknik statistik yang mudah untuk membantu mengenalpasti masalah proses dan ia boleh dilaksanakan semudah seperti menganalisis data dan memplot carta. Walau bagaimanapun, pembangunan SPC dalam perusahaan kecil dan sederhana Malaysia (PKS) didapati berkurangan kerana masih ada menggunakan teknik SPC tradisional dimana data dikira dan dianalisis secara manual. Oleh sebab itu, ianya menjurus kepada kerja manual SPC tradisional dimana ianya hanya memberi tumpuan kepada had tertentu, dengan hanya kesilapan kualiti sedikit dikesan, mengambil masa yang lama dan membebankan. Justeru itu, kertas kerja ini membincangkan hasil daripada usaha untuk merekabentuk sistem berasaskan komputer bagi menjalankan analisis statistik dengan mudah. Sistem yang dinamakan sebagai versi Magna 1.0, yang berasaskan perisian MATLAB, mampu untuk menawarkan lebih banyak faedah kepada PKS Malaysia khususnya untuk penggunaan industri automotif.

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**LIST OF ABBREVIATIONS**

CL	Centre line
CPL	Lower process capability index
CPU	Upper process capability index
LCL	Lower Control Limit
LSL	Lower Specification Limit
GUI	Graphical User Interface
SPC	Statistical Process Control
UCL	Upper Control Limit
USL	Upper Specification Limit



## LIST OF SYMBOLS

$\mu$	Mean
$\sigma$	Standard deviation
$\hat{\sigma}$	Estimate of population standard deviation
$\sigma_{\bar{X}}$	Population standard deviation of the subgroup averages
$\sigma_R$	Population standard deviation of the subgroup ranges
$n$	Sample size
$m$	Number of subgroup
$\bar{x}$	Sample mean
$C_p$	Process Capability
$C_{pk}$	Process Cpability Index
$\hat{C}_p$	Estimated process capability
$\hat{C}_{PL}$	Estimated lower process capability index
$\hat{C}_{PU}$	Estimated upper process capability index
$\bar{R}$	Average of the ranges
$R_i$	Individual range values for the sample
$S$	Sample standard deviation
$\bar{\bar{X}}$	Mean of the subgroups
$\bar{\bar{X}}$	Average of the subgroup averages
$\bar{X}_i$	Average of the ith subgroup

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 INTRODUCTION OF STUDY**

Quality is a term that carries important meaning to both producer and customer. With ever-increasing demands for improved quality, Statistical Process Control (SPC) is one of the most effective tools of total quality management (TQM). SPC was pioneered by Walter A. Shewhart in the early 1920s at Bell Telephone Laboratories (Charongrattanasakul *et al.*, 2011). By definition, SPC is a methodology for monitoring a process to identify special causes of variation and signalling the need to take corrective action when it is appropriate (Evans, 2004).

Under SPC, a process behaves predictably to produce as much conforming product as possible with the least possible waste. In a manufacturing environment, the SPC tool is used for continuous improvement of the production volume as well as quality which leads to achieve manufacturing excellence (Sultana *et al.*, 2009). SPC can be applied to all kind of manufacturing operations. The significant application of the SPC analysis elements to the operation will make the process more reliable and stable.

Nowadays, with the movement towards a computer integrated manufacturing environment, computer-based applications need to be developed to implement the various SPC tasks automatically. For this study, MATLAB is using as the computer-based. MATLAB stands for *Matrix Laboratory*. In 2004, MATLAB had around one million users across industry and academia (Goering, 2004).

MATLAB users come from various backgrounds of engineering, science, and economics. MATLAB is widely used in academic and research institutions as well as industrial enterprises. MATLAB was first adopted by researchers and practitioners in control engineering, but quickly spread to many other domains (Goering, 2004). It is now also used in education, in particular the teaching of linear algebra and numerical analysis, and is popular amongst scientists involved in image processing. Cleve Moler, the chairman of the computer-science department at the University of New Mexico, started developing MATLAB in the late 1970s (Goering, 2004).

## **1.2 PROJECT BACKGROUND**

In the global market place today, many organizations realized that its survival in the business world depend highly on bringing high quality product and services to their customers. Due to the global competition, some companies have indeed stressed that quality should have to be put in place, integrated into all aspects of products and services in their management system (Ab Rahman *et al.*, 2009). A part of that, SPC is one of the approaches that can be used to ensure continuous quality improvement.

The most successful SPC tool is control chart (Evans, 2004). The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data. By comparing current data to these lines, we can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

SPC can be applied whenever work is being done. Initially, it was applied to just production processes, but it has evolved to the point where it is applied to any work situation where data can be gathered (Evans, 2004). As companies work toward quality goal, SPC is used in more diverse situations. SPC involves the use of statistical signals to identify the source of variation, to improve performance and to maintain control of processes at higher quality levels. SPC is a powerful tool to optimize the amount of information needed for use in making management decisions.

Some companies nowadays still use manual method to implement SPC in their organization (Ab Rahman *et al.*, 2009). More amount of money is needed in almost all industry because they are failed to correct the faults in developing the product at first time (Ribeiro & Cabral, 1999). To reduce the cost and to increase the share market rate, non conformance elimination is the best choice. Most of the system gets failed because they won't confirm that the product is working properly after finishing the product. So this system has to be reprocessed and it needs rework to convert the product into good or confirm condition. This is an extra work and time; money is wasted in huge amount.

Statistical techniques provide an understanding of the business baselines, insights for process improvements, communication of value and results of processes, and active and visible involvement (Evans and Lindsay, 1988). SPC provides real time analysis to establish controllable process baselines; learn, set, and dynamically improve process capabilities; and focus business on areas needing improvement. SPC moves away from opinion-based decision making. These benefits of SPC cannot be obtained immediately by all organizations. SPC requires defined processes and a discipline of following them. It requires a climate in which personnel are not punished when problems are detected and strong management commitment.

### **1.3 PROBLEM STATEMENT**

Currently, computer-based SPC has not been widely used by the small and medium automotive industries. The reason the automotive industry is chosen for this research is because the automotive industry can be considered as one of the most important and strategic industries in the manufacturing sector. Eventually, it has been desired to boost the industrialization process so that Malaysia can be a developed nation by 2020, compared to the other manufacturing sector in Malaysia.

However, there are also many automotive companies remain to use traditional SPC techniques such as calculating and analyzing data manually and also manual charting. Consequently, manual work on traditional SPC has focused on particular limitations; with only little quality faults are detectable, time-consuming and burdensome. The corrective actions by production or quality engineers and technicians

are taken only after the occurrence of an out of control signal. By using manual SPC, the number of fault that can be traced is limited. Furthermore, according to production manager, most workers had a very limited background in SPC and less understanding about this concept. They were not properly trained on SPC.

Today, in a global reach towards the use of computer-based especially in automotive sectors, it is important to find a way to quality section to construct control chart using the sustainable methods that will lead in reducing the time. As a concern of that problem, the project is all about to develop the integrated SPC MATLAB-base software. MATLAB is a high-level language and interactive environment that enables to perform computationally intensive tasks faster. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms and creation of user interfaces (MathWorks, 2012). Thus, it fulfills the requirement of the project in developing the software.

#### **1.4 PROJECT OBJECTIVES**

The main objectives of this project are:

- i) To develop SPC MATLAB-based software for automotive industry application.
- ii) To execute a software that user-friendly and customized for automotive industry.

#### **1.5 PROJECT SCOPES**

This project focuses on developing SPC MATLAB-based software which the criteria of this software are must include:

- i) The model shall analyze the raw data and its specification being entered into the database in which a control chart will be generated complete with its control limits.

- ii) The software shall have its own algorithm to recognize the pattern of the control chart.
- iii) The data entered will be able to detect unnatural runs indicating that the process is out-of-control.
- iv) The model shall analyze the process capability ( $C_p$ ) and process performance measurement ( $C_{pk}$ ).
- v) The software shall make crucial comments to the users; notice for corrective action.

In order to develop the reliable software, the information from automotive industries such as their problems and preferred model will be gathering. Also, analysis of the existing computer-based SPC available in the market will be conducted to look at its weakness so that the new model will be a reliable solution. The real data for parts will get from the industries as a sample while run the software.



## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 INTRODUCTION**

The purpose of this chapter is to provide a review of past research efforts related to statistical process control (SPC) and the important component in designing the software system for quality control. From the related journal and article, the idea in SPC and designing the software is developed before going further to the next chapter in completing this project.

#### **2.2 STATISTICAL PROCESS CONTROL (SPC)**

##### **2.2.1 History of Statistical Process Control (SPC)**

The first to apply the newly discovered statistical methods to the problem of quality control was Walter A. Shewhart of the Bell Telephone Laboratories (Charongrattanasakul *et al.*, 2011). He issued a memorandum on May 16, 1924 that featured a sketch of a modern control chart. Shewhart kept improving and working on this scheme (Deming, 1975).

##### **2.2.2 Why Statistical Process Control (SPC)**

SPC is proven technique for improving quality and productivity (Attaway *et al.*, 2011). To avoid non conformance this SPC will closely examine them. This statistical control process will not only help to monitor the process but also it correctly identifies the fault before the delivery of the product (Summers, 2003). The reoccurring problems are eliminated quickly. The significant application of the SPC analysis elements to the

operation will make the process more reliable and stable. SPC relies on control charts, one of the basic quality improvement tools.

The most widely used and popular SPC techniques include univariate methods that involve observing a single variable at a given time, obtaining the mean and variance of the variable, and checking its value against upper and lower control limits. While a univariate approach may indeed work for monitoring a small number of process variables that are not correlated, current capabilities in data acquisition hardware allow a large number of variables to be easily measured (Tatara *et al.*, 2002).

### **2.2.3 General Methodology of SPC**

The following is a summary of the steps required to develop and use control charts. Steps 1 through 4 focus on establishing a state of statistical control; in step 5, the charts are used for ongoing monitoring; and finally, in step 6, the data are used for process capability analysis (Evans, 2004).

1. Preparation
  - a) Choose the variable or attribute to be measured.
  - b) Determine the basis, size, and frequency of sampling.
  - c) Set up the control chart.
2. Data collection
  - a) Record the data
  - b) Calculate relevant statistics: average, ranges, and proportions.
  - c) Plot the statistics on the chart.
3. Determination of trial control limits
  - a) Draw the centre line (process average) on the chart.
  - b) Compute the upper and lower control limits.
4. Analysis and interpretation
  - a) Investigate the chart for lack of control.
  - b) Eliminate out-of-control points.
  - c) Recomputed control limits if necessary.

5. Use as a problem-solving tool
  - a) Continue data collection and plotting.
  - b) Identify out-of-control situations and take corrective action.
6. Determination of process capability using the control chart data

#### **2.2.4 The Basic Tools for SPC**

In order to implement continuous improvement in an organization, tools of SPC is quite benefit and essential to them. There are seven tools of SPC (Summers, 2003):

- i) Flow Chart;
- ii) Pareto Chart;
- iii) Check Sheet;
- iv) Cause-and-effect diagram;
- v) Histogram;
- vi) Control chart and
- vii) Scatter plot.

For the purpose of this study, control chart is chosen to be implemented as a SPC tool to develop the SPC MATLAB-based software. There is some function of control chart (Summers, 2003):

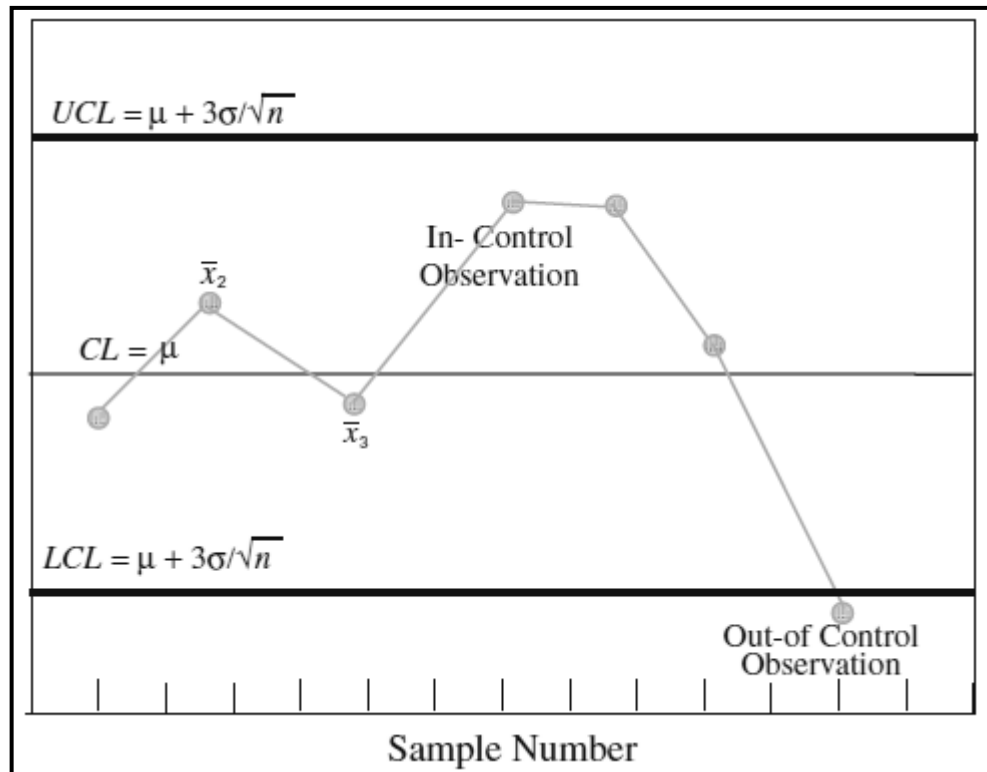
- i) As decision making tools
  - Provide information for timely decision on the products – such as out of control conditions during production, requiring products to be sort and rework.
  - Provide information used to determine process's ability to meet the specification set by the designer – to be used for decision to do continual process improvement.
- i) As problem solving tools
  - The control chart help locate the causes of poor quality. By observing the patterns on the chart, the engineer can determine the adjustment required.

- During daily production, the operator can monitor the trend and determine when to make adjustment to the process.

## 2.3 CONTROL CHART

A control chart is a graphical display of one or more quality characteristic/s versus samples' number or time (Zarandi *et al.*, 2010). Typically the chart contains a centre line (*CL*) that represents the in-control value of the quality characteristic, and two limits, namely upper control limit (*UCL*) and lower control limit (*LCL*), which determine the boundaries of the in- and out-of-control conditions which means in some applications the chart may have only one limit (Zarandi *et al.*, 2010). These limits are chosen in a way that if the process is in-control, almost all sample points fall within them.

$\bar{X}$  chart is the most common type of control charts for monitoring the mean of quality characteristics.  $CL = \mu$ ,  $UCL = \mu + 3\sigma / \sqrt{n_i}$  and  $LCL = \mu - 3\sigma / \sqrt{n_i}$  are the typical control limits of this kind of chart, when the in-control parameters, namely the mean ( $\mu$ ) and the standard deviation ( $\sigma$ ) of the quality characteristic are known.  $\bar{X}_i$  is the sample statistic plotted on the chart, while  $n_i$  is the sample size which is fixed in fixed sampling charts and variable in the variable sampling charts.  $\bar{X}_i$  chart is designed to monitor the mean of the quality characteristic, which is usually assumed to follow a normal distribution. To monitor the standard deviation of the process, R chart is employed.



**Figure 2.1:** Sample of control chart (Zarandi *et al.*, 2010)

### 2.3.1 Control Chart Rule (Western Electric Rule)

In Statistical Process Control, the Western Electric Rules are decision rules for detecting "out-of-control" or non-random conditions on control charts. Locations of the observations relative to the control chart control limits (typically at  $\pm 3$  standard deviations) and centerline indicate whether the process in question should be investigated for assignable causes. The Western Electric Rules were codified by a specially-appointed committee of the manufacturing division of the Western Electric Company and appeared in the first edition of its Statistical Quality Control Handbook in 1956. Their purpose was to ensure that line workers and engineers interpret control charts in a uniform way.

The rules attempt to distinguish unnatural patterns from natural patterns based on several criteria:

1. The absence of points near the centerline (identified as a mixture pattern).
2. The absence of points near the control limits (identified as a stratification pattern).
3. The presence of points outside the control limits (identified as an instability pattern).
4. Other unnatural patterns (systematic (autocorrelative), repetition, trend patterns).

To achieve this, the rules divide the chart into zones, measured in units of standard deviation ( $\sigma$ ) between the centerline and control limits, as follows:

**Table 2.1:** Divided zone of Western Electric Rule (GMcGlenn, 2009)

Zone	Region
Zone A	Within $2\sigma$ of the centerline and the control limit ( $3\sigma$ )
Zone B	Within $1\sigma$ and $2\sigma$ of the centerline
Zone C	Within $1\sigma$ of the centerline

Zones A, B, and C are sometimes called the three sigma zone, two sigma zone, and one sigma zone, respectively. The most important of the Western Electric rules are the zone rules, designed to detect process instability - and the presence of assignable causes. There are four basic rules that deal with appraising runs of observations within the various zones:

**Table 2.2:** Four basic rule in Western Electric Rule (GMcGlinn, 2009)

Rule	Description	Chart Example
<b>Rule 1</b>	Any single data point falls outside the $3\sigma$ limit from the centerline (i.e., any point that falls outside Zone A, beyond either the upper or lower control limit)	<p><b>Rule 1:</b> Any point beyond Zone A</p>
<b>Rule 2</b>	Two out of three consecutive points fall beyond the $2\sigma$ limit (in zone A or beyond), on the same side of the centerline	<p><b>Rule 2:</b> two out of three consecutive points fall Zone A or beyond</p>
<b>Rule 3</b>	Four out of five consecutive points fall beyond the $1\sigma$ limit (in zone B or beyond), on the same side of the centerline	<p><b>Rule 3:</b> Four out of five consecutive points fall Zone B or beyond</p>
<b>Rule 4</b>	Nine consecutive points fall on the same side of the centerline (in zone C or beyond)	<p><b>Rule 4:</b> Nine consecutive points on the same side of center line (mean)</p>

## 2.4 PROCESS CAPABILITY INDICES AND THEIR ESTIMATORS

Process Capability calculations indicate the ability of a process to meet specification limits. The capability of the process is defined as the spread of results around this value. High capability occurring when process results group closely around it (Summers, 2003). The most common measure of this spread is standard deviation, and 'Process Capability' may be defined as the range between three standard deviations either side of the average. Objectives of measuring the Process Capability include:

1. To prioritize process improvement projects.
2. To investigate causes of specification limit failure.
3. Setting realistic specification limits for process.
4. Determining results of improvements made.

### 2.4.1 $C_p$ Index

By equation, the process capability index is defined to be

$$C_p = \frac{\text{allowable process spread}}{\text{actual process spread}} = \frac{USL - LSL}{6\sigma}, \quad (2.1)$$

where  $USL$ ,  $LSL$ , and  $\sigma$  denote the upper specification limit, lower specification limit, and process standard deviation associated with the measurement, respectively. A process is said to be capable if the value of  $C_p$  associated with the process is at least 1.0 (Stoumbos, 2002). Since the process standard deviation is rarely known, it is estimated from a sample of  $n$  measurements  $X_1, \dots, X_n$ , and estimate  $\hat{C}_p$  of the process capability  $C_p$  is obtained by

$$\hat{C}_p = \frac{USL - LSL}{6\hat{\sigma}}. \quad (2.2)$$



Typically, the sample standard deviation

$$C_p^* = \frac{\min(T - LSL, USL - T)}{3\sigma} \quad (2.3)$$

is used to estimate  $\sigma$  (where  $\bar{X} = \frac{1}{n} \sum_{i=1}^n X_i$ ).

#### 2.4.2 $C_p^*$ Index

The  $C_p^*$  index is the generalization of  $C_p$  to the case where the target value  $T$  for the process mean is not necessarily equal to the midpoint  $m$  of the specification limits, and is defined by

$$CPL = \frac{\text{allowable lower spread}}{\text{actual lower spread}} = \frac{\mu - LSL}{3\sigma} \quad (2.4)$$

An estimate of  $C_p^*$  can be obtained by

$$\hat{C}_p^* = \frac{\min(T - LSL, USL - T)}{3S}. \quad (2.5)$$

Note that when  $T = m$ ,  $C_p^* = C_p$  and  $C_p^* = \hat{C}_p$ . The  $C_p$  and  $C_p^*$  indices merely relate the process spread to the specification limits and do not take into account possible shifts of the process mean away from the target value.

#### 2.4.3 $CPL$ and $CPU$ indices

Similarly to (2.1), the lower process capability index ( $CPL$ ) is defined to be

$$S = \left[ \frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2 \right]^{1/2} \quad (2.6)$$

and the upper process capability index (CPU) is defined to be

$$CPU = \frac{\text{allowable upper spread}}{\text{actual upper spread}} = \frac{USL - \mu}{3\sigma}. \quad (2.7)$$

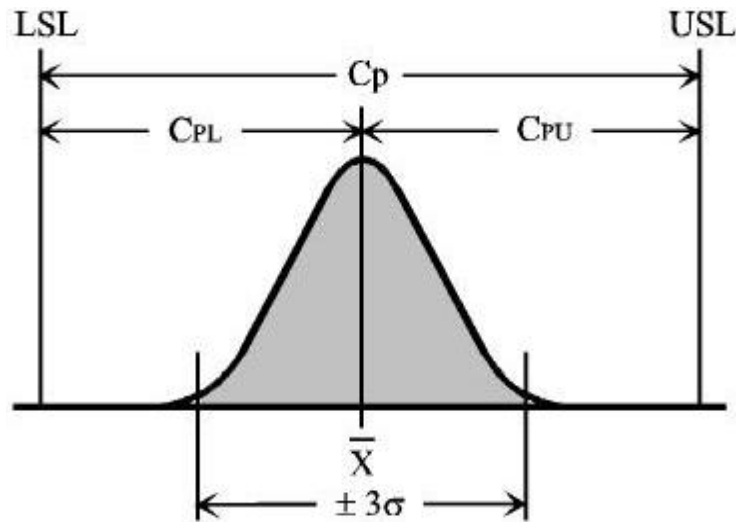
Estimates of  $\hat{CPL}$  and  $\hat{CPU}$  of  $CPL$  and  $CPU$ , respectively, are obtained by

$$\hat{CPL} = \frac{\bar{X} - LSL}{3S} \quad (2.8)$$

and

$$\hat{CPU} = \frac{USL - \bar{X}}{3S} \quad (2.9)$$

The  $CPU$  index was developed in Japan and is utilized by a number of Japanese companies (Stoumbos, 2002).



**Figure 2.2:** The connection between  $C_p$ ,  $CPL$  and  $CPU$  (Ruffner, 1996)

#### 2.4.4 $C_{pk}$ Index

$C_{pk}$  is an index (a simple number) which measures how close a process is running to its specification limits, relative to the natural variability of the process (Summers, 2010). The larger the index, the less likely it is that any item will be outside the specifications.  $C_{pk}$  tells what the process is capable of doing in future, assuming it remains in a state of statistical control.  $C_{pk}$  is calculated using an estimate of the standard deviation. By calculation, the process capability index  $C_{pk}$  is defined as

$$C_{pk} = \min(CPL, CPU). \quad (2.10)$$

$C_{pk}$  describes a distance scaled by  $3\sigma$ , between the process mean and the closest specification limit. Assuming that  $\mu$  is between the specification limits, let

$$k = 2|m - \mu|/(USL - LSL), \quad (2.11)$$

where  $m$  is the midpoint of the specification limits. The ratio  $k$  is used in Japan as an index describing the amount that the process mean is off-centre (Stoumbos, 2002). It is easily seen that if  $0 \leq k \leq 1$ , then

$$C_{pk} = (1 - k) C_p. \quad (2.12)$$

Note that when  $\mu = m$ ,  $C_{pk} = C_p$ . In order to interpreting values of  $C_{pk}$ , the value of 3 as a ‘total confidence’ limits (Summers, 2003). Studying Process Capability is more than just measuring  $C_p$  and  $C_{pk}$ ; it involves understanding what causes variation within the process, under what conditions, and how these variables interact. The purpose of doing this is to enable confident process improvement that steadily reduces variation.

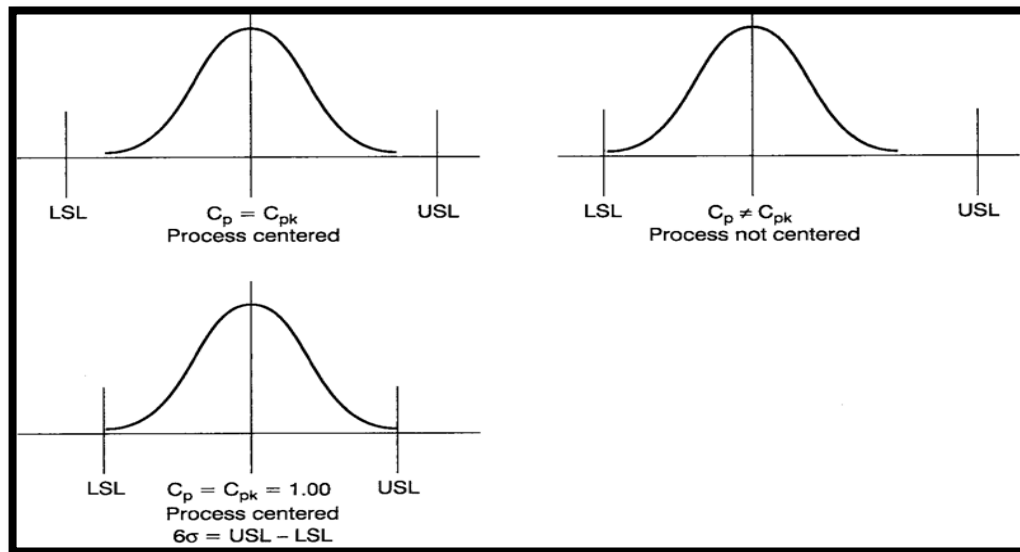
**Table 2.3:**  $C_{pk}$  values, capability and action taken for improvement (Summers, 2003)

Value of $C_{pk}$	Capability	Action
Less than 1	Incapable	Improve by reducing common causes of variation in process variables. Use 100% inspection.
Between 1 and 3	Capable	Do nothing or some process improvement. Dependent on sample size.
Greater than 3	Very capable	Do nothing or reduce specification limits. No inspection necessary.

## 2.5 RELATIONSHIP OF PROCESS CAPABILITY ( $C_p$ ) AND PROCESS PERFORMANCE MEASUREMENT ( $C_{pk}$ )

There are several relationships of Process Capability ( $C_p$ ) and Process Performance Measurement ( $C_{pk}$ ) which are (Summers, 2003):

1. When  $C_p$  has a value of 1.0 or greater, the process is producing product capable of meeting specification.
2.  $C_p$  value does not reflect process centering.
3. When the process is centered,  $C_p = C_{pk}$ .
4.  $C_{pk}$  is always less or equal to  $C_p$ .
5. When  $C_p$  is greater or equal to 1.0 and the  $C_{pk}$  has a value of 1.00 or more, it indicates the process is producing products that conform to specifications.
6. When  $C_{pk}$  has a value less than 1.00, it indicates the process is producing product that does not conforms to specifications.
7. A  $C_p$  value of less than 1.00 indicates the process is not capable
8. A  $C_{pk}$  value of zero indicates the process average is equal to one of the specification limits.
9. A negative  $C_{pk}$  value indicates that the average is outside the specifications limit.



**Figure 2.4:** Relationships of  $C_p$  and  $C_{pk}$  by using graph (Summers, 2003)

## 2.6 CONFIDENCE INTERVAL

### 2.6.1 Introduction

A confidence interval gives an estimated range of values which is likely to include an unknown population parameter, the estimated range being calculated from a given set of sample data (Easton *et al.*, 2012). If independent samples are taken repeatedly from the same population, and a confidence interval calculated for each sample, then a certain percentage (confidence level) of the intervals will include the unknown population parameter. Confidence intervals are usually calculated so that this percentage is 95%, but we can produce 90%, 99%, 99.9% confidence intervals for the unknown parameter. The width of the confidence interval gives us some idea about how uncertain we are about the unknown parameter. A very wide interval may indicate that more data should be collected before anything very definite can be said about the parameter. Confidence intervals are more informative for defining processes.

### 2.6.2 Theorem

The central limit theorem states that when the sample size is large, approximately 95% of the sample mean will fall within  $\pm 1.96$  (Bluman, 2003), standard errors of the population that is  $\mu \pm 1.96(\sigma/\sqrt{n})$ . If specific sample mean is selected, 95% probability will fall within the range of  $\mu \pm 1.96(\sigma/\sqrt{n})$ . Likewise, there is 95% probability that the interval specified by

$$\bar{x} - 1.96\left(\frac{\sigma}{\sqrt{n}}\right) < \mu < \bar{x} + 1.96\left(\frac{\sigma}{\sqrt{n}}\right) \quad (2.13)$$

where

$\bar{x}$  = sample mean

$\sigma$  = population standard deviation

$n$  = sample size

$\mu$  = hypothesized population mean

## 2.7 MATRIX LABORATORY (MATLAB)

MATLAB is a very powerful software package that has many built-in tools for solving problems and developing graphical illustrations (Attaway *et al.*, 2011). The simplest method for using the MATLAB is interactively; an expression is entered by the user and MATLAB immediately respond with a result. It is also possible to write scripts and programs in MATLAB, which are essentially groups of commands that are executed sequentially. MATLAB, which provides a procedural language that can be used for a broad range of mathematical applications, claims a seat count in the hundreds of thousands (Georing, 2004).

MATLAB is the language of choice for people doing mathematical development. Everyone simulates in MATLAB and goes to something else for implementation and the real key is getting synthesis working. For this project, MATLAB is using to develop the software that will come out with graphical statistical

which can guide user to take improvement action according to outcome result. The purpose of this project using MATLAB, it can solve technical computing problems faster than with traditional programming languages, such as C, C++, and FORTRAN (Georing, 2004). Thus, it will lead to achieve the first objective of this project.

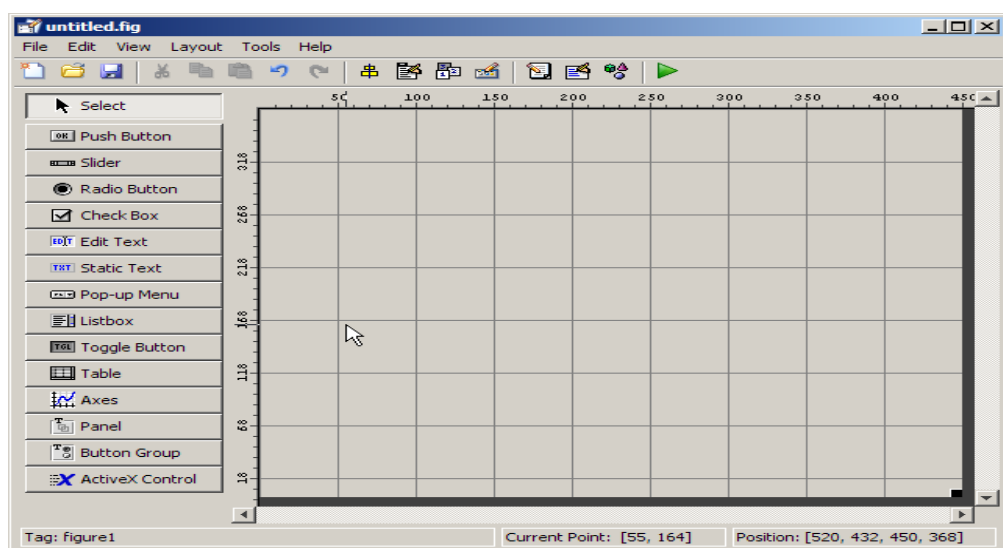
### **2.7.1 Graphical User Interface (GUI)**

A graphical user interface (GUI) is a graphical display in one or more windows containing controls, called components that enable a user to perform interactive tasks (Baez-Lopez, 2010). The user of the GUI does not have to create a script or type commands at the command line to accomplish the tasks. Unlike coding programs to accomplish tasks, the user of a GUI need not understand the details of how the tasks are performed (Baez-Lopez, 2010).

A graphical user interface provides the user with a familiar environment in which to work. This environment contains pushbuttons, toggle buttons, lists, menus, text boxes, and so forth, all of which are already familiar to the user, so that he or she can concentrate on using the application.

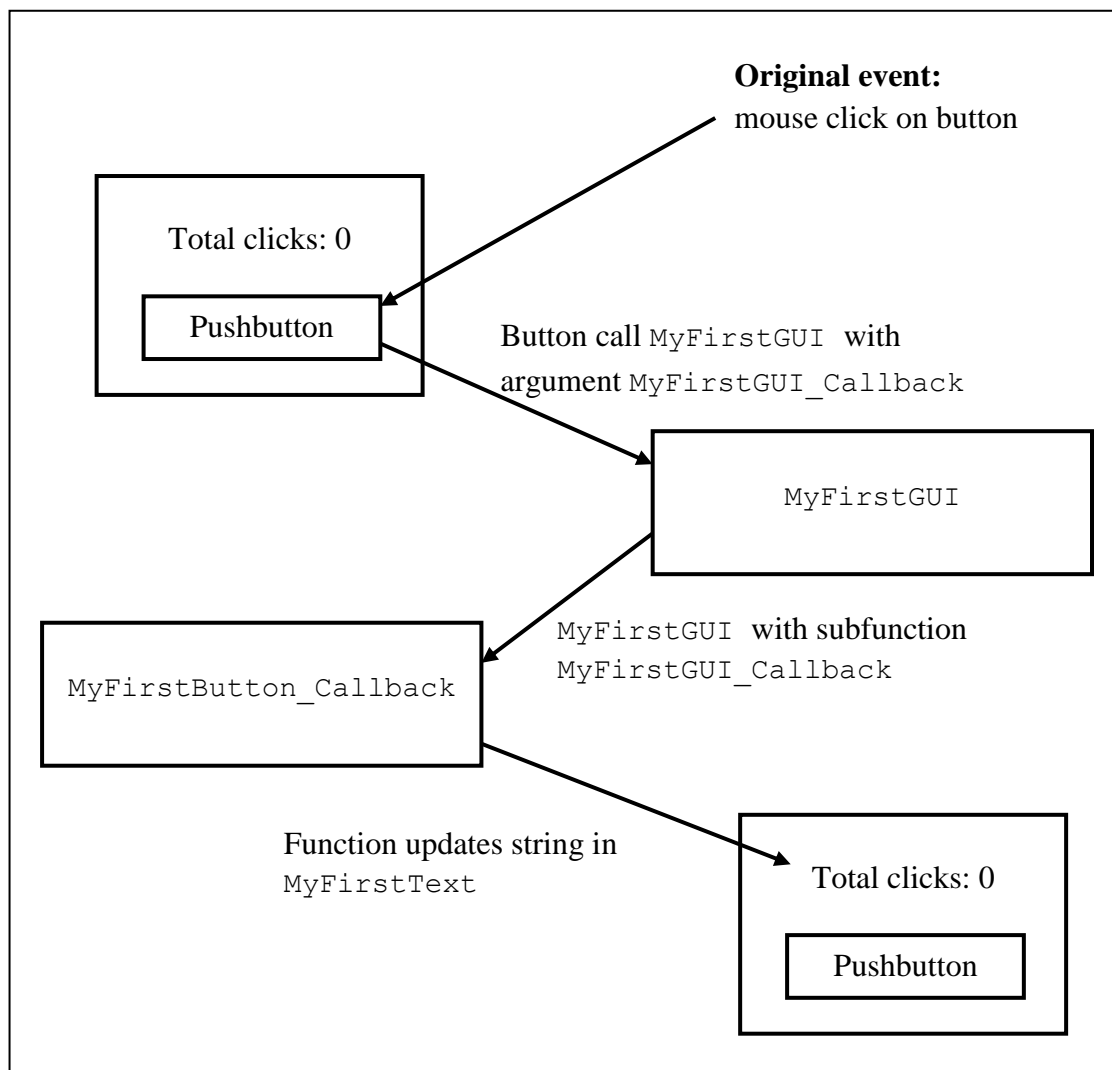
The three principal elements required to create a MATLAB Graphical User Interface are as follows (Ashi *et al.*, 2011):

1. **Components.** Each item on a MATLAB GUI (pushbuttons, labels, edit boxes, etc.) is a graphical component. The types of components include graphical controls (pushbuttons, edit boxes, lists, sliders, etc.), static elements (frames and text strings), menus, and axes. Graphical controls and static elements are created by the function `uicontrol`, and menus are created by the functions `uimenu` and `uicontextmenu`. Axes, which are used to display graphical data, are created by the function `axes`.
2. **Figures.** The components of a GUI must be arranged within a figure, which is a window on the computer screen.
3. **Callbacks.** Finally, there must be some way to perform an action if a user clicks a mouse on a button or types information on a keyboard. A mouse click or a key press is an event, and the MATLAB program must respond to each event if the program is to perform its function. For example, if a user clicks on a button, that event must cause the MATLAB code that implements the function of the button to be executed. The code executed in response to an event is known as a call back. There must be a callback to implement the function of each graphical component on the GUI.



**Figure 2.5:** The guide tool window (Ashi *et al.*, 2011)





**Figure 2.6:** Example on how GUI works (Baez-Lopez, 2010)

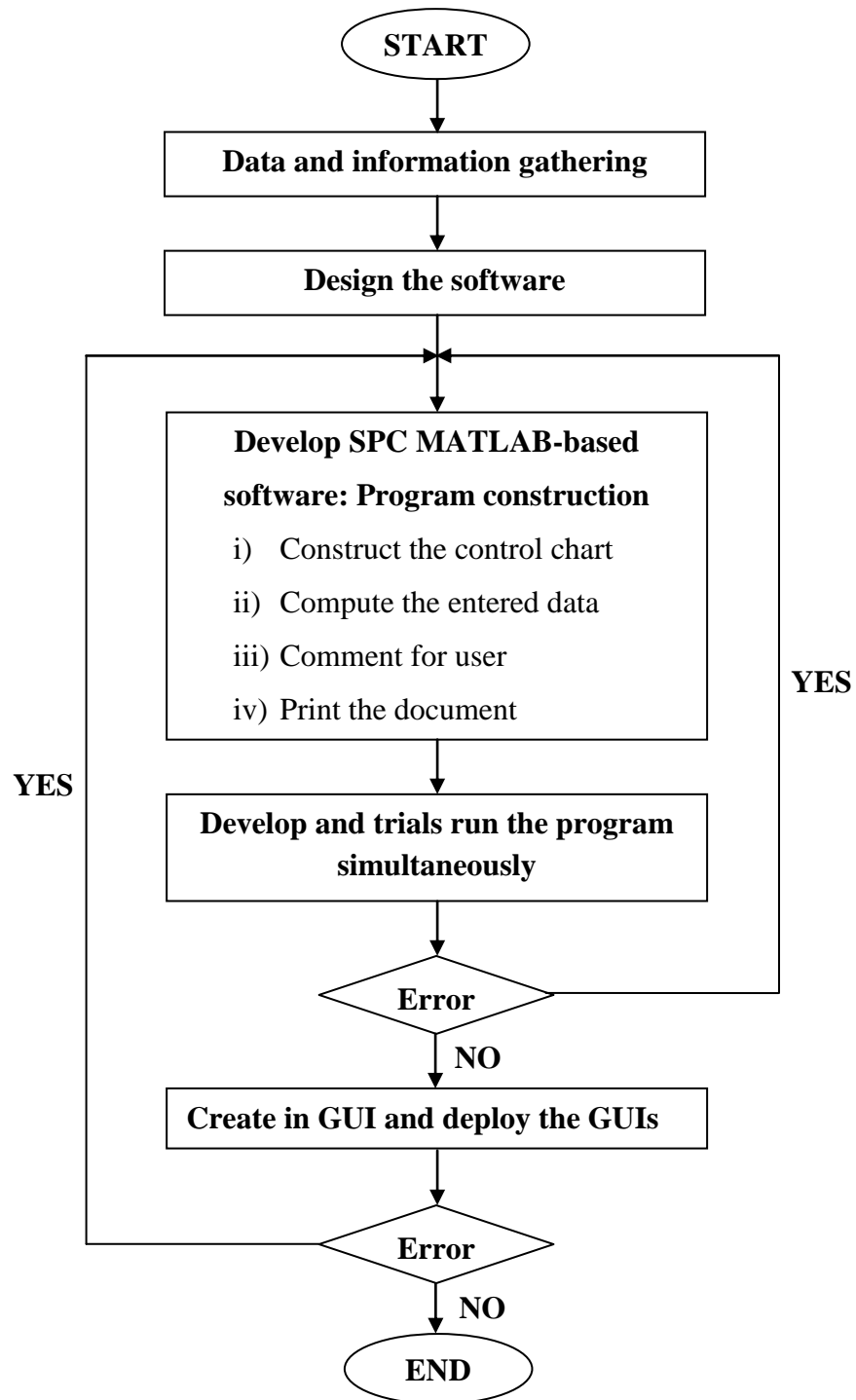
## **CHAPTER 3**

### **METHODOLOGY**

#### **3.1 INTRODUCTION**

This chapter will present a brief explanation on the methodology of carrying out the project from the beginning till end for the whole semester. The title including its synopsis is given by supervisor from the previous semester. Within the synopsis, it is contained the objective, problem statement and also scope of the project. Since the title is “Development of Statistical Process Control (SPC) MATLAB-base Software for Automotive Industries Application”, in the previous chapter, a detail literature review is done and important information are acquired and explained. The previous studies and investigations in journals, articles and others sources that relate with the development of software using MATLAB and topic that cover the SPC subject are helped while conducting the investigation. A simple research at the industries is done in developing the software and the information is gathered such as their problems and preferred model. Besides, analysis on the existing computer-based SPC available in the market is also conducted by interview the staff at the Quality Department. The design of the software that being developed is first has to be draft. The programs for the software are constructed in M-file before transfer to Guide User Interface (GUI) file. The program are built and run simultaneously.

### 3.2 OVERALL METHODOLOGY



**Figure 3.1:** Flow chart of overall methodology

### **3.2.1 Data and Information Gathering**

Data and information gathering is one of the main components that required in running the simulation of the developed software. A part from that, the project begins as their first step to gather the information and acquired data as a sample from the small and medium automotive industries. This step is done by conducting a simple research which consists of surveys and interviews.

Thus, the company that willing to cooperate to carry out this project is Burnmark Industries Sdn. Bhd., located at Bukit Sentosa, Selangor. This company is one of the small and medium automotive industries in Malaysia. From that company, the data acquired as a database that able to test the software. The sample consists of three different types of data where the data is in-control, out-of-control and normal manner. The information gathered at that company focus on their problems and preferred model.

### **3.2.2 Design the Software**

First and foremost, the software that going to built is designed roughly using a paper before transfer to the MATLAB software. The main concept of the design is interesting and user friendly while it will meet a certain requirements of the project. Within that design, it consist an arrangement of several buttons that need to press by the user. This design is the core of the software. It will control the created program from load the required data until the user print those document.

The design is constructed using Graphical User Interface (GUI) layout. After that, the sub-software is designed to come out with analysis of the specific criteria to compute after the data being entered by the users. Besides, another one of sub-software is designed to illustrate crucial comments to the users. This sub-software is also designed using the GUI layout.

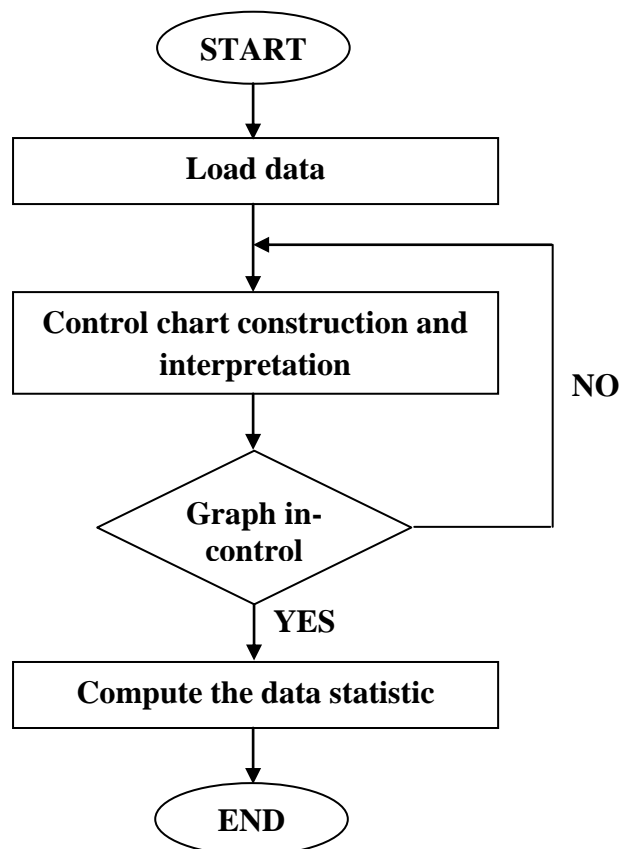
### 3.2.3 Program Construction

Under the program construction, there are divided into four sections as follows:

- i) Plot the control chart;
- ii) Compute the entered data;
- iii) Crucial comments for the user and
- iv) Print the document.

Here are the details explanations of methodology in creating and constructing the program for each section.

- i) Construct the control chart



**Figure 3.2:** Flow chart of constructing the control chart

In constructing the program for plotting the control chart, firstly, the data are load into the M-file and usually it shown as Editor at the window. The load data must be in a form of .xls file, which mean stored in a Microsoft Office Excel. The data are tabulated in a matrix form where first to be considered is row and then column  $[i, j]$ . So, the sample of observation,  $n$  is visualised as row, and the value of collected data will be the column. Below is the example on how the data are being tabulated.

	A	B	C	D
1	270	270	280	280
2	280	280	280	280
3	280	290	290	290
4	280	270	270	290
5	280	280	280	280

**Figure 3.3:** Example of tabulated data in Microsoft Office Excel

Then, after the data being load and becoming as a database, the control chart is construct and interpret. Control charts are created with the `controlchart` function. In a control chart, control rules are specified with the `controlrules` function which they are controlled by using the Western Electric 2 rule<sup>1</sup>.

A part of control chart, it consists of centreline, upper control limit of the  $\bar{X}$  and R chart and also lower control limit of the  $\bar{X}$  and R chart. The control limits and the centreline are calculating based on the following equation:

$$\bar{\bar{X}} = \frac{\sum_{i=1}^m \bar{X}_i}{m} \quad (3.1)$$

where

$\bar{\bar{X}}$  = average of the subgroup averages

$\bar{X}_i$  = average of the  $i$ th subgroup

$m$  = number of subgroups

<sup>1</sup> 2 of 3 points at least 2 standard errors above the centre line to mark out of control measurements.

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2 \bar{R} \quad (3.2)$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2 \bar{R} \quad (3.3)$$

where

$UCL_{\bar{X}}$  = upper control limit of the  $\bar{X}$  chart

$LCL_{\bar{X}}$  = lower control limit of the  $\bar{X}$  chart

$A_2$  = from table (refer appendix D)

$\bar{R}$  = average of the range

$$\bar{R} = \frac{\sum_{i=1}^m R_i}{m} \quad (3.4)$$

where

$\bar{R}$  = average of the ranges

$R_i$  = individual range values for the sample

$m$  = number of subgroups

$$UCL_R = D_4 \bar{R} \quad (3.5)$$

$$LCL_R = D_3 \bar{R} \quad (3.6)$$

where

$UCL_R$  = upper control limit of the R chart

$LCL_R$  = lower control limit of the R chart

$D_4, D_3$  = population standard deviation of the subgroup ranges

$\bar{R}$  = average of the range

After make a program on calculating the control limits, the centreline ( $\bar{\bar{X}}$ ) and the upper and lower control limits (UCL and LCL, respectively) are placed on the chart. The upper and lower control limits are shown by solid red lines in colour. The grand average, or  $\bar{\bar{X}}$ , is shown by solid green line in colour. The control limits on the  $\bar{X}$  chart will be symmetrical about the central line. These control limits are used to evaluate the variation in quality from subgroup to subgroup.

In order to know whether the program executed are right or not, the sample data are calculated manually. If the graphs are in-control, the next step is proceeding which the data statistic will be computed. If not, the program will be carried out by constructing and interpreting the control chart again. The common data statistic of standard deviation computed is as follows:

$$\sigma = \sqrt{\frac{\sum_{i=1}^n (X_i - \mu)^2}{n}} \quad (3.7)$$

where

$\sigma$  = standard deviation of the population

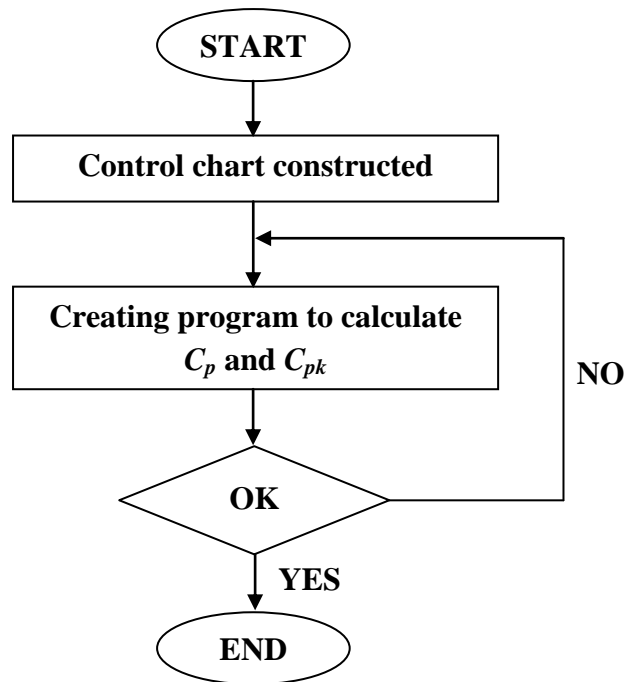
$\mu$  = mean value of the series of measurements

$X_i = X_1, X_2, \dots, X_n$  = values of each reading

$n$  = number of readings



- ii) Compute the entered data



**Figure 3.4:** Flow chart of creating program for computed the entered data

Since the control chart have been constructed and interpreted, now the entered data are ready to analyze by calculate the process capability,  $C_p$  and process performance measurement,  $C_{pk}$ .  $C_p$  is the mathematical ratios that quantify the ability of a process to produce products within the specifications. Meanwhile, the  $C_{pk}$  is indicated the centering of the process. The program created by entering and simulating the equation of those indices in M-file.

The equations involved are as follows:

$$Cp = \frac{USL - LSL}{6\hat{\sigma}} \quad (3.8)$$

where

$Cp$  = capability index

$USL - LSL$  = upper specification limit minus lower specification limit

$\hat{\sigma}$  = estimate of population standard deviation

$$Cpk = \frac{Z(\min)}{3} \quad (3.9)$$

where  $Z(\min)$  is the smallest of

$$Z(USL) = \frac{USL - \bar{X}}{\hat{\sigma}} \quad (3.10)$$

$$\text{or } Z(LSL) = \frac{\bar{X} - LSL}{\hat{\sigma}} \quad (3.11)$$

and where

$Cpk$  = process performance measurement

$USL$  = upper specification limit

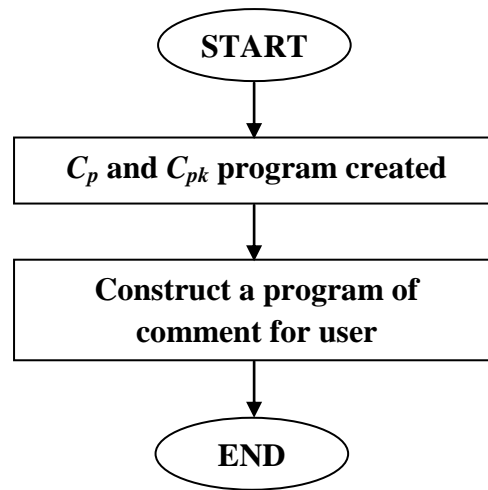
$LSL$  = lower specification limit

$\bar{X}$  = mean of the subgroups

$\hat{\sigma}$  = estimate of population standard deviation

To ensure the created program is correct, the manual calculation is done by using the similar sample. The program needs to upgrade and refine if the program did not get the correct answer as in manual. It is built and run simultaneously. The program is much related to the theory, so the calculation must get true to analyze the process behaviour.

iii) Comment for user



**Figure 3.5:** Flow chart of the comment for user constructed

After the program of interpret  $C_p$  and  $C_{pk}$  are done, then the program of comment for user is constructed. In this program, it is contain as follows:

- The process is capable or not;
- Comments and
- Action that user need to take in order to control the process behaviour.

This program will analyze the value of the  $C_{pk}$  in order to come out with the suggestion of the action. The program here is using *if else* command. It will be visualised by pop-up window after the user click the button to compute the data statistics. It will be appeared automatically.

iv) Print the document

In order to develop software that conceptually is user-friendly, it should have a button to print the document. So, it is same kind like this software. Here, the users are able to print out the overall data in the report format so that it easy for them to review and do the documentation for their organization.

### **3.2.4 Develop and Trials Run the Program Simultaneously**

The programs have been developed and trials run simultaneously to assess its effectiveness. If there is any problem occurred at the certain program, it needs to check and make an adjustment to ensure its success. Basically, the MATLAB software itself will give an error command and prevent the program from being executed.

### **3.2.5 Create within GUI and Deploy the GUIs**

After all steps are finished up, the software is created in Graphical User Interface (GUI) template. This template provide the layout where its component such as push button, edit text, static text, panel and so on are can be adjustable to follow the design of this software. Next, the GUIs are being deployed by packaging them to standalone software. Here, the software can be run without the MATLAB software in computer. This means the software distribution and execution in platforms without a MATLAB license. If there is error within creating and deployment of the GUI, it shall be updating and refine in order its success.

## **3.3 SPECIFICATION OF TOOL INVOLVED IN PROJECT**

### **3.3.1 Software**

Software is the core tool that involved in order accomplishing the requirement of this project. The following are the details of software that is being used while conducting this project:

Programming language	: MathWorks MATLAB R2008a
Version	: MATLAB version 7.6 (R2008a)
Software activation	: Standalone
License key	: 11111-11111-11111-02626
License file	: license_standalone.dat
Statistics Graphics	: Plus 3.0
Statistics View	: v4.5

EDGE Diagrammer	: 3.0D
Lottery Statistic Analyser	: 3.8.3
Minitab	: 14.13
Probability and Statistics	: v3.5
Stable Technical Graphs	: 2.4

### 3.3.2 Computer

Another main tool that also include in this project is computer. Below are the specifications in details of computer that is being used:

Computer	: Samsung.
Manufacturer	: Samsung Electronics.
Rating	: 3.0 Windows Experience Index
Windows edition	: Windows 7 Starter
Processor	: Intel® Atom™ CPU N550 @ 1.50GHz
Installed memory (RAM)	: 2.00 GB
System type	: 32-bit Operating System
Windows activation	: Windows is activated
Product ID	: 00342-OEM-8992752-30013

## **CHAPTER 4**

### **INTERFACE AND RESULT**

#### **4.1 INTRODUCTION**

This chapter discussed on the result obtained where the content of this chapter is more towards to the software itself and their interface. Thus, the results will be expressed in figure and brief explanation in providing a clearer view and understanding for the reader. This software is named as MagNa version 1.0. MagNa version 1.0 is an application that can simulate some implementation of graph and calculation in Statistical Process Control (SPC) especially for automotive application.

## **4.2 SOFTWARE INTERFACE**

After go through the whole semester in accomplish this research, the result obtained can be divided into six categories as follows:

1. Main menu
2. Part details
3. Plotting graph
4. Compute and analyze data
5. Print the document
6. Close the windows

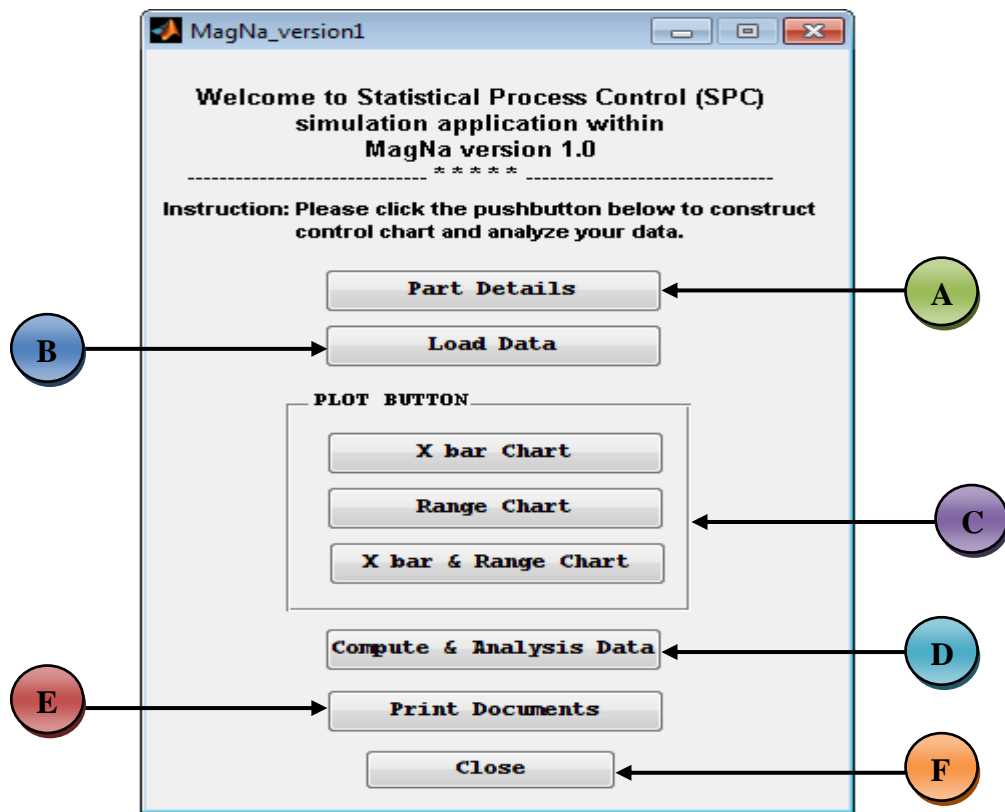
### **4.2.1 Main Menu**

The main menu is an element of computers and information appliances. It is a part of the user interface that allows users to interact with the machine. The primary purpose of the main menu is to organize the types of interactions such as commands, operations, requests, outputs, configurations and so on so forth that are possible between the user; usually a person and the machine or computer itself.

The main menu is the first layer of abstraction - or virtual organization - into which the entire set of interactions and commands are grouped. If this menu is organized in a way that most users will intuitively understand, then that menu is considered useful.







In developing this software, the main menu are designed for users who have never used a computer, for those who are beginners, for those with visual impairments, for those with cognitive difficulties, and even for very experienced users who may prefer to bypass them. In other words, it can be describing as user-friendly and portable with the user.

Figure 4.1 as below shows the main menu for this software; MagNa version 1.0.



**Figure 4.1:** Main menu of software

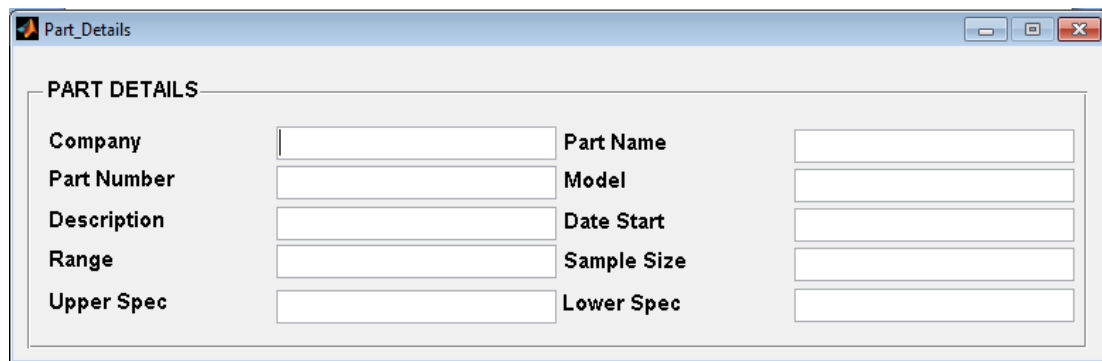
**Table 4.1:** General descriptions of pushbutton and its symbol

Symbol	General descriptions of pushbutton
	Labelled as Part Details where the user will enter the details or specifications of their part/product.
	Get the name as Load Data where the users are able to load their preferable data into this program.
	Consists of certain pushbutton to construct the prefer control chart to control the process performance.
	Functions as a calculator to compute and analysis data after constructing the control chart. Comment and action are also provided.
	Print the document as documentation for the company.
	Close the main windows after the utilizing are finished.



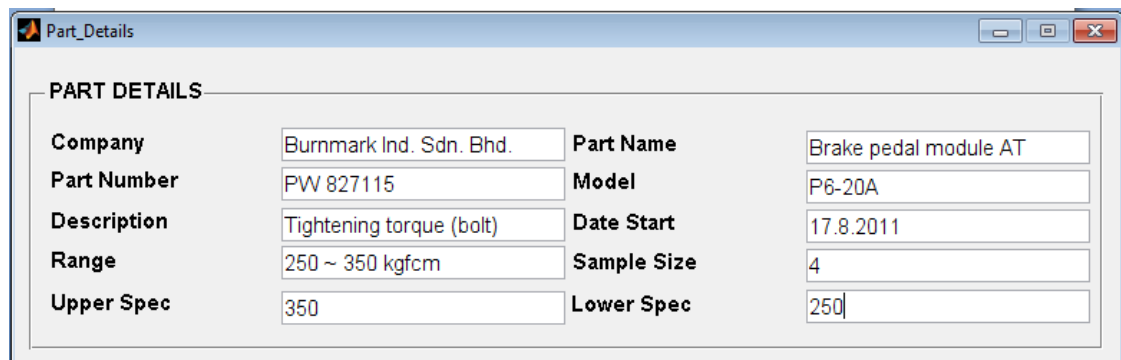
### 4.2.2 Part Details Pushbutton

By clicking this button, a figure which consists of a part details are appeared where it is needed to fulfil by the users as an introduction for the part itself. Besides, it helps the organization so that the workplaces can kept in neat, orderly and well-organized. Below is the figure of part details; before (4.2) and after (4.3) it fills by the users.



The screenshot shows a window titled "Part\_Details" with a tab labeled "PART DETAILS". Inside the window, there are two columns of input fields. The left column contains fields for "Company", "Part Number", "Description", "Range", and "Upper Spec". The right column contains fields for "Part Name", "Model", "Date Start", "Sample Size", and "Lower Spec". All fields are currently empty.

**Figure 4.2:** Windows for part details before it fills by users



The screenshot shows the same "Part\_Details" window, but now the input fields are filled with data. The left column contains: "Company" (Burnmark Ind. Sdn. Bhd.), "Part Number" (PW 827115), "Description" (Tightening torque (bolt)), "Range" (250 ~ 350 kgfcm), and "Upper Spec" (350). The right column contains: "Part Name" (Brake pedal module AT), "Model" (P6-20A), "Date Start" (17.8.2011), "Sample Size" (4), and "Lower Spec" (250).

**Figure 4.3:** Windows for part details after it fills by users

### 4.2.3 Load Data Pushbutton

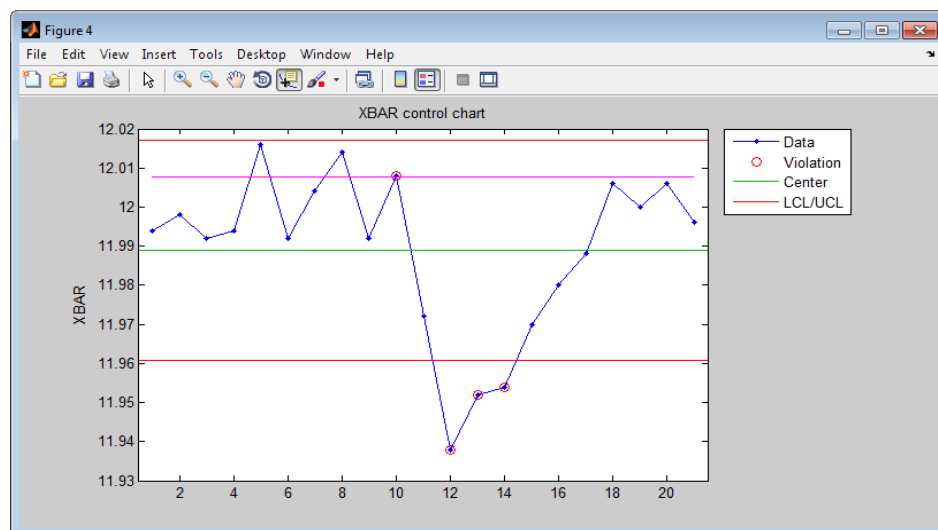
The data are selected by the user according to where they are saving those required data. For example, if we want to load a shaft.xls filename and it is saving at the user desktop, the pathname and the loadDataName will be as a figure 4.4 below:

```
filename = shaft.xls
pathname = C:\Users\User\Desktop\
loadDataName = C:\Users\User\Desktop\shaft.xls
```

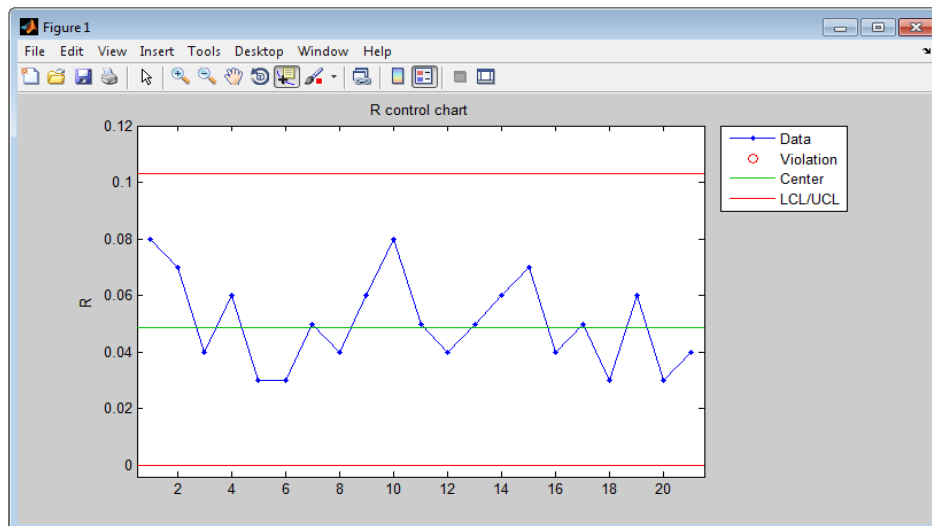
**Figure 4.4:** Acquired information after load the data

### 4.2.4 Pushbutton for Plot Graph

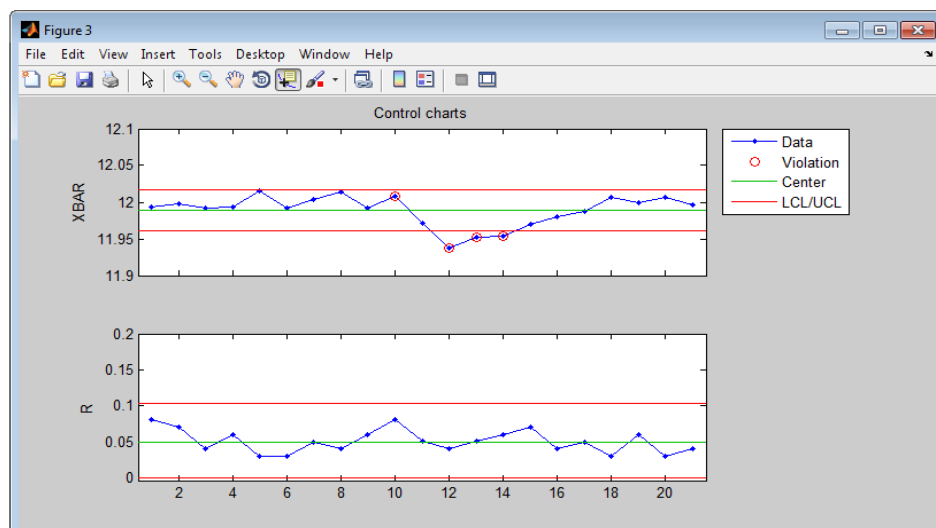
The pushbuttons for plot graph are arranged in a panel draft so that it will look more orderly. It consists of pushbutton for plot only  $\bar{X}$  chart, pushbutton for plot only R chart and also pushbutton for plot both  $\bar{X}$  and R chart. So the users are able to choose what kind of graph that they want to observe based on their job. The graphs are illustrated as figure 4.5, 4.6 and 4.7, respectively as the examples of control chart for all the three pushbutton.



**Figure 4.5:** Control chart for plot button X bar chart



**Figure 4.6:** Control chart for plot button R chart



**Figure 4.7:** Control chart for plot button both X bar and R chart

From those control charts, the users can define whether their process performances are in-control or out-of-control. They can be observed periodically after the data are started to measure.

#### 4.2.5 Compute and Analyze Data Pushbutton

For this windows, it works when the users are entered the value of Upper Specification Limit (USL) and Lower Specification Limit (LSL). Then, the compute raw data button is clicked and the raw items as in Figure 4.8 will be calculated. Next, the data are analyzed a moment after the users entered the observations in sample,  $n$  as required in the edit box. The calculate button then is clicked so that it will compute the capability indices and confidence interval. A part from this program, the comment and action will come out automatically based on the  $C_{pk}$  value. The users can follow the recommendation as a continuous improvement at their company.

This program will compute the capability indices and  
confident interval for the user based on Upper Specification Limit (USL)  
and Lower Specification Limit (LSL) of the part/product  
#####

---

**Instruction: Please enter your value of USL and LSL**

**Upper Specification Limit (USL)**

12.05

**Instruction: Please enter your observations in sample, n**

4

**Lower Specification Limit (LSL)**

11.95

**Compute**

**RAW ITEMS**

Number of readings (sample)	105
Maximum value of data	12.05
Minimum value of data	11.92
Average (X bar)	11.9889
Range (R bar)	0.0504762
Standard deviation of control limit	2.187
Standard deviation of capability indices	0.0214054
Upper Control Limit (X bar)	12.0257
Lower Control Limit (X bar)	11.9521
Upper Control Limit (R)	0.115187
Lower Control Limit (R)	0

**CAPABILITY INDICES & CONFIDENCE INTERVAL**

Process Capability (Cp)	0.778621
Estimated probability of being below USL (Cpu)	0.952142
Estimated probability of being below LSL (Cpl)	0.6051
Process Capability Index (Cpk)	0.6051
Confidence Interval	11.5705 to 12.4072

**COMMENT & ACTION**

<b>Capability</b>	This process is NOT CAPABLE!!!
<b>Comment</b>	This process will produce more than 2700 non-conforming part per million (ppm). It is impossible for the current process to meet specifications even when it is in statistical control. If the specifications are realistic, an effort must be immediately made to improve the process (i.e. reduce variation) to the point where it is capable of producing consistently within specifications.
<b>Action</b>	Improve by reducing common causes of variation in process variables. Use 100% inspection.

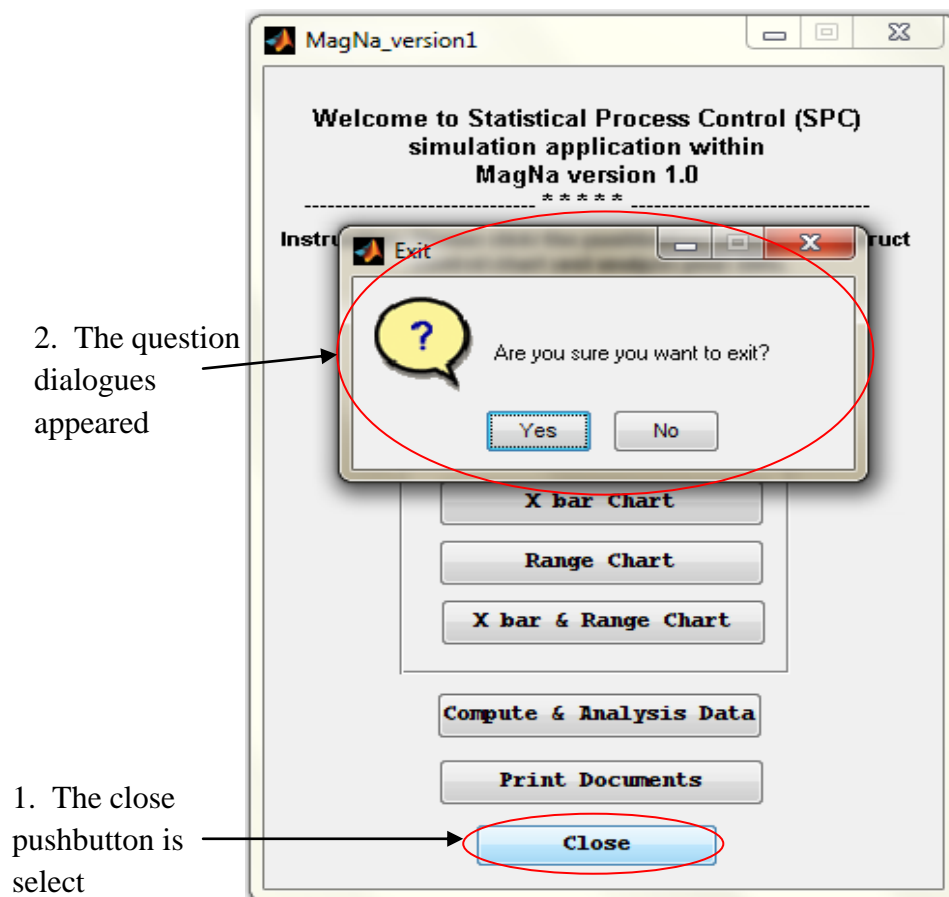
**Figure 4.8:** Windows for compute and analyze data

#### 4.2.6 Print Document Pushbutton

Then the documents are ready to print after they have been analyzed. All the data obtained are able to print. The users are able to set up their preferable requirement by adjusting the properties at the print windows. Refer appendix A to visualize the printed document.

#### 4.2.7 Close Pushbutton

Last but not least, the pushbutton is designed to function to close the windows after the users are choose to close the software, noted whether the data is being analyzed or not. Figure 4.9 as below is the question dialogue that appears after the close pushbutton is selected.



**Figure 4.9:** Windows to exit software

### 4.3 VALIDATION OF SOFTWARE

Validation is the process of determining the degree to which a model, simulation, or federation of models and simulations, and their associated data are accurate representations of the real world from the perspective of the intended use(s). Validation checks that the product design satisfies or fits the intended usage.

A part from that, the developed software in this project is needed to validate to check whether the software meets the user requirement or not. This is done through dynamic testing by using different kind of data as the samples.

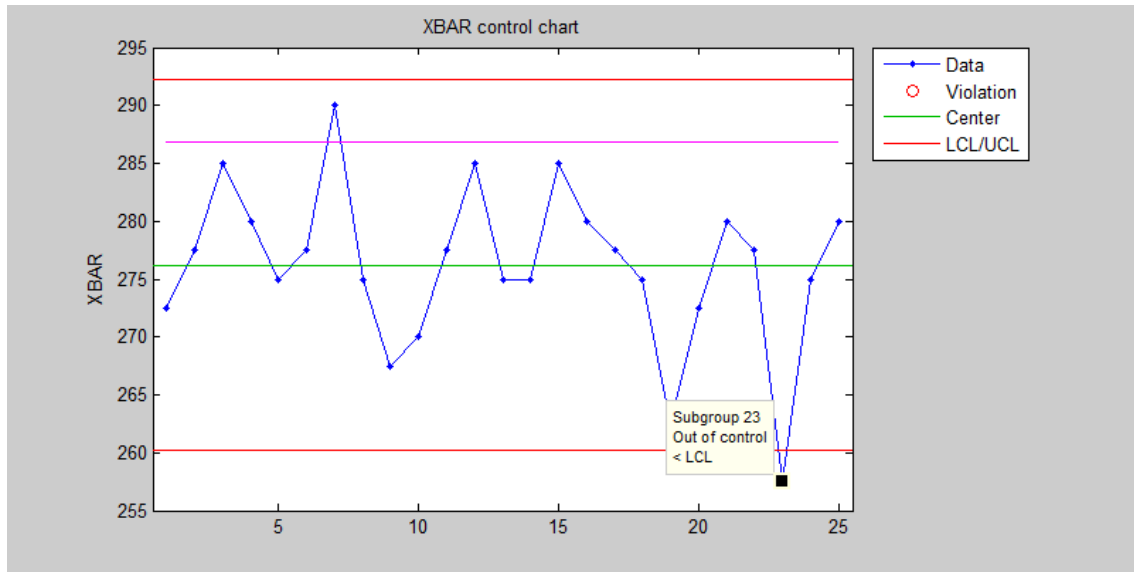
#### 4.3.1 Testing 1

The first testing is conducted to analyze the control chart by observing their behaviour and algorithm to recognize the pattern of the control chart and to calculate the statistic requirement;  $C_{pk}$  value less than 1 ( $C_{pk} < 1.0$ ) and come out with crucial comments to the users; notice for corrective action. The sample data of testing 1 is shows at appendix B. The results are as below, visualizing by figures and calculation.

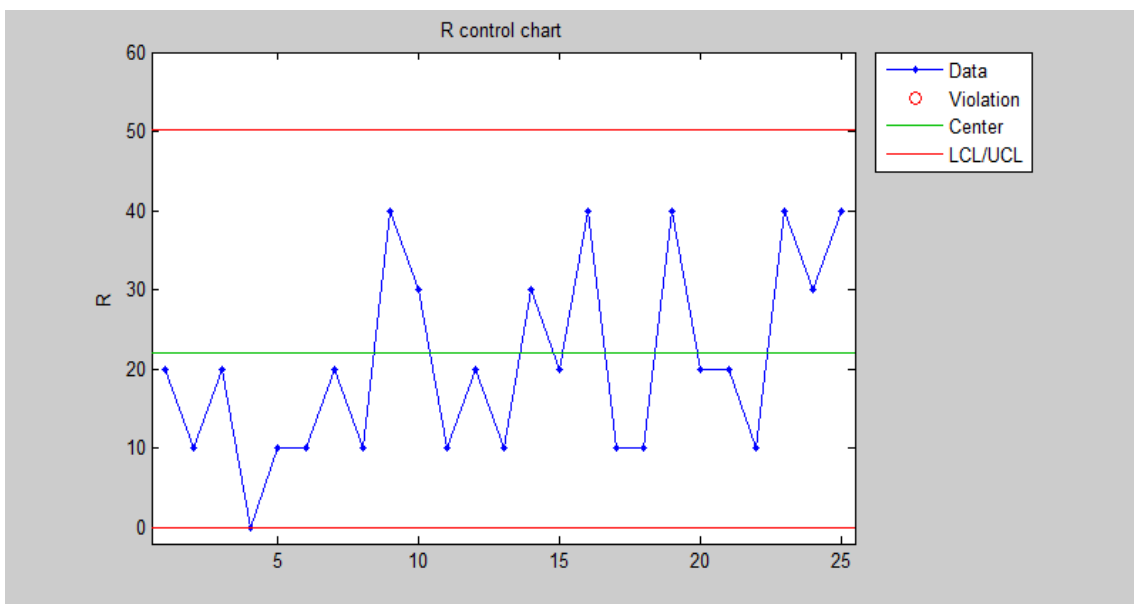
PART DETAILS			
Company	Burnmark Ind. Sdn. Bhd	Part Name	Brake Pedal Module MT
Part Number	PW 827104	Model	P6-20A
Description	Tightening Torque	Date Start	14/10/2010
Range	250 ~ 300kgfcm	Sample Size	4
Upper Spec	300	Lower Spec	250

**Figure 4.10:** Windows of part details for testing 1

Figure 4.10 shows that part details of first testing to validate the developed software. It as a result after clicked on part details pushbutton; they needed to fill up those criteria requirement as for introduction for their parts or products. The criteria are quite details to ensure the users are easy to do the documentation and organized their works.



**Figure 4.11:** X bar chart for testing 1



**Figure 4.12:** R chart for testing 1

The figure 4.11 illustrated the result of X bar chart while the figure 4.12 shows the result of R chart for testing 1. As a result, the data will be analyzed and able to detect unnatural runs indicating that the process is in-control or out-of-control. As a proven, the sample data for testing 1 is out-of-control and it visualized by X bar chart where one of the subgroup which is subgroup 23 are out-of-control. From that, the users will know that, the process is having some problem.

This program will compute the capability indices and confident interval for the user based on Upper Specification Limit (USL) and Lower Specification Limit (LSL) of the part/product  
#####

---

**Instruction: Please enter your value of USL and LSL**

**Upper Specification Limit (USL)**

300

**Instruction: Please enter your observations in sample, n**

5

**Lower Specification Limit (LSL)**

250

**Compute**

**RAW ITEMS**

Number of readings (sample)	100
Maximum value of data	300
Minimum value of data	240
Average (X bar)	276.2
Range (R bar)	20.8
Standard deviation of control limit	1.731
Standard deviation of capability indices	10.4766
Upper Control Limit (X bar)	288.202
Lower Control Limit (X bar)	264.198
Upper Control Limit (R)	43.9712
Lower Control Limit (R)	0

**CAPABILITY INDICES & CONFIDENCE INTERVAL**

Process Capability (Cp)	0.795424
Estimated probability of being below USL (Cpu)	0.757244
Estimated probability of being below LSL (Cpl)	0.833605
Process Capability Index (Cpk)	0.757244
Confidence Interval	275.861 to 276.539

**COMMENT & ACTION**

<b>Capability</b>	This process is NOT CAPABLE!!!
<b>Comment</b>	This process will produce more than 2700 non-conforming part per million (ppm). It is impossible for the current process to meet specifications even when it is in statistical control. If the specifications are realistic, an effort must be immediately made to improve the process (i.e.reduce variation) to the point where it is capable of producing consistently within specifications.
<b>Action</b>	Improve by reducing common causes of variation in process variables. Use 100% inspection.

**Figure 4.13:** Windows of analyzing data for testing 1

**COMMENT & ACTION**

<b>Capability</b>	This process is NOT CAPABLE!!!
<b>Comment</b>	This process will produce more than 2700 non-conforming part per million (ppm). It is impossible for the current process to meet specifications even when it is in statistical control. If the specifications are realistic, an effort must be immediately made to improve the process (i.e.reduce variation) to the point where it is capable of producing consistently within specifications.
<b>Action</b>	Improve by reducing common causes of variation in process variables. Use 100% inspection.

**Figure 4.14:** Windows of zoom in the comment and action

From the figure 4.13, the users are displayed on window of analyzing the entered data. This software is able to calculate the statistical data from the created control chart as in figure 4.11 and 4.12. Furthermore, the users will receive a comment and corrective action based on the  $C_{pk}$  value.



For this testing, it is evaluate the  $C_{pk}$  which value is not less than 1.0 ( $C_{pk} < 1.0$ ) and then, it will come out automatically with the capability, comment and action as shows in figure 4.14. As a result, the users are easy to take the corrective action as a recommended for their process performance.

Then, those data and graph can be print out after the user click on the print document pushbutton at the main menu. Refer appendix F to see the result of the printed document. On the other hand, to validate this software, the manual calculation for testing 1 is show in details.

$$\text{Average, } \bar{\bar{X}} = \frac{\sum_{i=1}^m \bar{X}_i}{m}$$

where

$\bar{\bar{X}}$  = average of the subgroup averages

$\bar{X}_i$  = average of the ith number

$m$  = number of subgroups

Thus,

$$\bar{\bar{X}} = \frac{6905}{25} = 276.2$$

By using equation 3.1, the value obtained is 276.2 for the average of the whole load data by user where the value is same as the software calculation. Then, it shows that the software calculation is tally with manual calculation. Furthermore, the software is validated.

$$\text{Range } (\bar{R}) = \frac{\sum_{i=1}^m R_i}{m}$$

where

$\bar{R}$  = average of the ranges

$R_i$  = individual range values for the sample

$m$  = number of subgroups

Thus,

$$\bar{R} = \frac{510}{25} = 20.8$$

By using equation 3.4, the value obtained is 20.8 for the average of the data range where the value is same as the software calculation. Then, it shows that the software calculation is tally with manual calculation. So, the software is validated.

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2 \bar{R}$$

where

$\bar{R}$  = average of the ranges

$\bar{\bar{X}}$  = average of the subgroup averages

$A_2$  = from table (appendix E)

Thus,

$$UCL_{\bar{X}} = 276.2 + 0.577(20.8) = 288.202$$

From the equation 3.2, the value obtained is 288.202 for the upper control limit of average chart where the value is same as the software calculation; 288.202. Then, it shows that the software calculation is tally with manual calculation. Hence, the software is validated.

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2 \bar{R}$$

where

$\bar{R}$  = average of the ranges

$\bar{\bar{X}}$  = average of the subgroup averages

$A_2$  = from table (appendix E)

Thus,

$$LCL_{\bar{X}} = 276.2 - 0.577(20.8) = 264.198$$

From the equation 3.3, the value obtained is 264.198 for the lower control limit of average chart where the value is same as the software calculation; 264.198. Then, it shows that the software calculation is tally with manual calculation. Hence, the software is validated.

$$UCL_R = D_4 \bar{R}$$

where

$\bar{R}$  = average of the ranges

$D_4$  = from table (appendix E)

Thus,

$$UCL_R = 2.114(20.8) = 43.9712$$

From the equation 3.5, the value obtained is 43.9712 for the upper control limit of range chart where the value is same as the software calculation; 43.9712. Then, it shows that the software calculation is tally with manual calculation. Thus, the software is validated.

$$LCL_R = D_3 \bar{R}$$

where

$\bar{R}$  = average of the ranges

$D_3$  = from table (appendix E)

Thus,

$$LCL_R = 0(20.8) = 0$$

From the equation 3.6, the value obtained is 0 for the lower control limit of range chart where the value is same as the software calculation; 0. Then, it shows that the software calculation is tally with manual calculation. So, the software is validated.

$$\bar{s} = \frac{\sum_{i=1}^m s_i}{m}$$

where

$s_i$  = standard deviation for each subgroup

$m$  = number of subgroups

Thus,

$$\bar{s} = \frac{246.2}{25} = 9.848$$

$$\hat{\sigma} = \frac{C_4}{\bar{s}}$$

where

$C_4$  = from table (appendix E)

Thus,

$$\hat{\sigma} = \frac{9.848}{0.9400} = 10.476$$

From the calculation above, the value obtained is 10.476 for the standard deviation of control limit where the value is same as the software calculation; 10.476. Then, it shows that the software calculation is tally with manual calculation. Thus, the software is validated.

$$C_p = \frac{USL - LSL}{6\hat{\sigma}} = \frac{300 - 250}{6(10.476)} = 0.795$$

By using equation 3.8, the value obtained is 0.795 for the process capability of the data loaded where the value is same as the software calculation; 0.795. Then, it shows that the software is validated.

In order to evaluate the process performance measurement,  $C_{pk}$  the data are computed in two ways where they are using the upper specification limit and lower specification limit. The smallest value is select to determine the  $C_{pk}$ .

$$C_{pk} = \frac{Z(\min)}{3}$$

where

$$Z(USL) = \frac{USL - \bar{X}}{\hat{\sigma}}, Z(LSL) = \frac{\bar{X} - LSL}{\hat{\sigma}}$$

Thus,

$$C_{pk} = \frac{USL - \bar{X}}{3\hat{\sigma}} = \frac{300 - 276.2}{3(10.476)} = 0.757$$

$$C_{pk} = \frac{\bar{X} - LSL}{3\hat{\sigma}} = \frac{276.2 - 250}{3(10.476)} = 0.834$$

By using equation 3.9, 3.10, and 3.11, the value obtained is 0.757 for the  $C_{pk}$  of the upper specification limit. Meanwhile, the value obtained for the  $C_{pk}$  of lower specification limit is 0.834. Both of the value obtained is same as the software calculation and shows that the software calculation is tally with manual calculation.

A confidence interval gives an estimated range of values which is likely to include an unknown population parameter, the estimated range being calculated from a given set of sample data. It is important in defining the range of processes. To validate the software, the confidence interval is calculated by referring to the equation 2.15.

$$\bar{x} - 1.96 \left( \frac{\sigma}{\sqrt{n}} \right) < \mu < \bar{x} + 1.96 \left( \frac{\sigma}{\sqrt{n}} \right)$$

where

$\bar{x}$  = sample mean

$\sigma$  = population standard deviation

$n$  = sample size

$\mu$  = hypothesized population mean

Thus,

$$276.2 - 1.96 \left( \frac{1.731}{\sqrt{100}} \right) < \mu < 276.2 + 1.96 \left( \frac{1.731}{\sqrt{100}} \right)$$

$$275.861 < \mu < 276.539$$

From the calculation above, shows that the manual calculation is tally with software calculation where the same values are obtained. The value for the upper range of hypothesized population mean,  $\mu$  is 275.861 while the lower range is 276.539. From this result, the process is in the range of the specification. Here, the user will know their processes are follows the specification; noted the processes can refer to the daily, weekly, or monthly observation.

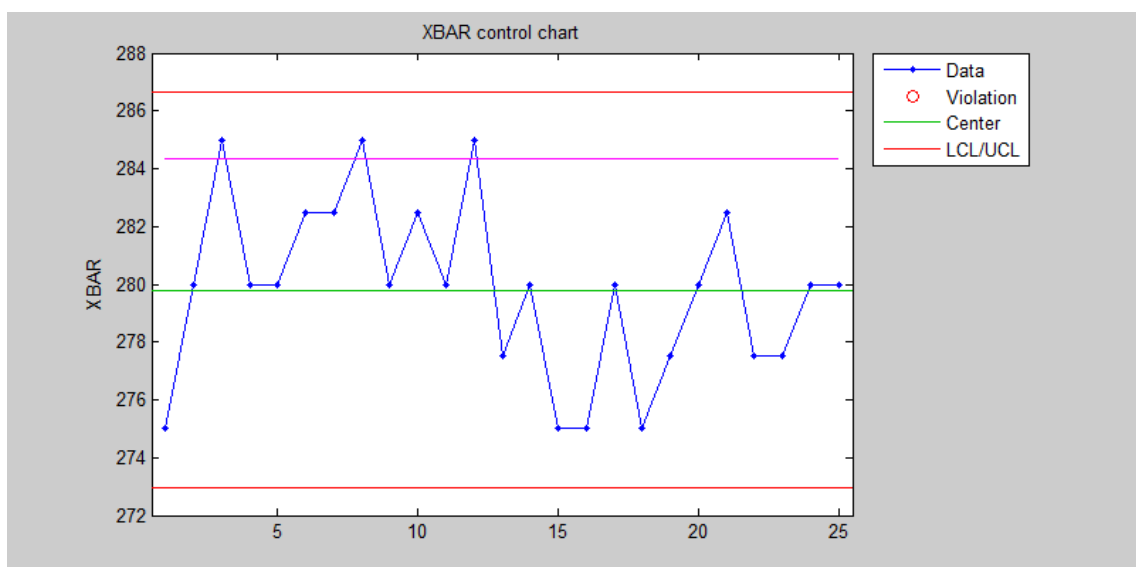
### 4.3.2 Testing 2

The second testing is conducted to analyze the data by observing their behaviour and algorithm to recognize the pattern of the control chart and to calculate the statistic requirement;  $C_{pk}$  value greater than 1.0 and not less than 3.0 ( $1.0 < C_{pk} < 3.0$ ) and come out with crucial comments to the users; notice for corrective action. The sample data of testing 2 is shows at appendix C. The results are as below, visualizing by figures and calculation.

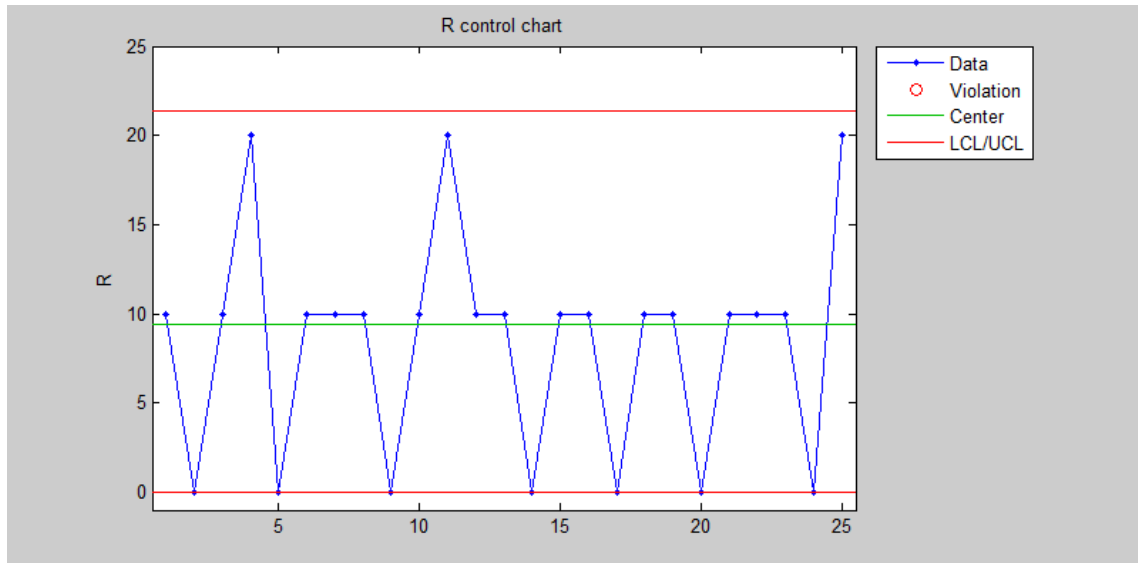
PART DETAILS			
Company	Burnmark Ind. Sdn. Bhd.	Part Name	Brake & Accel Pedal
Part Number	PW 825795	Model	BLM
Description	Weld Nut Strength	Date Start	20/01/2001
Range	250 ~ 350 kgfcm	Sample Size	4
Upper Spec	350	Lower Spec	250

**Figure 4.15:** Window of part details for testing 2

From the figure above, it shows that the details of part of second testing to validate the developed software.



**Figure 4.16:** X bar chart for testing 2



**Figure 4.17:** R chart for testing 2

The figure 4.16 indicated the result of X bar chart while the figure 4.17 shows the result of R chart for testing 2. As a result, the data will be analyzed and able to detect unnatural runs indicating that the process is in-control or out-of-control. This testing shows that all the data is in-control. From that, the users will know that, the process is not having problem.



This program will compute the capability indices and  
confident interval for the user based on Upper Specification Limit (USL)  
and Lower Specification Limit (LSL) of the part/product  
#####

---

**Instruction: Please enter your  
value of USL and LSL**

**Upper Specification  
Limit (USL)**

350

**Instruction: Please enter your  
observations in sample, n**

5

**Lower Specification  
Limit (LSL)**

250

**Compute**

**RAW ITEMS**

Number of readings (sample)	100
Maximum value of data	290
Minimum value of data	270
Average (X bar)	279.8
Range (R bar)	8.4
Standard deviation of control limit	1.731
Standard deviation of capability indices	4.46423
Upper Control Limit (X bar)	284.647
Lower Control Limit (X bar)	274.953
Upper Control Limit (R)	17.7576
Lower Control Limit (R)	0

**CAPABILITY INDICES & CONFIDENCE INTERVAL**

Process Capability (Cp)	3.73338
Estimated probability of being below USL (Cpu)	5.24166
Estimated probability of being below LSL (Cpl)	2.22509
Process Capability Index (Cpk)	2.22509
Confidence Interval	279.461 to 280.139

**COMMENT & ACTION**

<b>Capability</b>	This process is CAPABLE!!!
<b>Comment</b>	This process should produce less than 64 non-conforming ppm. This process will produce conforming products as long as it remains in statistical control. The process owner can claim that the customer should experience least difficulty and greater reliability with this product. This should translate into higher profits. Note: Cpk values of 1.33 or greater are considered to be industry benchmarks.
<b>Action</b>	Do nothing or some process improvement. Dependent on sample size.

**Figure 4.18:** Window of analyzing data for testing 2

**COMMENT & ACTION**

<b>Capability</b>	This process is CAPABLE!!!
<b>Comment</b>	This process should produce less than 64 non-conforming ppm. This process will produce conforming products as long as it remains in statistical control. The process owner can claim that the customer should experience least difficulty and greater reliability with this product. This should translate into higher profits. Note: Cpk values of 1.33 or greater are considered to be industry benchmarks.
<b>Action</b>	Do nothing or some process improvement. Dependent on sample size.

**Figure 4.19:** Window of zoom in the comment and action

From the figure 4.18, the users are displayed on window of analyzing the entered data. This software is able to calculate the statistical data from the created control chart as in figure 4.16 and 4.17. Furthermore, the users will receive a comment and corrective action based on the  $C_{pk}$  value.

For this testing, it is evaluate the  $C_{pk}$  which value is greater than 1.0 and not less than 3.0 ( $1.0 < C_{pk} < 3.0$ ) and then, it will come out automatically with the capability, comment and action as shows in figure 4.19. As a result, the users are easy to take the corrective action as a recommended for their process performance.

The manual calculation for testing 2 is shows at the appendix D. This step is taken to ensure the software calculation is tally as the manual. Then, those data and graph can be print out after the user click on the print document pushbutton at the main menu. Refer appendix G to see the result.

#### 4.4 SOFTWARE ADVANTAGES

There are several advantages that this developed software is carrying on for user especially for automotive industry application in order to achieve their quality goal respectively. The advantages of this software are as follows:

**i. User-friendly software**

This software is user-friendly according to its application that easy for user to use. The users only need to click the pushbutton to load the data, plot the control chart, analyze data and print the document. Besides that, the users are providing with comment and corrective action for their process performance.

**ii. Standalone software**

This software is standalone software after the programme and the GUI are deployed for distribution and execution in platform without a MATLAB license. This application is small in size, portable which can be carrying anywhere and also can be run in any Windows operating system.

**iii. Interesting**

This software provides the users with audio where it localized in the programme that displayed the capability, comment, and action. It is make this software looks more interesting with the attendance of audio while the background of the GUI is also quite colourful.

## **CHAPTER 5**

### **CONCLUSION AND FUTURE WORK**

#### **5.1 INTRODUCTION**

This chapter provide the summary of conducting the project from the beginning till the end. It concludes all the outcomes, observation of results and analysis, and discussion throughout the research to see whether the objectives will achieve or not. Furthermore, the future works will also be recommended to improve this study in the further research.

#### **5.2 CONCLUSION**

As a conclusion, this software named MagNa version 1.0 will bring a new hope for those small and automotive industry that used this simulation for their company. It is proved that by using Statistical Process Control (SPC), it will detect whether the production on that is in control or out of control. Besides, by applying that kind of theorem, the process capability and process performance measurement will be reliable on controlling the process behaviour of certain part and product.

The graphical method that provide by these tools play an important role in order to view the pattern of the graph produced from the data that had been collected from the selected company. Computer-based is the nowadays technology that should be applied to all company as it will give a good feedback and benefits on the production performance. It was very simple and user-friendly software. On the other hand, this application also is portable and can be run in any Windows operating system.

### 5.3 FUTURE WORK

There is no doubt that the first thing that had been developed is not perfect. From simulation and application of this software, it can be improved for future work as follows:

1. Revising the control limits by come out with more equation on the control chart such as  $\bar{\bar{X}}_{new}$  and  $\bar{\bar{R}}_{new}$  in order to determine the new limits against which the process will be judged in the future.
2. Come out with  $\bar{X}$  and standard deviation, s charts and not only  $\bar{X}$  and R chart because the s chart more accurate than the R chart. This greater accuracy is a result of the manner in which the standard deviation is calculated.
3. Provide the histogram other than control charts in order to see the dispersion of the process performance.
4. Providing a specific template so that the documents can be easier to print by the users.
5. Come out in better design for the software such as coming in tab as their menu, so that the users are easy to visualise and analysis the data in a manner way.

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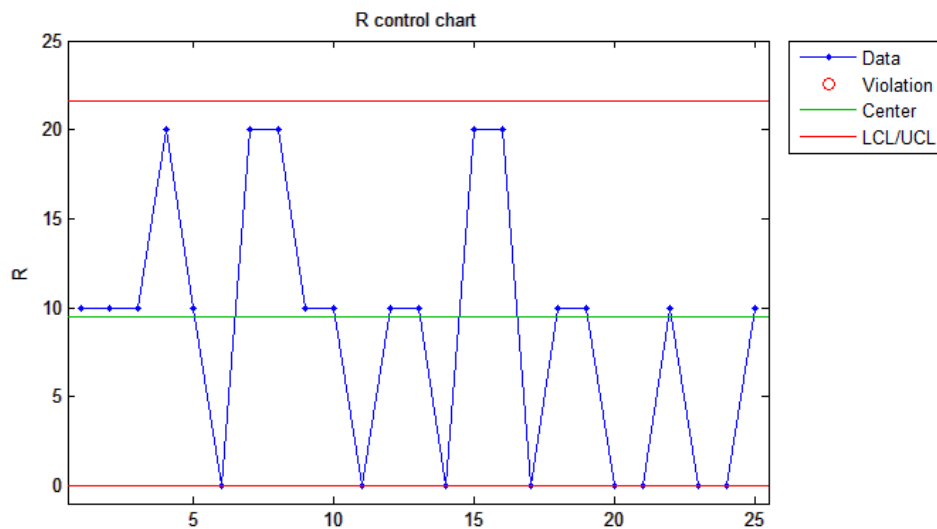
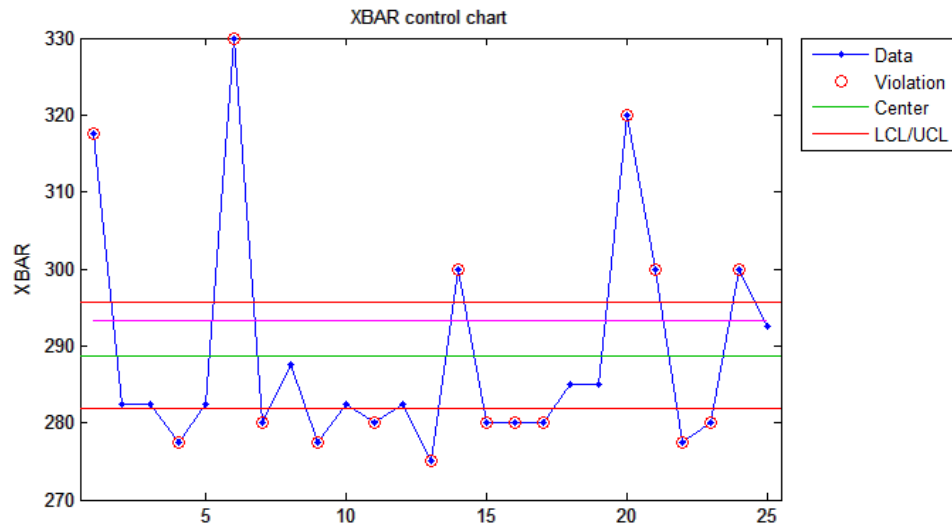
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## APPENDIX A

### SAMPLE OF PRINTED DOCUMENT

#### PART DETAILS

Company	Burnmark Ind. Sdn. Bhd.	Part Name	Brake Pedal Mount Assy
Part Number	PW 861635	Model	TRM
Description	Nut Strength	Date Start	15/12/2010
Range	250 ~ 350 kgfcm	Sample Size	4
Upper Spec	350	Lower Spec	250





This program will compute the capability indices and confident interval for the user based on  
Upper Specification Limit (USL) and Lower Specification Limit (LSL) of the part/product

#####

Instruction: PLEASE ENTER YOUR VALUE OF USL & LSL

Upper Specification  
Limit (USL)

350

Lower Specification  
Limit (LSL)

250

Compute raw data

#### RAW ITEMS

Number of readings (sample)	100
Maximum value of data	330
Minimum value of data	270
Average (X bar)	288.7
Range (R bar)	57.5
Standard deviation of control limit	7.38258
Standard deviation of capability indices	4.23856
Upper Control Limit (X bar)	310.848
Lower Control Limit (X bar)	266.552
Upper Control Limit (R)	79.6477
Lower Control Limit (R)	35.3523

#### CAPABILITY INDICES & CONFIDENCE INTERVAL

Instruction: Please enter your  
observations in sample, n

4

Calculate

Process Capability (Cp)	3.93216
Estimated probability of being below USL (Cpu)	4.82082
Estimated probability of being below LSL (Cpl)	3.04349
Process Capability Index (Cpk)	3.04349
Confidence Interval	287.253 to 290.147

#### COMMENT & ACTION

Capability

This process is VERY CAPABLE!!!

Comment

No inspection is required, process is very stable.

Action

Do nothing or reduce specification limits. No inspection necessary.

## APPENDIX B

### SAMPLE OF DATA FOR TESTING 1

280	280	270	260
280	270	280	280
280	280	300	280
280	280	280	280
270	280	280	270
270	280	280	280
300	300	280	280
280	270	280	270
280	280	270	240
270	280	280	250
270	280	280	280
280	280	280	300
270	270	280	280
290	280	270	260
280	300	280	280
300	280	280	260
280	270	280	280
280	280	270	270
270	260	240	280
280	270	280	260
270	280	280	290
280	270	280	280
270	280	240	240
290	270	280	260
300	280	280	260

## APPENDIX C

### SAMPLE OF DATA FOR TESTING 2

280	270	270	280
280	280	280	280
290	280	280	290
280	270	280	290
280	280	280	280
280	280	290	280
280	280	290	280
290	280	280	290
280	280	280	280
280	280	290	280
290	280	270	280
290	280	290	280
280	280	270	280
280	280	280	280
280	270	280	270
280	270	270	280
280	280	280	280
280	280	270	270
280	280	280	270
280	280	280	280
280	290	280	280
280	280	270	280
280	270	280	280
280	280	280	280
270	280	290	280

**APPENDIX D**  
**MANUAL CALCULATING FOR SOFTWARE VALIDATION FOR TESTING 2**  
**(1.0 < C<sub>pk</sub> < 3.0)**

Following are the data calculations of the developed software validation for testing 2:

**Data mean (average)**

$$\text{Average, } \bar{\bar{X}} = \frac{\sum_{i=1}^m \bar{X}_i}{m}$$

where

$\bar{\bar{X}}$  = average of the subgroup averages

$\bar{X}_i$  = average of the *i*th number

$m$  = number of subgroups

Thus,

$$\bar{\bar{X}} = \frac{6995}{25} = 279.8$$

**Data range**

$$\text{Range } (\bar{R}) = \frac{\sum_{i=1}^m R_i}{m}$$

where

$\bar{R}$  = average of the ranges

$R_i$  = individual range values for the sample

$m$  = number of subgroups

Thus,

$$\bar{R} = \frac{210}{25} = 8.4$$

### Upper and lower control limit for Xbar chart

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2 \bar{R}$$

where

$\bar{R}$  = average of the ranges

$\bar{\bar{X}}$  = average of the subgroup averages

$A_2$  = from table (appendix E)

Thus,

$$UCL_{\bar{X}} = 279.8 + 0.729(8.4) = 285.924$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2 \bar{R}$$

where

$\bar{R}$  = average of the ranges

$\bar{\bar{X}}$  = average of the subgroup averages

$A_2$  = from table (appendix E)

Thus,

$$LCL_{\bar{X}} = 279.8 - 0.729(8.4) = 273.676$$

### Upper and lower control limit for R chart

$$UCL_R = D_4 \bar{R}$$

where

$\bar{R}$  = average of the ranges

$D_4$  = from table (appendix E)

Thus,

$$UCL_R = 2.114(8.4) = 17.7576$$

$$LCL_R = D_3 \bar{R}$$

where

$\bar{R}$  = average of the ranges

$D_3$  = from table (appendix E)

Thus,

$$LCL_R = 0(20.8) = 0$$

### Standard deviation, Cp, and Cpk

$$\bar{s} = \frac{\sum_{i=1}^m s_i}{m}$$

where

$s_i$  = standard deviation for each subgroup

$m$  = number of subgroups

Thus,

$$\bar{s} = \frac{104.91}{25} = 4.196$$

$$\hat{\sigma} = \frac{C_4}{\bar{s}}$$

where

$C_4$  = from table (appendix D)

Thus,

$$\hat{\sigma} = \frac{4.196}{0.9213} = 4.554$$

$$C_p = \frac{USL - LSL}{6\hat{\sigma}} = \frac{350 - 250}{6(4.554)} = 3.660$$

$$C_{pk} = \frac{Z(\min)}{3}$$

where

$$Z(USL) = \frac{USL - \bar{X}}{\hat{\sigma}}, Z(LSL) = \frac{\bar{X} - LSL}{\hat{\sigma}}$$

Thus,

$$C_{pk} = \frac{USL - \bar{X}}{3\hat{\sigma}} = \frac{350 - 279.8}{3(4.554)} = 5.138$$

$$C_{pk} = \frac{\bar{X} - LSL}{3\hat{\sigma}} = \frac{279.8 - 250}{3(4.554)} = 2.181$$

### Confidence interval

$$\bar{x} - 1.96 \left( \frac{\sigma}{\sqrt{n}} \right) < \mu < \bar{x} + 1.96 \left( \frac{\sigma}{\sqrt{n}} \right)$$

where

$\bar{x}$  = sample mean

$\sigma$  = population standard deviation

n = sample size

$\mu$  = hypothesized population mean

Thus,

$$279.8 - 1.96 \left( \frac{1.731}{\sqrt{100}} \right) < \mu < 279.8 + 1.96 \left( \frac{1.731}{\sqrt{100}} \right)$$
$$279.461 < \mu < 280.139$$

# APPENDIX E

TABLE OF FACTORS FOR COMPUTING CENTRAL LINES AND  $3\sigma$  CONTROL LIMITS FOR  $\bar{X}$ ,  $s$ , AND  $R$  CHARTS

TABLE Factors for Computing Central Lines and  $3\sigma$  Control Limits for  $\bar{X}$ ,  $s$ , and  $R$  Charts

OBSERVATIONS IN SAMPLE, $n$	CHART FOR AVERAGES			CHART FOR STANDARD DEVIATIONS					CHART FOR RANGES					
	FACTORS FOR CONTROL LIMITS			FACTOR FOR CENTRAL LINE	FACTORS FOR CONTROL LIMITS				FACTOR FOR CENTRAL LINE	FACTORS FOR CONTROL LIMITS				
	$A$	$A_2$	$A_3$	$C_4$	$B_3$	$B_4$	$B_5$	$B_6$	$d_2$	$d_3$	$D_1$	$D_2$	$D_3$	$D_4$
2	2.121	1.880	2.659	0.7979	0	3.267	0	2.606	1.128	0.853	0	3.686	0	3.267
3	1.732	1.023	1.954	0.8862	0	2.568	0	2.276	1.693	0.888	0	4.358	0	2.574
4	1.500	0.729	1.628	0.9213	0	2.266	0	2.088	2.059	0.880	0	4.698	0	2.282
5	1.342	0.577	1.427	0.9400	0	2.089	0	1.964	2.326	0.864	0	4.918	0	2.114
6	1.225	0.483	1.287	0.9515	0.030	1.970	0.029	1.874	2.534	0.848	0	5.078	0	2.004
7	1.134	0.419	1.182	0.9594	0.118	1.882	0.113	1.806	2.704	0.833	0.204	5.204	0.076	1.924
8	1.061	0.373	1.099	0.9650	0.185	1.815	0.179	1.751	2.847	0.820	0.388	5.306	0.136	1.864
9	1.000	0.337	1.032	0.9693	0.239	1.761	0.232	1.707	2.970	0.808	0.547	5.393	0.184	1.816
10	0.949	0.308	0.975	0.9727	0.284	1.716	0.276	1.669	3.078	0.797	0.687	5.469	0.223	1.777
11	0.905	0.285	0.927	0.9754	0.321	1.679	0.313	1.637	3.173	0.787	0.811	5.535	0.256	1.744
12	0.866	0.266	0.886	0.9776	0.354	1.646	0.346	1.610	3.258	0.778	0.922	5.594	0.283	1.717
13	0.832	0.249	0.850	0.9794	0.382	1.618	0.374	1.585	3.336	0.770	1.025	5.647	0.307	1.693
14	0.802	0.235	0.817	0.9810	0.406	1.594	0.399	1.563	3.407	0.763	1.118	5.696	0.328	1.672
15	0.775	0.223	0.789	0.9823	0.428	1.572	0.421	1.544	3.472	0.756	1.203	5.741	0.347	1.653
16	0.750	0.212	0.763	0.9835	0.448	1.552	0.440	1.526	3.532	0.750	1.282	5.782	0.363	1.637
17	0.728	0.203	0.739	0.9845	0.466	1.534	0.458	1.511	3.588	0.744	1.356	5.820	0.378	1.622
18	0.707	0.194	0.718	0.9854	0.482	1.518	0.475	1.496	3.640	0.739	1.424	5.856	0.391	1.608
19	0.688	0.187	0.698	0.9862	0.497	1.503	0.490	1.483	3.689	0.734	1.487	5.891	0.403	1.597
20	0.671	0.180	0.680	0.9869	0.510	1.490	0.504	1.470	3.735	0.729	1.549	5.921	0.415	1.585

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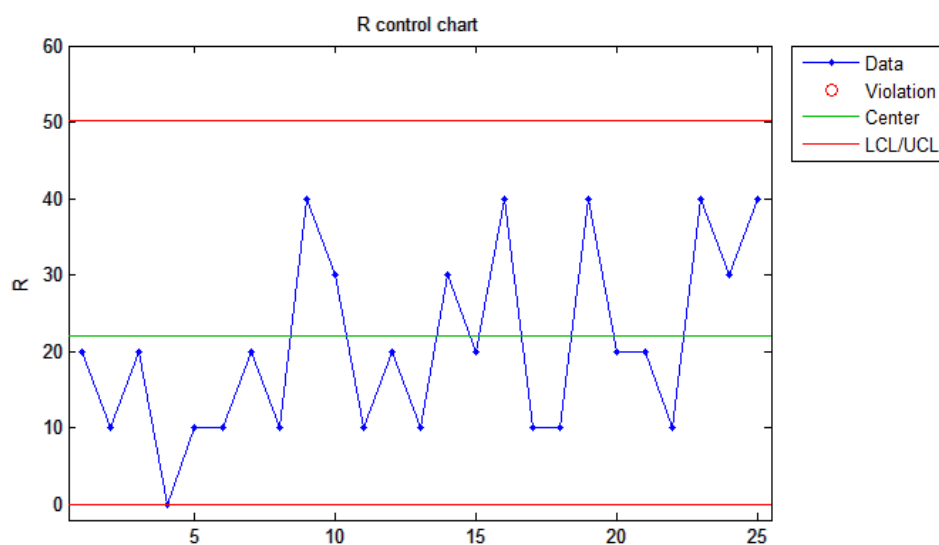
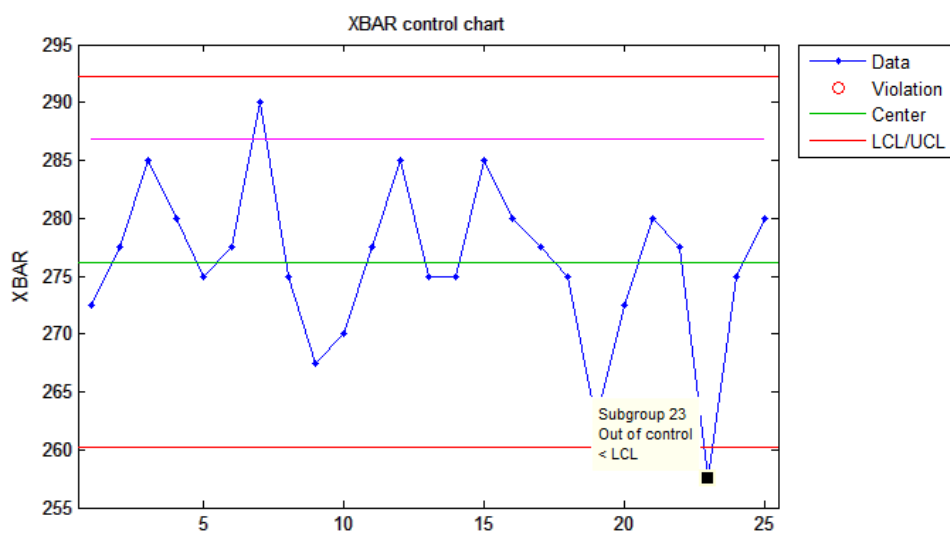


## APPENDIX F

### SAMPLE OF PRINTED DOCUMENT FOR TESTING 1

#### PART DETAILS

Company	Burnmark Ind. Sdn. Bhd	Part Name	Brake Pedal Module MT
Part Number	PW 827104	Model	P6-20A
Description	Tightening Torque	Date Start	14/10/2010
Range	250 ~ 300kgfcm	Sample Size	4
Upper Spec	300	Lower Spec	250



This program will compute the capability indices and  
confident interval for the user based on Upper Specification Limit (USL)  
and Lower Specification Limit (LSL) of the part/product

#####

Instruction: Please enter your  
value of USL and LSL

Upper Specification  
Limit (USL)

300

Instruction: Please enter your  
observations in sample, n

5

Lower Specification  
Limit (LSL)

250

Compute

#### RAW ITEMS

Number of readings (sample)	100
Maximum value of data	300
Minimum value of data	240
Average (X bar)	276.2
Range (R bar)	20.8
Standard deviation of control limit	1.731
Standard deviation of capability indices	10.4766
Upper Control Limit (X bar)	288.202
Lower Control Limit (X bar)	264.198
Upper Control Limit (R)	43.9712
Lower Control Limit (R)	0

#### CAPABILITY INDICES & CONFIDENCE INTERVAL

Process Capability (Cp)	0.795424
Estimated probability of being below USL (Cpu)	0.757244
Estimated probability of being below LSL (Cpl)	0.833605
Process Capability Index (Cpk)	0.757244
Confidence Interval	275.861 to 276.539

#### COMMENT & ACTION

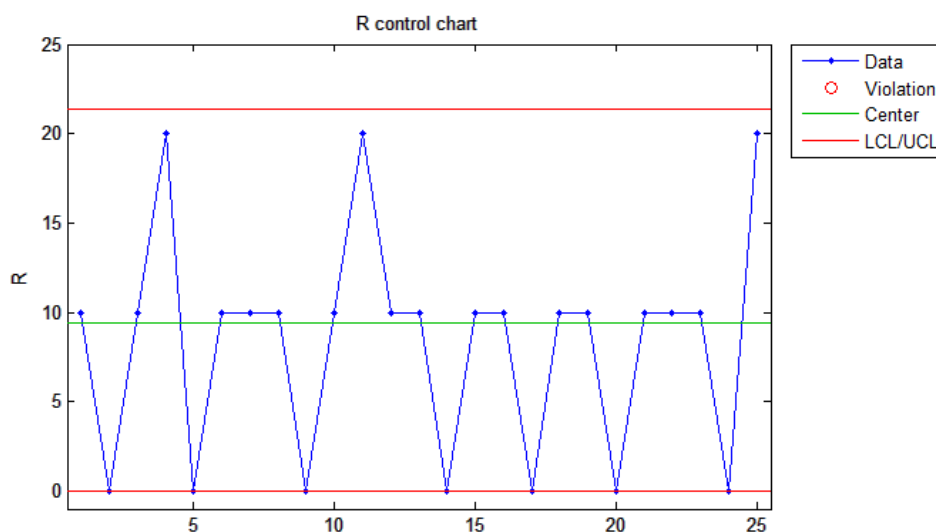
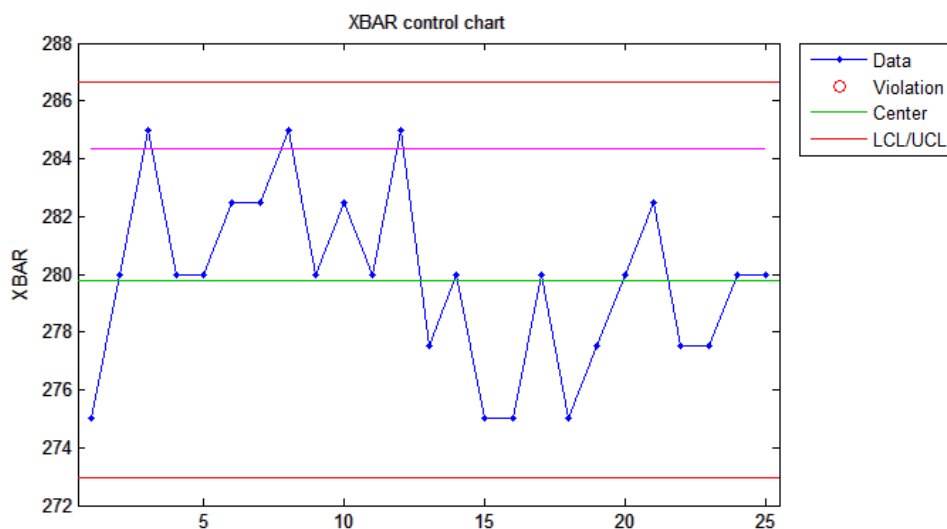
Capability	This process is NOT CAPABLE!!!
Comment	This process will produce more than 2700 non-conforming part per million (ppm). It is impossible for the current process to meet specifications even when it is in statistical control. If the specifications are realistic, an effort must be immediately made to improve the process (i.e. reduce variation) to the point where it is capable of producing consistently within specifications.
Action	Improve by reducing common causes of variation in process variables. Use 100% inspection.

## APPENDIX G

### SAMPLE OF PRINTED DOCUMENT FOT TESTING 2

#### PART DETAILS

Company	Burnmark Ind. Sdn. Bhd.	Part Name	Brake & Accel Pedal
Part Number	PW 825795	Model	BLM
Description	Weld Nut Strength	Date Start	20/01/2001
Range	250 ~ 350 kgfcm	Sample Size	4
Upper Spec	350	Lower Spec	250



This program will compute the capability indices and  
confident interval for the user based on Upper Specification Limit (USL)  
and Lower Specification Limit (LSL) of the part/product

#####

Instruction: Please enter your  
value of USL and LSL

Upper Specification  
Limit (USL)

350

Instruction: Please enter your  
observations in sample, n

5

Lower Specification  
Limit (LSL)

250

Compute

#### RAW ITEMS

Number of readings (sample)	100
Maximum value of data	290
Minimum value of data	270
Average (X bar)	279.8
Range (R bar)	8.4
Standard deviation of control limit	1.731
Standard deviation of capability indices	4.46423
Upper Control Limit (X bar)	284.647
Lower Control Limit (X bar)	274.953
Upper Control Limit (R)	17.7576
Lower Control Limit (R)	0

#### CAPABILITY INDICES & CONFIDENCE INTERVAL

Process Capability (Cp)	3.73338
Estimated probability of being below USL (Cpu)	5.24166
Estimated probability of being below LSL (Cpl)	2.22509
Process Capability Index (Cpk)	2.22509
Confidence Interval	279.461 to 280.139

#### COMMENT & ACTION

Capability	This process is CAPABLE!!!
Comment	This process should produce less than 64 non-conforming ppm. This process will produce conforming products as long as it remains in statistical control. The process owner can claim that the customer should experience least difficulty and greater reliability with this product. This should translate into higher profits. Note: Cpk values of 1.33 or greater are considered to be industry benchmarks.
Action	Do nothing or some process improvement. Dependent on sample size.

## APPENDIX H

### GANTT CHART FOR FINAL YEAR PROJECT 2

