## The Development of Multivariate Statistical Process Monitoring (MSPM) Tools using Microsoft<sup>®</sup> Excel

by

Mohd Syaufi Bin Che Elliaziz

Project Dissertation submitted in partial fulfillment of the requirements for the Bachelor of Engineering (Hons) (Chemical Engineering)

### JANUARY 2009

Universiti Teknologi PETRONAS Bandar Seri Iskandar 31750 Tronoh Perak Daruł Ridzuan

## The Development of Multivariate Statistical Process Monitoring (MSPM) Tools Using Microsoft<sup>®</sup> Excel

by Mohd Syaufi Bin Che Elliaziz

A project dissertation submitted to the Chemical Engineering Programme Universiti Teknologi PETRONAS in partial fulfilment of the requirement for the BACHELOR OF ENGINEERING (Hons) (CHEMICAL ENGINEERING)

Approved by,

(Ir Dr. Abdul Halim Shah Bin Maulud)

UNIVERSITI TEKNOLOGI PETRONAS

#### TRONOH, PERAK

January 2009

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(MOHD SYAUFI BIN CHE ELLIAZIZ)

#### ABSTRACT

Multivariate statistical process control methods have been proven in the process industries to be an effective tool for process monitoring, modelling and fault detection. This paper describes the approach used by the writer in the development of a Multivariate Statistical Process Monitoring (MSPM) tools using Microsoft Excel. This developed MSPM tools will act as a process monitoring tools in order to monitor the performance of any equipment or process. In addition, this project will be testing on actual plant data to see the performance of the project. The tool will be developed in Microsoft Excel and Matlab. Microsoft Excel is chosen because of it is easy to use and user-friendly. Furthermore, it has macro function and easier to use when the user wants to develop many tools to the Microsoft Excel. In multivariate statistical process monitoring, a process monitoring model must be developed firstly. The model must be free from any abnormality, fault or outliers. Then the model will be tested on the future data to detect any abnormality in the process by applying the appropriate limits. As a conclusion, the MSPM method can be develop in Microsoft Excel. This tool can help to detect the problem or abnormality of the process and help in diagnoss assignable cause for the process

# **TABLE OF CONTENTS**

CERTIFICATI	ON OF APPROVAL
CERTIFICATIO	ON OF ORIGINALITY
ABSTRACT	i
ACKNOWLED	GEMENTiv
LIST OF FIGU	RESv
CHAPTER 1:	INTRODUCTION1
	1.1 Problem Statement1
	1.1.1 Background1
	1.2 Objectives and Scope of Study2
	1.3.1 Objectives2
	1.3.2 Scope of Study2
CHAPTER 2:	LITERATURE REVIEW AND THEORY
	2.1 Theory
	2.1.1 Statistical Process Control Charts
	2.1.2 Multivariate methods for monitoring product quality4
	2.1.3 Multivariate methods for process monitoring4
	2.2 Principal Component Analysis (PCA)
	2.2.1 Using standardized variables7
	2.3 The Control Chart
	2.4 Limit
	2.5 Biplots
CHAPTER 3:	METHODOLOGY
	3.1 Step in Multivarriate Statistical Process Control (MSPC)11
	3.1.1 Data Loading11
	3.1.2 Data Processing/Normalization11

	3.1.3 Outlier Detection	12
	3.1.4 Principal Component Analysis (PCA)	12
	3.1.5 Limit	12
	3.2 Concept of Idea in Microsoft Excel	12
CHAPTER 4:	RESULTS AND DISCUSSION	15
	4.1 Interface	15
	4.2 Example	21
CHAPTER 5:	CONCLUSION	28
CHAPTER 6:	REFERENCES	29

# LIST OF FIGURES

Figure 1	The Shewhart Chart or Process-Behaviour Chart	8
Figure 2	The Biplot	10
Figure 3	Input Interface	15
Figure 4	Normalize Interface	16
Figure 5	Control Chart Interface	17
Figure 6	Data Interface	18
Figure 7	Future Data Interface	19
Figure 8	Normalization of Future Data Interface	20
Figure 9	Input Interface with Sample Data	21
Figure 10	Normalization Interface with Sample Data	22
Figure 11	Control Chart Interface with Sample Data	23
Figure 12	Remove Outliers Interface with Sample Data	24
Figure 13	Future Data Interface with Sample Data	25
Figure 14	Normalization of Future Data Interface with Sample Data	26
Figure 15	Result Interface with Sample Data	27

### ACKNOWLEDGEMENTS

First and foremost, the group would like to thank God for constantly strengthen and enlighten the author every step through the project and make all things possible in the end.

Throughout the progress of Final Year Project, the author would like to acknowledge his family for always being there to provide moral support to him.

Next, the author's utmost gratitude goes to the author's supervisor, Ir. Dr. Abdul Halim Shah Maulud. Without his guidance and patience, the author would not be succeeded to complete the project. To the Final Year Project Coordinator, Mr Tazli Azizan for provide her with all the initial information required to begin the project.

To the entire technician in Chemical Engineering, thank you for assisting the author in completing her project.

To all individuals that has helped the author in any way, but whose name is not mentioned here, the author thank you all.

# CHAPTER 1 INTRODUCTION

#### 1.1 Problem Statement

#### 1.1.1 Background

In today's competitive oil and gas industry, the pressure to improve the performance of processing facilities is intense. The advent of modern process measurement, automation, and information systems has resulted in a significant in amount of process data available. Unfortunately, it is often very difficult to monitor such a large amount of data. Multivariate Statistical Process Control (MSPC) methods, and Principal Component Analysis (PCA), have been demonstrated to provide a powerful approach for detection and isolation of abnormal conditions.

Multivariate Statistical Process Control (MSPC) concept and method has become significant in manufacturing and process industrial to control the process. Of these techniques, MSPC methods have been demonstrated to provide a powerful approach for detection and isolation of abnormal conditions. To perform this method, it's required an expensive commercial software or research computing software (e.g Matlab) to process the data. In this project, MSPC will be develop in Microsoft Excel in such the software can be widely used and shared with Microsoft Excel platform.

#### 1.2 Objective and Scope of Study

#### 1.2.1 Objective

The objectives of this study are stated below:-

- 1. To develop the multivariate statistical process monitoring tool by using Microsoft Excel.
- 2. To monitor and analysis the performance using the developed Multivariate Statistical Process Control method.
- 3. To test the developed software using actual plant data

#### 1.2.2 Scope of Study

The project would concentrate on development of monitoring tools based on multivariate statistical method.

- 1. To study about the fundamental concept of Multivariate Statistical Process Monitoring.
- 2. To learn more about the software uses in develop the monitoring tools.

# CHAPTER 2 LITERATURE REVIEW

#### 2.1 Theory

#### 2.1.1 Statistical Process Control Chart

Statistical process control (SPC) involves using statistical techniques to measure and analyze the variation in processes. Most often used for manufacturing processes and process industries, the intent of SPC is to monitor product quality and maintain processes to fixed targets. Statistical quality control refers to using statistical techniques for measuring and improving the quality of processes. Their objective is to monitoring the performance of a process over time in order to verify that the process is remaining in a "state of statistical control". Such a state of control is said to exist if certain process or product variables remain close to their desired values and only source of variation is "common-cause" variation, that is, variation which affect the all process the time and is essentially unavoidable within the current process. (J.F MacGregor and T. Kourti, 1995).

Shewhart, CUSUM and EWMA charts which SPC chart used to monitor key product variables in order to detect the occurrence of any event having a "special" or "assignable" cause. SPC monitoring methods should be applied on top of the process and its automatic control system in order to detect process behavior that indicates and occurrence of a special event. By diagnosing cause for the event and removing, the process is improved.

3

Unfortunately, most SPC methods are based on charting only small number of variables, usually the final product quality variables(Y). Many industrial processes involve a set of input variables and quality variables, which are highly correlated. If one of the variable changes, it will affect the other correlated variables. Thus, ignoring the cross-correlation between the variables can lead to misinterpretation of the process behavior. (M.W. Yee and Kamarul A.I.). Therefore, it is very difficult to diagnosis and makes interpretation, as though the variables were independent. Such methods only look at the magnitude of the deviation in each variable independently to each others.

The multivariate method is the only way to treat all the data simultaneously and also extract information on the directionality of the process variations. In addition, when important events occur in progress they are often difficult to detect due to the signal to noise ratio is very low in each variable. But, the multivariate method can extract the information from observations on many variables and can reduce the noise level through averaging.

#### 2.1.2 Multivariate method for monitoring product quality

In most cases, the traditional SPC charts (Shewhart, CUSUM and EWMA) are used to separately monitor key measurement on the final product which define the quality of the product. On this approach, the difficulty is to determine which one of the variables defines the product quality. The product quality only can be defined by correct simultaneous values of all the measured properties, that is, it is a multivariate property.

#### 2.1.3 Multivariate method for process monitoring

The main approach of statistical quality control (SQC) method are only monitor the product quality data (Y) and all of the data on process variables (X) are being ignored.

To perform the SPC, all the data must be look and analyst. The process variables are much more frequently measured than the product quality data. Furthermore, any special event which occur will also have their fingerprints in these process data (J.F MacGregor and T. Kourti, 1995). It will use useful to know if the product is good before using it. Monitoring the process would help early in detection of poor-quality product.

The most practical approaches to multivariate SPC appear to be those based on multivariate statistical projection method such as PCA and PLS. the methods are ideal for handling the large number of highly correlated and noisy process variable measurement that being collected by process computer.

#### 2.2 Principal Component Analysis (PCA)

Although there may be hundreds of plant variables that measured in any given process, there tend to be only a small number of underlying characteristics that actually drive the process. The purpose of PCA is to identify a new set of variables that reflect these characteristics. These new variables, termed scores or latent variables are linear combinations of the original process variables. The expectation is that there will be fewer scores than plant variables and therefore the plant can be monitored with much greater ease by simply analyzing these new variables.( A. AlGhazzawi and B. Lennox, 2007).

Principal component analysis (PCA) was first introduced by Karl Pearson in the early 1900's. The other main advantage of PCA is that once have found these patterns in the data, and compress the data, i.e. by reducing the number of dimensions, without much loss of information.

In mathematical term, PCA decomposes the data matrix X of size [m,n]. Consider an mdimensional data set

$$\mathbf{X} = [\mathbf{x}_1, \mathbf{x}_2, \dots, \mathbf{x}_m] \tag{1}$$

The principal component decomposition of X can be defined as

$$X = TP^{T} + E = \sum_{i=1}^{i} t_{i} p_{i}^{T} + E \quad (i < \min(m, n))$$
(2)

Where n is number of samples,

$$\mathbf{T} = [t_1, t_2, ..., t_i]$$
(3)

Is the matrix of the principal component scores,

$$\mathbf{P} = [p_1, p_2, ..., p_i]$$
(4)

Is the matrix of principal component loading and E is the residual matrix in the sense of minimum Eucliean norm and i is the number of significant component retained.

To monitor the process using a PCA model, a data set of representative normal process operation is used to identify a reference model. When the new data are available, it is projected onto this reference model according to

$$T_{new} = x_{new} P + e \tag{5}$$

Where P is the loading matrix, and two complementary control charts are typically used to assess if the new data are consistent with that from the normal process condition: the Hotteling's  $T^2$  and the Squared Prediction Error (SPE). The hotelling's T2 statistic will detect deviations within then model, where as the SPE statistic will detect deviations from the model. These two statistics will be proceeding for the next semester.

#### 2.2.1 Using Standardized variables

Investigators frequently prefer to standardize the x variables prior to performing the principal component analysis. Standardization is achieved by dividing each variable by its sample standard deviation. This analysis is then equivalent to analyzing the correlation matrix instead of the covariance matrix.

#### 2.3 The Control Chart

The control chart was invented by Walter A. Shewhart in the 1920s. The control chart, (also known as the 'Shewhart chart' or 'process-behaviour chart') is a tool used to determine whether a manufacturing process is in a state of statistical control or not. The figure 1 shows the example of control chart. There are many type of control chart such as X- chart, R-chart and S-chart. But for this, it uses the X-chart to detect the statistical in control or not.

A control chart consists of the following:

- Points representing measurements of a quality characteristic in samples taken from the process at different times [the data]
- A centre line, drawn at the process characteristic mean which is calculated from the data
- Upper and lower control limits that indicate the threshold at which the process output is considered statistically 'unlikely'



Figure 1: The Shewhart Chart or Process-Behaviour Chart or Control Chart

#### 2.4 Limit

Natural extensions of the Shewhart chart to situations where one observes a vector of k variables y, 1 at each time period are the multivariate  $x^2$  and  $T^2$  charts. Given a  $(k \ x \ 1)$  vector of measurements y on k normally distributed variables with an in-control covariance matrix 2 one can test whether the mean  $\mu$  of these variables is at its desired target  $\tau$  by computing the statistic.

$$x^{2} = (y - \tau)^{T} \sum_{x} (y - \tau)$$
(6)

This statistic will be distributed as a central x2 distribution with k degrees of freedom if  $\mu = \tau$ . A multivariate x<sup>2</sup> control chart can be constructed by plotting x <sup>2</sup> vs. time with an upper control limit (UCL) given by  $\chi^2_{\alpha}(k)$  where (Y is an appropriate level of significance for performing the test (e.g.  $\alpha = 0.01$ ).

Mote that this multivariate test overcomes the difficulty .The  $x^2$  statistic in Eq. (6) represents the directed or weighted distance (Mahalanobis distance) of any point from the target  $\tau$ . All points lying on the ellipse would have the same value of  $x^2$ . (The ellipse is the solution to Eq. (8) for  $x^2 = x_{\alpha}(k)$  for two variables). Hence, a  $x^2$  chart would detect as a special event any point lying outside of the ellipse. When the in-control

covariance matrix  $\Sigma$  is not known, it must be estimated from a sample of n past multivariate observations as

$$S = (n - 1)^{-1} \sum_{i=1}^{n} (y_i - \overline{y})(y - \overline{y})^{T}$$
(7)

When new multivariate observations (y) are obtained, then Hotelling's  $T^2$  statistics given by

$$T^{2} = (y - \tau)^{T} S^{-1} (y - \tau)$$
(8)

can be plotted against time. An upper control limit (UCL) on this chart is given by:

$$T_{UCL}^{2} = \frac{(n-1)(n+1)k}{n(n-k)}F_{\alpha}(q, n-q)$$
(9)

where  $F_{\alpha}(q, n-q)$  is the upper 100 $\alpha$ % critical point of the F distribution with k and n-q degrees of freedom (T. Kourti and J F. MacGregor, 1994).

#### 2.5 Biplots

The biplot is based on the idea that any data matrix, Y ( $n \ge p$ ), can be represented approximately in d dimensions (d is usually 2 or 3) as the product of a two matrices, A ( $n \ge d$ ), and B ( $p \ge d$ ).

The rows of A represent the observations in a two- (or three-) dimensional space, and the columns of B prime represent the variables in the same space. The prefix "bi" in the name biplot stems from the fact that both the observations and variables are represented in the same plot, rather than to the fact that a two-dimensional representation is usually used. For the principal component analysis, the axes in the biplot represent the principal components or latent factors and the observed variables are represented as vectors. Below, the figure 2 shows the sample of biplots



Figure 2 : The Biplots

## **CHAPTER 3**

## **METHODOLOGY**

In this section, it will be explain about the work will be done for this project. For this project, it uses Microsoft Excel 2007 and also Matlab 7.1.

#### 3.1 Steps in Multivariate Statistical Process Control (MSPC)

#### 3.1.1 Data Loading

The data-load process reads a source data file, converts the data to a different format, and inserts the converted data into a database table. The source data can come from one or more of the following sources. During conversion, the source data is often manipulated so that the converted data displays different characteristics.

#### 3.1.2 Data processing/normalization

Normalization is the process of removing statistical error in repeated measured data. This normalization data will be doing before and after the outlier detection. There two goals of the normalization:-

- 1. Eliminating the redundant data
- 2. ensuring data dependencies make sense

#### 3.1.3 Outlier detection

Before sending the data to PCA, the outlier must be removing because the PCA is very sensitive to the present of outlier. These outliers are based on the control chart. The data which exceed the limit will be removing.

#### 3.1.4 Principal Component Analysis

Principal Component Analysis (PCA) is to identify patterns in data, and expressing the data in such a way as to highlight their similarities and differences without losing the original information.

#### 3.1.5 Limit Determination

For conventional Shewchart Control Chart, the Upper Control Limit (UCL) and Lower Control Limit (LCL) for mean-centered and variance-scaled variables are +3 and -3 respectively (McNeese and Klein, 1991). By using the equations from section 2.4 limit of chart are calculated.

#### 3.2 Concept of idea in Microsoft Excel

Before start doing the coding and interface, it must have concept of idea what will be happening for whole of the program from start until end of the program.

Before doing any calculation or construct a graph, it required a bunch of data at least 2 set of range data. The user will be uploading the data into input interface or windows. The user also must rename their variable to make sure their do not confuse. After the data are uploading into windows, the user will click the button to proceed. There will some instruction on the first interface.

12

Data from first interface will be paste on second interface. In this interface, the data will be normalizing. Before that, it must find the mean and standard deviations for each range of data which will be use for normalization. The data will be arrange that the data user it will be on left hand site while the normalize data on the right hand side. The mean and standard deviation will be calculated by using this formula:

Mean

$$= AVERAGE (Number1; number2:...)$$
(10)

Standard Deviation (SD)

$$= STDEV (Number1; Number2;...)$$
(11)

and, to calculate for normalization data, it will be use this formula

$$nomal = \frac{data - mean}{SD}$$

After data being normalize, the normalize data will be use to construct the control chart on other interface. Before construct, it must calculate the mean and standard deviation for normalize data. By using Upper Limit Control and Lower Limit Control formula, the control chart will be constructing to see the behavior of the data. Make sure all range of data must do the control chart.

If, in the control chart shows there are possible outlier, the outliers must be eliminate first before enter next interface which for Principal Component Analysis. After being remove the outliers, the data have to go back for normalization data because the mean and standard deviation have been change and construct back the control chart. After there are no outliers, the user cans proceed to next interface for Principal Component Analysis. In this interface, the data will be sent to Matlab for Principal Component Analysis calculation.

After doing the calculation for PCA, the data and figure which generate by the calculation, will be sending back to Microsoft Excel to show the result to the user. Then, for next step, the user will insert the future data. Future data is used to see whether the limits that had been calculated before is fixed or not to it. The future data will be normalizing by using mean and standard deviation from previous normalization.

Then, the normalize future data will be send to Matlab for the calculation and matlab will send back the result to Excel.

# **CHAPTER 4**

# **RESULT AND DISCUSSION**

5 x

### 4.1 Interface

ing 2) ♥ House Incent Date Launut Formulas Date	: • • • • • • • • • • • • • • • • • • •	keta-um-bit-mker (dat. Fiam : Deminost fist	vostibilo, Modej - Microsoft i m <b>icro</b>	6766) 	· · · · · ·	
A Cut Cating of the attent		TD then bet	General		nučotuja 🕱 💦 💦	A25.m
Copy		· · · · · · · · · · · · · · · · · · ·	പല്ലംഗ. ശ്. Cend	මින් කරන්න කරන්න කරන්න diamat Format Sett Insert	· Delete Format	Zi - III Sato Ende
/ Format Painter		And a second second	Forma	tting + as Table + Styles +	Clear™ Clear™	Filter Select
F6 → 6	. : :					
A B C D E F	6		J F	L M	N C	. F . C
						<i></i>
Input Data						
	1					
	1					
1 copy and paste your date on G6			100 C 100 C			
2 Alick " Jopan Bate"					·	7
L SHER, HIJDELDELD						
3 click "Normalization" to calculate the normalization			e de la composición d			
$\pm$ Glick "Constol Chart" to create the control chart for	· ·					1.1.1.1.1
each variable 5 Crick "Remove Outhers" to remove the out-liers		1. A.			11.	
		•	1 - A - A - A - A - A - A - A - A - A -			÷.
2 Repeat step 5 to 5-until the message box appear "//o outilen(s)"	· .					2.1
<ol> <li>Click 'FEA' and wait for 2 to 3 minutes and click (because)</li> </ol>			and the second			
secure . 5 Por future data, copy and paste the future data in	I .					1
"Future Data" on 66 10 Theo, cick "Marganitacity provided to provide the		1.1.1	· · · ·			
data,						
12 Click "Future Data" in "normalize FD" sheet		· · ·				
32 After few minutes, silck "Result"	}			1	· ·	
13 Select "Result" sheet to see the steph			i de la composición d			
<b>6</b>	· ·		1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -	:		
		1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -		1 ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) (		
		4 1	and the state		11 - 1 - A	10 A.
			a tati		1	
			· · ·			,
			1. P.			
				· .		
	1 N N	-	1. Sec.		1 y 4	

## Figure 3: Input interface

Figure 3 above shows the first interface that will be seen by the user. In this interface, the data inside the selected area will be copied and sent to the Normalization sheet. The user must put their data inside the selected area. Then, click the "Input Data" button 15

which the button is at the top left corner. The user must make sure that the ranges of data are equal. At the left hand side, there are procedures on how to use this.

ର ଅନ	*				erv or data o cos	r - og stillår -	andst- issera	off Facto					- <del>2</del> 2
Horae	Insect Page La	ຊາວນໄ Formula	as Deta Re	torens Viet	o; Develope:	Lillio FOF			n in a geo			5	-
as Cul	Calibri	11	A' 🗸 🗯 🗰	<b>965</b>	🚍 Wrep Text	General			a	<u>in in S</u>	Σ AutoSum ~	Ži J	3
Faste ∳format	Painter BZ	u >	-∆-#=#	₩ 課課	)波 Menge & Cente	- <b>∴</b> ∦- %	9 10 10 9 + 90	Conditional Constitution	Format Cell as Table - Styles -	Insert Delete Forma	∠ Clear	Sort & Find Filler - Sele	ta 1
Cipèreare	n e San an station e	. Fait		in de gra	199 <b>1</b>	1 . A.	osbev	e di tali	5lyle:	Seis .	Ed.	the state	a na d
M13		£.		F								e ar ar	8 P
1	P . ·			. <b>-</b>			·					•	
2 : 3												r.	1
4												21	. 
-													
7	endizatione 🕴					· · ·							-
2												11.0	
10 11		1.1		-								en de la composición de la com	
12		· ·	1	· .									:
1-					1								. L
16				÷.,			1. t 		•			15	
15							4. j					<i>.</i>	
17 20 :		1.1					1997 - 19						1
21		1 · · ·										$\mathbb{P}^{\mathbb{Z}_{p}}$	
23							1997 - 1997 1997 - 1997					la en esta esta esta esta esta esta esta esta	di la constante
25 .							et. Line e						
25 27		1											1. 1.
28 29												1.111.11	1
30 41		ĺ			. *								
32					•		- 1				· .		
34 )			1 A.				. t :					7	ni, est.
35 56				1								r = 22	\$
37 ' 32												17	1
29		.		10 L								š	27.428 428
41												e de la composición de la comp	. 4
23.				•								10	- A
ing 14 4 2 24 januar	Normalitation	Control Coart	Data Subura	data norr	TAIZE FD Rec	tatina '	en e se	×			Seringa Jak	n in 1949. Ng 1949.	an a
Ready "		Curreaul Crieft	unen fulure	ueca 11013	NERGET D RENG	<u>, (1917)</u>				an a	30° III : <b>85</b> 4 (	ang	÷

On the bottom, there is "Reset" button to reset or remove all data inside this worksheet.

#### Figure 4: Normalization interface

As illustrated in Figure 4, this is the second interface. The function of this interface is to normalize the data before constructing the control chart. The "Normalization" button is to run the calculation for normalization. First, it will calculate the mean and standard deviation.

non- ad the care of	bekaram bistolog. (Compatibility Model) - Likerase	oft Even		~ T X
Home Insert PageLayout Formulas Data Review	ienu Developei Natio PDF			🕐 – 🔨 Š
Ang ang TRecord Marro	import			1. Sec. 19
Visual Matros Insert Design	S Expansion Packs Document			
Baric Altario Security - Mode Run Dialog :	Panel		4	
CommandRutton? ▼ 5 #EMBEO/"Forms CommandButton	print a state of the second state of the secon			8
	G F S S S K	L 14 H C	P C R S	U Z
1 Control Chart		free reliations	Points are reformatted based on their va	رت. المع
2 Run Number			filled blue if <= mean	
			Diamond if within 1 5D of mean Circle if within 2 5D of mean	
5		0 0 0	Triangle if within 3.50 of mean	
7		ob	pigres spare a pagone la su pi nizar:	54e
3				1994 - 1994 - 1994 - 1994 - 1994 - 1994 - 1994 - 1994 - 1994 - 1994 - 1994 - 1994 - 1994 - 1994 - 1994 - 1994 -
12				447
11				All all a
13				
12				
15				1 8
17 . 18 '				
19.				ar inc
22				54 
22				
24				
25				
27				Sec. 1
28				
32				
32 , 32				6,77
33 '				1
35				(dense)
96 37				2
38				
. 39 20				1000
				1
- 42 123				
44				
H & F H oput Hormalization Control Chart Baca- Future data in	ormalize FD Result: testing 🖏	1	AND A CONTRACT OF AND AND A CONTRACT OF A	<u>고 등</u> 이야기를 했 되고
кеалу		100 A. 100 A	1993年11月1日1月19月2日により	ad 2015年1月1日

Figure 5: Control Chart Interface

Figure 5 shows the interface for control chart graph. The data will be inserted under the measurement column. The 'Control Chart' button is to create the control chart for each variable. Below the control chart button, there is 'Remove Outlier' button which use to remove outlier from the data. At the top right corner, there are legends for the control chart.

12



Figure 6: Data Interface

Figure 6 shows the interface for data. On this interface, data which have been removed the outliers will show on this interface. The 'PCA' button on this interface is used to send the data to Matlab for PCA calculation and generate figure. This figure will be sent back to Excel by using 'Result' button. The figure will be shown in result interface.

<b>G</b>			-ca-um dat -colon (Cons	połstility Maxiei – Mięse	n nit e voel	· ·		
Home	Insert Page Layout Formula: I	Data Review View	Developer Nitr	D FDF				
, , Cut ∵ ⇒ Canv	1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.	114 AZ 14 181	a de la composición d	Stream Stream			λ'. Υ	
Paste	$ \psi_{i}  = \frac{\theta_{i}}{\theta_{i}} + $	- 19 E E (19 IV)	and the spectra		angeneration of the second space of the second	and a start of the second s	∠ Clear -	na ang ang ang ang ang ang ang ang ang a
Ci <i>n</i> boars	Fast.	Aligen	en · · · ·	(Vumber	St.4++	e e e œlos d	. ĉč.u	ng 111
CommandButtor	nt ● × ✓ J Baj C D E =	1 4 2 2		<u>к</u> ц	M N	C f		- s 👻
4 								- F
3	o Kaanatushan O							
4	: Mone . Standard							
5.	Deviation Clight 2 C	1						
1		1 · · · ·						
9		· ·						
10 21				21 A				5
12 : 13			10.11 (1)					
14 15					1. S.			() (j)
15								ata a
38								and the second se
20 12			-					
21 22					·	•		
23 2-						· · ·		
25 26				e en			e : :	熟
27		1 · · · ·	1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -		14 14			
29						· · ·		and the second
30 ° 31 °					. :			
32 ' 33				100 A				
34. 55								
36		and a starter			· ·		ч. С. С. С	
38			1		÷		•	
39 40		· · ·		. 1		1 1 1 L		
41 42	n Stander Stevenster	1 - 1 - N	:				· .	
43 84	- 11:38(2)-11 - 11:38(3)-11:39					$\frac{1}{2} = \frac{1}{2} $		1000
HIJH MOUL	Normalization Control Chart Data	 Future data	nalze FD Result te	sting: (J. (States))	12	<u> Carater at sea</u>	: <u>ENER</u> E	
Enter							6070 <u>0</u> 6.3032	(1,1) and $(1,1)$ $(4)$

Figure 7: Future Data interface

Figure 7 shows the future data interface. For this interface, the user will place the future data at G7. Future data is used to see whether or not the limits that had been calculated before is fixed to it. On the left hand side, there are mean and standard deviation columns which are taken from previous data normalization. This mean and standard deviation will be used to normalize the future data. On the top left hand side, there is the 'Normalization' button. This button will function to normalize the future data.



Figure 8: Normalization of Future Data Interface

On this figure8, the normalized data from future data will be displayed on this interface. There are two buttons; 'Future Data' and 'Result'. 'Future Data' button is used to send the normalized future data to Matlab. The 'Result' will be used after the calculation in Matlab. Function for 'Result' is to display the result from the Matlab. The result will be shown in result interface.

#### 4.2 Example

(n) ∠1 <sup>(2)</sup>	· · ·	teria (1998) (	-celar (Com	paubility twodet	• Microsoft Even		· · ·	1
Home Insert Page Layout Formulas Data	Review	View Deve	loper Hiar	¢ PDF				j 🕸 🚽 🦈 🗡
				· · · · · ·			i i i i i i i i i i i i i i i i i i i	da l
20 C.H		1.1.1		19.000 Th				<b> </b>
Paste	B. 18 6. 18	20 S. S.			1997 - 1985 - 1985 - 1985 - 1985 - 1985 - 1985 - 1985 - 1985 - 1985 - 1985 - 1985 - 1985 - 1985 - 1985 - 1985 -	and the search inse	rt Delete Format	Find &
[1] A. C. Shini, M. B. B. Walk, "Control of the second system of the					i ki ya wa sa s	n an an Anna an Anna Anna Anna Anna Ann	<u>Z</u> Clear	Select
rem rem		. jamear	1. 2. 2. 2.	Pitaniqe:	لللبات متوملة بالالحة	78949	~evs	cerning
CommandButton1 - Jr = EMBED("Forms.C	mmandButtor	. <b>1</b> ";""]						.*.
	G	. *	1	1. 2. 1. 1.	κ	ц М ,	, N Q	F G 📩
1.								: 1
3 O Inpections D								· · · · · · · · · · · · · · · · · · ·
· · · · · · · · · · · · · · · · · · ·								÷
5	Temperature i	Temperature cl	niet Mass Flor	Temperature in				
6	76.51907794	41.28339601	19562.91236	27.9097772		1		20 J 1
2 :	76.47580553	41.48555556	20197.96117	27.82044592				· · · ·
c T coby and beste your date on date	77 07198902	41,43599595	20198.94932	25.192233377				
10 2 slick " input Date"	77.92243435	42,10805195	20798.53528	29.07438991				
51	73.33758149	42.15926114	20453,53511	25.60350574				40
32 3 cilck "Normalization" to calculate the normalization	77.93414741	41.16638803	20489.50626	25.913091BB				1 · · · · · · · · · · · · · · · · · · ·
13	71.55262739	40.2422834	20309.41835	27.1315385	. · · · · ·			14 A. 1
14 4 Click "Control Chart" to create the control chart for 15 each unclimble	76.84224551	41.5816374	21048.47159	25.41145917				
15 5 Click "Remove Outliers" to remove the outliers	77 80093202	42.07562125	21332.73743	26.86801215	·,			. k
	79,8322402	42.81345349	21772.45084	28.27555694	1990 B. 1990 B.	1. S.		
18 7 Repeat step 9 to 5 until the message box appear 'No	79.73254114	43.33132659	22368_59736	29.32793952				si e à
19 Outlier(s)"	73.04016564	41.86320532	20613,20666	28.07543256				1 X
20 8 Click "PCA" and wait for 2 to 3 minutes and click	78.46556765	42.18565371	20829.43943	27,84132772	'			
21 RESULT: 22. B For future data convend casts the future data in	77 83813669	41,009/34/2	20851 34203	25.97920033				. * · · · ·
23 "Future Date" on 66	79.65413402	43.12727458	22409.83546	29.49624199	1.1.1			
34 10 Then, click "Normalization" to proced for normalize	79.88785315	43.5109 <del>0</del> 695	22384.62579	29.3677007	÷ .			11 A A A A A A A A A A A A A A A A A A
25 deta.	81.10146764	<u>4</u> .368928	29799,59416	28.70034705				
25 11 Click "Future Data" in "normalize FD" sheet and an antipation of the sheet	\$1.04849527	44,49547885	23319.21199	29.78625962		· .		
27 26 53 Afractavinsiaman stak "Barium"	79.59528312	43.17209232	21759.10213	28.09788386				
29	73.86308943	43.54268919	22307,49743	29.35520655		1	1 - F	
30 18 Select "Result" sheet to see the graph	79.41003019	43.07027555	21652,45245	28.92220077				2 V
31	79.23598782	42.59663393	21473.41782	27.1208429				0
32	79.45816302	42.75248	21953.91644	27.5271946				
33	79.0616461	42,29253495	21167.37536	27.34954773		100 A. 100 A.		
35	75 05765356	40./029000/ 20.97213597	17609 61076	28.8104/140 . 79.95196073.				10 A.
38	75.42801929	41,04026963	15910,1406B	30,30717559	1.1	1		승규는 함
17	74.82782611	40,85588328	17931.60952	30.099143		1		
33	72.80813492	39.69045179	16955.76523	29.2239065				
39	75,8563282	40.94259745	17315.67495	30.13924512				
-0 2*	78,07507235	42.24617533	18785.51305	90.12581201 DR 645800000			1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -	
43	75 48220656	40 51762107	17503 09876	22.545550022		· · · ·		
< j	78.08145722	41,47590309	19361.8702	28.66603758		1		19 (A)
44	72.46277013	41.65964571	19173.63659	23.50185685				
45	77.99194868	41.05334795	19625.01957	25.44296751	1. I I I I I I I I I I I I I I I I I I I			
N + > > > > Input Normalization Control Chart Data	Future data	normalze FD	Result ta	strig 2	6	and a second	19949-2023	<b>公认确定的事实</b> 还是
Ready am	a provincia de				1		· (当:0) 中日:8	5% - (-) - (-) (-) (-) (-) (-) (-)

Figure 9: Input interface with sample data

From figure 9, the user has to paste their data into the selected area. The user can also put the variable name on the top of the data. After the date has been pasted, click the button 'input data' to proceed. The data will be selected, and then the user can move to the next sheet.

<b>.</b>		·• 7					tet uncht zeig	c IComnatibili	N Model - N	icrosoft Excel	· · · ·				
<b>6</b>	Hami	Insert	Pace Lavout	Formulas	Data	Review	View Developer	Nitro PDF							
		370	- uge cuyour	÷		the last	5		2						
14		Hecord Ma	scro	× 26	T Proper		<b>6</b> .		. <b>.</b> .						1
Visual	flacros	Use Relati	ve References	insert Design		Sourc	<ul> <li>A Expansion Pack</li> </ul>	3	Document				1		
Basic		A Macro Sec	urity	Flode	G Run B	alog			Panei		· .			1.6.1	4 - A - A
	a . 5.,	Cade	in in a land	689 National II.	trens III. I. I. I. I. I.	ali inserve			- MAGGOY				a a se da s		يدد بالمريد و
Comr	mandB	utton4 🔫	1	EMBED("For	ms.Comn	nandButton	.1";"")								
	A	B	c	D	£	F	G H		. J	ĸ	. М	N.	Ð .	P	<b>Q</b> .
2														*	
.3			1											-2	
5															
			Temperature	Temperature	Inial Mass	Temperature		Sile an	Standard Deviation					5	
7	0	0 0	76,51907734	4128369601	19562,91236	27.9097772		78.09017662	L710679508		-9.912560521	-0.71027345	-0.55295512	-0.2212	
8	8		76.4759055	41.49565956	20197.96117	27.80044532		418239599	0.810021194		-0.837855971	-0.488345043	-0.183568	0.33617	1.1
9 10	-		76.94406073	4146599396	20136.84332	28,0535339		20432,7646	001007302		-0.589349146	-0.640336231	0.164793342	-144465	
11			77.52243438	42,16805195	20738.53525	29.07489991	-				0.092230243	0.196700992	0.203500271	1004038	
12			78.33768145	42.15826114	20453.5851	28.60980574					0.150644795	0.250974641	-0.016929112	0.5139	
12			77.5349474	41,165,39903	20489.60529	26.91309289					-3.616763563	-1.054546371	-0.111734171	-103381	
15			76.8422486	41.6315374	21046.07155	28.41143917				1 A.	-0.723648065	-0.261996762	0.364841290	6.306348	
16			77 2497630	42,23634889	21352,70740	28.3964214		1. A. A. A. A.	-		-0.485428941 0.101893895	0.336683348	0.947360897	0.290555	
17			78,8322402	42,81345049	21772,45064	28.275566634		· · · · ·		1 - F	0.439628821	0.970946171	0.831196031	0.163464	1
19			79.7325414	43.33192559	22368.58736	29.32793952					0.955911268	U\$39927525	1215400738	1270144	
20			78.04016564	4186320632	20613/20666	20.07543255					-0.023386861	-0.073353678 0.290905687	0.004056515	-0.047	1.1.1
21			78,24281806	42.33973478	20898.13479	28.87020033					0.095073058	0.450291573	0.267691863	0.893944	
23			77,83812485	4103410156	20651.34703	25.44335427					-0.341484370	-0.964436794	0.237537294	-2.9145	7
24			79,68413402	43.12727458	22409.83546	29.49584199		1 A. 1. A. 1.			1/325322796	1393629795	1241978571	1311957	4.20
- 26			81,10146764	44.368928	23739,5941	28.70004705	. :				1.766135095	2.690122297	2,099004295	0.609849	
27			BL01819327	44,49547985	23318.21195	29.76625362		and the second sec			1,735168239	2.619196325	1827424694	1752109	· · · ·
28			79.35299922	42,98758102	21879.01685	28.2241624					0.743995639	1.162193945	0.893968794	0.109407	1.1
30			79.96308943	43,84468919	22387,48743	29.35520653		· · · ·			1042224976	L774386459	1.176022008	1,299818	
31			79.4100305	43,07027000	21662.46246 21473.41782	28.82220077		· ·			0.77737862	0.732591769	0.638460116	195074	
33			79.45016302	42.75248	21353,01644	27.5271946					0.005519363	0.903947188	0.561377373	-0.62353	1
34			79.061646	4229253495	2167.37536	27.34954773					0.573730831	0.399424841	0.441215637	-0.91034 0.741746	
36			78.00765356	40.37413582	17005.81076	29.95198073					1,749318298	1.050331678	-1.851752343	1926388	
37			75.42801925	4104026963	16910,14065	30.30717559				1.1	-1.550353075	-0.977656845	-2.302558789	2,298912	· ·
-38 29			74,8278261	40.03069.328	1/88/060562	29,2239065					-3.086840623	-2,460940619	-2273153993	1160742	10.1
40 :			75.0563282	40.94289745	17355.67495	30,13924512	-	- 1 - L - L - L - L - L - L - L - L - L			-129957952	-1084650757	-2.041193122	2.123316	1.1
41			78.0750723	42.24617633	18786.61305	30,12581201		1 A.			-0.002983709	0.347481392	-1093177778	2,10919	
43			76.48220656	49.51762307	17503.09976	27.66529349		× .			-0.83414167	-1551964554	-1920389024	-0.4783	1.1
44			78.00145722	4147596809	18361.0702	28.60603758					0.000749649	-0.458346416	1366823315	0,510989	
45			78,4627701	4146344795	19(73,63655	28.50186685					0,223650081	-0.257041646	-0.843742225 -0.552827204	-17574	
47			77.7944750	41,76848023	19609.26207	26.65346761	. · .	1 T.			-0.187010629	-0.178347982	-0.562989314	0.550866	
48			76.8256338	40.66143057	10507.12403	27.47138579					-0.733207308	-1383955372 -0 124401088	-1273307641	-0.68222	
49 50			77.64912395	41.73332195	19479.61485	29.63873734		1.1.1.1			-0.251977978	-0.216090744	-0.647184786	0.545372	·
51			77.7259754	4156055775	10543.8112	28.21776942		÷			-0.207052968	-0.405926976	-1243539433	0.102675	
53 53			73.9520907	42,81552444	20632.11793 20697.62978	27,63122903		1.00			1094251828 0,77534528	0.832106369	0.096244707	-0.51413	
54			78.11902586	12.0032632	19948.2047	28,4582016		1.00			0.022712222	0.060551194	-0.314536291	0.355523	
	* ns	ut Normali	zation Cont	of Chart D	ta Fut	ire data d	normalize FD Resu	alt : testing	3.5				- Northern	建树	and the second
Select d	lestinati	on and press Ef	ITER or choose Pz	ste										, H 🗐	(II) <b>70%</b>
	_														

Figure 10: Normalization interface with sample data

In figure 10, the data from the "Input" sheet have been pasted at C7. By clicking the "Normalization" button, Microsoft Excel calculates the mean and standard deviation value from each variable. The normalized data will be under normalization column. The normalized data shows that the mean for each data will be close to zero while for standard deviation it will be close to 1.

7

....



Figure 11: Control Chart interface with sample data

On this figure 9, the interface shows the control chart graph which most all data value inside range which the process remain close to their desired values. For this example, there are 4 variables and 4 control charts for each variable. The small red squares indicate that, there are two potential of the outliers existed in the process. The outliers have to be excluded from the graph. Therefore, the button 'Remove Outliers' will be used to remove the outliers from the data.

<b>B</b> 2	also a e		· · ·	bate-renat	C-color (Compa	ability (aloche) - t	vierdsoft Ex	el :		1
	Home Insert Page Layout	Formulas Da	ta Review	View De	eloper Nitro P	DF .				
ASIA.	*" Record Macro	Sec. A St	Properties	(ma <sup>2</sup> )	impor	t				
			Vrew Code	迴 g, Expansi	on Packs				•	
Visual Baciz	Macros	insert Design	Run Dialog	Source		Document Panel				
Basic	Code	Control:				(Articia)				10 2
Comr	nandButton3 - f.	=EMBED("Forms.	CommandBu	tton.1";""}						· ···· · · · · · · · · · · · · · · · ·
	A B C D	ε. ε	G 7	e de la competencia d	1 k	L 84	н	C F	Q .	3 5 ~
1	-1.05717 -0.77435 -0.62274	0.22056								-7
2	-1.11543 -0.54499 -0.20747	-0.33575			1					
4	-0.72606 -0.70241 0.245374	-1.44633		15.a	-					
5.1	-0.17062 0.163483 0.185247	1.007368		•						- ·.
£	0.100709 C.220628 -0.04032	0.51594	0	lt set	ò					
	-0.16297 -0.908251 -0.01685 -0.97611 -0.31045 -0.348944	-2.32428 0.807994	0	••	0					٠.
9	-0.60995 0.309501 0.939971	0,292171								
10.	-0.25035 D.124297 0.979933	-1.2971								2.7
11	0.42358 0.966315 0.822099	0.164838								
13	-0.09378 -0.11518 0.064058	-0.04602								
14	0.184103 0.251804 0.205455	-3.29265								1.
15	0.032521 0.427167 0.250376	0.896707								
15	-0.22569 -1.0588 0.219751 0.966599 1.323483 1.232891	-2.21919								21
15	1.115092 1.760172 1.222406	1.315515								
- 19	1,905636 2,755636 2,108439	0.612072								17
26	1.871058 2.880667 1.852867 7.672544 1.874491 0.817776	1.756504								
22	0.763628 1.164495 0.891785	0.110572								44. 
23	1.096539 1.793552 2.171971	1.302351								
24 -	0.600928 1.258611 0.75017 0.687307 0.710545 0.625558	0.546134								
25	0.832377 0.895921 0.54835	-0.62365								- A
27	0.575402 0.375448 0.426435	-C.81052								
28	-1.31433 -1.34469 -1.84705	0.74422								
30	-1.73975 -1.05178 -2.35741	2,30535	1							
31	2.19174 -1.2844 -1.65023	2.086165								- /
32	-1.52002 -1.1626 -2.09223	2.128417								
34	-0.07095 0.320665 -1.13037 -0.52814 -0.76048 -1.7376	2.114264								.,
35	-1.11125 -1.64662 -1.95967	-0.47215								
36	-0.06676 -0.55597 -1.40811	0.513023								
37	0.182276 -0.34626 -0.87729	0.403269								- 1
39	-0.25419 -0.22185 -0.59244	0.562996								
40	-0.98679 -1.48295 -1.31313	-0.69245								
- <u>1</u>	-0.1422 -0.16811 -0.67986	0.342081								
42 63	-0.34913 -0.26301 -0.67786 -0.39883 -0.65965 -1.28907	2.34/4/2 0.105935								
44	1.154966 0.741049 0.076425	-0.51404								
45	0.798664 0.822618 0.060411	-0.0478								
H + F	H nput Normalization Co	introl Chart Data	Future data	normalize FD	Result tests	ني وړ	ŧ,		18-180 MA	
Ready										「「「「「」」

Figure 12: Remove Outlier interface with sample data

On this figure 12, the normalized data has been removed from the outlier. After this, the user must go back to "Normalization" sheet to repeat the step back until no outliers in control chart or appear message box says "No Outlier(s)".

Then, this data will be sent to Matlab for calculation of Principal Component Analysis (PCA) by clicking the "PCA" button. The calculation will take a few minutes. Then, to see the result, the user must click the 'Result' button which will refer to the result sheet.

பிற்றின் ச	itel stanski to dvir. Kompatib	Sity Model - Anenosoft Excel	and the second second	
Horsé Insert Page (prout Formulas 1	ata Severe Meri Developer Nitro POP			· · · · · · · · · · · · · · · · · · ·
		na an air an tao an Tao an tao an		a a a a a a a a a a a a a a a a a a a
Aller stars Record Macro	Propertiesimport	3 <sup>1</sup> .	· · · · ·	
Proval Alarras	View Code	Dorument	1 A A A A A A A A A A A A A A A A A A A	
Basic Allacre Security Mode	Run Dialog	Panel		the tag of the
Caus Contro	22. ·	7.12 đếng		· · · · · · · · · · · · · · · · · · ·
CommandButton1 • fr =EMBED("Forms	CommandButton.1";"")			
A 5 C D E F	G E	K L 50 N	0 P	G R S
1				×.
2				
3 Exote algorite as				
Stordard -	Temperature Temperature Inlet Mass Temperature			
Méan Deviation	in out flowrate in			
5 78,08018 1.7106795	80.13717271 46.58934138 24915.83968 28.13047208.			
7 4192595 0.9100212	78.94684171 45.25340073 23448.32108 27.3526047:			1 - A A
2045278 1551.5974	79.50559767 46.76509442 24024.40732 23.83840646			No. States
s 28 12012 0.9509222	78.57298677 46.19092534 22648.97519 29.39807607			
	77 29226729 _£ 01932238 22133,585.33 27.0153-227.	1. A		
	81.03575908 47.28481112 25674.5809 28.23663222		1 A 4	
23	82.943339907 47.98148527 25991.42517 27.24029979	19 - C C C C C C C C	1. A 1.	
14) · · · · · · · · · · · · · · · · · · ·	83.59740555 49.23117841 25390.57679 29.17722199			
15	21,79699211 46,74353475 25786,93201 26,75011831	the second s	· · ·	
15	\$0.50706018 46.25563379 15304.52455 27.18705695	en a prime de la companya de la comp	and the second	
under an der Stander von der St In der Stander von der Stander v	29-8246575 48 37298264 25787 9751 27 96578399-		1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -	
35	77.58718629 47,04427944 23938.58101 28.35174565	•	· ·	1. A.
20	72.07584393 44,85432077 21058.09038 29,72929276			
21	75,52677611 43,20934821 16640,71624 29 07991359			and the second second
	75.12552152 44 11110468 21786 25782 26 38299303	the second se		· · · · · · · · · · · · · · · · · · ·
20 Contraction 1	78 57704666 47 5980367 33882 45219 29 74360017			
25 ALCONT	80,4108153 48,18241729 24899.08512 28,58075814			
25 · · · · · · · · · · · · · · · · · · ·	80,85040225 48,23502403 25001,37174 28,25264891	e a é	and the second second	1.1.1
27	80.05202202 46.7157261 25173.84793 26.95359624	A A A A A A A A A A A A A A A A A A A	1997 - C.	1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -
25 (a) (a) (b) (b) (b) (b) (b) (b) (b) (b) (b) (b	BC.7021014 46.76014768 25762.26898 27.55491718	- 1 M	1. P	
	B111040756 40.61410204 25080.58913 18.73825959			
9*1	80.51447651 46.37316535 25739.28713 27.15014259	1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -	the second second	
32	90,47000514 47,19252638 25001,74207 27,21143773		·	
33	79-97402974 47 24270279 25096.97687 27.19663925			*
34	78.71665449 46.57170396 24413.12702 29.16956062		and the second	
35	77,79234254 45,46889591 21140,78602 50,26705074	and the second second second second	4	- <b>-</b> -
az	78 91920602 46.15251915 22409 97796 30.40441884		. î -	
38.	20.55263467 47.13812382 24023.05205 29.62676137			
33	77.26632433 44.72008559 18534.81128 28.36532467		1	
40) KULU	77.43252923 44.87746568 19606.51433 26.74616403			4 - 11 - 11 - 11 - 11 - 11 - 11 - 11 -
会社 一般相関 しょうしょう しょうしょう しょうしょう	79.28655522 46.94495024 20681.6068 28.93419895			t tu i
	75 03998739 45 72155196 19450 89077 78 93467183			
44 State Sta	77.72526185 44.73158316 19573.65451 27.52173741			
H 4 + H input Normalization Control Chart Data	Future data	1 aj 2 m		Contraction of the second s
Ready '"			1481.0	311- <b>85%</b> = (-) ()

Figure 13: Future Data Interface with sample data

On figure 13, the interface shows the future data in blue box. The sequence for each column must be the same with the sequence in previous data which data modeling. This is to make sure the mean and standard deviation are related to each data. On left side, there are two columns representing the mean and standard deviation. By clicking the 'Normalization' button the 1<sup>st</sup> column will be normalized by 1<sup>st</sup> row in mean and standard deviation columns. The normalized data will appear in Normalize FD sheet.

3

Cm al	<ul> <li>veterand ratios for interaction to Noote the Noote Action of California (Single California)</li> </ul>	1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -
Home Insert Page Layour	a Formulas Data Peview View Developer Natro PDF	<b>v</b> - ***
CRecord Marro	A the construct listed	
		1. J. M. M. M. M.
Visial Marros	inser besign: Source cjexpansion Macks Document *	
Basic 💧 Macro Security	Stode Run Distog Panel	1.00
Sode 1	Zeetlagh. White Modify	and the second sec
CommandButton1 + .	=EMBEDI/Forms.CommandButton.1';"	*
		v w #
	1 237448 512629 2 357051 0 200822	<u></u>
2	C 50652 3 651243 1.91133 - 0.92816	2
3 0 0 0	0.838249 5.313211 1.282565 1.826953	( '
- o Ecocota o	0.288079 4.69226 1.396105 1.869701	
5 0 0	-0.9592 2.212216 1.054197 -0.53033	
е . , ,	-0.46251 2.283774 1.080364 -1.03747	
7 Pecult	1.727724 5.884315 3.346098 0.122541	
\$	2.842825 6.649873 3.350373 -0.29247	1
3	3.275162 8.02313 3.227355 1.11628	
10		
11	1.41555 4.23307 / 5.26377 / V.85122	
12	1 //2//// //2//2//2//2//2//2///////////	
12. 12	-07835 56 25712 02372	, (
15	-35055 3213574 3372753 1692108	
15	2.60329 2.064115 -2.4762 1.003698	1
17	-1.72712 2.396827 C.8-0035 -1.52677	
18 :	0.553781 6.490566 2.442623 1.342644	77
19.	0.290452 6.229514 1.675478 1.707254	
20	1362405 6.870673 2.485878 0.221504	2
21	1.677922 6.928422 2.932216 0.170932	1 A4
22	1.156175 5.259227 5:023441 -1.22684	2
23	13524 5.307775 3.432512 -0.59457	
24	1/21501_3_14/1285.9497145214 1/2506	
23 ' 72 '	1.13840 2 4012 2 21704	51 194
17		1
25	1107092 5 633043 3.553494 -0.23502	ž.
29	0.372061 5.100699 2.533094 1.103592	2
30	-0.36475 3.928951 0.42409 2.257737	di se
31	0.149538 3.3025 0.093028 1.255642	
32	D.490466 4,618089 1.34207 3,402174	· · · · · · · · · · · · · · · · · · ·
βå <sub>l</sub>	1,448915 5,778074 2,291692 1,594316	3 /3
3-	-1.47375 3.066031 -1.23346 0.257854	
35	-C.24236 3.232843 -C.5E475 -1.44426	đ
39		·
57 85		2
40		· 3
40 <sup>1</sup>	0.202113 3 852866 - 0.3939 - 0.07896	
41	-0.02021 4.598409 -0.12511 1.08726	
42	0.867549 4.489716 -0.22841 -0.37294	
45	1.209552 4.669982 0.552365 -1.42391	. ÷
. 44 <u>.</u>	1.512475 6.126474 1.174047 -0.88715	1
45	1.19512 6.439559 0.389791 0.773912	4
R + + H input Normalization C	Initral Chart Data Future data normalize FD Result testing 1	
Ready	1/41:39 四月 85% 約	-lon 2 Destace of the

Figure 14: Normalization of Future Data interface with sample data

In figure 14, the future data have been normalized by using mean and standard deviation from previous data. From this, the user can see that the data are mostly ranged between - 3 until 3. But, if the values exceed the range, there are possibilities of equipment malfunction. For the next step, the user must click the 'Future data' button. After a few minutes, the calculation is done. Then, the user should click the 'Result' button to show the result from Matlab.



Figure 15: Result Interface with sample data

For figure 15, the interface shows the result which came from the Matlab. On left hand side, the figure shows the  $T^2$  chart for modeling data and right hand side shows the  $T^2$  chart for future data.  $T^2$  chart for future data used the limit identical for the modeling data. From this, the user can see that the future data are beyond the limit. It is understood that something happened in the process which leads the process technologist to find the causes.

## **CHAPTER 5**

# **CONCLUSION**

This project has presented the tool which develop by using Microsoft Excel and matlab. The overall aim of the study was to develop a process monitoring tool using multivariate method that would enable process operators to quickly and easily identify any sources of abnormality in the process. This paper also provided an overview of the concepts behind multivariate statistical process control. The multivariate method can easily detect the abnormality of the process and diagnostics assignable cause. This tools also can share widely with other Microsoft Excel platform.

ì

## REFERENCES

- 1. T. Kourti and J F. MacGregor, *Process analysis, monitoring and diagnosis, using multivariate projection methods*,(1994)
- 2. A. AlGhazzawi and B. Lennox, Monitoring a complex refining process using multivariate statistics, (2006)
- 3. M. K. Yee and Kamarul A. Ibrahim, Fault Detection for distillation column using multivariate statistical process control (MSPC), (2003).
- 4. Sung H.Park and G.Geoffrey Vining, Statistical Process Monitoring and Optimization (2000)
- 5. Harald Martens and Magni Martens, Multivariate Analysis of Quality (2001)
- 6. L.H. Chiang, E.L. Russell and R.D. Braatz, Fault Detection and Diagnosis in Industrial system, Springer-Verlag London, 2001
- 7. D. Aguado and C. Rosen, Multivariate Statistical Monitoring of continuous wastewater treatment plants, (2006)
- 8. L. I. Smith, A tutorial on Principal Component Analysis,(2002)
- 9. M. Kano, S. Hasebe, I. Hashimoto and H. Ohno, A new multivariate statistical process monitoring method using principal component analysis, (2001)
- 10. R. Jacobson, Step by Step : Microsoft Office Excel 2007 Visual Basic for Application, 2007, Microsoft
- 11. J. Walkenbach, Microsoft Office Excel 2003 Power Programming with VBA, 2004, Wiley Publishing