OPTIMUM PARAMETER SETTING FOR POTTING MACHINE ON INDUCTANCE PRODUCTS

NURUL MUHAYU ASHIKIN BINTI RUKMI

BACHELOR OF MECHATRONICS ENGINEERING (UMP-HsKA)
(DUAL DEGREE PROGRAM WITH KARLSRUHE UNIVERSITY OF APPLIED SCIENCE, GERMANY)

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name : NURUL MUHAYU ASHIKIN BINTI RUKMI

Date of Birth : 17 FEBRUARY 1994

Title : OPTIMUM PARAMETER SETTING FOR POTTING MACHINE ON INDUCTANCE PRODUCTS

Academic Session : 2017/2018

I declare that this thesis is classified as:

☐	CONFIDENTIAL	(Contains confidential information under the Official Secret Act 1997)*
☐	RESTRICTED	(Contains restricted information as specified by the organization where research was done)*
☑	OPEN ACCESS	I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

____
(Student's Signature)

____
(Supervisor's Signature)

____
New IC/Passport Number
Date:

____
Name of Supervisor
Date:

NOTE : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach a thesis declaration letter.

THESIS DECLARATION LETTER

Librarian,
Perpustakaan Universiti Malaysia Pahang,
Universiti Malaysia Pahang,
Lebuhraya Tun Razak,
26300, Gambang, Kuantan.

Dear Sir,

CLASSIFICATION OF THESIS AS RESTRICTED

Please be informed that the following thesis is classified as RESTRICTED for a period of three (3) years from the date of this letter. The reasons for this classification are as listed below.

Author's Name
Thesis Title

Reasons (i)

(ii)

(iii)

Thank you.

Yours faithfully,

____
(Supervisor's Signature)

Date:

Stamp:

Note: This letter should be written by the supervisor, addressed to the Librarian, *Perpustakaan Universiti Malaysia Pahang* with its copy attached to the thesis.

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of Bachelor in Mechatronics Engineering.

____

(UMP Supervisor's Signature)

Full Name : DR NORAINI BINTI MOHD RAZALI

Position : LECTURER, FACULTY OF MANUFACTRUING ENGINEERING

Date :

____

(HsKA Supervisor's Signature)

Full Name : PROF.DR.-ING. ROBERT WEIß

Position : COORDINATOR OF DUAL AWARD PROGRAMS UMP-HsKA

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Author's Signature)

Full Name : NURUL MUHAYU ASHIKIN BINTI RUKMI

ID Number : HA13004

Date : 7 MARCH 2018

OPTIMUM PARAMETER SETTING FOR POTTING MACHINE ON INDUCTANCE PRODUCTS

NURUL MUHAYU ASHIKIN BINTI RUKMI

Thesis submitted in fulfillment of the requirements for the award of the degree of
Bachelor of Mechatronics Engineering (UMP-HsKA)
(Dual Degree Program with Karlsruhe University of Applied Science, Germany)

Faculty of Manufacturing Engineering
UNIVERSITI MALAYSIA PAHANG

MARCH 2018

ACKNOWLEDGEMENTS

Alhamdulillah, all praises belongs to Allah, the Almighty and the most Merciful for his blessing to complete this thesis and bachelor degree successfully. Not to forget, Peace and Prayer to the Prophet, Muhammad S.A.W.

First of all, I am heartily thankful to my supervisor, Dr Noraini binti Razali whose encouragement, guidance and support from the beginning till the end level of this project have enabled me to develop an understanding of this final year project. This thesis would not have been possible without her review and correction of the mistakes made, accompanied by the countless valuable suggestion.

Not to forget my deepest gratitude and special thanks to Mr. Hazharudin, the industrial supervisor at Vacuumschmelze Company that provides me the opportunity to conduct my final year project in the industry and give me the permission as well as guidance along the project conducted. I also would like to express my gratitude to the whole staffs and operators who have been involved directly or indirectly in completing my project and this thesis. Their cooperation, inspirations and supports during my time in Vacuumschmelze are one of the factors, why the project is complete successfully.

The one that I will never forget is the love and support from my parents, Sharifah Saffie and Rukmi Daud and other family members, who have motivated me to finish this project and bachelor thesis. Their sacrifice and the undeniable love gave me strength to complete the studies with all the hardship faced. It is a pleasure to also thank my confidant, Qistina Mohamad Ludin for the infinity support and love that she gave throughout this project. Thanks also to my friends who support and willing to go through the ups and downs. Lastly, my regards will be always to those who supported.

ABSTRAK

Tesis ini adalah mengenai penambahbaikan proses yang sedia ada pada mesin “potting” khas untuk produk induktor di sebuah syarikat industri iaitu Vacuumschmelze Sdn. Bhd., yang terletak di Pekan, Pahang. Bagi mencapai objektif untuk memperbaiki proses potting yang sedia ada, satu kaedah untuk penambahbaikan telah dijalankan untuk mengenalpasti parameter terbaik yang akan digunakan pada mesin “potting” khas bagi model induktor yang tertentu iaitu model “common mode choke R5010-X101”. Teknik Taguchi telah dipilih sebagai kaedah yang sesuai dalam melaksanakan projek ini untuk memperoleh parameter yang optimum kerana ketepatannya, kos rendah, dapat menjimatkan masa, sistematik dan memiliki proses analisis yang mudah. “Orthogonal Array”, nisbah “Signal-to-Noise”, dan analisis varians (ANOVA), merupakan kaedah-kaedah untuk melakukan eksperimen dan analisis bagi mendapatkan parameter yang terbaik untuk mengenalpasti parameter optimum bagi proses “potting”. “Minitab Software” digunakan sebagai alat untuk menganalisis keputusan daripada eksperimen yang telah dijalankan. Akhir sekali, eksperimen untuk menguji keberkesanan parameter optimum yang diperoleh diuji dengan menganalisis data terbaru dengan data-data terdahulu.

ABSTRACT

This thesis is about the improvement of the existing process on potting machine for inductance products in an industrial company, Vacuumschmelze Sdn. Bhd., located in Pekan, Pahang. In order to achieve the objective which is to make an improvement on the potting process, a method for optimization is conducted to investigate the best parameter that should be used on the potting machine that depends on the model of inductance. The approach in this project is based on the design of experiment of Taguchi method to determine the setting of the process parameters due to its precision, low cost and low time consuming, systematic and easy to analyze the result. Orthogonal Arrays of Taguchi, the signal and noise ratio, the analysis of variance (ANOVA) are employed to find the optimum parameter levels of factors. The results obtained from the experiment in Taguchi technique is analyzed using statistical software, Minitab. Confirmation test with the optimum level obtained is carried out to investigate the effectiveness of the experiment conducted.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

η	Signal to Noise Ratio
°C	Degree Celsius
m	Number of Levels
mm	Millimetre
SS_D	Sum of squared deviation
SS_T	Total sum of squares
t	Time

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CNC	Computer Numerical Control
DoE	Design of Experiment
OA	Orthogonal Array
S/N ratio	Signal-to-Noise ratio
SOP	Standard Operating Procedure

CHAPTER 1

INTRODUCTION

1.1 Introduction

Optimization issues are ubiquitous in many applications involving decision making, whether in engineering or economics. The task of decision making involves the choosing of the best decision among various alternatives encountered. In simple words, optimization theory and methods deal with selecting the best alternative in the sense of the given objective function (Edwin K.P.Chong; Stanislaw H.Zak, 2001). This project highlights the optimization of parameter at potting machine to diminish the quantity of defect inductances and maximize the profit, output, machine performance and efficiency.

In order to achieve the project objectives and identifying the optimum parameters, efficient experiments are designed using the Design of Experiment of Taguchi's Method. Design of Experiments (DoE) is a procedure that allows studying effects on process outputs with controlled variation of input variables. With the experimental results obtained, it is possible to perform an analysis that allows characterizing and optimizing the process, which led to allowed data decisions that led to a better control process and optimization of effects on product (Souza, Alves, Damiani, & Silva, 2013). Taguchi method is a statistical approach to optimize the process parameters and improve the quality of components that are manufactured. It involves identification of control factors to obtain the optimum results of the process. Orthogonal Arrays (OA) are used to conduct a set of experiments (Athreya & Venkatesh, 2012) . The results of these experiments are used to analyze the optimum parameter. In this project, an attempt of using Taguchi's Method has been made to decide the best parameters used at potting machine in minimizing the potting unclean defects of inductances.

Regardless of the any implications, there is no doubt that productivity increases with the proper application on the machine used in the industry. The optimum utilization of automation facilities in the industry provided can affect the manufacturing process and cost expenses if the machine does not operated correctly. During manufacturing process, by optimizing the machine parameter, it will enables the manufacturers to improve the productivity including quality, accuracy and precision, and also in labor costs. More importantly, it is undeniable that by optimizing machine parameter, defects, cost and waste in the company can be reduced.

1.2 Problem Statement

In manufacturing industry, quality and efficiency is one of the major concerns to increase the productivity of the products. In Vacuumschmelze, there is an issue regarding to potting unclean defects which can affect the productivity of the manufacturing. Since today's industries are aiming for "zero defects" concept, an experiment must be conducted to investigate the suitable improvement that should be made on the potting machine to reduce the defect percentage of potting unclean.

In the company, numerous models of inductances are produced per month which consists of various sizes and shapes which requires different input of parameters on the potting machine. The potting unclean defect is a poor resin dispense onto the inductance which consists of excess resin, resin on inductance pin, and resin on inductance casing. From the discussion with the engineers and the operators at the production line, the tiny models of inductances have the highest percentage defects on the potting machine. Therefore, this study assigns to determining if the parameter of the nozzle's needle size affect the number of unit defect on potting machine especially on the smaller size of inductances. Complimentary to this experiment, it is also necessary to investigate if the defects produced are related with the manpower skills in handling the potting machine.

Basically, this project focuses on the experiment in confirming if the factors chosen can give a significant effect on the productivity of components at the potting machine and to reduce defects of potting unclean. Defective product is an imperfection in a product that has a manufacturing or design defect. Important to point out, that high percentage of products defects can consume high financial losses. The company or manufacturer absorbs the cost of replacing and fixing products that can accumulate to multi-billion ringgit losses for the repairing cost of faulty merchandise. In solving and reducing the problem involving profits and losses, it is necessary to eliminate and diminish the factors that cause the losses.

1.3 Background of Company

First and and foremost, this project is an attachment or collaboration with Vacuumschmelze Sdn. Bhd. Company that is located at Pekan Pahang. Vacuumschmelze is a leading global manufacturer of advanced magnetics materials and related products. In 1914, the first vacuum melting furnace laid foundation for today's Vacuumschmelze. In 1923, melting alloys in a vacuum went into production on an industrial scale. The initial operation was located in Hanau, Germany and later grew into a company that operates on a worldwide basis with 4300 employees in more than 50 countries with annual sales about approximately 380 million Euros. Vacuumschmelze range of products comprises a broad array of advanced semi-finished materials and parts, inductive components for electronics, magnets and magnet assemblies for use in a wide variety of fields and industries spanning watchmaking and medical technology, renewable energies, shipbuilding, automotive and aviation (Vacuumschmelze, 2017). Logo of Vacuumschmelze is shown in the Figure 1.1 below.

Figure 1.1: Logo of Vacuumschmelze

Since the company manufactures a large scale of product which requires an effective automation process and machine, the company needs a high precision and accuracy of machine parameter to have a high yield in production and reduce the total units rejected. As a consequence, this thesis is about an improvement in automation process for potting machine on inductance product that currently being produced by the company.

1.4 Objectives of Project

In this paper, several objectives must be covered throughout this project. Below are the listed objectives for this project.

1. To provide the optimum parameter for potting machine on inductance products.
2. To improve the performance of existing process at potting machine by reducing the percentage defects of excess resin on the potting machine.

1.5 Scope of Study

An optimized setting of machine parameter offers a higher productivity system that can help reducing the numbers of defects units produced after the automation process. In order to accomplish the objectives, an experiment is proposed and conducted using Taguchi's Method of DOE. The experimental design proposed is a low cost and time efficient conduction of experiments. Several set of data will be collected as experimental result to be analyzed which does not required dummy units of component to conduct the experiments. There are two potting machines provided in the companies for potting process with different parameter of nozzle size as shown in Figure 1.2.

Figure 1.2: Potting Machines at Vacuumschmelze

There are different types of inductance models produced by Vacuumschmelze. In this project, the selected models is type R5010-X101 which is a small unit of inductance that owned a significant defect of potting unclean compared to any other defects based on the information collected in the company. Figure 1.3 shows the percentage of defects on the small size inductances. The size of the small components is less than 8 mm of width and less than 15 mm of length.

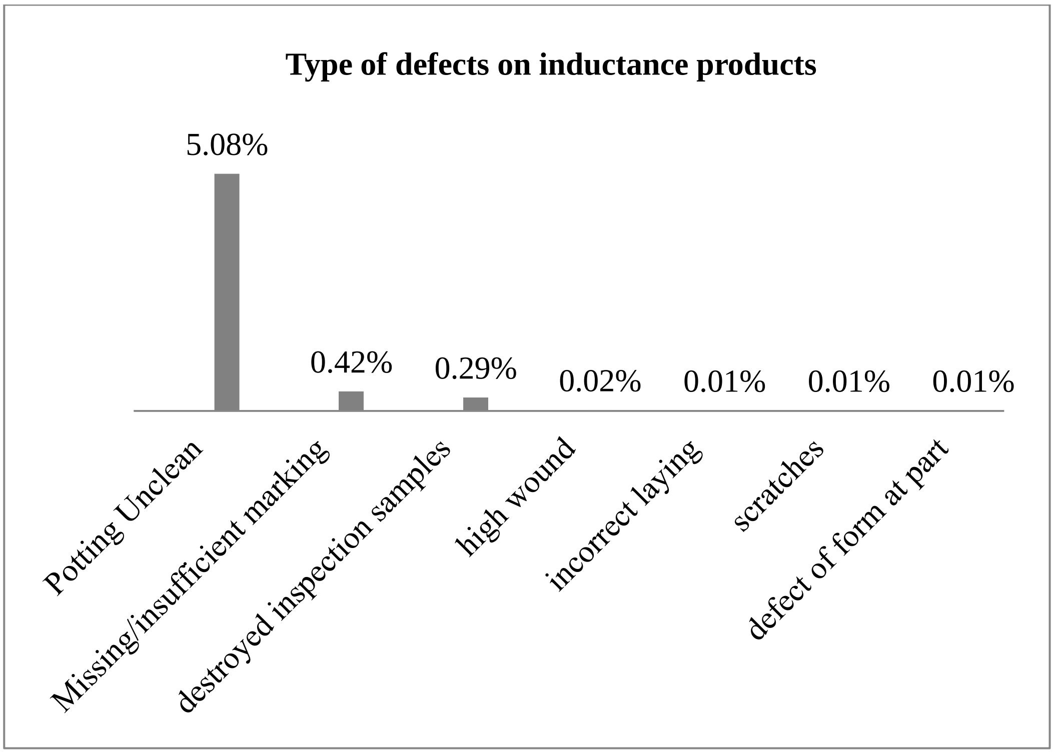

Figure 1.3: Percentage defects on small inductances products

From the graph in Figure 1.3, potting unclean defects portrayed the highest percentage of defect occurs on the small inductances products produced which is the main concerned in this project. Potting unclean defect is a poor resin dispense onto the inductance which consists of excess resin, resin on inductance pin, and resin on inductance casing. In approaching the zero defect concept, this project aims to reduce the percentage defect of potting unclean on potting machine by conducting experiments in determining the optimum parameter setting for potting machine.

After defining the project problem and confirming the significant issues on the inductances product, the defect factors of potting unclean is identified using the cause and effect diagram. Cause and Effect diagram is also known as Fishbone Diagram and Ishikawa Diagram which is a visualization tool for categorizing the potential causes of a problem in order to identify its root causes. The experiments designed are based on the root cause discussed with the technician and supervisor in the company. The results of experiments will be analyzed with the aid of Minitab Software for statistical analysis to determine the optimum parameter setting of potting machine.

1.6 Summary

Chapter 1 explains the details about the project background to have a better understanding on the project issues and objectives. Overall of this project will be focused on the experimental design and analysis to improve the existing performance of potting machine and to minimize the percentage defects of potting unclean on the potting machine. Based on the observation and discussion with the industrial supervisor in Vacuumschmelze, an experiment is proposed with 2 factors considered, which are “Diameter of nozzle’s needle”, and “Operators” using Taguchi Method of DOE.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The general objective for this project is to analyse the optimum parameter setting for potting machine on inductance product. Currently in Vacuumschmelze at Pekan, Pahang is facing a high percentage of potting unclear defect such as excess resin, exposed tape, and poor resin. Potting unclean is seen to be high on small inductance product which is 169 mm2 of inductances' area. The parameter used to pot the inductance product are varies on the product model which every product model have their own specifications and definition of potting unclean.

Literally, literature review is a method of deep learning about the project. Literature review was conducted to help in achieving the project's objectives and in selecting a better method in conducting experiment to obtain the optimum parameter for potting machine on inductance products. A correct and proper method selection plays an important rule so that, the design of experiment proposed does not consume high cost expense and can be completed within specific time.

2.2 Potting and Encapsulation of Inductances

Potting is a technique of filling the small spaces or surfaces of electronics with a material that will protect the components from the physical and environmental damage. Potting components also provides additional insulation capability. Material used to pot the electronics is called potting compounds. Potting compounds usually exhibit good chemical properties and high adhesion to plastics and metals, these being the materials of construction of the casing or containers and also of the components. Typical resins used for potting are epoxies, polyurethanes, silicones and acrylics, the latter usually being the UV-curing formulations (Gould, 2004).

Figure 2.1: Manual electronic potting

Source: https://www.youtube.com/watch?v=opSSB9hVV9w

Figure 2.2: Automatic electronic potting

Source: https://www.youtube.com/watch?v=bzAluV3nRI0

2.2.1 Potting Defects and Failure

Defects are undesirable and unintended features in the package that are created during the manufacturing and assembly processes. Defects can occur in an encapsulated microelectronic package at any stage in manufacturing and assembly including die passivation, lead frame fabrication, chip adhesion, wire bonding, encapsulation, and lead forming. With new package designs, materials, and manufacturing and process parameter controls, many plastic encapsulated microelectronics defects and failures are being eliminated or significantly reduced. An understanding of the encapsulation defects and failure mechanisms and respective models, relevant contributing factors, acceleration factors, and methods of eliminating such defects and failures is critical in ensuring a high quality and reliability encapsulated product (Ardebili & Pecht, 2009). In this project, the defects discussed are potting unclean which occurs after the final stage of potting process. Potting unclean consists of poor resin, excess resin, and resin on pin and casing.

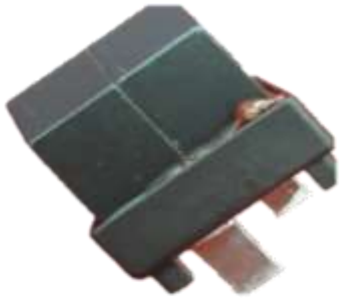

Figure 2.3: Example of Potting Unclean (Excess Resin)

Source: Vacuumschmelze Company

2.2.2 Potting Applications

Table 2.1 shows the applications and importance of electronics potting process on each application.

Applications	Descriptions
Automotive	Electronics is encapsulated to avoid the exposure to gasoline vapour, salt spray and brakes fluid for engine management system and on board computers.
Aerospace	The requirement of high reliability, rapid compression and decompression, pressurized and depressurized areas make the electronics to be encapsulated.
Marine	Encapsulated electronics is protected from both fresh and salt water environments that will attack electronics circuitry, under the dash of high performance boat, to exterior equipment used on larger maritime systems.

Table 2.1: Potting applications

Source: (May, 2014)

2.3 Optimization

Optimization process is the controls of adjusting a process to optimize several specified set of parameters without disrupting the other constraint. The aim of optimization process is to minimize cost, maximizing throughout, and efficiency. Optimization is one of the major quantitative tools in industrial decision-making. Over the years, many methodologies have been developed for optimization process including Taguchi method, six sigma, lean manufacturing and others (Semioshkina & Voigt, 2006). In recent years, determining an optimal set of process parameters values to achieve a certain output characteristics has been the prime interest by many researchers (Kolahan, Manoochehri, & Hosseini, 2011). In this project, the potting machine parameter for diameter of nozzle and operator will be specified using the optimization technique.

2.4 Design of Experiments

Experiment is a process or study the results obtained from collection of data. Statistical experiments usually conducted in situation in which the researchers can manipulate the conditions of experiment and control the factors that are unrelated to the research objectives. Hence, design of experiment (DoE) is the process of planning a study to meet specified objectives. It is important to plan the experiment to ensure that the right type of data and a sufficient sample size are available to answer the research questions of interest as clearly and efficiently as possible (SAS Institute Inc., 2005).

In the early 1920s, design of experiments is a statistical method introduced by Sir R. A. Fisher in England. DoE is a structured and organized method that is used to determine the relationship between the different factors of input variables that affect a process and output of the process. DoE involves designing a set of experiments, in which all the relevant factors are varied systematically. When the results of these experiments are analysed, they help to identify the optimal conditions, the factors that most influence the results, and those that do not, as well as details such as the existence of interactions and synergies between factors. When applied to product or process design, the technique helps to seek out the best design among the alternatives (N.S., R, & Prab, 2012). The design of experiments of Taguchi method that will be used in this project will be discussed in the next topic.

2.5 Taguchi Method

Taguchi method has been used for improving the quality of Japanese products with great success since 1960. Many companies, during 1980's realized that the old methods to ensure quality were not competitive with the Japanese methods. The old technique of quality assurance relied heavily upon inspecting products as they rolled off the production line and rejected those products that did not fall within the specific acceptance range. However, Taguchi was quick to highlight that no amount of inspection can improve a product; quality must be designed into a product from the start. Recently, companies in the United States and Europe began adopting Taguchi's design approaches in an effort to improve product quality and design robustness (Wysk, R. A., Niebel, B. W., Cohen, P. H., and Simpson, 2000).

Taguchi's method is a powerful tool for the design of a high quality system. Taguchi designs pledge a simple, efficient, and systematic approach for optimization, quality, and cost. Besides, the method for experimental design is easy to apply to many engineering issues as it allows the analysis of many parameters without high amount of experimentation (Mitra, Jawarkar, Soni, & Kiranchand, 2016). Taguchi method is widely used for product designs and process optimization worldwide. Lesser number of experiments required in this method resulted in reducing of cost and time considerably (S. Kamaruddin, Khan, & Wan, 2004).

Response Surface Methodology (RSM) is also one of the DoE methods which is used by some researchers for analysis and prediction of process. Traditional experimental design procedures are complicated compared to Taguchi method. The greatest advantages of this method is saving effort in conducting experiments, save the experimental time, low cost consumption and can discover significant factors quickly using S/N ratio (Kowalczyk, 2014).

The experimental results recorded are computed into signal and noise ratio to measure the quality characteristics. The optimal level of the process parameters is the level with the highest S/N ratio. A statistical analysis of variance (ANOVA) is performed to see which process parameters are statically significant. To verify the optimal process parameters obtained from the parameter design, a confirmation experiment is conducted (Shahrul Kamaruddin, Khan, & Foong, 2010). The result of experiments are analysed to achieve those objectives which are, to identify the best or optimal condition for product or process, to identify the contribution of individual factors and to estimate the response under optimal conditions (Nando, n.d.). Table 2.2 shows the major steps to implement Taguchi method in the design of experiment.

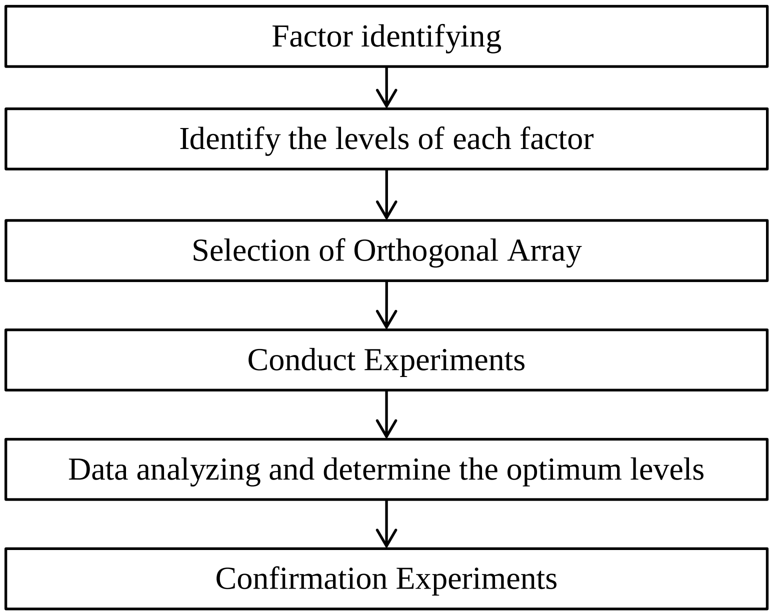

Table 2.2: Major steps of implementing Taguchi method

Source: (Nando, n.d.)

2.5.1 Taguchi Parameter Design

There are two types of factors that affect a product functional characteristic in parameter design which are control factors and noise factors. Those factors that are easily been controlled is control factors. As example, material choice, material ratio, speed of resin, diameter of nozzle, volume of resin dispensed, and operator assigned. Noise factors are defined as factors that are difficult, impossible, or too expensive to control. Noise factors can be divided into 3 types which are outer noise, inner noise and between the product noises (Wysk, R. A., Niebel, B. W., Cohen, P. H., and Simpson, 2000). The examples for the type of noises are stated in the Table 2.3 below.

	Product Design	Process Design
Outer Noise	Consumer's usage conditions Low temperature High temperature Temperature change Shock Vibration Humidity	Ambient Temperature Humidity Seasons Incoming material variation Operators Voltage change Batch to batch variation
Inner Noise	Deterioration of parts Deterioration of material Oxidation (rust)	Machinery aging Tool wear Deterioration
Between Product Noise	Piece to piece variation where they are supposed to be the same, e.g., Young's modulus shear modulus allowable stress	Process to process variation where they are supposed to be the same, e.g., variations in feed rate
Controllable Factors	All design parameters, e.g., • dimensions • material selection	All process design parameters All process setting parameters

Table 2.3: Examples of Noise and Control Factors

Source: (Wysk, R. A., Niebel, B. W., Cohen, P. H., and Simpson, 2000)

Further steps of Taguchi method cannot be proceed without pointing out all the factors that are going to affect or influence the process or products. After the control factors and noise factors are listed, decisions on the factors that significantly can affect the performance will have to be established and only those factors must be taken in to consideration in constructing the matrix of experimentation. The rest of the other factors are considered noise factors (Athreya & Venkatesh, 2012).

2.5.2 Orthogonal Array (OA)

Taguchi designs experiments using a special constructed table known as "Orthogonal Array". The use of these tables makes the design of the experiments so easy and consistent and it requires relatively lesser number of experimental trials to study the entire parameter space (Shahrul Kamaruddin et al., 2010). Orthogonal Arrays are used to systematically vary and test the different levels of each of the control factors. Commonly used OAs includes L4, L9, L12, L18 and L27 (N.S. et al., 2012). Figure 2.4 shows the Array selector to determine the Orthogonal Array of the experiments. The columns in the OA indicate the factor and its corresponding levels.

Each row in the OA constitutes an experimental run which is performed at the given factor settings (Wysk, R. A., Niebel, B. W., Cohen, P. H., and Simpson, 2000).

Number of Levels	Number of Parameters (P)														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	L4	L4	L8	L8	L8	L8	L12	L12	L12	L12	L16	L16	L16	L16	L32
3	L9	L9	L9	L18	L18	L18	L18	L27	L27	L27	L27	L27	L36	L36	L36
4	L'16	L'16	L'16	L'16	L'32	L'32	L'32	L'32	L'32						
5	L25	L25	L25	L25	L25	L50	L50	L50	L50	L50	L50				

Number of Levels	Number of Parameters (P)														
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32
3	L36	L36	L36	L36	L36	L36	L36								
4															
5															

Figure 2.4: Array Selector

Source: (Karna, Singh, & Sahai, 2012)

2.6 Signal to noise ratio

Signal to noise ratio is used as measurable value instead of standard deviation due to the fact that, as the mean decreases, the standard deviation also decrease and vice versa. In other words, the standard deviation cannot be minimized first and then mean brought to the target. In practice, the target mean value may change during the process development. Two of the applications in which the concept of S/N ratio is useful are the improvement of quality through variability reduction and the improvement of measurement (Simha, 2012). In the Taguchi method, the term ‘signal’ represents the desirable value (mean) for the output characteristic and the term ‘noise’ represents the undesirable value (signal disturbance) for the output characteristic which influence the outcome due to external factors namely noise factors (Shahrul Kamaruddin et al., 2010) (Goyat & Sharma, 2014). Therefore, signal to noise ratio is the ratio of the desirable value to the undesirable value.

Signal to noise ratios of Taguchi, which are log function, is based on Orthogonal Array (OA) experiments which give much reduced ‘variance’ for the experiment with the ‘optimum setting’ of control parameters. Thus, the combination of Design of Experiments with optimization of control parameters to obtain the best results can be achieved in Taguchi Method (Semioshkina & Voigt, 2006). Regardless of the category of the quality characteristics, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio. The aim of any experiment is always to determine the highest possible S/N ratio for the result, which means that high value of S/N ratio shows that the signal is much higher than the random effects of noise factors or minimum variance (Shahrul Kamaruddin et al., 2010). There are three types of signal to noise ratio which are "the lower/smaller the better", "the nominal the better", and "the larger the better". The description of each type of S/N ratio is explained in the Figure 2.5.

Signal-to-noise ratio	Goal of the experiment	Data characteristics	Signal-to-noise ratio formulas
Larger is better	Maximize the response	Positive	$S/N = -10 * \log(\Sigma(1/Y^2)/n)$
Nominal is best	Target the response and you want to base the signal-to-noise ratio on standard deviations only	Positive, zero, or negative	$S/N = -10 * \log(\sigma^2)$
Nominal is best (default)	Target the response and you want to base the signal-to-noise ratio on means and standard deviations	Non-negative with an "absolute zero" in which the standard deviation is zero when the mean is zero	$S/N = 10 \times \log((\bar{Y}^2) \div \sigma^2)$ The adjusted formula is: $S/N = 10 \times \log((\bar{Y}^2 - s^2 \div n) \div s^2)$
Smaller is better	Minimize the response	Non-negative with a target value of zero	$S/N = -10 * \log(\Sigma(Y^2)/n))$

Figure 2.5: Types of Signal-to-Noise Ratio

Source: (Minitab, 2017)

2.7 Analysis of Variance (ANOVA)

ANOVA is a statistically tool which helps to reduce the error variance and quantifies the dominance of control factor. The analysis aids in justifying the effects of input changes on the responses in experiment (Simha, 2012). In other words, ANOVA helps in formally testing the significance of all the factors and their interactions by comparing the mean square against an estimate of the experimental errors at specific confidence levels (Rao & Padmanabhan, 2012).

The original ideas of ANOVA were developed by English statistician Sir Ronald A. Fisher (1890-1962) in a book titled “Statistical Method for Research Workers” (1925). The early work in this area is mostly dealt with agricultural experiments. Since then, ANOVA method is a very useful procedure in revealing important information especially in interpreting experimental outcomes and in determining the influence of some factors on other processing parameters (Ostertagová & Ostertag, 2013). Besides, ANOVA also is a statistical treatment that commonly most applied to the results of the experiments to determine the percentage contribution of each factor. Hence, the factors that need to be control in the experiment is determined using the result obtain from ANOVA table (Kolahan et al., 2011).

2.7.1 Degree of Freedom (DOF)

Degree of Freedom are defined as the number of comparisons between process parameters that need to be made to determine which level is better and specifically how much better it is (Shahrul Kamaruddin et al., 2010). Degree of freedom can be calculated as shown in equation 2.1, where DOF is the degree of freedom, and m is the number of levels (Rao & Padmanabhan, 2012).

$$DOF = m - 1 \tag{2.1}$$

2.7.2 F-Test

Statistically, there is a tool called an F test, named after Fisher, to see which design parameters have a significant effect on the quality characteristic. F ratio is a ratio of the mean square error to the residual error, and is traditionally used to determine the significance of a factor (Rao & Padmanabhan, 2012).

2.7.3 P-Value

P-value reports the significance level and says the probability of rejection the null hypothesis in case the null hypothesis holds. If the value of P is less than the α value, where α value is the chosen significance level, the null hypothesis is rejected with probability greater that (1- α).100% probability (Ostertagová & Ostertag, 2013). What is null hypothesis? Null hypothesis is an identical normal distribution, in which the population means of each group are assumed to be identical to each other, does not matter if the calculated sample means from the experimental data is different (Sawyer, 2009). Therefore, if the value of the P is below 0.05, there is no need to consider the null hypothesis.

2.7.4 Percentage (%) Contribution

Percentage in ANOVA table is defined as the significance rate of the process parameters (Rao & Padmanabhan, 2012). The percentage of contribution can be calculated as shown in equation 2.2 (Kowalczyk, 2014). Where SS_D is the sum of the squared deviations and SS_T is the total of the sum of the squares.

$$Percentage(\%) = \frac{SS_D}{SS_T} \tag{2.1}$$

2.8 Ishikawa Diagram

Ishikawa Diagram which is also known as fishbone diagram is a tool for identifying the root cause of quality problems. Ishikawa diagram was named after Kaoru Ishikawa, a Japanese quality control statistician, the man who pioneered the use of this type of chart in 1960s. Ishikawa diagram is an analysis tool that provides a systematic way of looking at effects and causes that create or contribute to those effects. Due to the function of the fishbone diagram, it also can be refer as cause and effect diagram (Ciocoiu, Ilie, & Ciocoiu, 2010).

Fishbone diagram usually represents a model of suggestive presentation for the correlations between an event (effect) and its multiple happening causes. The structure provided by the diagram helps team members to think in a very systematic way. Some of the benefits of constructing a Fishbone diagram are that it helps determine the root causes of a problem or quality characteristic using a structured approach, encourages group participation and utilizes group knowledge of the process, identifies areas where data should be collected for further study (Basic-Tools-for-Process-Improvement, 1995).

The design of Ishikawa diagram imitates the skeleton of a fish. The presentation can be simple; through bevel line segments which on a main horizontal axis, suggesting the distribution of the multiple causes and sub-causes which contribute to the causes. This diagram also can be completed with qualitative and quantitative appreciations, with names and coding of the risks, which symbolize the causes and sub-causes. The cause and effect diagram has nearly unlimited application in studies or research, manufacturing, marketing and office operations. The participation and contribution from the team involved in brainstorming process is one of the strongest assets of this technique. Solutions are developed to discover the right causes to improve a process. The next stage of testing and implementation will follow after the team involved agreed with the solutions (Masoud Hekmatpanah, 2011). Figure 2.6 shows the example of fishbone diagram structure which will be used in this project in brainstorming the factor for potting unclean at potting machine.

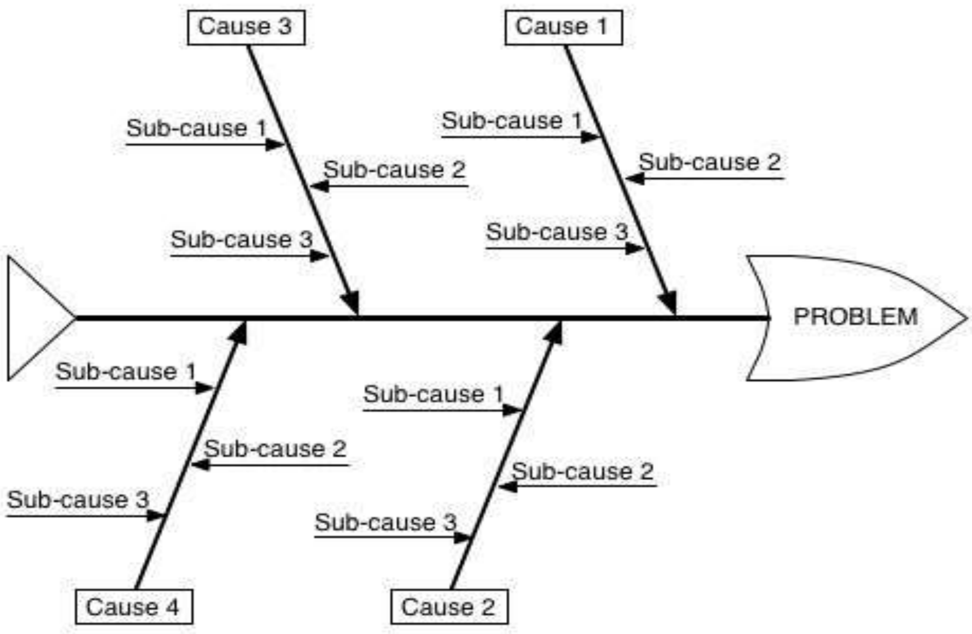

Figure 2.6: Example of Ishikawa diagram structure

Source: http://www.becreate.ch/en/methods/fishbone-diagram.aspx

2.9 Previous Study

From the previous study by (Goyat & Sharma, 2014), the parameter setting for CNC Milling machine was optimized using experimental design of Taguchi Method. The milling parameters evaluated was feed rate, cutting speed and depth cut by considering quality characteristic of surface roughness. Therefore, this project utilized the same technique and method in optimizing the machine parameter. However, in this project the potting machine was used and the parameter was optimized by considering several factors which are diameter of nozzle and operators' experience.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the research methodologies that are used in this project in achieving the objectives listed. Generally, the required process in completing the study is by clarifying the research methodology, which is combined with a general framework for the study. As a consequence, the methodology will illustrate the details of planning methods of study after the going through the journal research and reading materials regarding this project. Flow chart is one of the planning methods which are useful and important to ensure that all work regarding this project will be carried out as planned. Besides, in order to ensure the project is finished within the given time, a Gantt chart is one of the important tools to be concern and prepare before the project begin.

3.2 Study Planning

Project planning is the most important step to ensure that the project can be completed successfully, which embrace the whole stage of the process. Project planning starts by defining the project background, problem statement of the organization and by clarifying the aim of the study. As the problem statement and derivation of objectives are branded, the subsequent step is by constructing a process flow chart to have a clear vision of the project's structure. Table 3.1 shows the summary methodology corresponds to the objectives of this project.

Objectives	Methodology
To provide the optimum parameter for potting machine on inductance product.	1. Literature Review 2. Design a suitable experiments 3. Propose and conduct experiments
To improve the performance of existing process at potting machine by reducing the unit defects of potting unclean on potting machine.	1. Implements the experimental results 2. Analyse the data collected 3. Comparison results from the previous data.

Table 3.1: Summary of Methodology

3.2.1 Flowchart

The flow chart designed in Figure 3.1 will provide more information and clear vision about the structures of the whole project study in general. The general process elements are stated in the Gantt chart as references. Figure 3.2 shows the step on how to analyse the experimental result. Figure 3.3 show the flow process of the implementation after the optimum parameter is define through the experiments conducted.

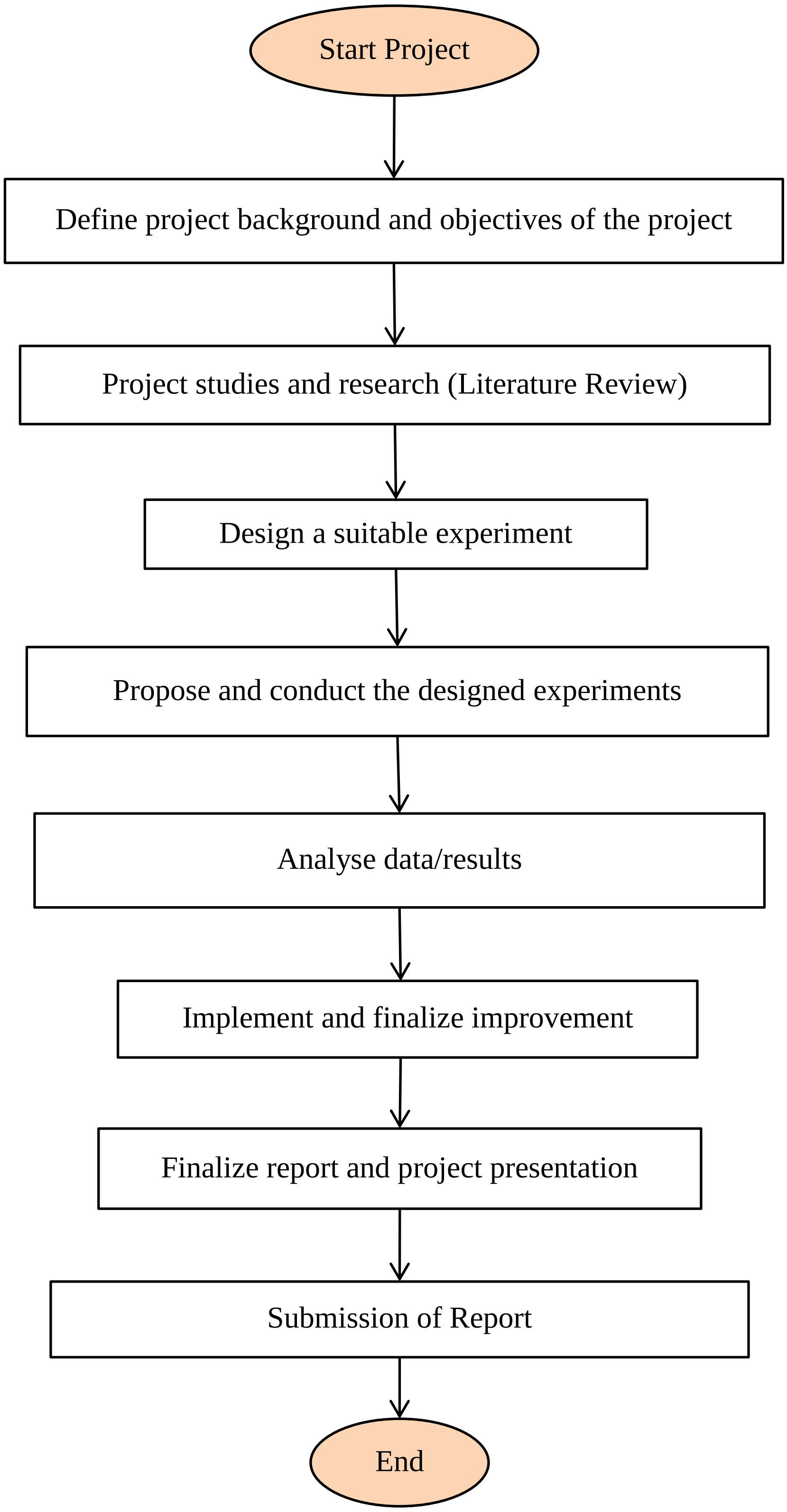

Figure 3.1: Project Flow Chart

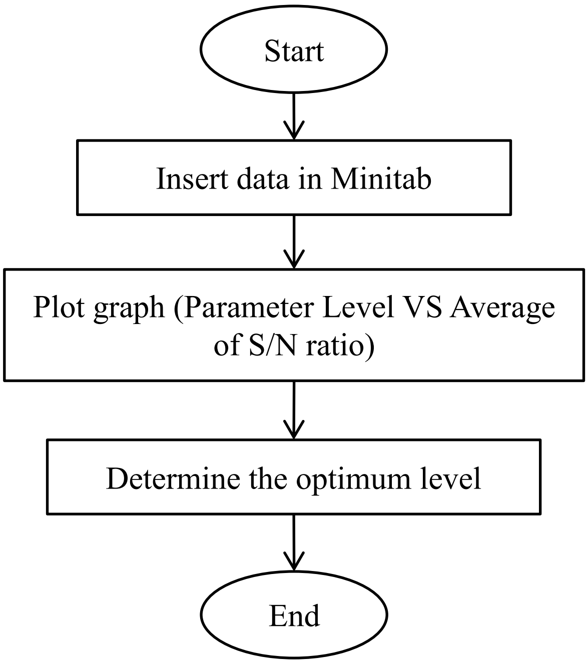

Figure 3.2: Flow Chart to analyze the experimental results

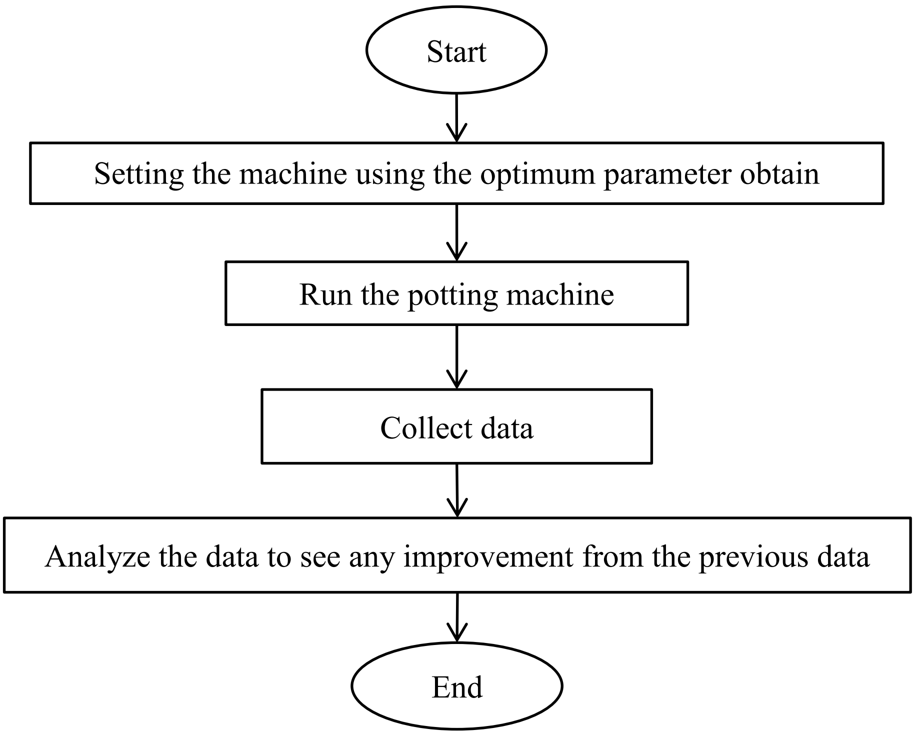

Figure 3.3: Flow Chart on Confirmation Experiment

3.3 Approaches to the Experimental Design

According to the steps that are involved in Taguchi's Method, a series of experiments are to be conducted. In this experimental design, potting process on inductance product using potting machine has to be carried out as a case study. The procedure in designing the experiment is discussed in the next subtopics.

3.3.1 Factors Identifying

Before proceeding on the further steps, it is necessary to list down all the factors that are going to affect or influence the potting process and from those factors; one has to be identify the control and noise factors. The factors that affect the potting process on potting machine are listed in the Ishikawa diagram in Figure 3.4.

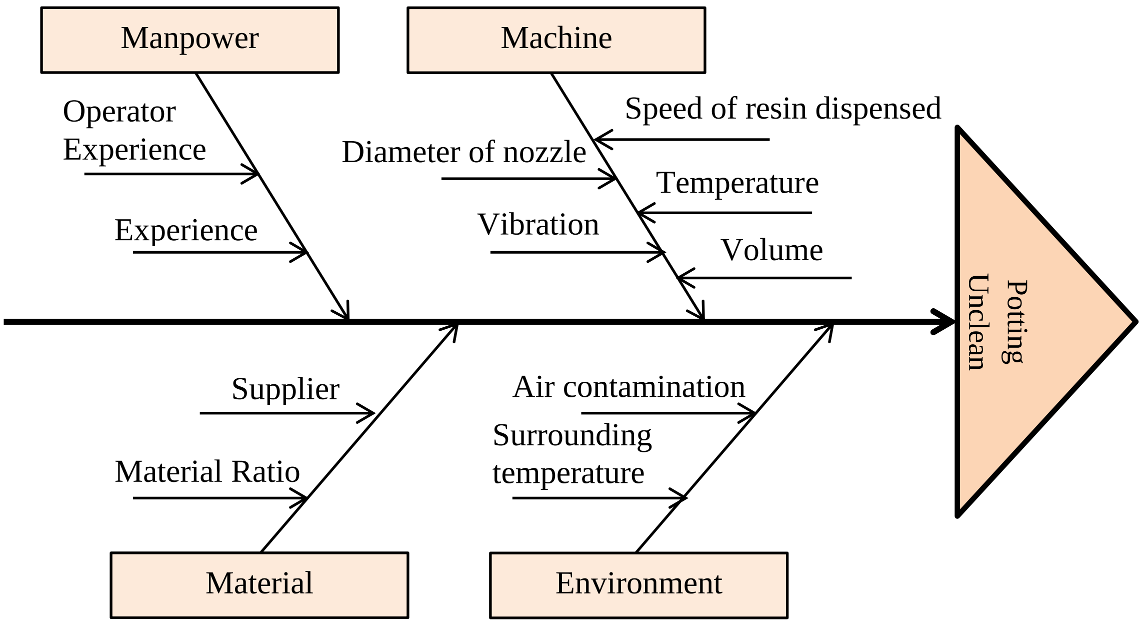

Figure 3.4: Ishikawa Diagram

Decisions on the factors that significantly affect the performance and can be controlled will have to be ascertained and only those factors must be taken in to consideration in constructing the matrix for experimentation.

3.3.2 Identifying of Level of Control Factors

From Figure 3.2, the factors chosen are Operator and Diameter of nozzles. The decision made is based on the discussion with the engineers and supervisors at the Vacuumschmelze. The factors levels are decided based on the model specifications of the inductance, and also considering the guide lines given in the operator's manual provided by the manufacturer. These specifications data are provided by the company, which shows that every factor has their own level of tolerance. The factors and their level are shown in the Table 3.3.

Symbol	Factors	Levels	
		1	2
A	Diameter of Nozzles (mm)	2.2	4.1
B	Operators	X	Y

Table 3.2: Level of Control Factors

The manufacturer has provided two size of nozzle which are 2.2 mm and 4.1 mm of diameter, to investigate if the factor can reduce the defect units of inductance on the potting machine when comes to the smaller size of inductance model which is model type R5010-X101. The second factor is operators, which to investigate if differences of man power in charge at the potting machine will affect the number of inductance units rejected. Operators A is an operator with 1 years of working experience and Operator B with 5 years of working experience at the potting machine. The experiment conducted with the help of these operators, technician and the manual guide provided by manufacturer.

3.3.3 Selection of Orthogonal Array

In selecting an appropriate orthogonal Array in conducting the experiments, the degree of freedom is to be computed. From the factors identified, there are only two factors that need to be considered which each factors have 2 levels. Therefore, the orthogonal array selected is L4 orthogonal array of Taguchi method. L4 of orthogonal array consists of 4 experiments that will be conducted. Table 3.3 shows experiment setting of Orthogonal Array obtained by Taguchi Design of Experiment matrix.

Experiments	A	B
1	1	1
2	1	2
3	2	1
4	2	2

Table 3.3: Orthogonal Array

3.3.4 Conduct the Experiments

As shown in Table 3.4, there are 3 trials for every experiment. Therefore, there are a total of 12 experiments were performed to gather the required data before analysing the experimental result. Result of experiment can be collected after the operator records the total of unit defect over the total of unit experimented. Each experiment required 12 hours 4 minutes before the result is analysed due to 3 hours of pre-heating process, 4 minutes of potting process and 9 hours of baking process.

Experiment	No of inductance products with Potting unclean (%)			S/N Ratio
	Trial 1	Trial 2	Trial 3	
1	y_{11}	y_{12}	y_{13}	
2	y_{21}	y_{22}	y_{23}	
3	y_{31}	y_{32}	y_{33}	
4	y_{41}	y_{42}	y_{43}	

Table 3.4: Table Design for Experimental Result

3.4 Selection of Quality Characteristics

Selection of Quality Characteristics is the response of the experiments. The response selected for the experiments was percentage of defective inductance products. The results of experiments for every trial is computed by calculate the percentage defect on potting machine using Equation 3.1. The data collected is recorded in the table as shown in the Table 3.4 for further analysis.

$$Defect\ Percentage\ (\%) = \frac{number\ of\ units\ defect}{total\ number\ of\ units\ run} \tag{3.1}$$

3.5 Selection of Objective Function

Signal to Noise method is used in order to identify a proper set of process parameters that can produce the less potting unclean defects. The objective function used to calculate the signal to noise ratio (S/N Ratio) is “smaller the better”. This objective function usually chosen S/N ratios for all undesirable characteristics such as “defects”, for which the ideal value for the data collected is zero. Equation 3.2 shows the formula on how to calculate the signal to noise ratio.

$$\mathrm{S/N}\ Ratio, \eta = -10\log\left(\sum \frac{(\mathrm{y}^2)}{\mathrm{n}}\right) \tag{3.2}$$

Where,

y = percentage value of the experiment for each trial

n = trial numbers

η = signal to noise ratio

3.6 Plan of Experiments

Planning is a compulsory element in the experiments to ensure that the data collected is precise and conducted within specified time. The potting process needs 2 days of working days to finish due to time restriction for every process. Total oven provided is 14 ovens but not all the 14 ovens will be used to preheat and bake the inductances R5010-X101. 14 ovens can bake at least 16128 units of inductances. The total unit experimented for each experiment is varying depends on the unit produced by the production line which consists of winding, stripping, tinning and looping process. Hence, the total of inductance unit for every experiment cannot be predicted. Figure 3.5 shows how the operator works on the machine for each experiment.

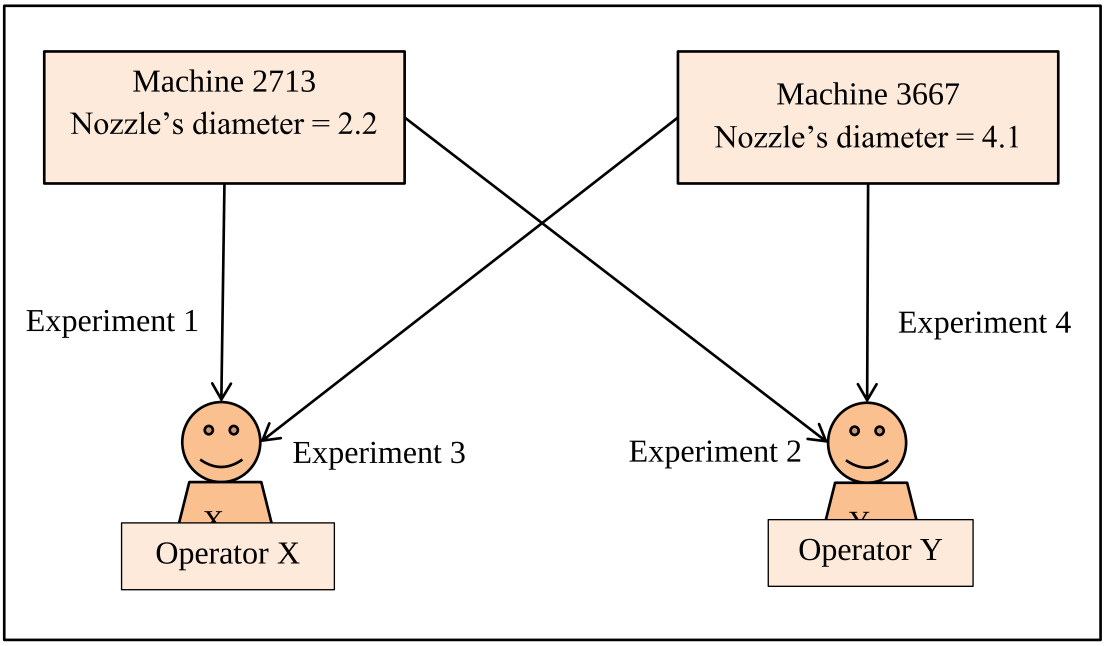

Figure 3.5: Plan of Experiments

Experiment 1 and experiment 2 will run on the same day for 2 days before the result is collected. Operator X will works with machine 2713 and operator Y will work with machine 3667 for 3 trials. Result for each trial is recorded. For experiment 2 and 3, the operators will exchange their position and work with the machine assigned for the other 3 trials of experiments. Table 3.5 shows the planning date of experiments and the date of resulted collected for each experiment and trial.

Date of experiments conducted	Date of data collected	Trials	Experiments
26/12/2017 27/12/2017	29/12/2017	1	1 & 4
02/01/2018 03/01/2018	04/01/2017	2	1 & 4
04/01/2018 05/01/2018	08/01/2017	3	1 & 4
08/01/2018 09/01/2018	10/01/2017	1	2 & 3
10/01/2018 11/01/2018	12/01/2017	2	2 & 3
12/01/2018 15/01/2018	16/01/2017	3	2 & 3

Table 3.5: Planning date of experiments and data collection

3.7 Potting Process on model R5010-X101

The manufacturer have provide the guidelines or Standard Operating Procedure (SOP) on how to conduct the potting process on the inductance using the two machines provided based on the specific model of the inductance. The model used in this experiment is R5010-X101 which also known as Common Mode Choke as shown in the Figure 3.6.

Figure 3.6: R5010-X101

The figures show the inductances before the potting process takes place. The unit is arranged on the potting tray which inhabits the magnetic properties to stabilize the inductance position in the potting tray. Each potting tray can fit 64 units of inductance components. The potting process for model R5010-X101 is summarized as shown in the flow chart in Figure 3.7.

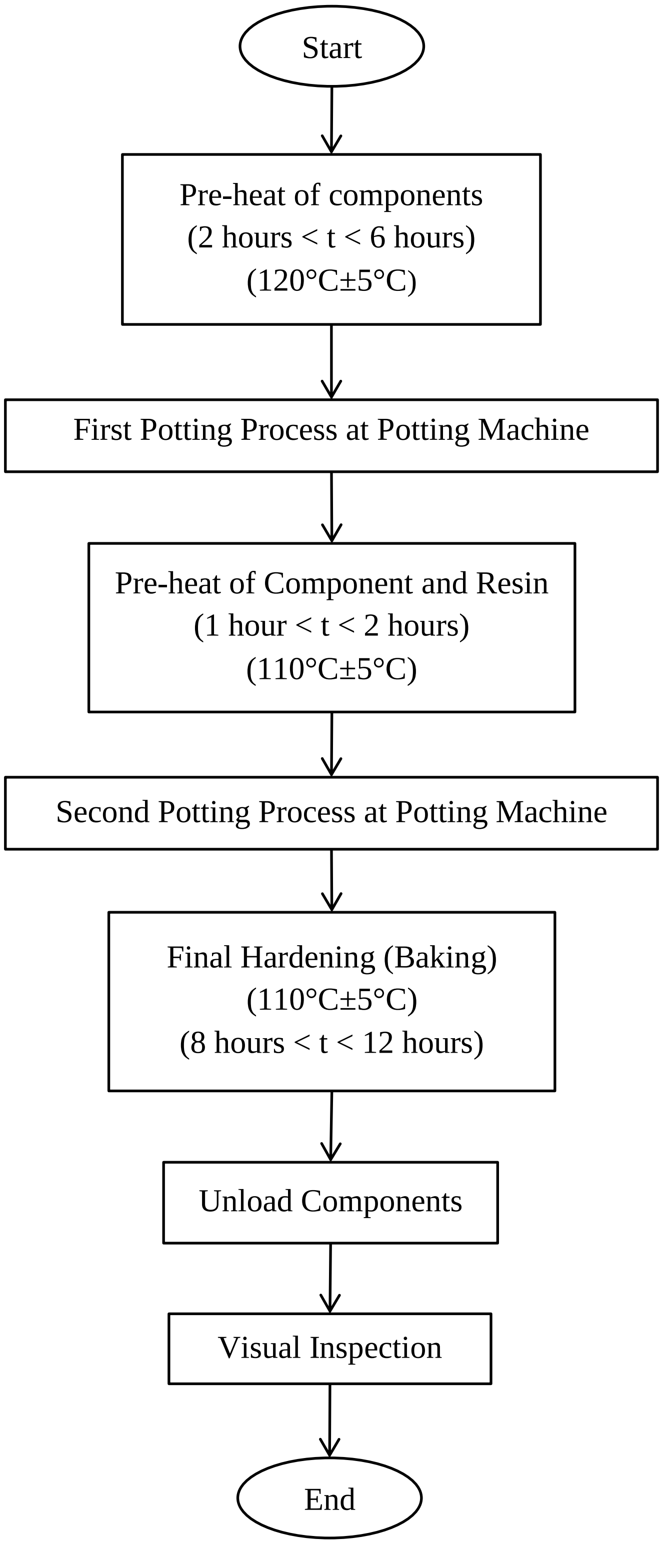

Figure 3.7: Summary of Potting Process

From the tray, the components is pre-heated by putting the tray filled with the Common Mode Choke into the oven for pre-heating process which consume about 2 hours at 120°C±5°C. The range for pre-heating time is 2 hours < t < 6 hours. The pre-heating process must not be less than 2 hours as states in the manual. Figure 3.8 shows the oven where the components are pre-heated and baked. The manufacturer has 14 ovens provided in the company for potting process.

Figure 3.8: Oven for Pre-heating and Baking Process

Pre-heated components is then transfer to the potting machine to pot the components for the first time. There are two potting machines will be used which one of them are using 2.2 mm of needle size of nozzle while the other machine is equipped with 4.1 mm of needle size of nozzle. Figure 3.9 shows the potting machine that use 2.2mm of nozzle diameter and Figure 3.10 show the potting machine installed with 4.1 mm of nozzle diameter.

Figure 3.9: Potting Machine K2713

Figure 3.10: Potting Machine K3667

As stated, the machines are installed with difference diameter of nozzle which will be used in the experiments as shown in the Figure 3.11. The sizes of the nozzle provided determine the level of control factor 1 and 2 of nozzle diameter in Taguchi Method.

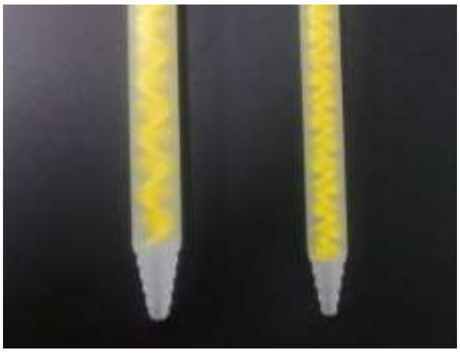

Figure 3.11: Nozzle used for Potting Process

Proceed with the first potting of common mode choke R5010-X101, the next step for this type of model is by pre-heating the components with resin for 1 hour with 110°C±5°C of temperature in the oven shown in the Figure 3.12 above. The visualization of the first potting is shown in the Figure 3.13 and the second potting will cover up the white tape of the component after 1 hour of pre-heating process. After the second encapsulation process on the common mode choke, the components are put in the oven for the baking process which is the final hardening process. The hardening process takes place for about 9 hours which then give the potting result as shown in Figure 3.10.

Figure 3.12: First potting of the inductance

Figure 3.13: Second Potting and Final Hardening of Inductance

The finished product is unloaded from the potting tray and loaded all the good units onto transport tray as shown in the Figure 3.14.

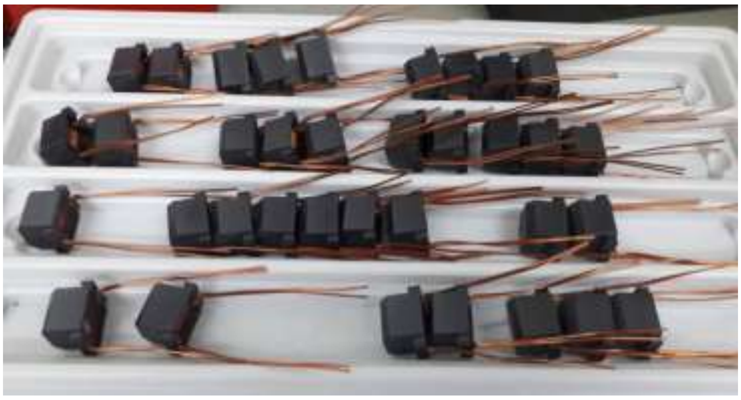

Figure 3.14: Transport Tray

The last stage for the experiments is the Visual Inspection which is to obtain the data for the experimental analysis with the help of the operators in charge. The total of units defect is recorded for further analysis. Figure 3.15, 3.16 and 3.17 show the examples of potting unclean of model R5010-X101 after the baking process.

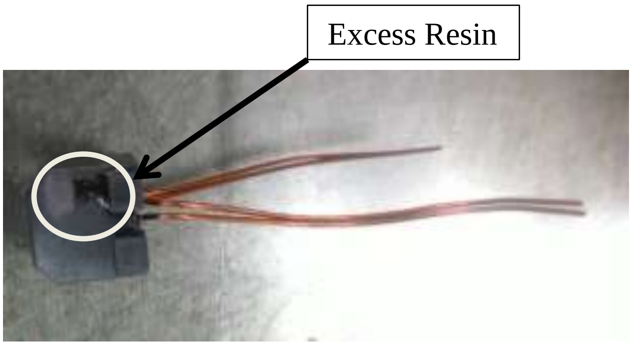

Figure 3.15: Potting unclean of excess resin

Figure 3.16: Potting unclean of poor resin

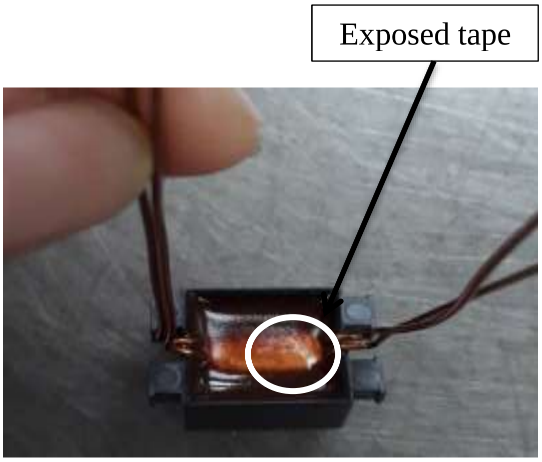

Figure 3.17: Potting Unclean of exposed tape

3.8 Summary

At the end of this project, there should be results that achieve the objectives of this project which to provide the analysis on optimum parameter of the potting machine. The result obtained also should give a positive impact to the production which is can improve the existence potting process by reducing the percentage defects of potting unclean.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the experimental results obtained are analysed using statistical analysis with an appropriate tool which is Minitab Software. The analysis will conclude the optimum parameter that will be implemented in the next potting process to achieve the next project's objective which is to improve the performance of existing process of potting machine. Therefore, the optimum parameters obtained from the Taguchi method are applied on the parameter setting of potting machine as confirmation experiment. As the final step, the data collected from the improvement applied will be analysed and discussed. At the end of this chapter, the optimum parameter for potting machine need to be confirmed and ensure that the parameters obtained can improve the process performance at the potting machine which is able to reduce the percentage of potting unclean defects occurs at potting process.

4.2 Result of the Experimental Design

The results obtained required three weeks of observation and data collection. The totals of inductance product of R5010-X101 produced for three weeks is 20996 units. The total of defects from the experiments is 92 units which resulted in 0.44% of percentage defects in overall. Table 4.1 shows the experimental results for the percentage of potting unclean defect on inductance products for each trial and the corresponding Signal to Noise ratio using equation (3.2).

Experiments	**Percentage of inductance units with potting unclean (%)**			**S/N Ratio**
	Trial 1	Trial 2	Trial 3	
1	0.35	0.33	0.38	9.0216
2	0.35	0.29	0.33	9.7812
3	0.53	0.65	0.45	5.2004
4	0.50	0.43	0.61	5.7025

Table 4.1: Experimental results for percentage defects and S/N Ratio

Since the experimental design is orthogonal, it is then possible to separate out the effect of each parameter at different levels. To obtain the mean S/N ratio for each level, the value of S/N ratio for the specific experiments needs to be averaged respectively. The mean of S/N ratio for each parameter at each level can be calculated using Minitab or using the equations (4.1) until (4.8). Table 4.2 shows the mean S/N ratio for each level of the parameters which is called the S/N response table.

$$S_{A1} = (\eta_1 + \eta_2) \qquad (4.1)$$

$$S_{A2} = (\eta_3 + \eta_4) \qquad (4.2)$$

$$S_{B1} = (\eta_1 + \eta_3) \qquad (4.3)$$

$$S_{B1} = (\eta_2 + \eta_4) \qquad (4.4)$$

$$Avg_{A1} = {S_{A1}}/{2} \qquad (4.5)$$

$$Avg_{A2} = {S_{A2}}/{2} \qquad (4.6)$$

$$Avg_{B1} = {S_{B1}}/{2} \qquad (4.7)$$

$$Avg_{B1} = {S_{B1}}/{2} \qquad (4.8)$$

Where,

η_k = the S/N ratio corresponding to experiments k.

S_{A1} = Summation of S/N ratio of parameter A with level 1

S_{A2} = Summation of S/N ratio of parameter A with level 2

S_{B1} = Summation of S/N ratio of parameter B with level 1

S_{B2} = Summation of S/N ratio of parameter B with level 2

Avg_{A1} = Mean of S/N ratio of parameter A with level 1

Avg_{A2} = Mean of S/N ratio of parameter A with level 2

Avg_{B1} = Mean of S/N ratio of parameter B with level 1

Avg_{B2} = Mean of S/N ratio of parameter B with level 2

Level	**Diameter of Nozzle (A)**		**Operators (B)**	
	Sum of S/N ratio	**Mean of S/N ratio**	**Sum of S/N ratio**	**Mean of S/N ratio**
1	18.8028	9.4014	14.2220	7.1110
2	10.9029	5.4515	15.4837	7.7419

Table 4.2: S/N response table

Figure 4.1 shows the S/N ratio graph for percentage defect of potting unclean on inductance product for model R5010-X101. Based on the equation of S/N ratio in equation 3.2, the greater the S/N ratio, the smaller the variance of percentage defect of products around the desired (the lower the better) value. It is evident from the graph in Figure 4.1 that the percentage defect of potting unclean is minimal at first level of Nozzle's diameter and the second level of Operator which conclude the optimum parameter from S/N Ratio analysis is A1, B2 as shown in the Table 4.3.

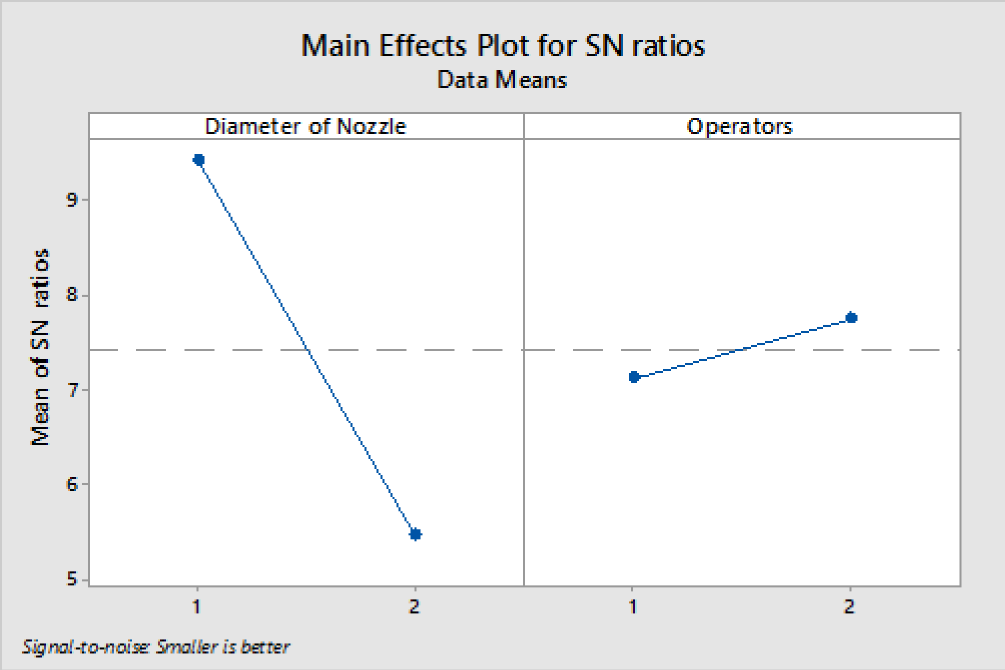

Figure 4.1: S/N response graph

Factor	Optimal condition
Diameter of nozzle	2.2 mm
Operator	Y

Table 4.3: Optimum Parameter

However, the relative importance amongst the parameter for percentage defect still needs to be known so that optimal combinations of the parameter levels can be determined more accurately. Besides, the further analysis also conducted to determine if the factors investigated is significantly important or influence the response of potting unclean. This will be discussed in the next section using the analysis of variance (ANOVA).

4.3 Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) method is powerful in determining which parameter critically can affect the defect on potting process. Analysis of variance commonly applied for optimization to determine the percentage of the contribution of each factors. The study of ANOVA table helps to determine which factors need to be control and which do not significantly influence the experimental result (Kolahan et al., 2011). This analysis was run with the aid of Minitab Software using the general linear model of ANOVA.

Symbol	**Parameter**	**Degree of Freedom**	**Sum of square**	**Mean square**	**F test**	**P value**	**Percent (%) contribution**
A	Diameter of nozzle	1	15.6024	15.6024	941.18	0.021	97.41%
B	Operator	1	0.3979	0.3979	24.00	0.128	2.48%
Error		1	0.0166	0.0166			0.10%
Total		3	16.0169				100.00%

Table 4.4: Results of ANOVA of S/N Ratio

Table 4.4 shows the result of ANOVA analysis of S/N Ratio for percentage of potting unclean. The analysis was carried out for a level of significant of 5%, which 95% of confidence level. The last column of the table represents the "percent" contribution of each factor as the total variation, indicating the influence on the results obtained. It can be seen from the table 4.2, that for potting unclean, the contribution of factor of diameter of nozzle, 97.41% is more significant than the operator which is contributes only 2.48%. Figure 4.2 shows the percentage of the factors that affecting the potting unclean defect. The bar chart illustrates that Diameter of Nozzle has a high significant effect on the output response (potting unclean defects). On the other hands, factor of operator clearly showed that operators that handling the potting machine give no significant effect on the potting process. Which conclude that only factor of nozzle diameter does not need to be considered in the confirmation experiments.

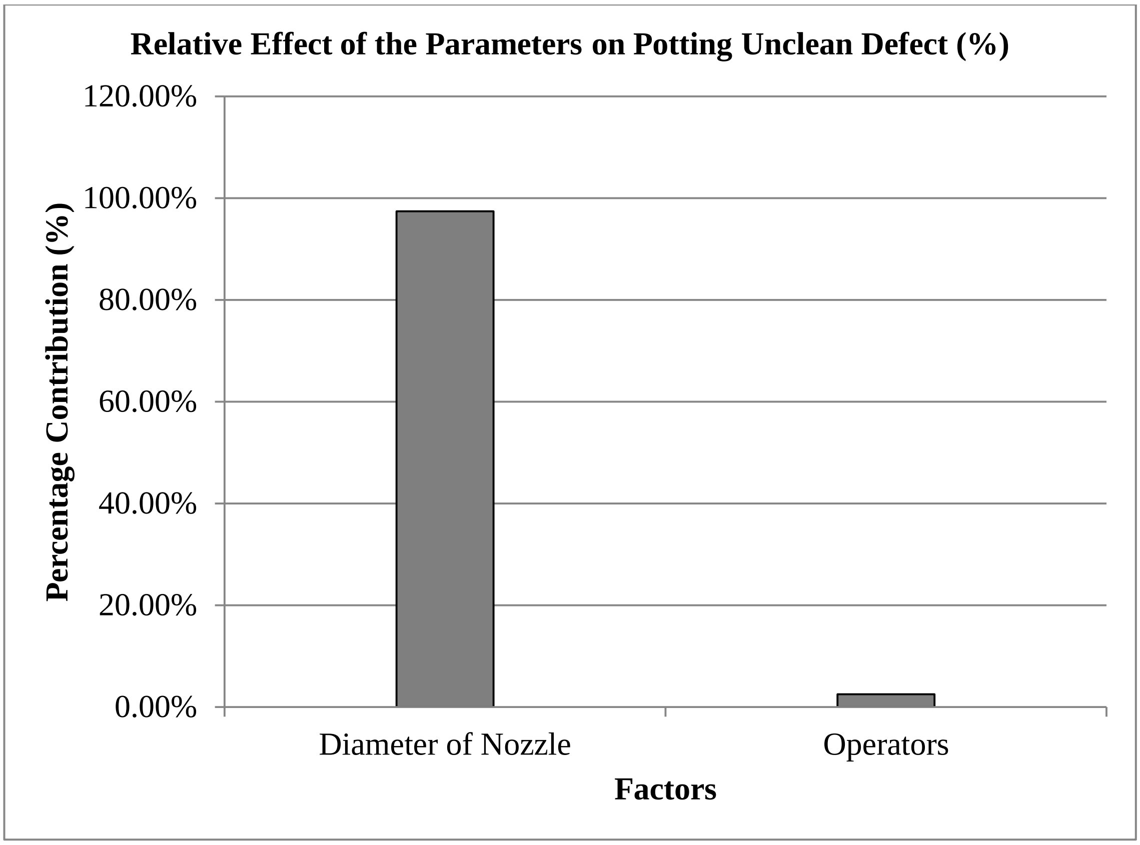

Figure 4.2: Effect of factors on potting unclean

From the Table 4.4, higher F-test value of nozzle diameter indicates that variation in this process parameter affects the process greatly. Besides, since P-value of Diameter of nozzle is less than the given significance level which is 0.05, the null hypothesis is rejected. Therefore, there is a difference between the mean of the levels which need to be considered while the factors did affect the potting unclean process. From all the analysis in ANOVA table can be concluded that diameter of nozzle can greatly affect the potting unclean at potting machine, while operator did not contribute much effects on the potting process.

4.4 Confirmation Experiment

Once the optimum condition is determined, it is usually a good practice to run a confirmation experiment (Kolahan et al., 2011). The confirmation experiment is used to verify the estimated result with the experimental results. If the optimal combination of the parameters and their level match with one of the experiments in the Orthogonal Array, then the confirmation experiment is not required. Therefore, there are no confirmation experiments required due to the optimum parameter obtained is match with the Orthogonal Array of experiment 2. However, to ensure that the optimum parameter obtained can improve the existence performance, a bulk of data was collected during the implementation of the improvement made to compare the percentage of potting unclean on potting machine with the previous data from the manufacturer.

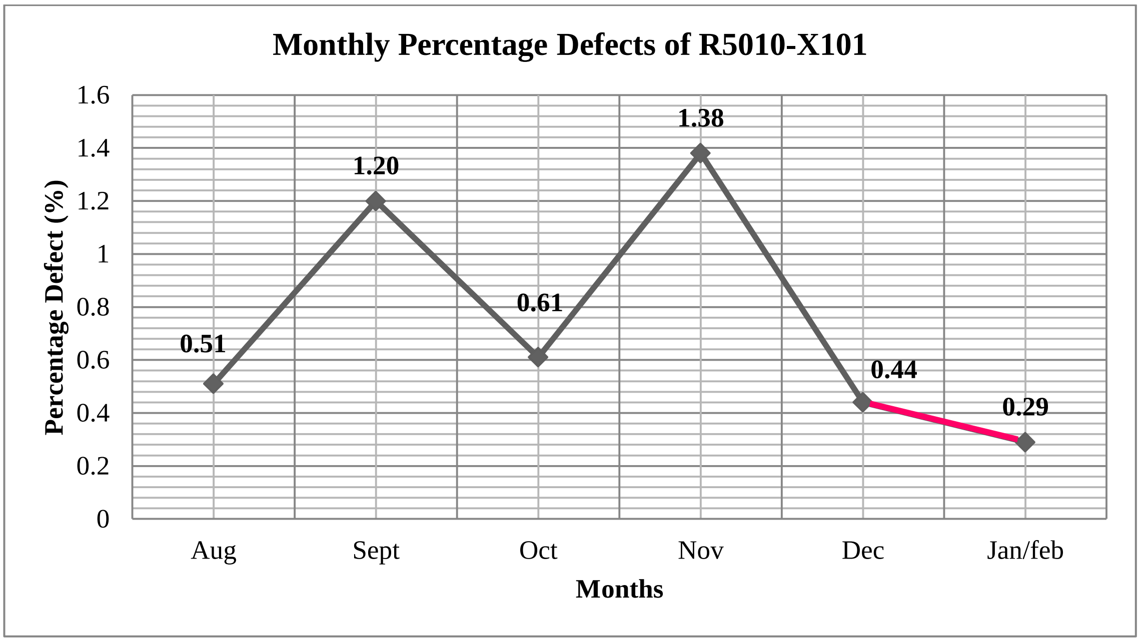

Figure 4.3: Monthly data comparison

Figure 4.3 clearly shows the decreasing of the percentage defects in January and February compared to the previous months after the potting process was conducted using only the small diameter of nozzle (2.2 mm), regardless which operator were assigned in handling the process. Data collected for January and February is about 3 weeks of data collection (2 weeks in January and 1 week in February), which contributes 0.29% of percentage defects. The previous months which are August, September, October, November, and December, recorded a higher percentage of unit defects compared to January/February. Therefore, the experiment conducted which determine the optimum level for nozzle diameter do improve the potting process performance at potting machine for inductance model of R5010-X101.

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter will give a brief summary for the whole project, a short conclusion and recommendations for the future search to give improvement ideas for the project.

5.2 Conclusions

As conclusion, the results and analysis obtained clearly shows that the objectives of this project had been achieved and successfully carried out at Vacuumschmelze Sdn. Bhd. The project area for this final year project was manufacturing which focus on experiment as the project task.

In the end of this project, there are two main objectives that had been covered. First objective is to find the optimum parameter setting for potting machine, which the parameters chose are Diameter of Nozzle and Operators. Through a series of experiments and analysis, the best parameter was identified which concluded that 2.2 mm of nozzle diameter and Operator Y are the optimum setting parameter of potting machine. However, using the analysis of variance, the factor of operator did not affect the potting process as much as diameter of nozzle which contributes 97.41% while operator only contributes 2.58%. The analysis shows that the factor of operator for the potting process was not the biggest concern but the size of diameter.

The experiments designed consumed very low cost due to minimum time utilized and number of experiments. The project conducted gave benefits to the company especially in applying the right technique and analysis in finding the optimum parameter for potting machine. Besides, the determined parameters in this project help in increasing the product yield for production and reduce cost consumption due to the high percentage of defect inductance product, especially the small sized inductance products.

5.3 Recommendations

Although the objectives of the project were successfully achieved, there were several ways and alternatives could be done to improve the result's accuracy. The recommendations can be considered for the good of the future study. Due to the lack of time and facilities, the Taguchi experiments conducted in this project only considering 2 factors and 2 levels of parameter which can ease the procedure in the company, can reduce cost expense, and can be conducted in the given time which is less than 3 months.

As a recommendation for the future work study, the parameter of the potting machine in the design of experiment can included the rest of the factors that can cause potting unclean in the potting process. The factors examples are temperature of resin, the material ratio, speed of resin, and volume of resin. Therefore, the accuracy of the experiments is more accurate and precise in determining the optimum setting of potting machine and significant factors that can affect the potting process on potting machine. Besides, the number of trials in the experiments also can be improve by doing 3 trials and above to see more variation of the results throughout the experiments. Hence, the results obtained from such experiments are more convincing to be analyzed. However, in order to improve the experimental design, a manufacture must take a risk in investing high cost, time, and machine downtown for the experimentation.

As mentioned before, due to the time constraint, this project only focuses on the factors which are diameter of nozzle and operator in improving the potting process at the potting machine. Therefore, it is really recommended to advance the experimental design by increasing the experiment size to get more accurate result and analysis.

REFERENCES

Ardebili, H., & Pecht, M. G. (2009). Encapsulation Defects and Failures. *Encapsulation Technologies for Electronic Applications*, 225–285. https://doi.org/http://dx.doi.org/10.1016/B978-0-8155-1576-0.50009-7

Athreya, S., & Venkatesh, Y. D. (2012). Application Of Taguchi Method For Optimization Of Process Parameters In Improving The Surface Roughness Of Lathe Facing Operation. *International Refereed Journal of Engineering and Science*, *1*(3), 13–19. https://doi.org/2319-1821

Basic-Tools-for-Process-Improvement. (1995). CAUSE-AND-EFFECT DIAGRAM, 1–25.

Ciocoiu, I. G., Ilie, G., & Ciocoiu, C. N. (2010). Application of Fishbone Diagram To Determine the Risk of an Event With Multiple Causes. *Management Research and Practice*, *2*(1), 1–20.

Edwin K.P.Chong; Stanislaw H.Zak. (2001). *An Introduction to Optimization* (2nd ed.). Jon Wiley and Sons, Inc.

Gould, J. (2004). Mini Briefing: Adhesives in Electronics (Prime Faraday Partnership). *Polym. Electron.*, 1–6.

Goyat, P., & Sharma, Y. (2014). To Determine the Optimum Parameter of CNC Milling Machine for Surface Roughness, *5*(3), 1–6.

Kamaruddin, S., Khan, Z. A., & Foong, S. H. (2010). Quality characteristic improvement of an injection moulding product made from blends plastic by optimizing the injection moulding parameters using Taguchi method. *International Journal of Plastics Technology*, *14*(2), 152–166. https://doi.org/10.1007/s12588-010-0014-2

Kamaruddin, S., Khan, Z. a., & Wan, K. S. (2004). The use of the taguchi method in determining the optimum plastic injection moulding parameters for the production of a consumer product. *Jurnal Mekanikal*, (18), 98–110.

Karna, S. K., Singh, R. V., & Sahai, R. (2012). Application of Taguchi Method in Indian Industry, *2*(11), 387–391.

Kolahan, F., Manoochehri, M., & Hosseini, A. (2011). Application of Taguchi Method and ANOVA Analysis for Simultaneous Optimization of Machining Parameters and Tool Geometry in Turning. *Journal of Mathematics*, *74*(3), 82–85. Retrieved from http://profdoc.um.ac.ir/paper-abstract-1019575.html

Kowalczyk, M. (2014). Application of Taguchi and Anova Methods in Selection of Process

Parameters for Surface Roughness in Precision Turning of Titanium. *Advances in Manufacturing Science and Technology*, *38*(2). https://doi.org/10.2478/amst-2014-0008

Masoud Hekmatpanah. (2011). The application of cause and effect diagram in the oil industry in Iran: The case of four liter oil canning process of Sepahan Oil Company. *African Journal of Business Management*, *5*(26), 10900–10907. https://doi.org/10.5897/AJBM11.1517

May, C. (2014). Coatings and Pottings – Issues and Challenges. Retrieved from https://www.smta.org/chapters/files/Central-Texas_Coatings_and_Pottings-CTEA.pdf

Minitab. (2017). What is the signal-to-noise ratio in a Taguchi design? Retrieved from https://support.minitab.com/en-us/minitab/18/help-and-how-to/modeling-statistics/doe/supporting-topics/taguchi-designs/what-is-the-signal-to-noise-ratio/

Mitra, A. C., Jawarkar, M., Soni, T., & Kiranchand, G. R. (2016). Implementation of Taguchi Method for Robust Suspension Design. *Procedia Engineering*, *144*, 77–84. https://doi.org/10.1016/j.proeng.2016.05.009

N.S., M. D., R, P. N. G., & Prab, M. P. M. S. (2012). Optimization of milling process parameters of en33 using taguchi parameter design approach. *Journal of Engineering Research and Studies*, *III*(I), 70–74.

Nando, S. M. and G. B. (n.d.). *RSC Advances*.

Ostertagová, E., & Ostertag, O. (2013). Methodology and Application of Oneway ANOVA. *American Journal of Mechanical Engineering*, *1*(7), 256–261. https://doi.org/10.12691/ajme-1-7-21

Rao, S. R., & Padmanabhan, G. (2012). Application of Taguchi methods and ANOVA in optimization of process parameters for metal removal rate in electrochemical machining of Al/5% SiC composites. *International Journal of Engineering Research and …*, *2*(3), 192–197. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Application+of+Taguchi+methods+and+ANOVA+in+optimization+of+process+parameters+for+metal+removal+rate+in+electrochemical+machining+of+Al+/+5+%25+SiC+composites#0

SAS Institute Inc. (2005). Concepts of experimental design. *Biostatistics for Animal …*, 34. Retrieved from http://www.cabdirect.org/abstracts/20083014785.html

Sawyer, S. F. (2009). Analysis of variance: the fundamental concepts. *Journal of Manual & Manipulative Therapy*, *17*(2), E27-38. https://doi.org/10.1179/jmt.2009.17.2.27E

Semioshkina, N., & Voigt, G. (2006). An overview on Taguchi Method. *Journal Of Radiation Research*, *47 Suppl A*(2), A95–A100. https://doi.org/10.1016/j.steroids.2009.10.005

Simha, S. (2012). Experimental investigation on Seismic Resistance Recycled Concrete in filled Steel Columns - Taguchi's approach. *15th World Conference on Earthquake Engineering (15WCEE)*.

Souza, J. P. E., Alves, J. M., Damiani, J. H. S., & Silva, M. B. (2013). Design of Experiments: Its Importance in the Efficient Project Management. *22nd International Conference on Production Research*, (May). https://doi.org/10.13140/RG.2.1.2470.6404

Vacuumschmelze. (2017). VACUUMSCHMELZE GmbH & Co. KG. Retrieved from http://www.vacuumschmelze.com/en/the-company.html

Wysk, R. A., Niebel, B. W., Cohen, P. H., and Simpson, T. W. (2000). Taguchi's Robust Design Method. *Manufacturing Processes: Integrated Product and Process Design*, 1–9.

APPENDIXES

APPENDIX A
GANNT CHART

No.	Task Description	Deliverables	14/11-18/11	19/11-25/11	26/11-2/12	3/12-9/12	10/12-16/12	17/12-23/12	24/12-30/12	31/12-6/1	7/1-13/1	14/1-20/1	21/1-27/1	28/1-3/2	4/2-10/2	11/2-17/2	18/2-24/2	25/2-28/2
			W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
1.0	**Project Background Research**	**Report Chapter 1**																
1.1	Define project background																	
1.2	Define problem statement & objectives																	
1.3	Define project scope of study																	
2.0	**Project Literature Review**	**Report Chapter 2**																
2.1	Search through the sources																	
2.2	Study the processes involved																	
2.3	Collecting information or data																	
3.0	**Project Methodology**	**Report Chapter 3**																
3.1	Design an experiments																	
3.2	Propose the experiments																	
3.3	Conduct the experimets																	
4	**Result, Analysis and Discussion**	**Report Chapter 4**																
4.1	Analyse the experimental results																	
4.2	Implement improvement																	
4.3	Analyse the implementation																	
4.4	Study and discuss the implementation result																	
5.0	**Conclusion and Recommendation**	**Report Chapter 5**																
5.1	Conclude the project																	
5.2	Identify the future works																	
6.0	**Report & Presentation**	**Complete Thesis**																