# THE EFFECT OF IRON POWDER PARTICLE SIZE TO THE CRACKED CORE DEFECT – A CASE STUDY ON MOLDED INDUCTOR (HM72A-12XXX)

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## ABSTRACT

Cracked core defect is a visible fracture or point of separation which appear on the surface of the part, but does not propagate through the entire thickness of the part. In semiconductor industries, it is a challenge to manufacture products that is free of crack defects. The effect of iron powder particle size to the cracked core defect has been studied in this research. This research is conducted at molded inductor section at BI Technologies Corporation Sdn Bhd. The part HM72A-12XXX series has been selected as a case study because it has the highest number of reject with the percentage of 34.1 percent. In order to obtain sample with different average particle size, two samples of iron powder from different supplier has been selected. These two powders are ATMIX-11 and TP-18. The size of TP-18 is smaller than ATMIX-11, ranging from 6µm - 8µm while ATMIX-11 is 12µm after the particle size distribution analysis. The surface morphology, roughness and the width of crack are observed from the experimental results. The results show that a larger particle size is better than small particle size because the percentage of crack defect by using ATMIX-11 is lower than TP-18 which is 9.4 percent and 18.1 percent respectively.

# ABSTRAK

Kecacatan teras retak ialah keretakan yang dilihat atau titik pemisahan yang muncul di permukaan sesuatu bahagian, tetapi tidak tersebar ke seluruh ketebalan sesuatu bahagian itu. Dalam industri semikonduktor, ia adalah satu cabaran untuk mengeluarkan produk yang bebas daripada kecacatan retak. Kesan saiz zarah serbuk *iron* terhadap kecacatan teras retak telah dikaji dalam kajian ini. Kajian ini dijalankan di bahagian *molded inductor* di BI Technologies Corporation Sdn Bhd. Model siri HM72A-12XXX telah dipilih sebagai kajian kes kerana ia mempunyai bilangan *reject* tertinggi dengan peratusan sebanyak 34.1 peratus. Dalam usaha untuk mendapatkan sampel dengan purata saiz zarah yang berbeza, dua sampel serbuk *iron* daripada pembekal yang berbeza telah dipilih. Kedua-dua serbuk adalah ATMIX-11 dan TP-18. Saiz TP-18 adalah lebih kecil daripada ATMIX-11, dari 6µm - 8µm manakala ATMIX-11 adalah 12µm selepas analisis *particle size distribution*. Morfologi permukaan, kekasaran dan lebar retak diperhati daripada keputusan eksperimen. Keputusan menunjukkan bahawa saiz zarah yang lebih besar adalah lebih baik daripada saiz zarah kecil kerana peratusan kecacatan retak dengan menggunakan ATMIX-11 adalah lebih rendah daripada TP-18 yang merupakan 9.4 peratus dan 18.1 peratus masing-masing.

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| | |
|---|---|
| LPS | Lean Production System |
| AC | Alternate Current |
| DC | Direct Current |
| SPC | Statistical Process Control |
| TQM | Total Quality Management |
| FTA | Fault Tree Analysis |
| C&E | Cause-and-effect |

# CHAPTER 1

# INTRODUCTION

## 1.1 RESEARCH BACKGROUND

Today manufacturing industries has very tight competition and struggle to meet the challenges to improve the productivity of the company. In this modern era, the customers generally demand very good quality of products with the reasonable price. Because of this current trend, many companies have taken Lean Production System (LPS) as a management tools to improve their quality and productivity of their products. LPS was originally established by the Toyota philosophy. Through the lean practice the companies make effort to reduce the waste that will affect the quality, cost, delivery of product, increase safety and morale.

As the market gets more competitive and the demand of a product increases, the question of production capacity will occur. This means that the quality aspect becomes more important in order to keep the market shares and produce as many error-free products as possible without having to invest in new and costly production equipments. According to Ishikawa (1985) this is the most important factor when it comes to gaining a high quality level by building quality into each design and process, which means that the quality control and must begin in the raw material processing and machining, as the raw material and the basic component is the fundamental part of the product.

As the demand of the product increases, the pressure of producing in a higher speed becomes a daily situation. The quality outcome of the process decreases, especially in the manual working areas. Therefore it is important that the product has the right quality and dimensions according to a company's standards.

BI Technologies Corporation Sdn Bhd was established since 1976 and makes their operation at Jalan Tanjung Api, Kuantan, Pahang. BI Technologies is a division of TT electronics Plc, a public listed company listed in the London FT stock exchange. TT electronics global EMS operations are based in the UK, US, China and Malaysia. This company specializes in providing high quality manufacturing support for customers operating in the Industrial, Telecom, Defense and Aerospace sectors in premier markets throughout the world. The main activities of BI Technologies are producing electrical components like inductors, semiconductor products and connectors.

(a) (b) (c)

**Figure 1.1**: BI Technologies' product; (a) Low profile SMD inductor (b) Toroidal SMD inductor (c) Isolation transformer

In overall, the implementation of LPS at BI Technologies is going well, but unfortunately at moulded inductor section there is a problem that influenced BI Technologies quality level that need serious concern and improvement. This is because, at this section area, there is a problem that related with quality issue such as the high number of defects occurs for the moulded inductor part. Therefore, the number of customer complaint is also increase due to the defects.

## 1.2 PROBLEM STATEMENT

At moulded inductor section there is a problem that has been affecting the score for BI Technologies quality. The problem is there are a high number of defects for the product produced at this section. For this company, the target production yield per month is 95 %, but this section cannot achieve that target. The average yield that they can achieve until now is only 80 %. The critical defect that needs to be considered is cracked cores defect because it has the higher defect yield than the other. The defect yield of cracked core for November 2012 is 9.8 %. There are four models of inductors which are produced; HM72A – 6 series, HM72B – 6 series, HM72A – 10 series, and HM72B – 12 series. To go further for this research some of research question need to be taken with serious consideration. There are:

i. What are the types of defect that happen on the molded inductor parts?
ii. Which type of the defects is higher?
iii. What is the root cause for that defect?
iv. How to reduce the defect?
v. Is the current procedure is the correct method to produce the molded inductor?
vi. Is there any better method to produce moulded inductor with fewer defects?

## 1.3 RESEARCH OBJECTIVES

The purposes of the research are:

i. To analyze the mechanical defects that occurs on the molded inductor parts.
ii. To analyze the root cause for the cracked cores defect.
iii. To understand the relationship between particle size of iron powder and the cracked core defect.

## 1.4 SCOPE OF THE PROJECT

The scope of the project is important to make sure that the research is not being out from the research objectives. The scopes of this research are:

Time

This research is involved for two semesters starting from September 2012 until June 2013.

Area of research

The research is conducted at BI Technologies Corporation Sdn Bhd. The area of research is at the moulded inductor section. This area has been selected because the number of defects is higher compare to the other section.

Part concentration

The moulded inductor (HM72A-12XXX) is selected because this part have problem related to the quality issues (high number of defects).

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 FAILURE IN PRODUCTION

Failure is the state or condition of not meeting a desirable or intended objective, and may be viewed as the opposite of success. Their clarifications are based on various perspectives. For example, failure can be divided into two types: functional and potential (Rosmaini Ahmad et. al, 2012). Functional failure is the inability of an item (or the component containing it) to meet a specified performance standard, whereas potential failure is an identifiable physical condition indicating an imminent functional failure. The failure is the termination of the ability of an item (i.e., any part, component, device, subsystem, functional unit, component, or system that can be individually considered) to perform a required function (SS-EN 13306). In other words, failure can be referred to as an event or process of component deterioration. According to Marius Bazu and Titu Bajenescu in their book (Failure Analysis: A practical guide for manufactures of electronic components and systems), from a technical perspective, failure can be defined as the cessation of function or usefulness. Failure analysis (FA) is the process of investigating the failure modes (FMos) with the aim of identifying the failure mechanisms (FMs), by using optical, electrical, physical and chemical analysis techniques.

There are four possible classifications of failures which are: omission, value, timing, and arbitrary. For example, a component that does not respond to an input from another component, and thereby fails by not producing the expected output is exhibiting an omission fault and the corresponding failure an omission failure. A fault that causes a component to respond within the correct time interval but with an incorrect value is termed a value fault (with the corresponding failure called a value failure). A timing fault causes the component to respond with the correct value but outside the specified interval (either too soon, or too late). The corresponding failure is a timing failure. Timing failures can only occur in systems which impose timing constraints on computations. The previous failure classes have specified how a component can be considered to fail in either the value or time domain. It is possible for a component to fail in both the domains in a manner which is not covered by one of the previous classes. A failed component which produces such an output will be said to be exhibiting an arbitrary failure (Byzantine failure).

### 2.1.1 Failure analysis on crack

In many industries, it is extremely difficult to manufacture products that will totally immune to cracking. Cracking hairline crack appear on the surface of the part but do not propagate through the entire thickness of the part. Cracks may be due to excessive stress transferred to the substrate during centrifuge (Dale W. Swanson, Leonard R. Enlow, 2000).

According to E. Smith, 1989, as the toughness of a material increases; the failure behavior of a cracked engineering structure progressively changes from being fracture mechanics controlled to being primarily flow stress controlled. Related to my study, this is important to select the correct material used according to the characteristics of the material. Iron has high melting point and other properties like strength, hardness, ductility, heat resistance and stability, which can be regulated by alloying with different materials both in prealloy as well as in the production of the friction composite itself (N.M Talijan et al, 2000).

The particle size of the material whether it small or large also can give the effect to the hardness due to the position of the atoms. This means that provided the toughness is sufficient, failure, even though it occurs as a result of crack extension, can be predicted via classic limit-load theories using an appropriate value for the net-section stress across the uncracked section. The cracking process is predominantly controlled by the residual stress (F. Malek Ghani et al, 2011). According to M. Anhalt, 2008, varying in particle size of filler material shown that with the larger particle size coercivity and dynamic losses are lowered due to fewer defects than with the smaller particles. The size distribution of particles is an important consideration because it affects the processing characteristics of the powder (Serope Kalpakjian and Steven R. Schmid).

## 2.2 INDUCTOR

An inductor is a component designed to resist changes in current. Inductors are often referred to as “AC resistors”. Inductors are one of the bulk devices which limit the performance in most of the power electronic circuits (B.S. Sreeja and S. Radha, 2011). The ability to resist changes in current and store energy in its magnetic field account for the bulk is the useful properties of inductors. Current passing through an inductor will produce a magnetic field. For an inductor, only the energy stored in the magnetic field is of interest. Therefore, the energy stored is equal to the difference between peak magnetic and electric energies (Alireza Zolfaghari, Andrew Chan, and Behzad Razavi, 2001). A changing magnetic field induces a voltage which opposes the field-producing current. This property impeding changes of current is known as inductance.

An inductor is basically a wire coiled in such a way as to increase the magnetic flux linkage between the turns of the coil. This increases the self-inductance of the wire beyond what it would have been without flux linkage (Jayanthi Suryanarayanan, 2002). In general, the relationship between the time-varying voltage v(t) across an inductor with inductance L and the time-varying current i(t) passing through it is described by the differential equation:

$$v(t) = L \frac{di(t)}{dt}$$

When there is a sinusoidal alternating current (AC) through an inductor, a sinusoidal voltage is induced. An ideal inductor is characterized by purely reactive impedance ($Z = jX_L$) which is proportional to the inductance only. The phase of the signal across the ideal inductor would always be +90 degrees out of phase with the applied voltage and there would be no effect of DC current bias on its behavior (Jayanthi Suryanarayanan, 2002).

### 2.2.1 Q - Factor

An ideal inductor will be lossless irrespective of the amount of current through the winding. However, typically inductors have winding resistance from the metal wire forming the coils. Since the winding resistance appears as a resistance in series with the inductor, it is often called the series resistance. The inductor's series resistance converts electric current through the coils into heat, thus causing a loss of inductive quality. The quality factor (or Q) of an inductor is the ratio of its inductive reactance to its resistance at a given frequency, and is a measure of its efficiency. The higher the Q factor of the inductor, the closer it approaches the behavior of an ideal, lossless, inductor.

The Q factor of an inductor can be found through the following formula, where $R$ is its internal (Series Model) electrical resistance and $\omega L$ is the inductive reactance at resonance:

$$Q = \frac{\omega L}{R}$$

## 2.3 MOLDING PROCESS

According to Robert A. Tatara, compression molding is the oldest among materials processing techniques. But, it was the first industrial method for plastic and also known as matched die molding. In this process, the basic process consist of heating a thermoset resin, under severe pressure, within a closed mold cavity until the resin cures through a chemical reaction of cross-linking polymeric chain. Under pressure, the resin liquefies and flows, taking the shape of the mold cavity, and then hardens into the desired product. The part is removed from the mold once it's sufficiently cooled and strong. The curing reaction was continued while cooling to room temperature or ambient condition. The common resins include phenol-formaldehyde, urea-formaldehyde, melamine-formaldehyde, epoxy, polyester, silicone, and various rubbers and elastomers. This molding process is suitable for a wide range of industrial, commercial, and consumer parts and products ranging from very small to large automobile body panel.

Compression molding is a manufacturing process for producing composites structures which work by compressing a precharge on a mold (Moo Sun Kim et. al, 2009). It stated that the main advantage by using this method is its relatively short process cycle which is suited for mass production and the fact that the mechanical properties of the final product are generally good.

## 2.4 QUALITY

"Quality is the degree to which the product or service conforms to customer requirement" and "it implies meeting these requirements the first time and every time" (Amra Jusufagic and Johanna Skoog, 2007). Quality issues have become increasingly important in the production electronic, especially when dealing with electronic products not assimilated to the mainstream of consumers electronics, but rather to the group of industrial electronic devices and machinery designed to last for years or even decades (Mika Liukkonen, Elina Havia, Hannu Leinonen and Yrjo Hiltunen, 2011). The importance of data acquisition and exploitation in the electronics industry has been highlighted in this recent time due to intention to achieve process improvements and optimal manufacturing process. The equipment of modern electronics process can be used to store data which flexible exploitation is, however, laborious to process expert.

According to Sauer et al, 2006 and Smith and Whitehall, 1997, it is typical for the production of electronics that practically the only operation using the historical process data is the statistical process control (SPC), whereas the proactive operations for the process improvement such as diagnostic and optimization often lack this valuable and abundant information. It also can be said that process equipment is regularly used in the production without a thorough analysis of the data or it could be at least stored during the process. The most common method of checking quality for sampled product and service is SPC to draw conclusion by analyzing the outputs of the process. This method deals with sampling the process while producing or delivering goods and is also based on decision that are made whether the process is operating or if there any problem then the process can be stopped and the problem was identified and solved (Slack, Chambers, Johnston and Betts, 2006).

In the manufacturing of electronics, the method traditionally used in the process improvement is through the data-driven which is statistical linear method or experimental testing (Castillo, 2007, Sauer et al, 2006 and Smith and Whitehall, 1997). For example, to optimize the process setting for wave soldering of electronic components, the method that commonly used is trial-and-error based process tuning, design of experiment, analysis of variance and linear regression (Arra et al, 2002, Santos et al, 1997, Mesenbrink et al, 1994, Barbini, 2007, and Tsenev and Marivov, 2004). Furthermore, Coit, Jackson and Smith, 2002, have suggested that the operator's trial-and-error experiments cannot form a reliable basis for proactive control and that the linear methods such as regression may not be the optimal solution for a soldering process.

### 2.4.1 Quality tools

There are seven quality control tools that are helpful for quality improvement which are flow charts, check sheet, histograms, Pareto diagrams, Cause-Effect diagrams, Scatter diagram and control chart (Amra Jusufagic and Johanna Skoog, 2007). All these 7 QC tools are included in Total Quality Management (TQM) which is Japanese concept for managing a company with the aim to achieve quality in every activity and also to accomplish the company's goal (Grimsdal and Gunnarson, 1993). The different areas of application for different tools are (Evan and Lindsey, 2002):

1. The flow chart is used to identify the sequence of activities or the material flow and information in a process, and is used for understanding and establishing control procedures.
2. The check sheet is tables that are used for the collecting data.
3. Histogram is the statistical tool that shows the frequencies or number of observation of particular value.
4. Cause and effect diagrams are used for generating ideas and identify possible causes to problems.
5. Pareto diagrams are used for identifying problems and analyzing the collected data from the check sheets.
6. Scatter diagrams are used for developing solution and appoint the important relationship between particular variables.
7. Control charts are used for understanding the variation. A tool used to identify the changes over time and defects in samples with constant size.

#### 2.4.1.1 Pareto diagram

According to Dale H. Besterfield in his book, Quality Improvement (ninth edition), a Pareto diagram is a graph that ranks data classifications in descending order from left to right. This chart is developed by Alfredo Pareto in 1848-1923. In this case, the data classifications are types of field failures. Besides that, the other possible data classifications are problem, causes, types of noncomformities, and so forth. The vital few are on the left, and the useful many are on the right. It is sometimes necessary to combine some of the useful many into one classification called *other*. When the *other* category is used, it is always on the far right. Two scales are used; the one on the left is frequency and the one on the right is percent.

#### 2.4.1.2 Cause-and-effect diagram

According to Dale H. Besterfield in his book, Quality Improvement (ninth edition), a cause-and-effect (C&E) diagram is a picture composed of lines and symbols designed to represent a meaningful relationship between an effect and its causes. It was developed by Kaoru Ishikawa in 1943 and is sometimes referred to as an Ishikawa diagram. C&E diagrams are used to investigate either a “bad” effect and to take action to correct the causes or a “good” effect and to learn those causes responsible. For every effect, there are likely to be numerous causes.

## 2.5 RELIABILITY

Product reliability is importance to both manufacturer and consumer since inadequate reliability result in higher cost to both of the parties (D.N.P Murthy, T. Osteraes, M. Rausand, 2009). According to the issue and the optimal investment in reliability, it has involve two tasks which is; (1) deciding on the reliability requirement and (2) deciding on component specification (SP) to achieved the desired reliability (Murthy et al).

According to Man Cheol Kim and Poong Hyun Seong, 2002, the term of system reliability analysis refers to the evaluation of the reliability of the system based on the reliabilities of its elements. There are several methods that can be applied to this system reliability analysis. For examples, a reliability graph, fault tree analysis (FTA), Markov chain and Monte Carlo simulation. Each of the methods had their own characteristics, merits and also demerits. Among of the existing methods, the fault tree analysis is most widely used due to its expression power, applicability to complex system and various tool supports.

For each of single point failure, the three dimensional understanding and analysis gives an explicit and separate consideration and also helps identify the weak links in the design for further action in order to improve reliability (Om Prakash Yadav, Nanua Singh, Parveen S. Goel, 2005). Besides that, the framework helps to identify what types of test to be performed and which physical element is subjected to the identified test based on the knowledge of the potential failure mechanism and failure analysis results.

# CHAPTER 3

# METHODOLOGY

This chapter describes the research methods that will be used to conduct this study. Research methodology is a set of procedures or methods used to conduct research. It can be defined also as the study or the description of method. A methodology can be considered to include multiple methods, each as applied to various facets of the whole scope of the methodology. There are two types of research methodologies. These two types of methodologies are qualitative methodologies and quantitative methodologies. Both methodologies will be used during the analyzing phase. Qualitative research involves the use of qualitative data such as interviews, direct observations, survey and analysis of documents and material. Direct observation and experimental analysis are the research method for this research. The flow chart below shows the steps that have been taken in doing this research.

## 3.1 METHODOLOGY

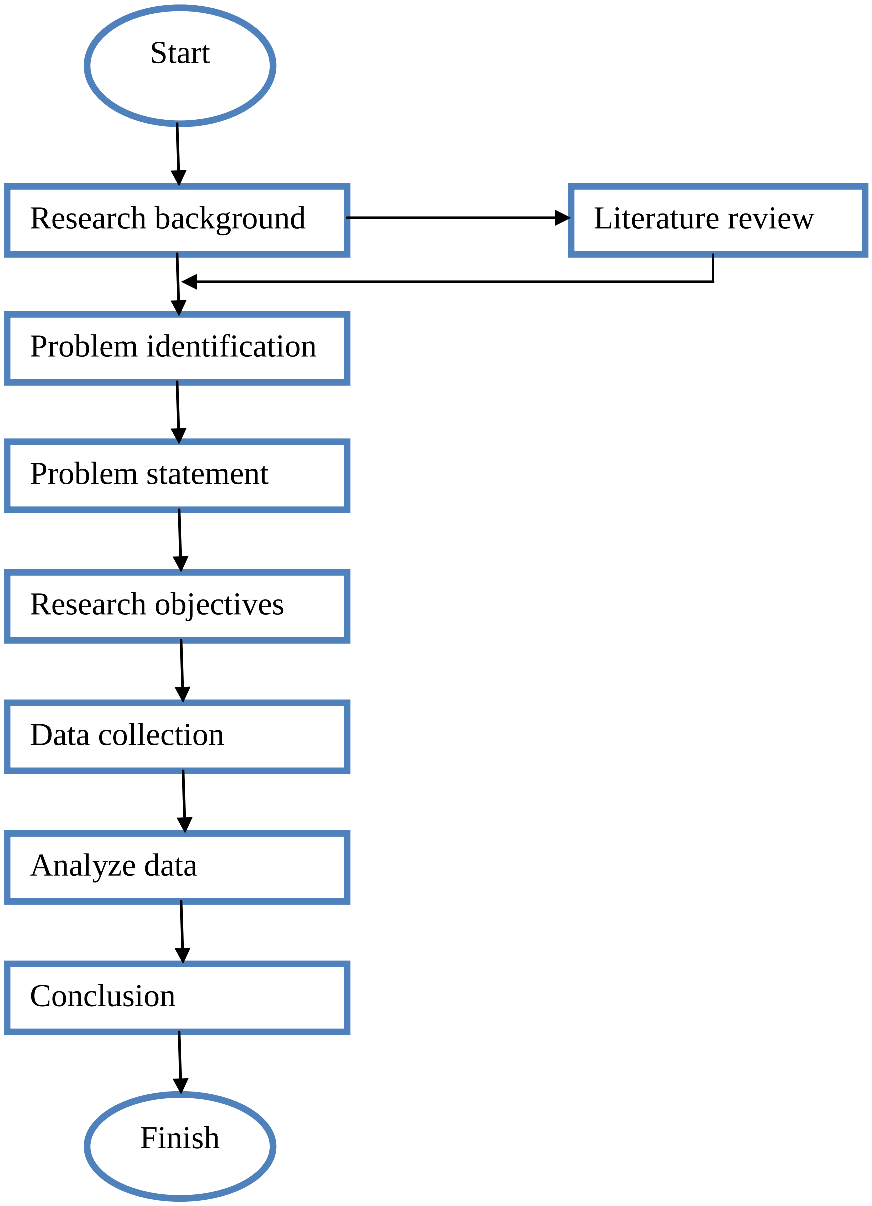


**Figure 3.1**: Flow chart of research methodology

## 3.2 EXPLANATION OF FLOW CHART

### 3.2.1 Field Research

Field research deals with creation and collection of actual and authentic information by field of operation in any organization. It is also can be defined as the collection of information outside of the laboratory and workplace setting. The process involves determining what precise data is necessary and from where this information needs to be obtained, methods: informal interviews, direct observation, participation in the life of the group, collective discussions, analyzes of personal documents produced within the group, self-analysis, and life-histories. At this stage, the method used is focus on the direct observation in order to collect the information in general view of the problem at the selected company. First of all, a company must be selected to make the observation and case study. The selection of BI Technologies as the area of research because of the company has the quality issues that lead to the high number of defect in product. After that, the direct observation has been done at the company. The purpose of this observation is to collect the general view of information such as company profile, their product, and others.

### 3.2.2 Problem Identification

Problem identification is actually seeing the problem before trying to solve it. In other word, it is a first strategy in solving a problem. First, it has to realize and accept there is a problem. Once the problem have identified, then do the observation and reflect what is going on, gather the information that is related and begin working on the solution. For this step, the problem that has been identified is the high number of defects occurred in moulded inductor part.