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IMPLEMENTATION OF A SIX SIGMA TECHNIQUE IN A MANUFACTURING PROCESS: A CASE STUDY

تطبيق تقنية 6σ علي عمليات التصنيع (دراسة حالة)

Thesis Submitted in Partial Fulfillment to the Requirements for The Degree of Master of Science in Mechanical Engineering (Production)

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الآيـــــــة

بسم الله الرحمن الرحيم

قال تعالى

(وَقَالَ رَبِّ أَوْزِعْنِي أَنْ أَشْكُرَ نِعْمَتَكَ الَّتِي أَنْعَمْتَ عَلَيَّ وَعَلَى وَالِدَيَّ وَأَنْ أَعْمَلَ صَالِحاً تَرْضَاهُ وَأَدْخِلْنِي بِرَحْمَتِكَ فِي عِبَادِكَ الصَّالِحِينَ)

(النمل: من الآية19)

Dedications

“This research Dedicated to my beloved parents & family” For their love, endless support, encouragement & sacrifices.

“Author”

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I would like to express my special thanks of gratitude to my teacher (Dr. Elkhawad Ali Elfaki) as well as (Marbil Engineering Company Management)whom gave me the golden opportunity to do this wonderful research on (Six Sigma), which also helped me in doing a lot of Research and I came to know about so many new things so I am really thankful to them.

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Abstract

Quality and productivity have been identified as an important role in any organization, especially for manufacturing sectors to gain more profit that leads to success of a company. This research reports a work improvement project in MARBLE Engineering Company (MEC), It involves problem identification in production of Housing and proposing an effective framework to improve the current situation effectively. Based on the observation and data collection on the work in progress, the major problem has been identified related to function of the product which is the parts can't assemble properly due to dimension of the product is out of specification. The six sigma has been used as a methodology to study and improve the problems identified. Six Sigma is a highly statistical and data driven approach to solving complex business problems. It uses a methodical five phase approach's: define, measure, analysis, improve and control (DMAIC) to help understand the process and the variables that affect it so that can be optimized the processes. Finally, the root cause and solution for the production of housing problem has been identified and implemented then the result for this product was successfully followed the specification of fitting.

المستخلص :

في هذة الدراسة تم تحديد الجودة والإنتاجية لما لهما من دور مهم في أي مؤسسة ، خاصة لقطاعات التصنيع لتحقيق المزيد من الأرباح التي تؤدي إلى نجاح الشركة. يفيد هذا البحث عن مشروع لتحسين العمل في شركة ماربيل للهندسة. ويشمل ذلك تحديد المشكلات في إنتاج Housing واقتراح إطار فعال لتحسين الوضع الحالي بفعالية. استنادًا إلى الملاحظة وجمع البيانات حول العمل الجاري ، تم تحديد المشكلة الرئيسية المتعلقة بوظيفة المنتج التي بها لا يمكن تجميع المنتج بشكل صحيح نظرًا لأن أبعاد المنتج غير مطابقة للمواصفات. تم استخدام six sigma كمنهج لدراسة وتحسين المشاكل التي تم تحديدها. Six Sigma هو نهج إحصائي يعتمد على البيانات بدرجة كبيرة لحل مشكلات الأعمال المعقدة. ويستخدم أسلوبًا منهجيًا من خمس مراحل تحديد وقياس وتحليل وتحسين ومراقبة (DMAIC) للمساعدة في فهم العملية والمتغيرات التي تؤثر عليها حتى يمكن تحسين العمليات. وأخيرًا ، تم تحديد جزور المسببات لمشكلة إنتاج الـ Housing وتم تطبيق الحلول ، اظهرت النتائج مطابقة المنتج بنجاح مواصفات التجميع.

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List of Abbreviations

TQM	Total Quality Management.
DMAIC	Define – Measure – Analyse – Improve – Control.
COPQ	the cost of poor quality.
PPM	parts-per-million.
SPC	statistical process control.
CTQ	critical to quality.
SIPOC	Suppliers – Input – Process – Output – Customers.
RTY	Rolled Throughput Yield.
FTY	First Time Yield

Chapter One

Introduction

1-1 General Introduction

One of the major problem in manufacturing companies is the product defects, defects are when products or service deviate from what the customer requires or the specification. When talking about waste most people think of defects rather than the other wastes such as waiting and transportation.

Defects can be caused by many different problems, many that should be avoided by a little thought when designing products, processes and equipment.

Many defects are caused by incorrect method due to non-standard operations, differences in the way that processes are undertaken by different operators on different shifts. When the wrong parts are ordered, when engineering changes aren't effectively communicated or when designs aren't properly executed on the manufacturing line. Fail to maintain equipment, machines and fixtures allowing defects to occur. a culture that empowers and makes our operators confident enough to highlight problems and allow them to be solved, they often continue and make the best of a poorly fitting component rather than stopping to have either the fixtures or the components corrected. provide training to people also reward the wrong behaviours, paying for quantity rather than quality, encouraging employees to work as fast as possible and even penalizing them if they do not make the numbers with little thought to the consequences on the quality of products or services.

Scrap and rework costs are a manufacturing reality impacting organizations across all industries and product lines, There are costs associated with problem solving, materials, rework, rescheduling materials, setups, transport, paperwork, increased lead times, delivery failures and potentially lost customers who will take their custom elsewhere.

To eliminate defects completely, Can reduce the amount of scrap and rework in your organization by optimizing the way you document product data, review manufacturing processes and communicate manufacturing and engineering changes throughout supply chain. If priority is given to evaluating and improving your manufacturing processes, it becomes much easier to reduce the amount of scrap and rework in your organization

By reducing defects from processes will reduce costs, and every saving made within costs is added directly to the profits

1-2 Research Problem

The product defects are major problem in marble engineering company. And it cost the company material consumption to replace the rejected products by others accepted. Sometimes the raw material is not available in the local market and the company need to import it from outside and this process takes a lot of time. The process of work and rework also lead to tools consumption and machine consuming. It also cost the company time. Reducing product defects will help to increase productivity.

1-3 Research Importance

This research will help Marble engineering company in reducing product defects in machining processes. Increasing operator knowledge about causes of defects in machining products, reducing the production cost and time and increasing the productivity and profit.

1-4 Objectives:

The Six Sigma Methodology is a customer focused continuous improvement strategy that minimizes defects and variation. Towards an achievement of defects per million opportunities in product design, production, and administrative process. Gutierrez et al. (2004) state that, Six Sigma is a strategy of continuous improvement of the organization to find and eliminate the causes of the errors, defects and delays in business organization processes.

The main objective of this research is to implement six sigma methodology in housing machining processes. The specific objectives of the project were grouped in three categories;

1. Housing dimensions Failure measurements.
2. Failure Analysis, and eliminate.
3. Process productivity improvement.

1-5 Scope:

The research work will Utilizing Six Sigma methodology to improve the machining processes to help Marble Engineering Company to eliminate product defects and increase productivity.

1-6 Outline:

This research cared out through six chapters as follow. chapter one is a general introduction, chapter two contains a literature review, chapter three explains six sigma methodology the methodology which is used in this research and the tools which is used also like case and effect and Pareto analysis. Chapter four explains the case study which is done in Marbil engineering company including the analysis to Marbil data and the implementation of six sigma, chapter five discuss the result and chapter six gives the conclusion and recommendation. And finally the references.

CHAPTER TWO

Theoretical Background and Literature Review

2-1 Preface

Six Sigma is a rigorous, focused, and highly effective implementation of proven quality principles and techniques. Incorporating elements from the work of many quality pioneers, Six Sigma aims for virtually error-free business performance. Sigma, σ, is a letter in the Greek alphabet used by statisticians to measure the variability in any process [1]. A company's performance is measured by the sigma level of their business processes. Traditionally companies accepted three or four sigma performance levels as the norm, despite the fact that these processes created between 6,200 and 67,000 problems per million opportunities! The Six Sigma standard of 3.4 problems-per-million opportunities∗ [2] is a response to the increasing expectations of customers and the increased complexity of modern products and processes. Despite its name, Six Sigma's magic isn't in statistical or high-tech razzle-dazzle. Six Sigma relies on tried and true methods that have been used for decades. By some measures, Six Sigma discards a great deal of the complexity that characterized Total Quality Management (TQM) [3]. Six Sigma takes a handful of proven methods and trains a small cadre of in-house technical leaders, known as Six Sigma Black Belts, to a high level of proficiency in the application of these techniques. To be sure, some of the methods Black Belts use are highly advanced, including up-to-date computer technology. But the tools are applied within a simple performance improvement model known as Define-Measure-Analyse-Improve-Control, or DMAIC. DMAIC is described briefly as follows:

D Define the goals of the improvement activity.

M Measure the existing system.

A Analyse the system to identify ways to eliminate the gap between the current performance of the system or process and the desired goal.

I Improve the system.

C Control the new system [1].

2-2 Six Sigma?

When a Japanese firm took over a Motorola factory that manufactured Quasar television sets in the United States in the 1970s, they promptly set about making drastic changes in the way the factory operated. Under Japanese management, the factory was soon producing TV sets with 1/20th as many defects as they had produced under Motorola's management [1]. They did this using the same workforce, technology, and designs, and did it while lowering costs, making it clear that the problem was Motorola's management. It took a while but, eventually, even Motorola's own executives finally admitted "Our quality stinks" (Main, 1994). It took until nearly the mid-1980s before Motorola figured out what to do about it. Bob Galvin, Motorola's CEO at the time, started the company on the quality path known as Six Sigma and became a business icon largely as a result of what he accomplished in quality at Motorola. Using Six Sigma Motorola became known as a quality leader and a profit leader. After Motorola won the Malcolm Baldrige National Quality Award in 1988 the secret of their success became public knowledge and the

Six Sigma revolution was on [1]. Today it's hotter than ever. Even though Motorola has been struggling for the past few years, companies such as GE and AlliedSignal have taken up the Six Sigma banner and used it to lead themselves to new levels of customer service and productivity. It would be a mistake to think that Six Sigma is about quality in the traditional sense. Quality, defined traditionally as conformance to internal requirements, has little to do with Six Sigma. Six Sigma focuses on helping the organization make more money by improving customer value and efficiency. To link this objective of Six Sigma with quality requires a new definition of quality: the value added by a productive endeavour. This quality may be expressed as potential quality and actual quality. Potential quality is the known maximum possible value added per unit of input. Actual quality is the current value added per unit of input. The difference between potential and actual quality is waste. Six Sigma focuses on improving quality (i.e., reducing waste) by helping organizations produce products and services better, faster, and cheaper. There is a direct correspondence between quality levels and "sigma levels" of performance. For example, a process operating at Six Sigma will fail to meet requirements about 3 times per million transactions. The typical company operates at roughly four sigma, equivalent to approximately 6,210 errors per million transactions [2]. Six Sigma focuses on customer requirements, defect prevention, cycle time reduction, and cost savings. Thus, the benefits from Six Sigma go straight to the bottom line. Unlike mindless cost-cutting programs which also reduce value and quality, Six Sigma identifies and eliminates costs which provide no value to customers: waste costs. For non-Six Sigma companies, these costs are often extremely high. Companies operating at three or four sigma typically spend between 25 and 40 percent of their revenues fixing problems [1]. This is known as the cost of quality, or more accurately the cost of poor quality. Companies operating at Six Sigma typically spend less than 5 percent of their revenues fixing problems COPQ values [4] are at the lower end of the range of results reported in various studies. The dollar cost of this gap can be huge. General Electric estimated that the gap between three or four sigma and Six Sigma was costing them between $8 billion and $12 billion per year [5] . One reason why costs are directly related to sigma levels is very simple: sigma levels are a measure of error rates, and it costs money to correct errors. Note that the error rate drops exponentially as the sigma level goes up, and that this correlates well to the empirical, Also note that the errors are shown as errors per million opportunities, not as percentages. This is another convention introduced by Six Sigma. In the past we could tolerate percentage error rates (errors per hundred opportunities) today we cannot.

2-3 The Six Sigma Philosophy

Six Sigma is the application of the scientific method to the design and operation of management systems and business processes which enable employees to deliver the greatest value to customers and owners. The scientific method works as follows:

- Observe some important aspect of the marketplace or your business.
- Develop a tentative explanation, or hypothesis, consistent with your observations.
- Based on your hypothesis, make predictions.
- Test your predictions by conducting experiments or making further careful observations. Record your observations. Modify your

hypothesis based on the new facts. If variation exists, use statistical tools to help you separate signal from noise.

- Repeat steps 3 and 4 until there are no discrepancies between the hypothesis and the results from experiments or observations.

At this point you have a viable theory explaining an important relationship in your market or business. The theory is your crystal ball, which you can use to predict the future. As you can imagine, a crystal ball is very useful for any organization. Furthermore, it often happens that your theory will explain phenomena other than that you initially studied. Isaac Newton's theory of gravity may have begun with the observation that apples fell toward the earth, but Newton's laws of motion explained a great deal about the way planets moved about the sun. By applying the scientific method over a period of years you will develop a deep understanding of what makes your customer and your business tick. When this approach is applied across the organization, the political influence that stalls organizations is minimized and a "show me the data" attitude prevails. While corporate politics can never be eliminated where human beings interact, politics is much less an influence in Six Sigma organizations than in traditional organizations. People are often quite surprised at the results of this seemingly simple shift in attitude. The essence of these results is stated quite succinctly by "Pyzdek's law":

The Six Sigma philosophy focuses the attention on the stakeholders for whom the enterprise exists. It is a cause-and-effect mentality. Well-designed management systems and business processes operated by happy employees cause customers and owners to be satisfied or delighted. Of course, none of this is new. Most leaders of traditional organizations honestly believe that this is what they already do. What distinguishes the traditional approach from Six Sigma is the degree of rigor and commitment to the core principles.

2-4 Six Sigma versus Traditional Three Sigma Performance

The traditional quality model of process capability differed from Six Sigma in two fundamental respects:

It was applied only to manufacturing processes, while Six Sigma is applied to all important business processes. It stipulated that a “capable” process was one that had a process standard deviation of no more than one-sixth of the total allowable spread, where Six Sigma requires the process standard deviation be no more than one-twelfth of the total allowable spread.

These differences are far more profound than one might realize. By addressing all business processes Six Sigma not only treats manufacturing as part of a larger system, it removes the narrow, inward focus of the traditional approach. Customers care about more than just how well a product is manufactured. Price, service, financing terms, style, availability, frequency of updates and enhancements, technical support, and a host of other items are also important. Also, Six Sigma benefits others besides customers. When operations become more cost-effective and the product design cycle shortens, owners or investors benefit too. When employees become more productive their pay can be increased. Six Sigma’s broad scope means that it provides benefits to all stakeholders in the organization. The second point also has implications that are not obvious. Six Sigma is, basically, a process quality goal, where sigma is a statistical measure of variability in a process. As such it falls into the category of a process capability technique. The traditional quality paradigm defined a process as capable if the process's natural spread, plus and minus three sigma, was less than the engineering tolerance. Under the assumption of normality, this three sigma quality level translates to a process yield of 99.73%. A later refinement considered the process location as well as its spread and tightened the minimum acceptance criterion so that the process mean was at least four sigma from the nearest engineering requirement. Six Sigma requires that processes operate such that the nearest engineering requirement is at least Six Sigma from the process mean. One of Motorola's most significant contributions was to change the discussion of quality from one where quality levels were measured in percent (parts-per-hundred), to a discussion of parts-per-million (PPM) or even parts-per-billion. Motorola correctly pointed out that modern technology was so complex that old ideas about "acceptable quality levels" could no longer be tolerated. Modern business requires near perfect quality levels. One puzzling aspect of the "official" Six Sigma literature is that it states that a process operating at Six Sigma will produce 3.4 parts-per-million non-conformances. However, if a special normal distribution table is consulted (very few go out to Six Sigma) one finds that the expected non-conformances are 0.002 PPM (2 parts-per-billion, or PPB). The difference occurs because Motorola presumes that the process mean can drift 1.5 sigma in either direction. The area of a normal distribution beyond 4.5 sigma from the mean is indeed 3.4 PPM. Since control charts will easily detect any process shift of this magnitude in a single sample, the 3.4 PPM represents a very conservative upper bound on the non-conformance rate. In contrast to Six Sigma quality, the old three sigma quality standard of 99.73% translates to 2,700 PPM failures, even if we assume zero drift. For processes with a series of steps, the overall yield is the product of the yields of the different steps. For example, if we had a simple two-step process where step #1 had a yield of 80% and step #2 had a yield of 90%, then the overall yield would be 0.8 × 0.9 = 0.72 = 72%. Note that the overall yield from processes involving a series of steps is always less than the yield of the step with the lowest yield. If three sigma quality levels (99.97% yield) are obtained from every step in a 10-step process, the quality level at the end of the process will contain 26,674 defects per million. Considering that the complexity of modern processes is usually far greater than 10 steps, it is easy to see that Six Sigma quality isn't optional, it's required if the organization is to remain viable.[2]

It's important to note that Six Sigma organizations are not academic institutions. They compete in the fast-paced world of business, and they don't have the luxury of taking years to study all aspects of a problem before deciding on a course of action. A valuable skill for the leader of a Six Sigma enterprise, or for the sponsor of a Six Sigma project, is to decide when enough information has been obtained to warrant taking a particular course of action. Six Sigma leadership should be conservative when spending the shareholders' dollars. As a result, project research tends to be tightly focused on delivering information useful for management decision-making. Once a level of confidence is achieved, management must direct the Black Belt to move the project from the Analyze phase to the Improve phase, or from the Improve phase to the Control phase. Projects are closed and resources moved to new projects as quickly as possible. Six Sigma organizations are not infallible; they make their share of mistakes and miss opportunities. Yet, research has shown they make fewer mistakes than their traditional counterparts and perform significantly better in the long run. Their systems incorporate the ability to learn from these mistakes, with resulting systematic improvements.

2-5 Statistical Process Control

a. Variable Charts

In statistical process control (SPC) ,the mean, range, and standard deviation are the statistics most often used for analyzing measurement data. Control charts are used to monitor these statistics. An out-of-control point for any of these statistics is an indication that a special cause of variation is present and that an immediate investigation should be made to identify the special cause.

b. Averages and Ranges Control Charts

Averages charts are statistical tools used to evaluate the central tendency of a process over time. Ranges charts are statistical tools used to evaluate the dispersion or spread of a process over time.

Averages charts answer the question: ‘‘has a special cause of variation caused the central tendency of this process to change over the time period observed?’’ Ranges charts answer the question: ‘‘has a special cause of variation caused the process distribution to become more or less consistent?’’ Averages and ranges charts can be applied to any continuous variable such as weight, size, etc. The basis of the control chart is the rational subgroup. Rational subgroups are composed of items which were produced under essentially the same conditions. The average and range are computed for each subgroup separately, then plotted on the control chart. Each subgroup’s statistics are compared to the control limits, and patterns of variation between subgroups are analyzed.

c. Averages and Standard deviation (Sigma) Control Charts

Averages and standard deviation control charts are conceptually identical to averages and ranges control charts. The difference is that the subgroup standard deviation is used to measure dispersion rather than the subgroup range. The subgroup standard deviation is statistically more efficient than the subgroup range for subgroup sizes greater than 2. This efficiency advantage increases as the subgroup size increases However, the range is easier to compute and easier for most people to understand. In general, this author recommends using subgroup ranges unless the subgroup size is 10 or larger. However, if the analyses are to be interpreted by statistically knowledge able personnel and calculations are not a problem, the standard deviation chart may be preferred for all subgroup sizes.

d. Control Charts for Individual measurements (X charts)

Individuals control charts are statistical tools used to evaluate the central tendency of a process over time. They are also called X charts or moving range charts. Individuals control charts are used when it is not feasible to use averages for process control. There are many possible reasons why averages control charts may not be desirable: observations may be expensive to get output may be too homogeneous over short time intervals the production rate may be slow and the interval between successive observations long, etc. Control charts for individuals are often used to monitor batch process, such as chemical processes, where the within-batch variation is so small relative to between-batch variation that the control limits on

(a standard $\bar{X}$chart would be too close together. Range charts are used in conjunction with individuals charts to help monitor dispersion.)

e. Control Charts for Proportion Perfective (p charts)

p charts are statistical tools used to evaluate the proportion defective, or proportion non-conforming, produced by a process. p charts can be applied to any variable where the appropriate performance measure is a unit count. p charts answer the question: ‘‘Has a special cause of variation caused the central tendency of this process to produce an abnormally large or small number of defective units over the time period observed?’’

f. Control Charts for Count of Defectives

Np charts are statistical tools used to evaluate the count of defectives, or count of items non-conforming, produced by a process. np charts can be applied to any variable where the appropriate performance measure is a unit count and the subgroup size is held constant. Note that wherever an np chart can be used, a p chart can be used too.

g. Control Charts for Average Occurrences-Per-Unit (u charts)

u charts are statistical tools used to evaluate the average number of occurrences-per-unit produced by a process. u charts can be applied to any variable where the appropriate performance measure is account of how often a particular event occurs. u charts answer the question: ‘‘Has a special cause of variation caused the central tendency of this process to produce an abnormally large or small number of occurrences over the time period observed? ’’Note that, unlike p or np charts, u charts do not necessarily involve counting physical items. Rather, they involve counting of events. For example, when using a p chart one would count bruised peaches. When using a u chart one would count the bruises.

h. Control Charts for Counts of Occurrences-Per-Unit (c charts)

C charts are statistical tools used to evaluate the number of occurrences-perunit produced by a process. c charts can be applied to any variable where the appropriate performance measure is a count of how often a particular event occurs and samples of constant size are used. c charts answer the question: ‘‘Has a special cause of variation caused the central tendency of this process to produce an abnormally large or small number of occurrences over the time period observed? ’’Note that, unlike p or np charts, c charts do not involve counting physical items. Rather, they involve counting of events. For example, when using an np chart one would count bruised peaches. When using a c chart one would count the bruises.

i. Control Chart Selection

Selecting the proper control chart for a particular data set is a simple matter if approached properly. The proper approach is illustrated in Figure12.8. To use the decision tree, begin at the left-most node and determine if the data are measurements or counts. If measurements, then select the control chart based on the subgroup size. If the data are counts, then determine if the counts are of occurrences or pieces. An aid in making this determination is to examine The equation for the process average. If the numerator and denominator involve the same units, then a p or np chart is indicated. If different units of measure are involved, then a u or c chart is indicated. For example, if the average is in accidents-per-month, then a c or u chart is indicated because the numerator is in terms of accidents but the denominator is in terms of time.

2-6 Cost of Poor Quality

quality cost accounting systems are part of every modern organization's quality improvement strategy, as well as many quality standards. Quality cost systems identify internal opportunities for return on investment. As such, quality costs stress avoiding defects and other behaviors that cause customer dissatisfaction, yet provide little understanding of the product or service features that satisfy or delight customers. It is conceivable that a firm could drive quality costs to zero and still go out of business. Cost of quality includes any cost that would not be expended if quality were perfect. This includes such obvious costs as scrap and rework, but it also includes less obvious costs, such as the cost to replace defective material, expedite shipments for replacement material, the staff and equipment to process the replacement order, etc. Service businesses also incur quality costs

For most organizations, quality costs are hidden costs. Unless specific quality cost identification efforts have been undertaken, few accounting systems include provision for identifying quality costs. Because of this, unmeasured quality costs tend to increase. Poor quality impacts companies in two ways: higher cost and lower customer satisfaction. The lower customer satisfaction creates price pressure and lost sales, which results in lower revenues. The combination of higher cost and lower revenues eventually brings on a crisis that may threaten the very existence of the company. Rigorous cost of quality measurement is one technique for preventing such a crisis from occurring.

As a general rule, quality costs increase as the detection point moves further up the production and distribution chain. The lowest cost is generally obtained when errors are prevented in the first place. If non-conformances occur, it is generally least expensive to detect them as soon as possible after their occurrence. Beyond that point there is loss incurred from additional work that may be lost. The most expensive quality costs are from non-conformances detected by customers. In addition to the replacement or repair loss, a company loses customer goodwill and their reputation is damaged when the customer relates his experience to others. In extreme cases, litigation may result, adding even more cost and loss of goodwill.

2-7 Previous Studies

- This case study [6] deals with the reduction of defects in the fine grinding process in an automobile part manufacturing company in India. The company with manpower of approximately 2550 people is manufacturing common rail direct injection (CRDI) system pumps for vehicles. These pumps were used in cars, trucks and buses throughout the world. An injector primarily consists of nozzle and nozzle holder body. the application of the Six Sigma methodology in reducing defects in a fine grinding process of an automotive company in India. The DMAIC (Define–Measure–Analyse–Improve–Control) approach has been followed here to solve the underlying problem of reducing process variation and improving the process yield. This paper explores how a manufacturing process can use a systematic methodology to move towards world-class quality level. The application of the Six Sigma methodology resulted in reduction of defects in the fine grinding process from 16.6 to 1.19%. The DMAIC methodology has had a significant financial impact on the profitability of the company in terms of reduction in scrap cost, man-hour saving on rework and increased output. A saving of approximately US$2.4 million per annum was reported from this project.

- This paper [7] presents a Six Sigma project conducted at a semiconductor company dedicated to the manufacture of circuit cartridges for inkjet printers. They are tested electrically in the final stage of the process measuring electrical characteristics to accept or reject them. Electrical failures accounted for about 50% of all defects. Therefore, it is crucial to establish the main problems, causes and actions to reduce the level of defects. With the implementation of Six Sigma, it was possible to determine the key factors, identify the optimum levels or tolerances and improvement opportunities. The major factors that were found through a design of experiments 3 factors and 2 levels were: abrasive pressure (90-95 psi), height of the tool (0.06-0.05) and cycle time (7000-8000 msec.). The improvement was a reduction in the electrical failures of around 50%. The results showed that with proper application of this methodology, and support for the team and staff of the organization, a positive impact on the quality and other features critical to customer satisfaction can be achieved

Chapter Three

Methodology

3-1 Preface:-

Six Sigma is a well-structured methodology that focuses on reducing variation, measuring defects and improving the quality of products, processes and services. Six Sigma methodology was originally developed by Motorola in 1980s and it targeted a difficult goal of 3.4 parts per million defects1. Six Sigma has been on an incredible run over 25 years, producing significant savings to the bottom line of many large and small organizations2. Leading organizations with a track record in quality have adopted Six Sigma and claimed that it has transformed their organization3. Six Sigma was initially introduced in manufacturing processes; today, however, marketing, purchasing, billing, invoicing, insurance, human resource and customer call answering functions are also implementing the Six Sigma methodology with the aim of continuously reducing defects throughout the organization's processes Using. This research presents the step-by-step application of the Six Sigma DMAIC (Define–Measure–Analyse–Improve–control) approach to eliminate the defects in a housing manufacturing process in Marbil company

3-2 DMAIC cycle phases:-

a. Define

Identify customers and their priorities; Identifies a project suitable for Six Sigma efforts based on business objectives as well as customer needs and feedback; Identify CTQs (Critical to quality characteristics) which the customer considers to have the most impact on quality

The first step in DMAIC procedures is to define the problems, The goal of define phase is to define the project scope by understanding background information about the SIPOC, the process (voice of process) , customers (voice of customer) and voice of business

b. Measure

Measure what is causing the problem, Measure the quantity and prepare baseline capability.

The purpose of the measure step is to evaluate and understand the current state of the process. This involves collecting data on measures of qualityand cost, it is important to develop a list of all of the key process input variables (sometimes abbreviated KPIV) and the key process output variables (KPOV). The KPIV and KPOV have been identified at the define step, but they must be completely defined and measured during the measure step. Important factors the defected products produced in machining processes.

In study Data collected by examining historical records, but this may not always be satisfactory, as the history may be incomplete, the methods of record keeping may have changed over time, and, in many cases, the desired information never may have been retained. Consequently, it is often necessary to collect current data through an observational study.

c. Analyse

Determine the most likely causes of defects; Understand why defects are generated, by identifying the key variables that are most likely to create process variation.

In the analyze step, the objective is to use the data from the measure step to begin to determine the cause-and-effect relationships in the process and to understand the different sources of variability. In other words, in the analyze step we want to determine the potential causes of the defects, quality problems, customer issues, cycle time and throughput problems, or waste and inefficiency that motivated the project. It is important to separate the sources of variability into common causes and assignable causes. generally speaking, common causes are sources of variability that are embedded in the system or process itself, while assignable causes usually arise from an external source. Removing a common cause of variability usually means changing the process, while removing an assignable cause usually involves eliminating that specific problem. A common cause of variability might be inadequate training of personnel processing insurance claims, while an assignable cause might be a tool failure on a machine.

Other random variables can be defined to model the effect of incomplete applications, erroneous information and other types of errors and defects, and delays in obtaining information from outside sources, such as credit histories. By running the simulation model for many loans, reliable estimates of cycle time, throughput, and other quantities of interest can be obtained.

d. Improve

Identify means of removing the causes of defects; Confirm the key variables and quality of their effects on the CTQs; Identify the maximum acceptance ranges of the key variables and a system for measuring deviations of the variables; Modify the process - keeping it within an acceptable range.

In the measure and analyze steps, we focused on deciding which KPIVs and KPOVs to study, what data to collect, how to analyze and display the data, identified potential sources of variability, and determined how to

interpret the data they obtained. In the improve step, they turn to creative thinking about the specific changes that can be made in the process and other things that can be done to have the desired impact on process performance.

A broad range of tools can be used in the improve step. Redesigning the process to improve work flow and reduce bottlenecks and work-in-process will make extensive use of flow charts and/or value stream maps. Sometimes mistake-proofing (designing an operation so that it can be done only one way—the right way) an operation will be useful. Designed experiments are probably the most important statistical tool in the improve step. Designed experiments can be applied either to an actual physical process or to a computer simulation model of that process, and can be used both for determining which factors influence the outcome of a process and for determining the optimal combination of factor settings.

The objectives of the improve step are to develop a solution to the problem and to pilot test the solution. The pilot test is a form of confirmation experiment: it evaluates and documents the solution and confirms the solution attains the project goals. This may be an iterative activity, with the original solution being refined, revised, and improved several times as a result of the pilot test's outcome.

e. Control

Determines how to maintain the improvements; Put tools in place to ensure that key variables remain within the maximum acceptance ranges under the modified process.

The objectives of the control step are to complete all remaining work on the project and to hand off the improved process to the process owner along with a process control plan and other necessary procedures to ensure that the gains from the project will be institutionalized. That is, the goal is to ensure that the gains are of help in the process and, if possible, the improvements will be implemented in other similar processes in the business. The process owner should be provided with before and after data on key process metrics, operations and training documents, and updated current process maps. The process control plan will be a system for monitoring the solution that has been implemented, including methods and metrics for periodic auditing. Control charts are an important statistical tool used in the control step of DMAIC; many process control plans involve control charts on critical process metrics.

The transition plan for the process owner will include a validation check several months after project completion. It is important to ensure that the original results are still in place and stable so that the positive financial impact will be sustained. It is not unusual to find that something has gone wrong in the transition to the improved process. The ability to respond rapidly to unanticipated failures should be factored into the plan.

3-3 cause and effect diagram

A cause and effect diagram, often called a “fishbone” diagram, can help in brainstorming to identify possible causes of a problem and in sorting ideas into useful categories. A fishbone diagram is a visual way to look at cause and effect. It is a more structured approach than some other tools available for brainstorming causes of a problem. The problem or effect is displayed at the head or mouth of the fish. Possible contributing causes are listed on the smaller “bones” under various cause categories. A fishbone diagram can be helpful in identifying possible causes for a problem that might not otherwise be considered by directing the team to look at the categories and think of alternative causes. Include team members who have personal knowledge of the processes and systems involved in the problem or event to be investigated.

3-4 Pareto Chart

A Pareto chart, also called a Pareto distribution diagram, is a vertical bar graph in which values are plotted in decreasing order of relative frequency from left to right. Pareto charts are extremely useful for analyzing what problems need attention first because the taller bars on the chart, which represent frequency, clearly illustrate which variables have the greatest cumulative effect on a given system.

Chapter four

Implementing Six Sigma

4-1 Data Collection

The data used in this research collected from Marbil Engineering Company records, the data show the process of manufacturing the housing and the result of machining processes table () show the number of good and defected parts, and table (4-1) show the number of defected parts in every process.

4-2 Defining Phase:

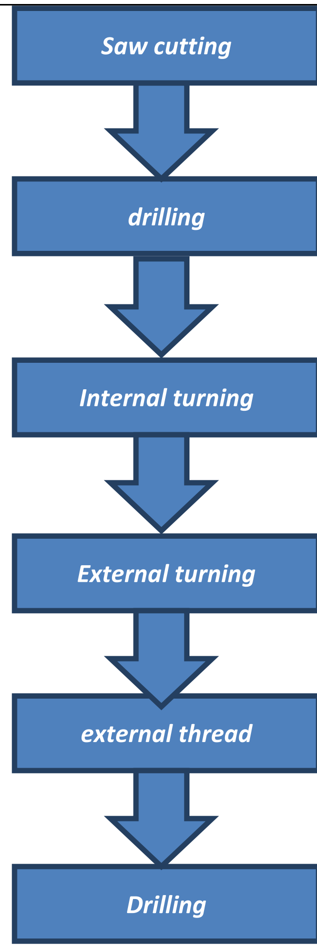
a. SIPOC

SIPOC is an acronym for ***S***uppliers, ***I***nput, ***P***rocess, ***O***utput, and ***C***ustomers, defined as:

- The Suppliers are those who provide the information, material, or other items that are worked on in the process.
- The Input is the information or material provided.
- The Process is the set of steps actually required to do the work.
- The Output is the product, service, or information sent to the customer.
- The Customer is either the external customer or the next step in the internal business.

The SIPOC diagrams give a simple overview of a process and are useful for understanding and visualizing basic process elements, Table (4-2) show SIPOC diagrams of housing manufacturing

Table (4-1) SIPOC Diagram

Supplier	Input	Process	Output	Customer
- production management - sales management - financial management - suppliers	-raw material -machine -tools -man		-housing	-final assembly

b. VOICE OF BUSINESS:

This project started by this step, and the losses that caused by defect in machining of housing during one year was determined, Table (4-2) show defects in housing machining

Table (4-2) Defect in housing machining

Annual Production Rate	Good	Reject
5000	3850	1150
100%	77%	23%

The cost of producing one piece is 1173.54 SDG

The total cost of rejects is 173.54 *1150 = 199571 SDG

Important performance dimension that is not captured in defect measurement or Sigma measurement is financial impact of defect, or so called “cost of poor quality” or CPQ.

Because of that reason, CPQ becomes an important key on starting point of quality measurement. For this, problems and defect interpret into a cost of money per incident –including cost of operator and material for rework, or for the delivery delay- and also opportunity cost. CPQ measurement is a very useful way to strengthen consensus, to improve, and also to help choosing problems with clearer benefit.

c. Voice of Process

In this step Rolled Throughput Yield (RTY) is calculated.

RTY is process performance that provide great insight in to the cumulative effects of an entire process. It measures the yield for each of several process steps and provides the probability that a unit will come through that process defect free.

First Time Yield = (Number of First Time Right products)/ Total Inputs of the process.

Rolled Throughput Yield = Multiplication of FTY of all the process. RTY always in percentage values, table (4-3) show the RTY of Housing manufacturing.

Table (4-3) RTY of Housing manufacturing.

S	Process	FTY
1	Cutting	100%
2	Drilling	100%
3	Internal turning	94%
4	Internal thread	96%
5	External turning	93%
6	External thread	96%

RTY = 100% X100%X 93% X96% X 94% X 96% =80.57%

4-3 Measuring Phase

In this phase, a check sheet has been developed in order to record all the data from the measured part. The data has been presented in a number of defects, table (4-4) show numbers of defects in Housing manufacturing processes.

Table (4-4) numbers of defects in Housing manufacturing

S	Process	Number of defects
1	Cutting	0
2	Drilling	0
3	Internal turning	300
4	Internal thread	200
5	External turning	350
6	External thread	200

a. Process map

In order to have a detailed understanding of the different processes in Housing manufacturing processes and their relationships, the process map as one of the tools of six sigma was used. Figure (4-1) show the process map.

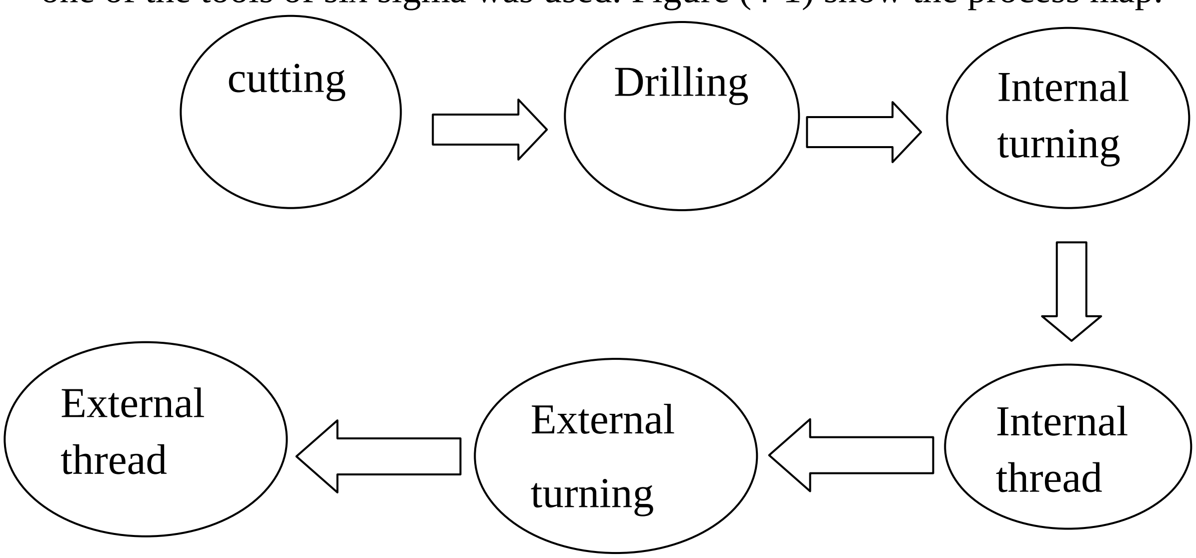


Figure. (4-1): process map

The process map highlights the different areas where the defects may be generated.

b. Pareto analysis

In this phase the criticality of each process analyzed. A Pareto chart as one of the tools of Six Sigma methodology was used to display the criticality of each process as shown in figure (4-2)

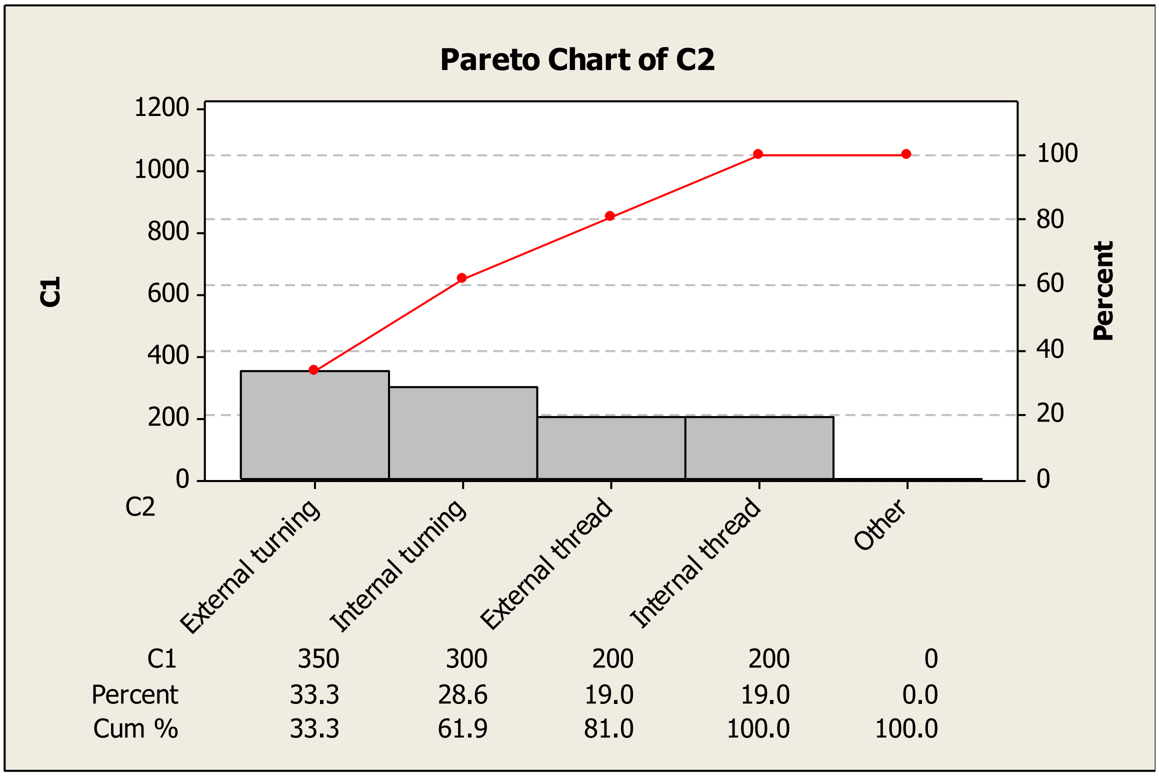


Figure (4-2) Pareto chart

4-4 Analyzing phase

a. Cause and effect

Data analysis were conducted to identify the root cause and the possible solution as to eliminate defects problem. Fishbone diagram used as a tool to study the causes of problem based on five criteria which is man, machine, method, measurement, material and environment. The first cause is probably came from measurement factor which is because of inaccurate cutting tool size. Second cause is from material which is maybe due to cutting tool worn out. Man also one of the factor that cause to this problem which is machine was conducted by low skill operator. The third cause is come from method which is inaccurate parameter setting will also contribute to this problem. All causes were verified through experiment for improve the existing process, figure (4-3) show cause and effect diagram

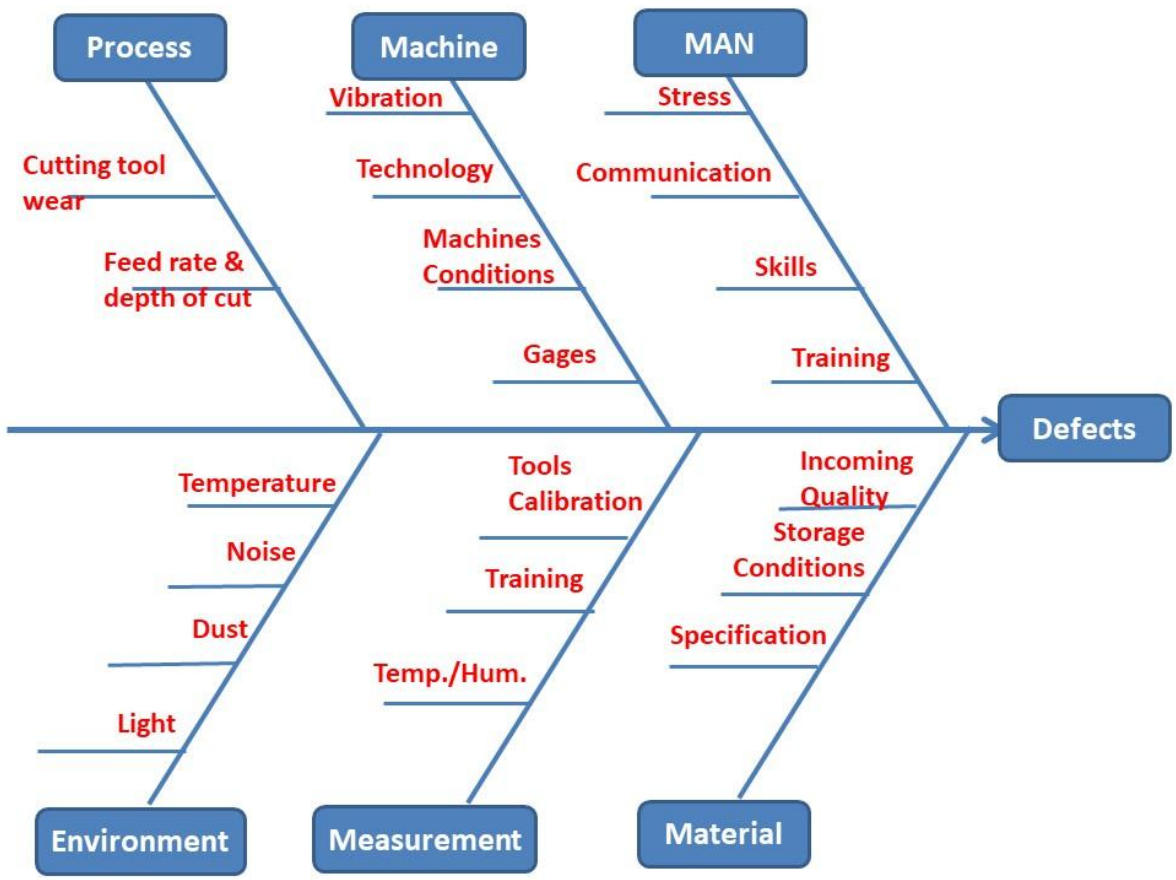


Figure (4-3) cause and effect diagram

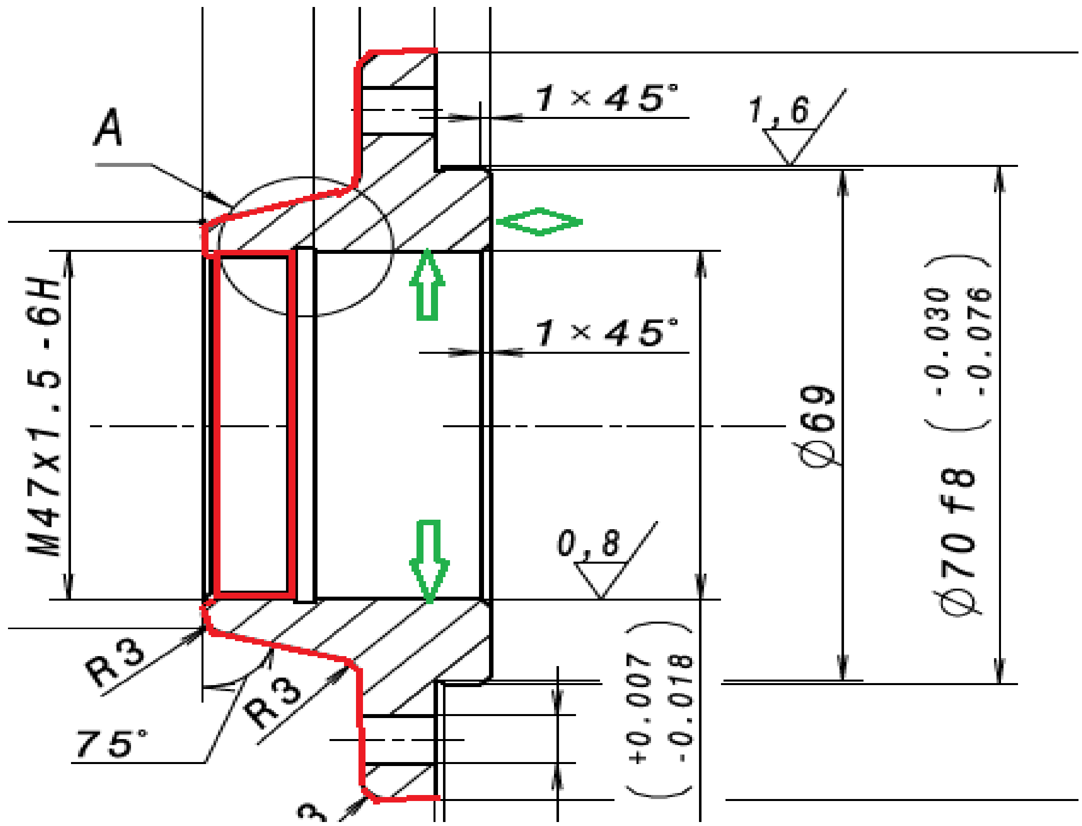


Figure (4-4): working drawing

b. Experiment 1

Experiment has been conducted to study the effect of feedrate and depth of cut parameter to the product dimension. This experiment is divided into two which is first to increase the feed rate with constant depth of cut and second is increase depth of cut with constant feed rate. Table (4-5) shows the result obtain from increase the feed rate with constant depth of cut. Table (4-6) shows the result obtain from increase depth of cut with constant feed rate.

Table (4-5) result obtain from increase the feed rate

No	comment	Spindle speed (RPM)	Feed rate (mm/m)	DOC	Measurement (120 mm - 0.02)	Result
1	Change the Feed rate value	1544	0.2	0.4	101.03	All data is out of specification
2		1544	0.25	0.4	101.02	
3		1544	0.3	0.4	101.01	

Table (4-6) result obtain from increase depth of cut

No	comment	Spindle speed (RPM)	Feed rate (mm/m)	DOC	Measurement (60mm + 0.02)	Result
1	Change the DOC value	1544	0.15	0.2	101.03	All data is out of specification
2		1544	0.2	0.3	101.03	
3		1544	0.3	0.4	101.02	

c. Experiment 2

In this experiment,3 samples were proceed for turning process based on parameter setting defined in table (4-5) and table (4-6). The dimension of the sample has been measured and the result show all the dimension is out of specification. Based on that result, it shows the trend of the dimension is decrease when value of feed rate and depth of cut is increase. Based on finding on experiment 1, the second experiment has been conducted by reducing the feed rate and depth of cut value to the minimum parameter. For this experiment, three samples has been used for turning and the result shows in Table (4-7)

Table (4-7) reducing the feed rate and depth of cut value

No	Comment	Spindle speed (RPM)	Feed rate (mm/m)	DOC	Measurement (60mm+0.02)	Result
1	Reduce to minimum value of Feed Rate & DOC	1544	0.3	0.2	101.03	All data is out of specification
2		1544	0.2	0.2	101.03	
3		1544	0.15	0.2	101.04	

The result obtain is still didn't achieve to the required specification. Therefore, the parameter setting problem is not the root cause of this problem and no possible solution from this parameter and need to proceed for the next experiment.

The next experiment (experiment 3) is to change the tool radius. In the turning process, there is a setting to tool wear offset for length and radius. The function of this setting is to change the cutting tool setting (length and radius) if that was worn out. For this experiment, only the radius value is changed and monitor whether affect the product dimension or not

Table (4-8) change the tool radius

No	Comment	Spindle speed (RPM)	Feed rate (mm/m)	DOC	Measurement (60mm+0.02)	Result
1	Increase the DOC value for reduce the processing time	1544	0.15	0.4	100.99	All data accepted
2		1544	0.15	0.4	100.98	
3		1544	0.15	0.4	100.99	

This Experiment was conducted to verify the new cutting tool diameter with the best parameters setting get from previous experiment whether effect the final product dimension. Based on Table (4-8), It show all dimensions are in the specification and acceptable. The finding and solution from this experiment can be accepted for improving product quality on dimensions and also become more productive to manufacture in large quantity.

4-5 Improve Phase

In the improve phase, a true solution that obtained from the analysis phase implemented. There are lot of inputs and findings were gained from the experiment conducted during the analysis phase. For this case study, all inputs were considered for developing a model for effective six sigma implementation for Housing manufacturing process. This model used as a guideline for machinist in order to get the best quality with high productivity. In statistics, a mediation model is used to identify and explain the mechanism or process that underlies an observed relationship between an independent variable and a dependent variable via the inclusion of a third hypothetical variable, known as a mediator variable. In this project, the mediation model has been developed based on three independent variables to achieve the two dependent variables. Figure (4-5) show the mediation model used.

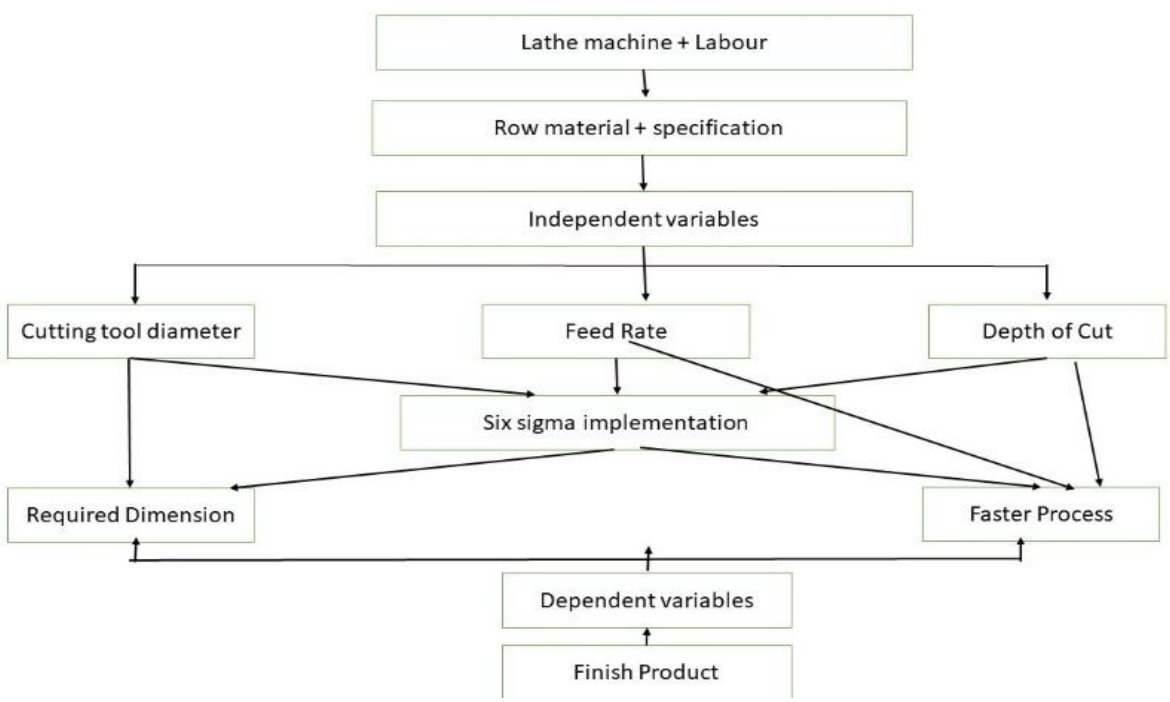


Figure (4-5) mediation model

This model established by examining the inter relationship between cutting tool diameter, feed rate, depth of cut (DOC) and quality & productivity of the product. In this model, cutting tool, feed rate and DOC were made as a predictor variable. While the product quality & productivity (dimension and process time) as the outcome variable as illustrated in Figure5. From the five experiment conducted, the result shows that the feed rate and DOC have a direct positive influence on process time and the tool diameter is influence to the dimension Most interesting findings from this research is the combination of this three independent variables will produce the best product quality and productivity in term of product dimension and also the faster process time. Therefore, by implementing this model, it will eliminate the all the wastes that contribute to the process and directly increase the production productivity.

a. Validate the model

The validation model was established as to ensure the final result obtained is according to the specification target. A case study has been designed and developed for producing 3 samples Housing based on procedure and parameters as suggested in the developed model This case study used the new cutting tool with the suggested parameters of feed rate and depth of cut, and results are in the specification and acceptable.

4-6 Controlling Phase

Control is the last step of the Six Sigma five step process DMAIC. The objective of Control is to develop and implement the best controls to maintain the gains and to celebrate, share and reward the successes. In this project, the control has been set by documenting and standardizes the procedures and parameter as carried out in the analysis phase. The machinist who will manufacture Housing must understand the model and how it is work. A proper training and explanation from the expert is necessary to ensure the process is running as per plan in order to produce the good quality product.

Chapter Five
Results and discussion

5-1 Results

In Implementing of six sigma in Housing machining defect. six sigma implemented and the defect is measured as shown in table (4-2) 23% of the production is reject.

Failure analysis is done and the root cause of the problem is determined to be the wear in cutting tool as shown in table (4-8)

The elimination of root cause of Housing machining lead to eliminate the time waste of repair and rework process and that lead to increase the productivity.

5-2 Results discussion

This case study conducted based on problem of Housing. Which use to direct the body, Housing could not be slotted into the base part. Based on the initial design of Housing, the base part as shown in figure (5-2) is used as the female part which Housing slots on the top, While Housing as shown in figure (5-1) as a male part which its design have a rib at the bottom of the part for assembly purpose. Some samples were taken and conducted the fitting test Some samples were taken and conducted the fitting test. The results discover all parts cannot be assembled correctly because some of them are too big. Therefore, a study based on the DMAIC methodology was conducted to identify the cause of this problem

Figure (5-1) Housing

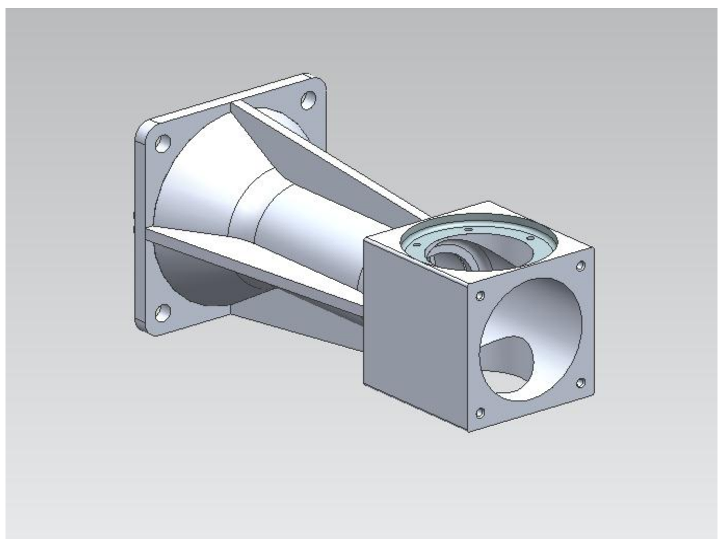


Figure (5-2) base part

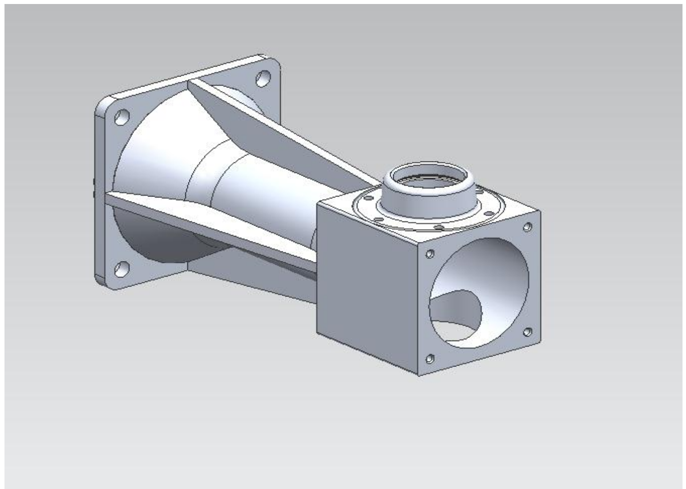


Figure (5-3) The Assembly of Housing

Before implementing six sigma 1150 of 5000 products are defected and that represent 23% of the total production and the defect cost the company 1173.54 SDG for one piece and the total cost of rejects is 173.54 *1150 = 199571 SDG.

A six sigma methodology used to solve this problem, SIPOC diagram is used to identify ***S***uppliers, ***I***nput, ***P***rocess, ***O***utput, and ***C***ustomers, for the process of manufacturing Housing, the measuring phase clearly determined the biggest number of defects in the External turning 350 reject of 5000 products.

Analysis is done in analyzing phase and analytical tools are used, cause and effect one of tools used determine the root cause of the problem, the feed rate, depth of cut and cutting tool wear were studied and it shows that the cutting tool wear is the cause of the problem.

Chapter six

Conclusion and Recommendations

6-1 Conclusion

The implementation of six sigma in the production of Housing has been considered successful because the process performance improved tremendously. This research has been successfully eliminate the process variability and unfit product through identifying actual cutting tool diameter. In order to ensure the process is sustained, the improvement process was transformed into model development. This model has been positively validated. As a conclusion, Six Sigma implementation can be helpful in eliminating the nonconforming product or improving the organization quality and cost reduction.

6-2 Recommendations

The study recommends the following :-

- Share the culture of six sigma in all the organization
- Management commitment and support is required to ensure better implementation of six sigma
- Train the employ in six sigma
- encourage empower employees to be tem members in six sigma projects

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