PROCESS IMPROVEMENT USING DMAIC IN TYRE MANUFACTURING COMPANY

M.TECH. DISSERTATION

BY

VIKASH GUPTA

(2014PIE5116)

DEPARTMENT OF MECHANICAL ENGINEERING

MALAVIYA NATIONAL INSTITUE OF TECHNOLOGY JAIPUR

JUNE 2016

A

DISSERTATION REPORT

ON

PROCESS IMPROVEMENT USING DMAIC IN TYRE MANUFACTURING COMPANY

Submitted in partial fulfillment of the requirements for the award of degree of

MASTER OF TECHNOLOGY

IN

INDUSTRIAL ENGINEERING

Submitted By

VIKASH GUPTA

(2014PIE5116)

Supervised by

Dr. M. L. Meena

Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

JUNE 2016

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF MECHANICAL ENGINEERING

Jaipur-302017 (Rajasthan)

Certificate

This is to certify that the dissertation work entitled "Process Improvement Using DMAIC In Tyre Manufacturing Company" by **Mr. VIKASH GUPTA** is a bona fide work completed under my supervision and guidance, and hence approved for submission to The Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur in partial fulfillment of the requirements for the award of the degree of Master of Technology with specialization in Industrial Engineering. The matter embodied in this Seminar Report has not been submitted for the award of any other degree, or diploma.

(Dr. M. L. MEENA)

Assistant Professor

Place: Jaipur

Date:

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF MECHANICAL ENGINEERING

Jaipur-302017 (Rajasthan)

Candidate's Declaration

I hereby certify that the work which is being presented in the dissertation entitled "Process Improvement Using DMAIC In Tyre Manufacturing Company", in partial fulfilment of the requirements for the award of the Degree of Master of Technology in Industrial Engineering, submitted in the Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur is an authentic record of my own work carried out for a period of one year under the supervision of Dr. M. L. Meena, Assistant Professor of Mechanical Engineering Department, Malaviya National Institute of Technology Jaipur.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

(Vikash Gupta)

ID: 2014PIE5116

Place: Jaipur

Date:

Acknowledgement

It has been a great experience working on this dissertation project **"Process Improvement Using DMAIC In Tyre Manufacturing Company"** towards the partial fulfillment of the requirements for the award of the Degree of Master of Technology in Industrial Engineering.

I would like to express my heartfelt gratitude to my respected guide **Dr. M. L. Meena**, Assistant Professor, Department of Mechanical Engineering, MNIT Jaipur who has enabled me to accomplish this work through his ever-smiling, understanding and benevolent guidance. I could not have completed this seminar paper without his keen interest, incessant encouragement, invaluable guidance and patient steering. I am thankful to him for his confidence and support provided so painstakingly by him to an unworthy pupil.

My heartily thanks to **Prof G. S. Dangayach**, Head, Department of Mechanical Engineering, MNIT Jaipur and **Prof. S.L. Soni**, DPGC Convener for their expertise and all rounded personality they have imparted me.

My special thanks to those unnamed one and many peoples who helped me in many direct and indirect ways.

Finally, I have shortage of words to express my love and thanks to my beloved parents to whom I owe my knowledge.

Vikash Gupta

ID: 2014PIE5116

Place: Jaipur

Date:

Abstract

Globalization, advancement of technologies, and increment in the demand of the customer changes the way of doing business of the companies. Existing business procedures no longer work in today competitive economy. Defects rate of product or process plays an important role for the improvement of productivity and financial state of any organization. The aim of this research is to select and evaluate processes of the organization and to find out present process capability and at last to improve existing process capability by implementing DMAIC methodology. Firstly, present process capability of the process is calculated and given corrective action for improvement of the process. The Current process capability is evaluate by using six-sigma DMAIC methodology. By implementing DMAIC methodology we are able to improve process. This methodology is applied in a tyre manufacturing company to improve its process quality. The research work which is carried out in this thesis is related not only to tyre manufacturing company but also in any other manufacturing organizations. By implementing of six-sigma DMAIC methodology a perfect compromise among cost, quality of the process and cycle time will be observed. In this research work we implement Six Sigma DMAIC phases to enhance the process capability (Long term) to above 1.33 in Bead overlap splice – 6x7. In define phase, the problem was identified with the help of voice of the customer. Than the present Cpk – Bead Splice overlap is measure as 0.71 in measure phase. Than the next phase is analysis phase, in this phase the reason for the variation of bead splice overlap was identified with the help of cause and effect diagram. In improve phase, the existing process was improve and the value of process capability index Cpk is increase to 2.19. In control phase, to maintain and continue the improvements new control methods are develops

<u>**Content**</u>

List of Figures

List of Tables

Chapter 1 Introduction

1.1 Background

Wheel is known as one of the most important innovation of the man, Wheel make life of man easy. As wheel is use from old time, as time passes many changes in tire occur. Tires have gone through many stages of evaluation since it was use first time 100 years ago. And as time elapses, in 19th century the People use solid tyres of rubber mostly. Mostly, for bicycles and horse driven carts solid rubber tire was used. Later in 1888 a tire which consist a tube and rim, between the wheels spokes made by John Dunlop. After that Charles Welch suggested that placing a circle of bead wire into each edge of tire. Than in 20th century with the arrival of motor vehicles, the use of pneumatic tires was started, and then due to the increase demand for more long lasting, safe and reliable performance tire change in design of tire, from pneumatic tire of single tube to tubeless tire occur. Although, there are so many changes occur until but there is continuous need for improved design of tires to make them more useful and reliable. And for continuous improvement in quality of tyres many tools and methods are use by the companies. One of the improvement tool uses by the companies is Six-Sigma DMAIC Methodology. Training of employees for problem solves and decision making skills helps to solve particular issues or problems of the process (Sandeep singh, 2004).

1.2 Tyres

The automobile tires are made from flexible materials having a complex structure and so that cannot be made to high tolerances. At the time of manufacturing of tires approximately 200 different raw materials combine into a unique mixture for providing the highest degree of performance and reliability to the customer. The manufacturing process of tires begins with selection of rubber as well as special oils, carbon black etc. these various raw materials are formed into a homogenized unique mixture of black colored material with the help of gum. The mixing process is controlled by computer to assure uniformity of the raw materials. Further, this mixture is processed into the sidewall, treads, or other parts of tire. The first component which is use on the building machine of tyre is the inner liner, which is resistant to air, resistant to moisture penetration and replace inner tube in tubeless tires. After this body plies and belts are use in tyres. Body plies and belts are manufactured from different raw material combination polyester, nylon, rayon and steel. Plies and belts have two purposes first they give strength to the tire and second they provide flexibility to the tyre. Theses belts are cut at optimize angle and size of these belts are depend upon various performance standards of tyres. In Figure: 1-1 we see cross section of tire with its all components (Khatra, 2004). These components work as one unit. One type of tire which is mostly used is bias ply tire as it has plies running diagonally towards the center line. And another type of tire which is used is radial tires. Radial tires have the sidewall cords in radial directions. The common feature for both is the bead and belts that are same for both types.

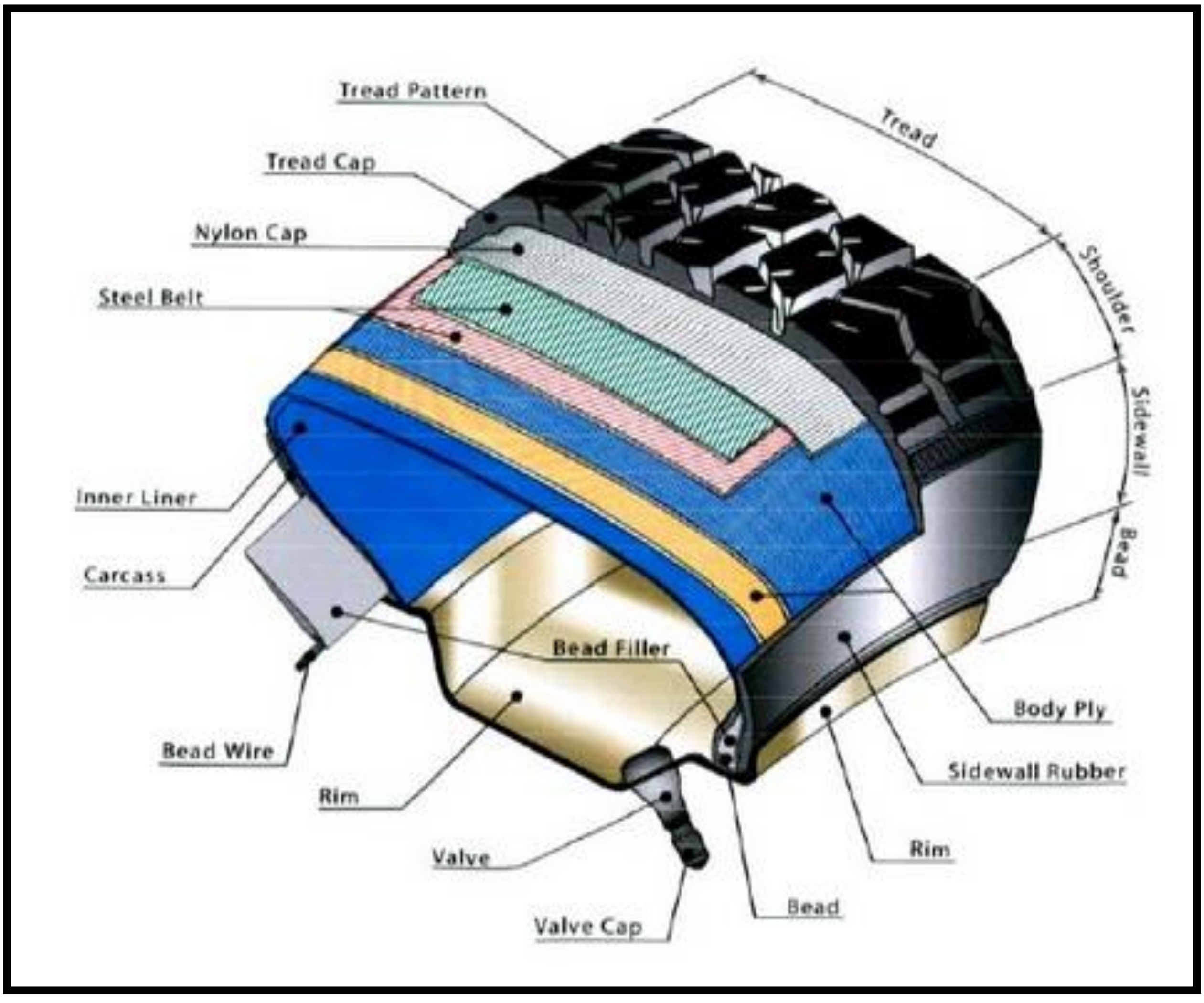


Figure 1-1: Tire Components

Sometimes, Strands of steel wire are coated with bronze and forged into two hoops, are implanted into sidewall of the tires to form the bead. The tread and sidewalls are setting up over belt and body plies, after this all the parts are pressed together. After pressing Tire obtained is called green tire or uncured tire. This green tire is placed inside a mold and presses it against the mold by inflating. After this process tires are vulcanized i.e. heated at pressure of 400 PSI and at temperature of around 300^0 F for a time period of 12 to 15 minutes approximately. To make stronger green tire is treated with sulphur which is known as vulcanization of tyres.

1.3 Process Capability

Process capability is used to analyze the data of a process. We analyze process capability by combining the statistical tools obtained from the normal curve and control charts with better engineering judgment. Results obtained from the process capability analyses for application of new design, planning and evaluation techniques. With the help of process capability we can reduce the defects from production cycle by better design of machine. (Nagesh et. al., 2014)

1.3.1 Why We Study Process Capability

Studies of Process Capability provide a baseline for us to understand how the process is performs relative to the specifications. Process capability is the first concept, through which we look how our process is affected by variability, and gives us metrics for measuring that variability. Such studies also provide information regarding how the process performs under best conditions, and thus give a performance target. Also Process capability is use to measures the goodness of a process by comparing the voice of the process with the voice of the customer, the voice of the customer mean the specification range or the customer nearest specification limit. Process Capability compares the output of a process to the specification limits with the help of process capability indices. This comparison is made by forming the ratio of the spread between the process specifications to the spread of the process values.

1.3.2 Process Capability Indices

Main requirement is to compare the process specifications with the output of a stable process and then we able to know how well the process meets specification. A capable process is a process for which almost all values fall in the range of the specification limits. There are many statistics that can be used to measure the capability indices of a process: Cp, Cpk and Pp and Ppk. A process capability index uses the process variability and the process specifications to determine whether the process is "capable" or not. The Cp, Cpk statistics assume that the population of data values is normally distributed. Assuming a two sided specification, the mean and standard deviation, of the normal data and USL and LSL are the upper and lower specification limits respectively. Process Capability looks at short term capability and long term performance of a process with regard to customer specifications. Cpk is measured in the short term is only applicable to normally distributed variable data. Process Capability studies for non-normal data do not give Cpk values. A Process Capability study is the end result of the analysis done on process output data.

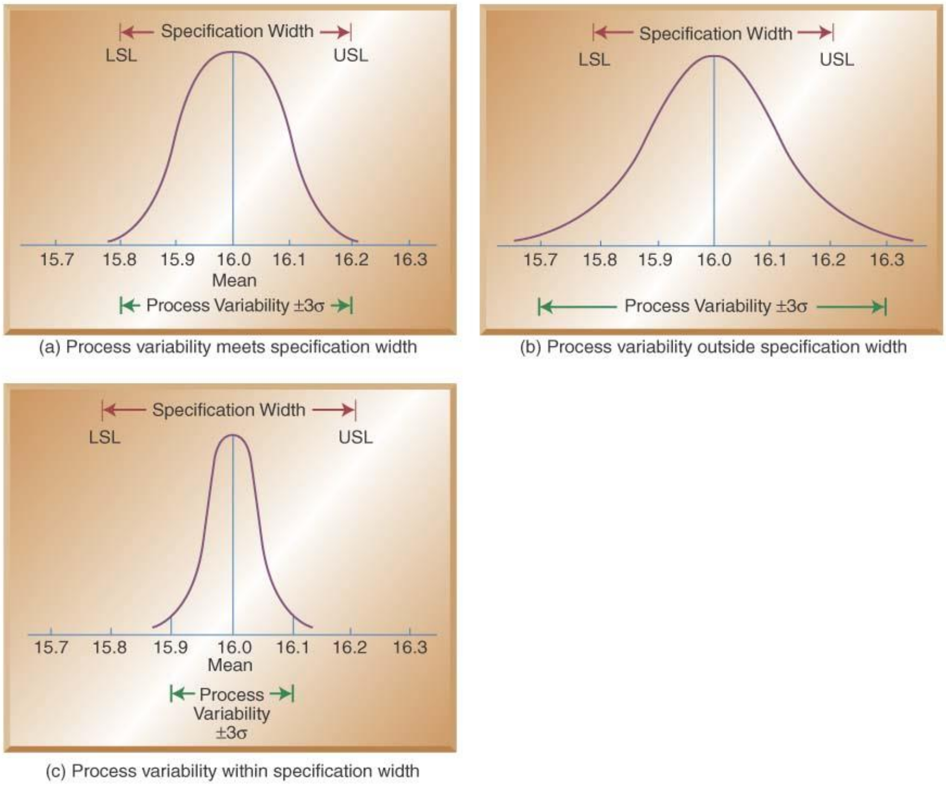


Figure 1-2: Different results with different process capability indices values

- As in Fig. (a) Cp = 1, i.e. process variability just meets specifications width.
- As in Fig. (b), Cp ≤ 1, i.e. process variability is more than the specification width.
- As in Fig. (c) Cp ≥ 1, i.e. process exceeds minimal specifications.

1.4 Six- Sigma and DMAIC in industries

In current economy, industries are becoming more conscious about quality for their product and process. In this atmosphere in order to maintain their reputation in market, companies need to adopt a powerful and efficient methodology that can evaluate and take a needful action to meet requirements and service level of customers (Pipan et. al., 2010). Six sigma is a approach that enables the organizations to review their existing process and guide them to improve the process (Hikmet Erbiyika and Muhsine Saru, 2015)

The industrial sector has known that to solve their shop floor problems they can use Six Sigma methodology as a powerful and reliable technique. Today six-sigma has become one of the critical subjects of concerned in quality management. Six –sigma DMAIC is a powerful methodology that can fulfill the requirement of a customer and help industry to achieve expected goal through continuous improvement. For most of the industries, Sigma is a level that measures the process improvement and thus can be used to measure the defect rate. Six-Sigma DMAIC is a highly disciplined approach that helps industrial world to focus on development perfect products, process and services. "Sigma" is used to measures how much a given process departs from perfection. Sigma quality level also helps to set an objective for betterment of quality of process with the help of DMAIC methodology. A perfect implementation of DMAIC methodology ensures us to removing the reasons of defects by concerning on outcomes of the process which is critical important to the customers. By using DMAIC methodology, the variation in the product or process, wastage of material and process errors can be removed. DMAIC cycle is an integral part of Six Sigma. DMAIC also used for defined the project, measure the project, analyze the project, improve the project and control the project improvement. As a conclusion of the research work, if you cannot define your process properly, you cannot able to measure it. That means for proper utilization of DMAIC methodology for your process aur product you have to explain problem properly.

1.5 Need of study

Reducing the variations in the process is the main objective of Six Sigma DMAIC methodology project, if variation in process quality are high it means there is loss of quality. The main target of a Six Sigma DMAIC methodology is the reducing of perspicacity in decision-making, by making a system, where each employ in the company collects the data, and analyzes this data, and displays data in a mannered way. The DMAIC methodology enhances thinking capability about the problem and more improve solution. At most all organization implements DMAIC methodology of six sigma for process improvement. So study of Six-Sigma DMAIC methodology is essential in order to fulfill the demands of customer and increase the productivity of the organization, reduction in wastage of material and to remove the defects of product or process. When the performance of the process is poor than it is necessary to designed the original process in new way. And for design Industries use Six-Sigma DMAIC methodology.

1.6 Objectives

Every organization always tries to removing the defects of their product, process, or services. They use many quality improvement tools for minimize these defects. And with implementing these tools, defects in process and financial loss of the organization is minimized. DMAIC is known as a best problem-solving procedure which is used in improvement of quality of product or process. The objective of this thesis is to reduce the wastage of bead splice by reducing the bead splice overlap variation. And increase the process capability indices (C_{pk}) beyond 1.33. In order to reduce bead splice overlap variation and increase the process capability indices we implement quality improvement tool Six-Sigma DMAIC.

1.7 Overview of Dissertation

At first we introduce the concept of quality improvement tool Six-Sigma and DMAIC methodology. Next we introduce the concept of process capability and the use of these quality tools to improve the process capability indices. The bead splice overlap variation, process betterment to reducing the wastage of the material using DMAIC methodology is done, inter relationship between bead splice overlap variation and DMAIC in the organization of this dissertation. Than presents a literature reviews on the Process capability improvement and process betterment through Six Sigma DMAIC Methodology. In this chapter basically we discuss Literature review on six-sigma, Process capability, DMAIC in industries.

Than we discuss about the methodology of project, the general background of the company, and its product portfolio. Than we describe the implementation of six-sigma based DMAIC. DMAIC methodology applied to the process for root out defect in Bead splices overlap variation and it is also used for improvement in the process.

At last we give the conclusion. Conclusion shows the utility of the DMAIC methodology and the improvement tool to other companies. The methodology can be implemented very effectively and in a fast manner for process improvement.

Chapter 2 Literature Review

2.1 Introduction

Six-Sigma is use as a improvement methodology which is used to increase business profitability by reducing the wastage of material, also by bring down the cost of bad quality and to increase the output of all processes so as we can obtained customer's expectations (Anthony and Banuelas, 2001). In other way, Six Sigma is a well-defined method for process improvements and for development of new product that depend completely on statistical and the scientific approach to remove defects pointed out by customers (Linderman et al., 2003). The word Six Sigma defined as approach designed for make new processes that results in not more than 3.4 defects per million (Nuñez et. al., 2008). Six sigma is also beneficial to very small scale companies in reduction of cost of wastage material. Six-Sigma DMAIC are implemented in different process industries, for material saving as well as reducing financial loss can be achieved (Kaushik and Khanduja, 2009).

2.2 Literature Review on Six Sigma

Quality improvement tool Total quality management (TQM) is still use in modern industry, but industries are tries to extend this kind of initiative to incorporate strategic and financial issues. After TQM in early 1980s, six sigma come as an element of TQM, can be seen as current stage of evolution in quality (Cagnazzo and Taticchi, 2009). Six-sigma is a strategy that helps in identifies the defects and eliminating these defects; defects which are lead to customer dissatisfaction (Patwardhan et. al., 2012). Any organization that is working in direction of implement six sigma into practice, working to build six sigma concepts, in daily activity, with improvement in process performance and improvement in customer satisfaction is considered as six-sigma company (lutfi et. al., 2013). The six sigma methodology is a quality improvement approach to improve the quality of organization's products or processes by continually removing defects in the system. Its main aim is focuses on improving customer requirements, improvement in productivity, and financial performance of the system. Six-Sigma is implemented for finding the defects and removing their root cause (Kumar et. al., 2008). Six-Sigma is a data driven methodology for reduction of variation, by eliminating defects and errors so that the efficiency and quality were improved of the product, process and services. (Roth and Franchetti, 2010). Almost every company, apply Sigma quality level to improve the quality of the manufacturing process by removing the defects of the process. In order to obtained objectives of the Six Sigma, one of the most known methodologies use by the companies is the DMAIC approach (Koning and Mast, 2004). Up to now, Six Sigma has been used by many companies and got success in quality improvement after implementation (Maleyeff and Kaminsky, 2002). Six Sigma approach improve performance of the process in order to complete customers' requirements by company improved products and services (Rajagopalan et al., 2004). Six-sigma is a strategy that helps in identifies the defects and eliminating these defects; defects which are lead to customer dissatisfaction (Fadavinia et. al., 2008). It use Normal distribution curve. Six sigma approaches is not limited to process level, it is extended to all level of organization to reduce cost and producing quality products. Six sigma implemented in different types of industries as a innovation methodology to improve quality of product and reduce the cost at all level of an organization. Two well known companies of successful six sigma implementation are General Electric and Motorola. Six sigma implemented in manufacturing sector, healthcare sector, marketing sector, engineering sector, financial, and service sector. For successful implementation of six sigma organization must have understand the obstacles and shortcomings of the six sigma (Fadavinia et. al., 2008). Six sigma aim is to achieve perfection in every single process of a company (Virender Narula and Sandeep Grover, 2015).

Many applications of the Six Sigma methodology give more stress on the use of the DMAIC phases to integrate in new project, which include five phases define-measure-analyze-improve-control (Kuei and Madu, 2003). (Snee, 2002) told that a good Six Sigma implemented project must possess some features that are connected to priorities of business, reliable scope, etc. Six sigma method discuss from three points of view a first statistical, second probabilistic and last is quantitative. The term six sigma means having less than 3.4 DPMO or a success rate of 99.9997% in six-sigma term sigma used to represent the variation of the process (Antony and Banuelas, 2002). If an industry is works upon three sigma levels for control of quality, this mean it is obtained a success rate of 93% or 66,800 DPMO. Due to this reason, the six sigma method is a very demanding concept of quality control where many organizations still works at three sigma level (McClusky, 2000).

2.3 Literature Review on Process Capability

Process capability indices means studying the process ability for manufacturing a product that meets specifications. Three basic means Process yield, process expected loss and process capability indices that have been widely used in measuring product potential and performance. Among the three, process capability indices are easily understood and can be straightforwardly applied to the manufacturing industry (LI et. al., 2001). The larger process capability index implies the higher process output, and lower process expected loss. (Kotz et. al., 2009). Therefore, the process capability index can be used as an effective and excellent means of measuring product quality and performance. (Boyles RA, 1996) has presented multivariate capability indices, those indices were appropriate for products with numerous unilateral specifications or products with bilateral specifications exclusively. The automotive industry is consistently tries to applied statistical process control in their plants. Capability indices derived from SPC have increased usage not only in process assessments, but in evaluation of purchasing decisions. Process capability indices the C_p and C_{pk} used in Japan (Sullivan, 1984) and in the U.S. automotive industry (e.g., Ford Motor Company). These process capability indices relate the natural tolerance (6σ) used in the U.S. quality control literature (e.g., Juran and Gryna, 1980) to engineering specifications. Cheng in 1994 has developed a procedure to estimate of Cp and Cpk for practitioners to use to determine whether a process meets the capability requirement or not. During manufacturing operation of product, variability is creates during operation. Prime objective of process management is to eliminate this variability (W. L. Pearn AND K. S. Chen, 1999). Before determine the process capability we have to ensure that process must be under statistics control (mean all the points on X-bar and R-bar chart are within 3 sigma limits and these points are vary in random manner) i.e. the process have only chance variation. Sometime, a process that produces large number of products but these products does not meet the specifications, although the process is under statistical control. One reason of not meet the specification even though process is under statistical control is presence of common-cause variation (although the process is centered at nominal value) Or this can be happened due to lack of centering of process mean i.e. there is significant different between mean value of the products and specified nominal value of product. In this case, we can do adjustment of machine so mean value get close to the nominal value. Process capability procedure use control charts to detect and remove the common cause of variation until process not come under statistical control (Boyles RA, 1994). Process capability indices use in many areas like continues measure of improvement, prevention of defects in process or products, to determine directions for improvement etc (Victor E. Kane, 1986). Multiple processes are control and monitored by multi process performance analyses chart, based on process capability indices (singhal, 1991). We can improve process by compare the process location on chart before and after the improvement effort. Process capability is used to determine process ability of producing parts that meet engineering specifications. And process control evaluate that a process is stable or not overtime. Or process control evaluates process ability to maintain good statistical control. (Nagesh et. al., 2014)

2.4 Literature Review on DMAIC in industries

DMAIC methodology is a perfect method for analyzing & improving processes. It is used as a tool for solving problem (Vujovic et. al., 2009). The advantage of such method is that they are very versatile and useful for solving the problem (E. et. al., 2014). DMAIC methodology applied in various manufacturing industries to increase the sigma level, to improve the process capability and to reduce the wastage of material. (Rohini and Mallikarjun, 2011) applied DMAIC in improving the Quality of Operation Theatre of a hospital. They use DMAIC Model as a template for improving the Operation Theatre Process in hospitals. (Vijay, 2014) reduces and optimizes the cycle time of patients discharge process in a hospital using six sigma DMAIC approach. And after applying DMAIC methodology the cycle time of discharge of patient is reduced by 61%. Six Sigma DMAIC phases applied to enhance the effectiveness of heat exchanger in a small sized furnace manufacturing company (Sugumaran et. al., 2014). And after applying DMAIC methodology effectiveness of Heat Exchanger is increased to 0.61 to 0.664. (Yen et. al., 2004) applied DMAIC methodology to the manufacturing of surface mounted printed circuit boards (PCB) to increase the process capability beyond 1.33. (Prajapati et. al., 2011) applied DMAIC methodology to a foundry for increase the quality (for reducing casting defects). (Satheesh et. al., 2014) applied Six Sigma DMAIC methodology in manufacturing of shock absorber. They applied DMAIC methodology for reduction of paint line defects in shock absorbr and increase the sigma level up to 4.5.

2.5 DMAIC Phases and Six Sigma Tools

There are different six sigma tools are used in different phases of DMAIC. E.g. project charter, voice of customer, data mining, run charts, cause and effect diagram, SPC, FMEA etc. Table 2-1 an overview of the Six Sigma tools used in DMAIC phases.

Table 2-1: Project phases and six sigma tools

Phases	Six sigma tools
Define	• Project charter • Voice of customer • Process map

	• Quality function deployment • SIPOC • Benchmarking tool
Measure	• Measurement the systems analysis • Exploratory the data analysis • Data mining • Use Run charts • Use Pareto analysis
Analyze	• Cause-and-effect diagrams • Brainstorming • SPC • Process maps • Design of experiments • Hypothesis tests • Inferential statistics (Xs and Ys) • FMEA • Simulation • Improvement Force field diagrams • 7M tools • Project planning and management tools • Prototype and pilot studies
Control	• SPC • FMEA • Reporting system

2.6 Summary

DMAIC methodology used as an iterative problem-solving method to eliminate variation in an existing process. Quality and process improvement learner often starts with learning the DMAIC approach because most other methodologies are derived from its fundamental structure. The DMAIC methodology works as a problem solving methodology that helps a organization to obtain required results and conclusions. By DMAIC we are able to generate a feasible solution of problem. In other words we can say, DMAIC as the foundation of Six-Sigma. The six-sigma approach provides a useful methodology DMAIC for establishing best results for the company. It also provides the company a long-term performance process or product on which it could base its next quality improvement programs. As it has been observed that first thing is to obtain the required level of sigma if sigma level is not satisfactory, there is no way to improve the process by DMAIC. The implementation of six-sigma reduces the wastage of material which will save money in result higher profit of the organization.

Chapter 3 Research Methodology

3.1 Company Profile

3.1.1 Apollo Tyres limited

Apollo Tyres Limited known as a top most tyre manufacturing company in india. Apollo tyres limited produces tyres and tubes for automobiles in India and other countries also. Apollo tyres ltd. is the first Indian company of manufacturing exclusive branded outlets of truck tyres and also first to introduce new range of radial tyres for the farm category. Apollo tyres were constituted on September 28, 1972. Apollo tyres started their first manufacturing plant in india at Perambra in Kerala in the year 1977. Further, in 1991, the company starts their second manufacturing plant in Limda in Gujarat. Further, Company expands their business and establishes their third plant at Kalamassery in Kerala in year 1995, where they produces Premier type Tyres. Further, Apollo tyres establish their special tubes plant in the year 1996 at Ranjangoan in Maharashtra. Further, they started exclusive radial tire capacity in Limda in Gujrat in year 2000. Apollo tyre ltd. Started alliance with Michelin of France On November 17, 2003 for establishing a jointly venture company known as Michelin Apollo Tyres Pvt. Ltd for manufacturing dual branded radial tyres for trucks and buses in India. Apollo tire is the first organization who initiates production of High-speed rated tubeless radial tyres for passenger cars of India in 2004. Also they increased the production capacity of Automobile Tyres and Automobiles Tubes by 1283560 Nos. and 414000 Nos. respectively and in the next year, they further increased the production capacity by 1466432 Nos. and 1567200 Nos. respectively. The company increased the production capacity of Automobiles Tyres and Automobile Tubes by 1045632 Nos. and 1379360 Nos. respectively during the year 2005-06 and they further increased the production capacity by 888340 Nos. and 218440 Nos. during the next year. During the year 2006-07, they increased the manufacturing capacity of Camel Back/Pre Cured Tread Rubber by 217000 Nos. to 220000 Nos. and in the next year they further increased to 248040 Nos. During the year 2007-08, they increased the production capacity of Automobile Tyres by 836620 Nos. Thus the total capacity for Automobile Tyres and Automobile Tubes increased to 9659232 Nos. and 6741000 Nos. Further, for manufacturing the new range of Dunlop tyres Apollo tyres establish Dunlop Tyres International (Pty) Ltd, South Africa On April 21, 2006. In 2007, Company establishes a new manufacturing plant in Switzerland known as Apollo Tyres AG. Also, from December 21 2007 two auxiliary company, one is known as Apollo Automotive Tyres Ltd and another is known as Apollo Radical Tyres Ltd. The company establishes a new plant of cost of Rs

12000 million for making of radial tyres in Hungary. They are also works on establishing a manufacturing facility for production of special type of tyres bias OTR tyres at Limda plant with the capability of producing 10 MT/day. The company produces 3.5 million tyres per year approximately at Oragadam in Tamilnadu passenger car. Further, company started their first complete tire outlet for branded commercial vehicle known as Apollo Trust in Salem, Tamilnadu in 2008. In 2015 for unique performances Apollo Tyres launches XT-100K a special type of cross-ply tyre.

3.2 Product Portfolio

Apollo Tyres Ltd. is works in manufacturing of tires, tubes and compound for automobiles. The product range of the Company consists of tyres are uses for:

- Passenger car
- Sport utility vehicle
- Multi utility vehicle
- Truck
- Bus
- Agriculture
- Industrial
- Bicycle
- And alloy wheels etc.

Figure 3-1: Acelere Sport Tubeless Tyre

Figure 3-2: Alnac 4G Tubeless Tyre

Figure 3-3: Aspire Tubeless Tyre

Figure 3-4: Hawkz HL Tubeless Tyre

Figure 3-1 to Figure 3-4 shows the different type of tubeless tire.

Figure 3-5: Passenger car radial portfolio

Figure 3-5 show different type of tyres for passenger cars.

Figure 3-6: Off highway portfolio

Figure 3-6 show the type of tyres of off highway.

Figure 3-7: Trucks and Buses portfolio

Figure 3-7 shows the different type of tyres for trucks and buses.

Its brands in different countries include:

- Apollo Tyres in India
- Dunlop in 32 African countries
- Vredestein in Europe.

In India the Company has four tire manufacturing plants, two in Cochin, one in Vadodara and one in Chennai. Company has two tire manufacturing plants in South Africa and its products are sold in Africa and Europe. In year, 2012 the Company launched Apollo Aspire 4G, Vredestein Ultrac Vorti & Sportrac 5 and XT-7 Gold+ tires. The Apollo experience is not just about buying quality tyres – it is best-in-class service, learning more about how to maximize your product's performance and always finding a ready ear to hear your feedback. Apollo manufactures approximately 70,000 car tyres and 15,000 truck tyres every day in its plants in India. Now, with three new additional brands, that number will only go north. Add the Vredestein name to the mix and it creates a company that will have tyres for everything from the Maruti Alto to the Audi R8. Going Dutch has probably never been this fruitful. Apollo, traditionally a truck tyre supplier, had recently entered the small car tyre market and is now expanding into tyres for luxury cars like the Audi A4, BMW 5 series and VW Passat, among others three new brands – Aspire 4G, Alnac 4G and Amazer 4G, represent Apollo's fourth generation of car tyres which should fit pretty much every size requirement you have.

The Amazer 4G will fit small hatchbacks like the Maruti Alto, Tata Indica and VW Polo as well as compact sedans like the Maruti DZire, and will be available in sizes from 12 to 14 inches. It is T speed rated, meaning it should be safe up to 190kph. Apollo Tyres (NSE:APOLLOTYRE), one of India's largest tire companies, sealed a deal on Wednesday to purchase North American Cooper Tire and Rubber Company (NYSE:CTB), The deal is for $2.5 billion in cash. Today, the company manufacturing the complete range of automotive tyres for passenger cars, truck and bus which are running at ultra and high speed. These are produced across Apollo's different manufacturing plants in different countries like India, Netherlands and Southern Africa. The most brands produced in these plants are: Apollo, Dunlop, Kaizen, Malloy, Regal and Vredestein.

3.3 Tire Bead

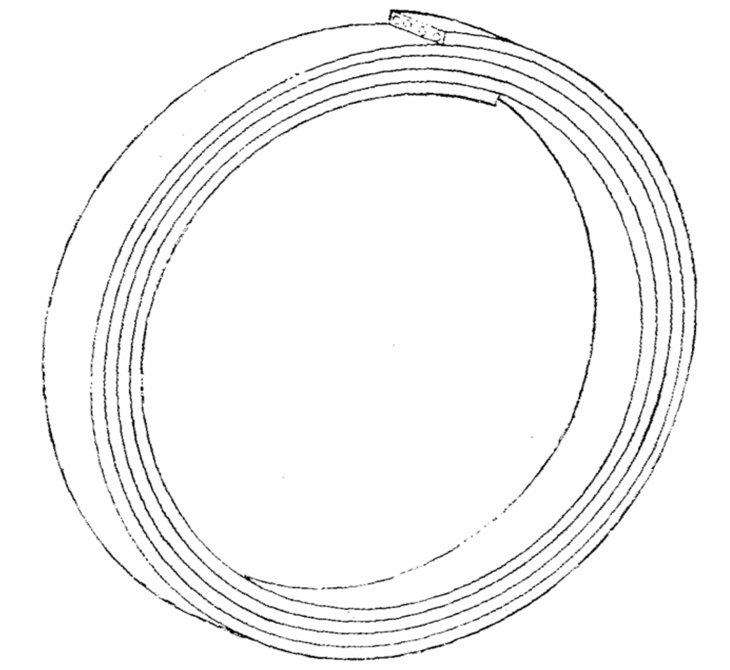


Figure 3-8: Tire Bead

Figure 3-8 shows the cross section of Tire Bead. The main function of bead is to grasp the tire on the rim. Bead is made of tensile wire high carbon. The bead wire of functional tyre can work at pressures of 30- 35 psi. Tire bead wire is linking the automobile with road, with the help of bead load of vehicle is transferred to the tire, and from tire load is transferred to the rim. When vehicle is running the inflation pressure in tire is consistently trying to beads off the rim from the tyre. Special elements Bead–grommet together with the help of each other are trying to stop bead to move towards rim centre. The bead humps gives extra stress on bead wire while bead humps are mounting on wheel. Components of bead consist of:

- bead wire
- rubber insulation
- fabric
- Wrapping and flipper strips.

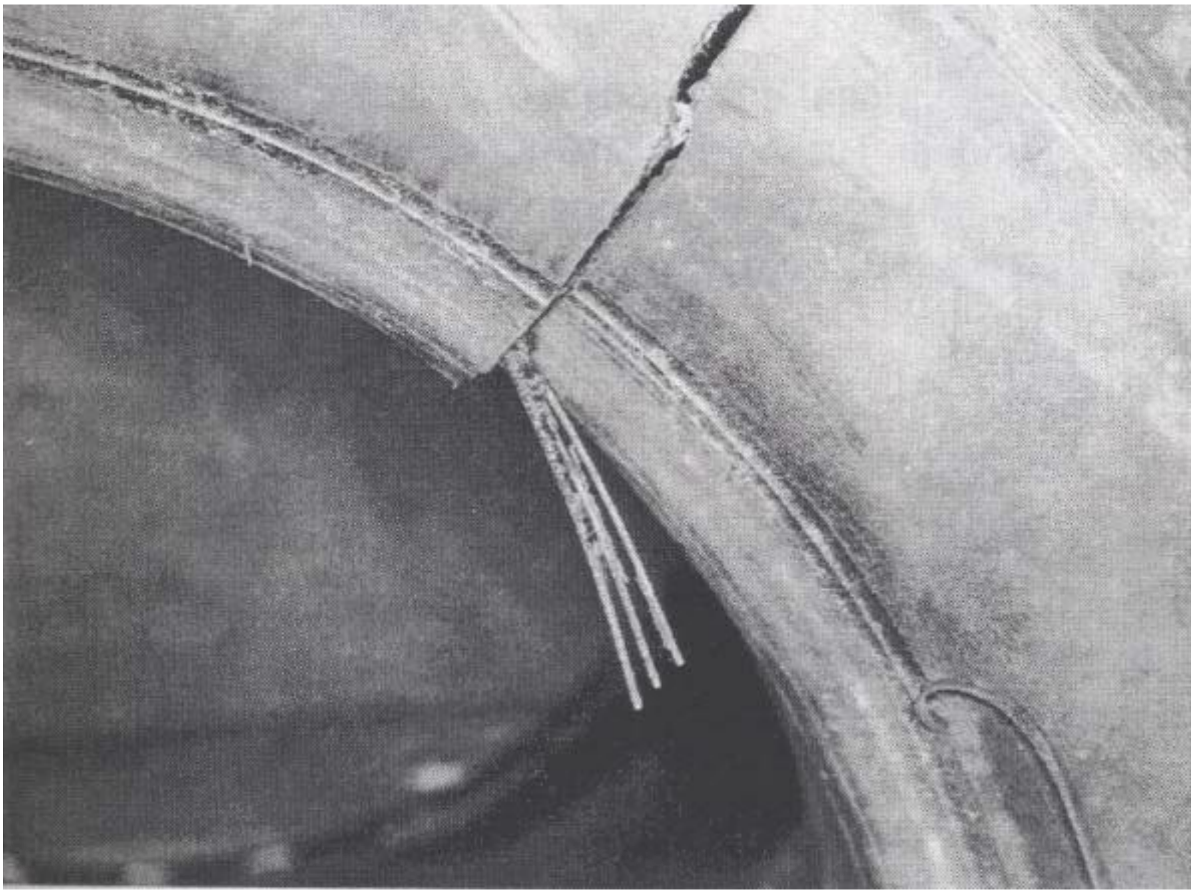


Figure 3-9: Failure of Bead Splices due to Overlap variation

Figure 3-9 shows the failure of tire bead due to bead splice overlap variation. Two types of plies placed in the tire, first is known as turn-up plies the turn up plies placed on the inside of the bead splice and then turned up and second plies are known as turn-down plies the turn down plies placed down over the outside area of the bead splice and then turned down.

3.4 Methodology

From the above discussion, we see the importance of quality as a important factor in the formation of competitive market. Our research work is help companies to improve their product and process quality so that they can able to achieve world class ranking in the field of quality. Our research is of data base type because we tried to find out cause and effect relationships to find out various types of defects. We applied Six Sigma DMAIC methodology in which every phase is a compound of both techniques qualitative as well as quantitative.

3.4.1 Define

First phase is Define i.e. define the goals for the betterment of the process. In this the most critical goals are acquired from customers of the organization. First At most at top level the goals will be of the important objectives of the company, such as greater customer reliability, a higher share of market and greater employee satisfaction. Second At the operations level, a goal could be to increase the production of a production plant. And third at the project level goals may be to bring down the defect level and increase output for a specific process. These goals can be achieved from direct conveying information from customers, share holders of organization, and employees of the organization. Figure 3-1 shows the define phase.

- Firstly identify the projects which can be measurable.
- Than define the projects including the requirements of the customer.
- Than develop a team charter to define.
- And than define process map of problem.
-

Figure 3- 10: Define Phase

3.4.2 Measure

First target of Measure phase is to establish a good measurement system to measure the process performance or defects of product or process. Measure the defects or problem of the goals which are defined in previous step. Figure 3-2 shows the requirement of the measurement phase.

- First step is defining the performance standards of the goals.
- And Measure current level of Sigma to measure the quality. It tells about the area of problem.
- At last identify all possible causes or defects for such problems.

Figure 3- 11: Measure Phase

3.4.3 Analyze

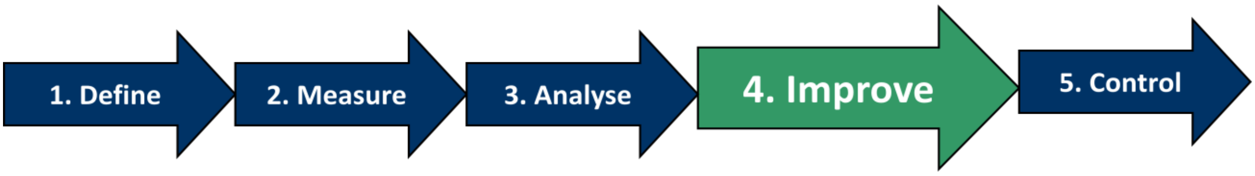
In Analyze phase we analyze the process to identify possible ways to eliminate the gap between the present quality performance of the process and the goal defined by us. Analyze phase start by determining the present performance. Use statistical tools to conduct the analysis. In figure 3-3 we show the process of analyses.

- At first find process capability of the problem.
- Than define performance objectives of the problem.
- And at last Identify sources of variation.

Figure 3- 12: Analyze Phase

3.4.4 Improve

In improvement phase to improve the system, we have to creative in searching new ways to do things better and faster at low cost. We can use different approach like project management and other planning and management tools to establish the new approach. Use statistical methods to continuous the improvement. Figure 3-4 shows the improvement phase steps.

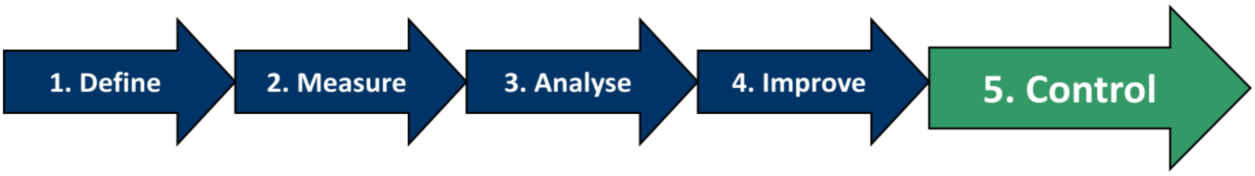


- Firstly in Improvement phase screen the potential causes.
- Establish variable relationships between causes and effects.
- Develop operating tolerances for the problem.
- Choose a method to resolve and ultimately finish the problems. It is also a phase to search the solution how to change, fix and modify the process.

Figure 3- 13: Improve Phase

3.4.5 Control

The improvement gained through previous steps is necessary to maintained for long time for continuous success of the organization. For this we use control phase to maintain these improvement in process. We have to control the new process and improved process by improved recompense, by improved policies of the organization, procedures of the organization etc. we can utilize certificate provided by ISO- ISO 9000 to ensure improvement. Figure 3-5 show the steps of control phase.



- In control phase monitor the improved process continuously to ensure long term sustainability of the new developments.
- Than Share the lessons learnt.

Figure 3-14: Control Phase

Chapter 4 Case Study

The company "Apollo Tyres" is facing with the problem of performance of tyres and wastage of material ultimately which results Financial Loss. This is due to uneven Bead Splice Overlap.

4.1 Objectives:

- In this research we implement the Six Sigma DMAIC (Define-Measure-Analyze-Improve-Control) phases to enhance the process capability (Long term) to above 1.33 in Bead splice overlap – 6x7.
- To shift the Splice Overlap variation to the mean.
- Collecting the data of Bead Splice Overlap
- Analyze the data and corrective action should be take

4.2 Define

In define phase we define the goals for betterment of the process. The define phase we defined the problem of the project. This phase is the strong phase of the DMAIC cycle. If we defined a problem in wrong way than we obtained the wrong result

Problem definition: Apollo Tyres Company producing tyres they got the complaint of wastage of material in the form of Bead Splice overlap variation. This loss of wastage increases financial loss to the company. So our objective is to search the problem and reduction of problem with the help of six sigma methodology.

Table 4-1: Bead splice Overlap specification

Bead Splice Overlap – Spec.	90±15 mm
Average Bead Splice Overlap	97 mm
Material loss due to Shifting of Splice overlap from Target Spec.	3.0 Kgs/ Day
Material loss due to Shifting of Splice overlap from Target Spec	90 Kgs/Month

Table 4-1 shows the specification for Bead Splice Overlap variation.

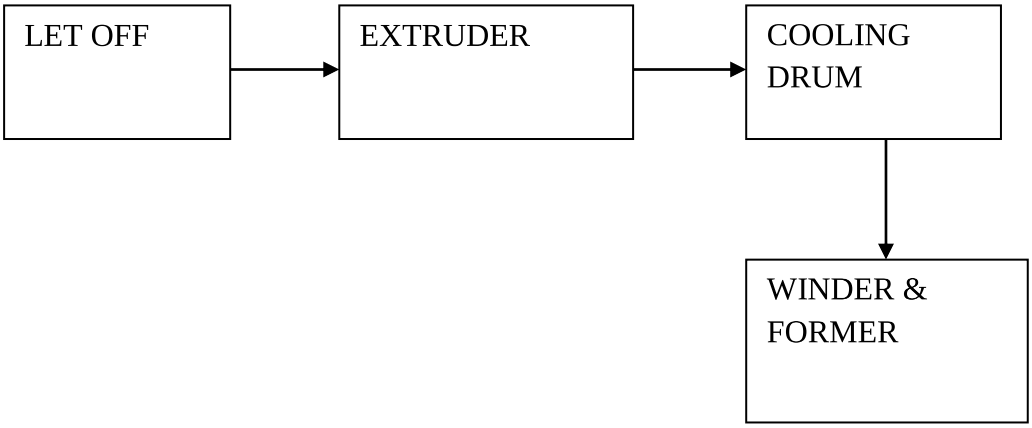


Figure 4- 1: Process Steps

Figure 4-1 shows the different stages process of manufacturing of the tire bead in workshop. Firstly we extrude the rod in wire form. And then it is go for cooling in cooling drum. Then winder for wrapping the strands of bead wire on the tire. At last it is go in former where tire bead overlap cut as per specification. Table 4-2 shows the phase diagram for DMAIC implementation.

Table 4-2: Phase diagram for DMAIC implementation

Phase	November				December				January			
	1	2	3	4	1	2	3	4	1	2	3	4
Define												
Measure & Analyze												
Improve												
Control												

Figure 4-2 shows the Advancer setting for cut of bead splices after each rotation.

Figure 4-2 : Advancer setting

4.3 Measure

In measure phase we take the observation of overlap variation. Figure 4-3 shows the sensor setting for variation measurement.

Figure 4-3: Sensor setting

Table 4-3: Observation data table

SR. NO.	OBSERVATIONS
1	97.04
2	100.21
3	97.08
4	96.34
5	89.64
6	94.38
7	96.02
8	99.89
9	96.09
10	92.41
11	94.75
12	97.01
13	95.49
14	96.62
15	95.68
16	94.02
17	99.74
18	96.06
19	97.12
20	96.23
21	96.92
22	99.95
23	97.93
24	97.74
25	94.46
26	97.77
27	96.41
28	97.56
29	96.14
30	98.07

These observations are taken before the corrective action takes place. Figure 4-4 shows the normality test for bead splice overlap.

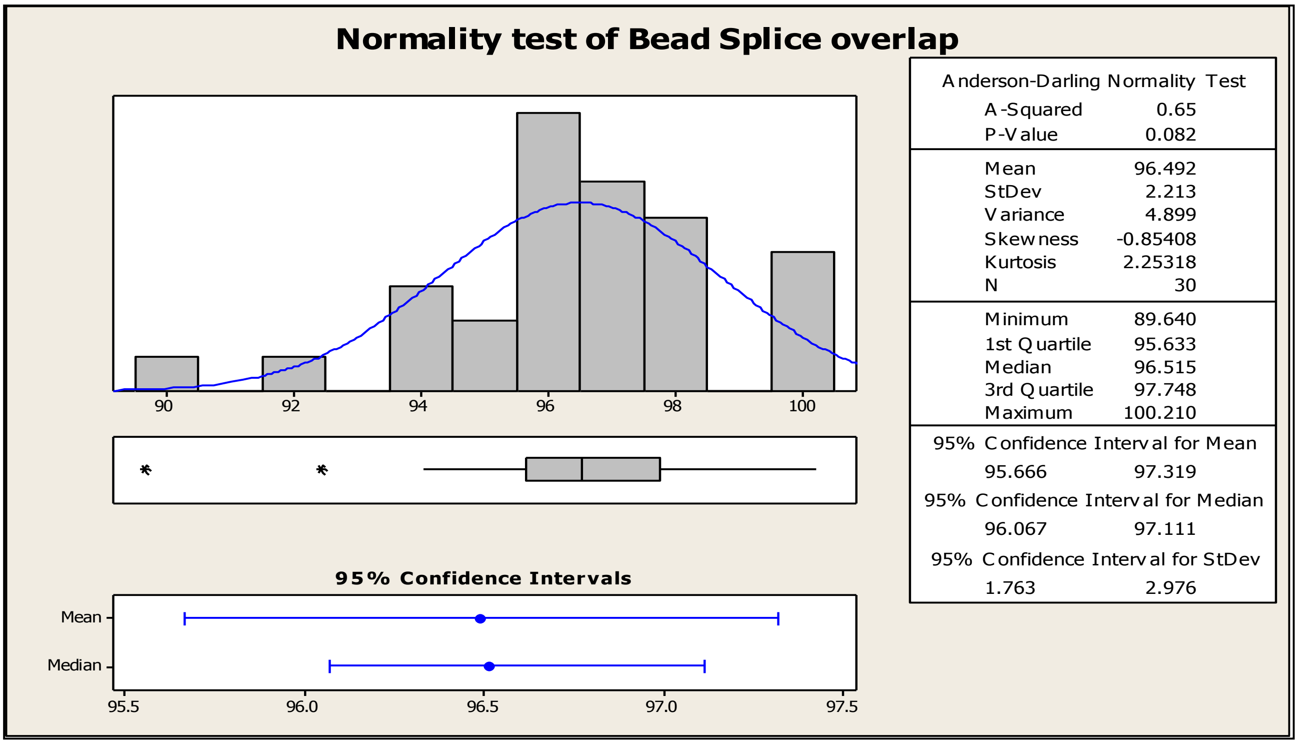


Figure 4-4: Normality Test of Bead Splice Overlap

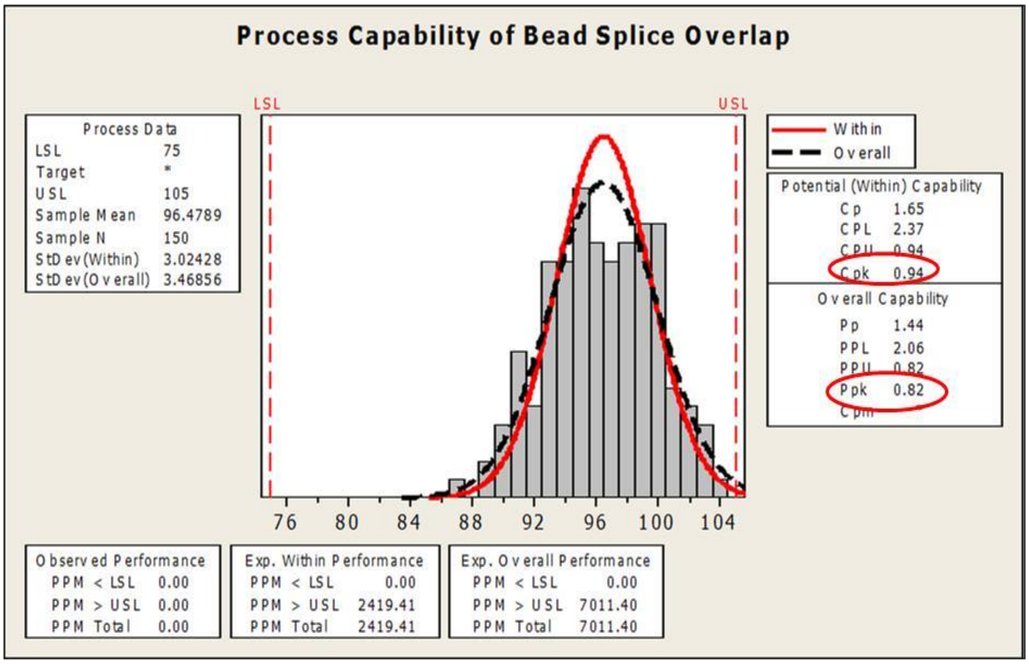


Figure 4-5: Process Capability test of Bead Splice Overlap

Figure 4-5 show the process capability indices C_{pk} value 0.94 and Ppk value 0..82 both are less than 1.33.

Table 4-5 shows process capability indices analyses with relationship between sigma level and process capability indices.

Table 4-4: Process Capability Indices Analyses

	C_p	C_{pk}	P_p	P_{pk}	SIGMA
RED (BAD)	< 1.00	< 1.00	< 1.33	< 1.33	< 4.5
YELLOW (OK)	1.00-1.33	1.00 -1.33	1.33-1.67	1.33-1.67	4.5-5.5
GREEN (GOOD)	> 1.33	> 1.33	> 1.67	> 1.67	> 5.5

4.4 Analyze

In this Analyze phase we analyze the data and find the best way from many ways to analyze the data. We use cause and root analyses tools.

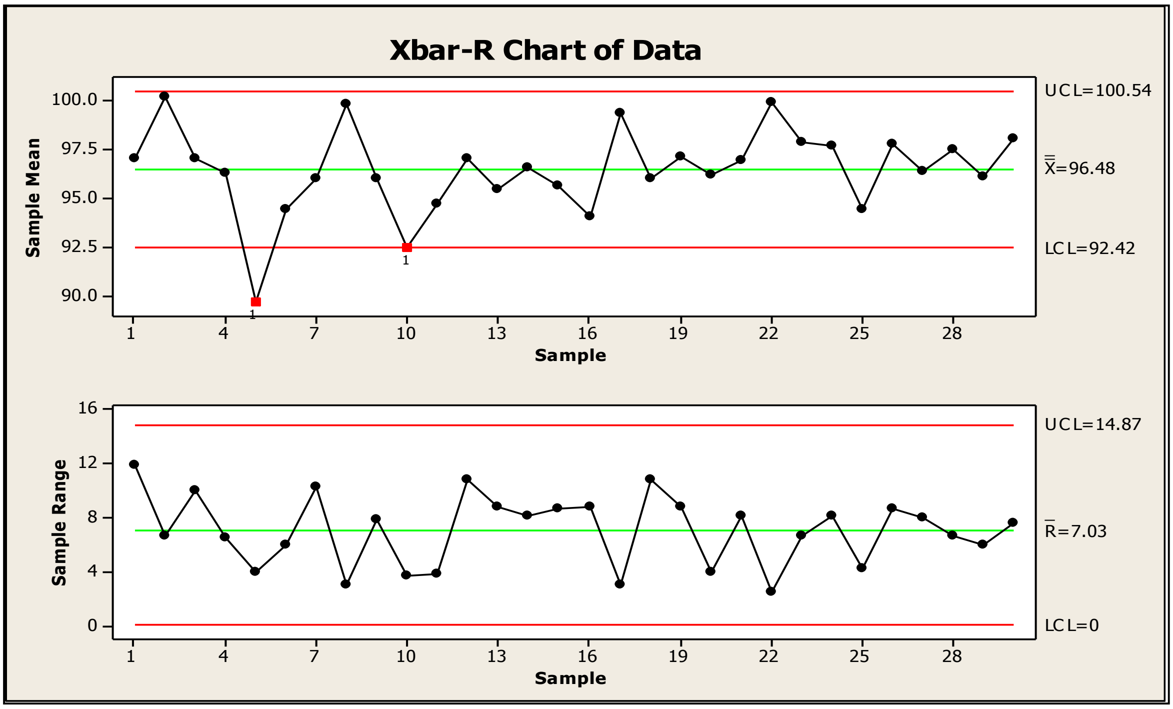


Figure 4-6: X bar & R bar chart of present data

Figure 4-6 shows the x-bar and R-bar chart of the observations and some points are outside the lower control limit.

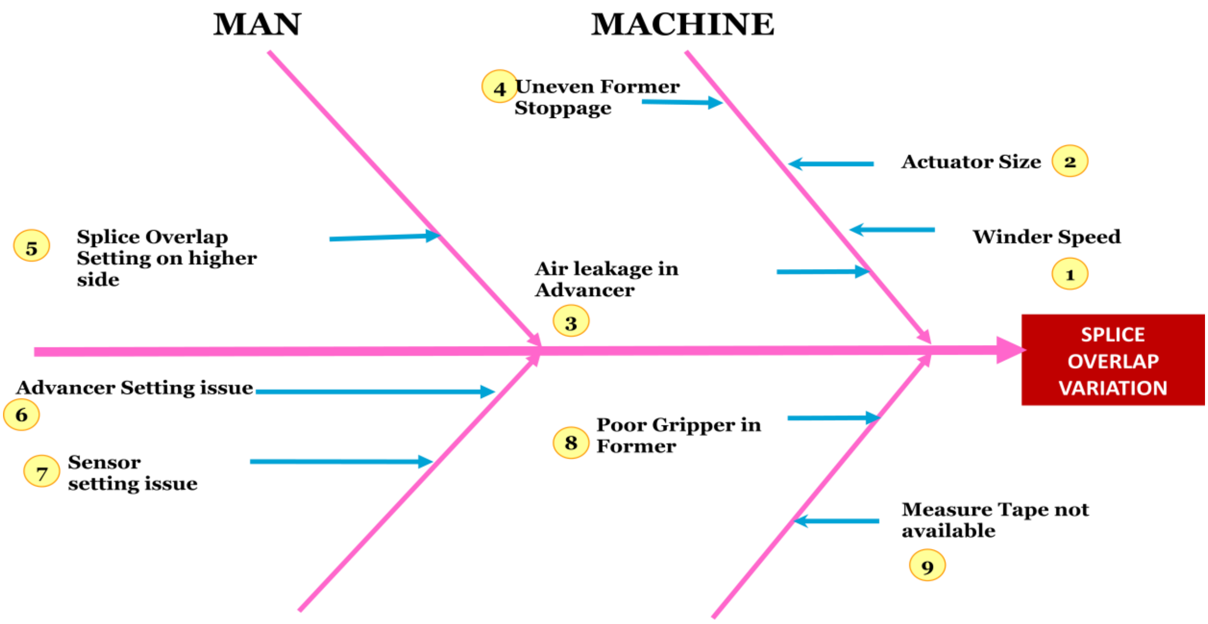


Figure 4-7: Cause and Effect Diagram

Figure 4-7 help to determine Root cause of the problem.

4.4.1 Identification of Root Cause (WHY-WHY ANALYSES)

First Cause of problem is Splice overlap setting on higher side; this is due to slippage of bead tape from gripper. The slippage of bead tape from gripper is due to worn out of the griper key. For eliminate this problem we suggested that fix an additional gripping key in former.

Second cause is related with Advancer setting. Change in advancer setting is due to man to man variation. This variation from man to man is because no guideline available on Machine for setup. So we provided Visual guideline on machine for advancer setting.

Third cause is related with the setting of sensor. Change in sensor setting required frequently due to change in former diameter. But due to non availability of guideline sensor setting could not change frequently. So we provide visual guideline for sensor setting.

Forth cause is non availability of measuring tape, so we provide measure tape on machine.

4.5 Improve

After finding the root cause, the corrective action should be taken which are as follows. Table 4-6 shows the corrective actions, first is for point on higher side and second for point on lower side.

Table 4-5: Corrective Actions

S. NO.	OUT OF POINTS	ACTIONS
1.	Point on Higher side	1. Check Splice Overlap after setup 2. Set Advancer as per guideline to get Splice on target value 3. Set Proximity as per guideline as per former diameter.
2.	Point on Lower side	1. Check Splice Overlap after setup 2. Set Advancer as per guideline to get Splice on target value 3. Set Proximity as per guideline as per former diameter.

Table 4-6 Observation table after Improvement

SR. NO.	OBSERVATIONS
1	89.1
2	93.0
3	89.0
4	91.0
5	91.6
6	93.5
7	89.5
8	88.0
9	91.3
10	89.0
11	93.9
12	91.0
13	91.0
14	89.2
15	93.1
16	91.0
17	93.1
18	93.9
19	94.5
20	93.8
21	91.5
22	89.0
23	93.0
24	90.5
25	92.9
26	91.4
27	89.1
28	91.5
29	94.0
30	93.0
31	90.0
32	89.3
33	93.0
34	91.5
35	92.0
36	90.0
37	91.3
38	91.0
39	91.6
40	93.0
41	92.7
42	91.6
43	92.7
44	90.1
45	90.0

In figure 4-8 for above observations we draw R-bar chart of bead splice overlap.

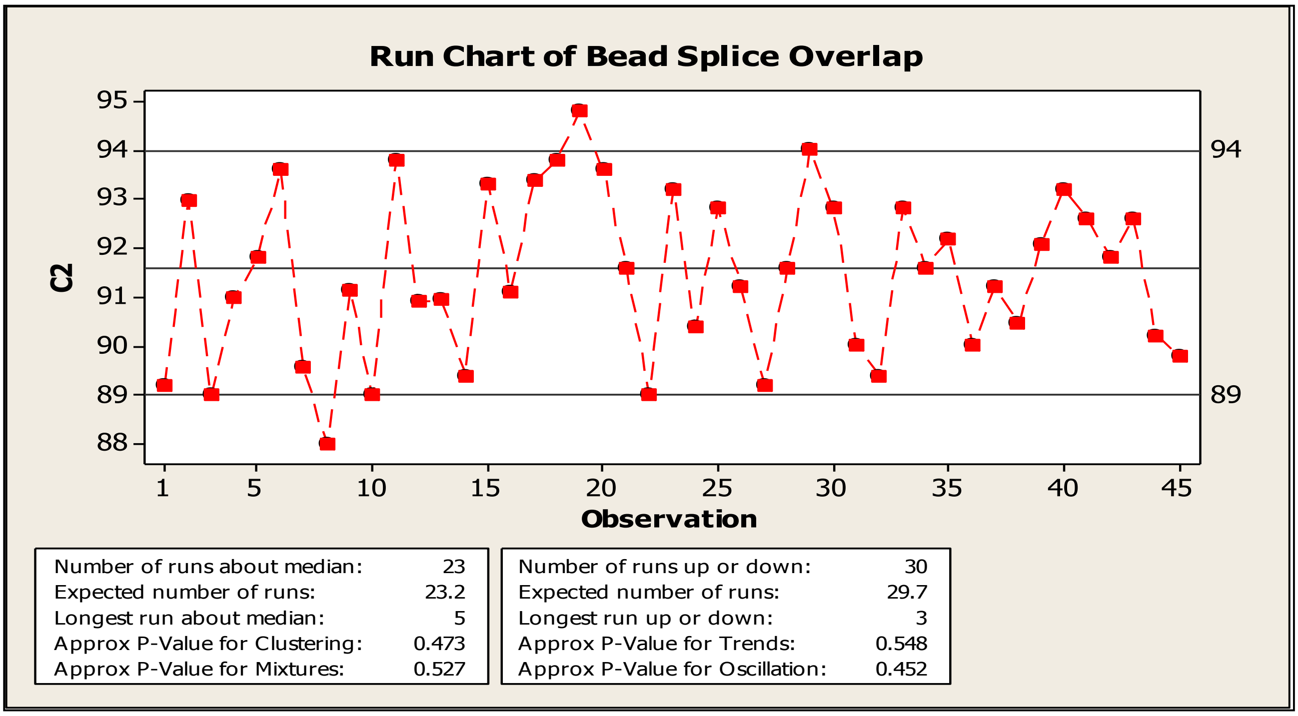


Figure 4-8: Run chart for Bead splice overlap

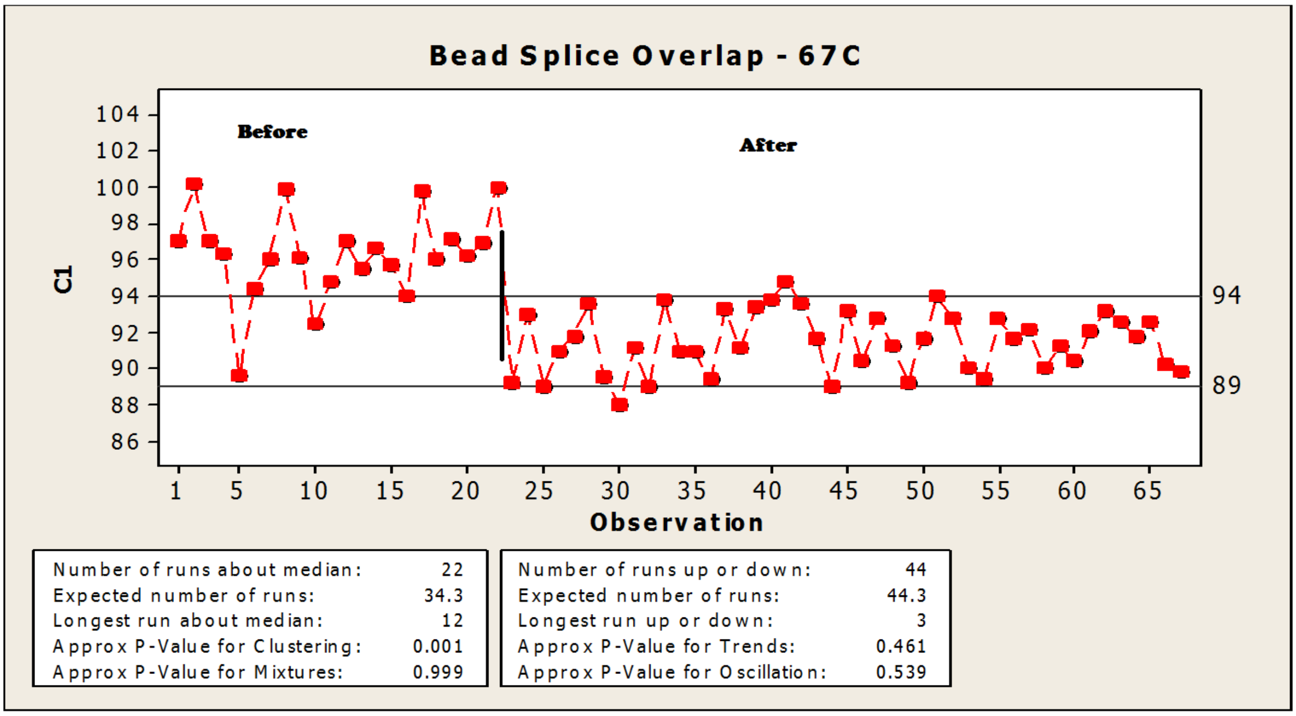


Figure 4-9: Run chart for Bead splice overlap before and after

Figure 4-9 shows the Run chart for bead splice overlap variation observations before and after the corrective action applied.

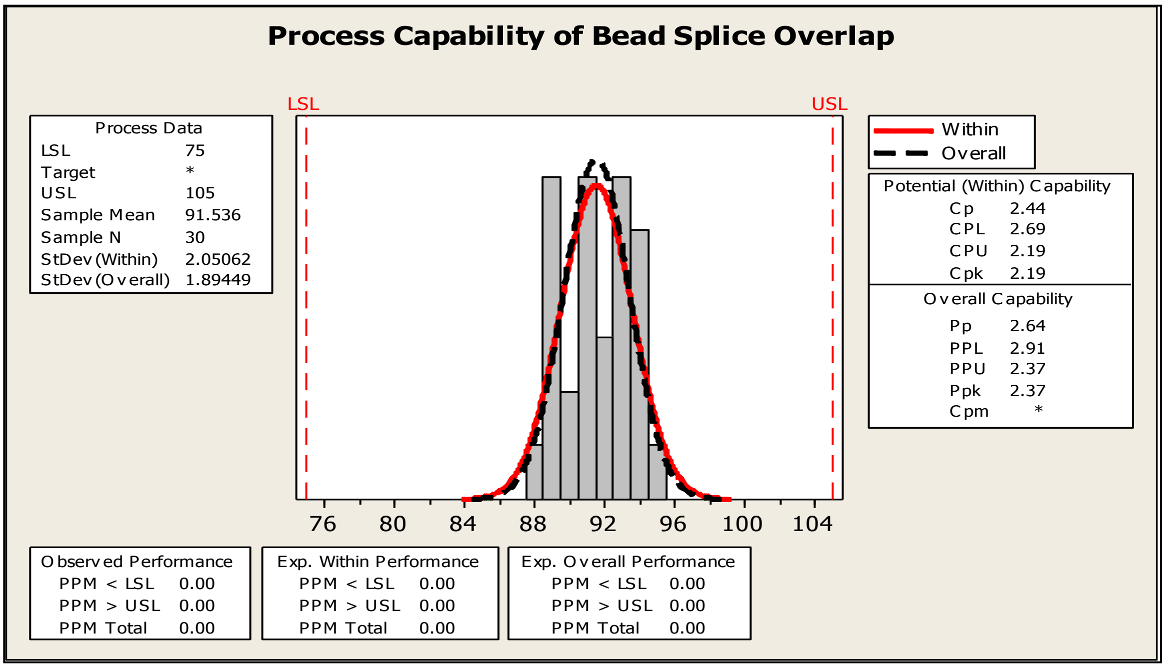


Figure 4-10: Process Capability of Bead Splice Overlap

Figure 4-10 shows improvement of process capability indices .So after process improvement process capability indices value is improve to 2.19.

4.6 Control

To maintain the betterment of the sigma quality level in the screening process, some control methods were recommended for the organization.

- From the obtained result Verify the reduction in Root Cause and sigma level improvement.
- Identify whether there are requirement of additional solutions to obtain the goal.
- Integrate lessons which are learned.
- Identify terms like next steps and plans for remaining process.

Chapter 5 Discussion and Conclusions

5.1 Discussion

Six-sigma is known as very effective method to find out the actual need of a process for improvement. Six-sigma also provide feasible methods for analytical analysis of data.

Results with successful implementation of six sigma in different applications in different organizations are:

- Reduced wastage of material
- Reduced costs of poor quality
- Increases process capability
- Process improvement

In this research, DMAIC approach implemented for process improvement. Firstly, we find current value of process capability indices C_p and C_{pk}. This is less than 1.33 so to improve the value of process capability indices we first find the root cause of the problem with the help of cause-effect diagram. Than in improve phase we improve process capability indices value after taking corrective action.

5.2 Conclusions

We can conclude from this research that quality level or performance level of a process can be improved by implementing of six-sigma DMAIC methodology. And this quality level can be obtained at lowest cost. The aim of this research is to increase the process capability indices of the Bead splice overlap variation, which contributes to betterment of the performance. We increase the value of process capability indices up to 2.19.

This project is based at six sigma DMAIC methodology provides information about the decisions making power for particular type of problem and the most significant tool for improvement of that type of problem. This project also support to develop an infra-structure that will initiate and support six sigma projects and initiative.

Six-sigma is powerful methodologies that can properly implemented, result with significance savings and improvements. Six-sigma is a standard of measurement of quality of the product or process, also a caliber of efficiency and excellence of process. Main aim of implementing six-sigma approach is delivering world class quality standards of product and service while removing all internal as well as external defects at lowest possible cost (Dedhia, 2005). A true Six Sigma implemented organization have aim not only produce excellent product or service but also manage this highly efficient production systems that work effectively and efficiently with the organization's other service and processes (Lucas, 2002). For proper and successful implementation of a six sigma project, organization must have the required resources, the guidance to the employees by top management and leadership of top management. Six sigma is powerful approach that can be implemented in organization easily and bring out result in the form of saving of money and improvements in product or services. Six sigma implementation means delivering better service and process or product with removing all internal as well as external defects (Dedhia, 2005). Successful implementation of six sigma in an organization is responsibility of each and every employ of the organization.

5.3 Future Scope

The work done in this thesis to reduce waste of material with the help of DMIAC methodology can be implemented in other industry also. As In order to be competitive companies try continuously improve their production processes, product quality and increase the level of customer satisfaction by implementing different quality improvement programs, methodologies and approaches this research is very helpful to the companies to improve their performance level.

References

- Antony, J. and Banuelas, R., 2002. Key ingredients for the effective implementation of Six Sigma program. *Measuring business excellence*, *6*(4), pp.20-27.
- Boyles, R.A., 1994. Brocess capability with asymmetric tolerances.*Communications in Statistics-Simulation and Computation*, *23*(3), pp.615-635.
- Cagnazzo, L. and Taticchi, P., 2009, December. Six sigma: A literature review analysis. In *Proceedings of the international conference on e-activities and information security and privacy* (pp. 29-34).
- Chen, K.S., Huang, M.L. and Li, R.K., 2001. Process capability analysis for an entire product. *International Journal of Production Research*, *39*(17), pp.4077-4087.
- Erbiyik, H. and Saru, M., 2015. Six Sigma Implementations in Supply Chain: An Application for an Automotive Subsidiary Industry in Bursa in Turkey. *Procedia-Social and Behavioral Sciences*, *195*, pp.2556-2565.
- Gupta, N., 2013. An Application of DMAIC Methodology for Increasing the Yarn Quality in Textile Industry. *Journal of Mechanical and Civil Engineering*, *6*(1), pp.50-65.
- Gupta, V., Acharya, P. and Patwardhan, M., 2012. Monitoring quality goals through lean Six-Sigma insures competitiveness. *International Journal of Productivity and Performance Management*, *61*(2), pp.194-203.
- Hekmatpanah, M., Sadroddin, M., Shahbaz, S., Mokhtari, F. and Fadavinia, F., 2008. Six Sigma process and its impact on the organizational productivity. *World Academy of Science, Engineering and Technology*, *43*, pp.2070-3740.
- Kabir, M.E., Boby, S.M.I. and Lutfi, M., 2013. Productivity improvement by using Six-Sigma. *International Journal of Engineering and Technology*, *3*(12), pp.1056-1084.
- Kane, V.E., 1986. Process capability indices. *Journal of quality technology*,*18*(1), pp.41-52.
- Kaushik, P. and Khanduja, D., 2009. Application of Six Sigma DMAIC methodology in thermal power plants: A case study. *Total Quality Management*, *20*(2), pp.197-207.
- Kuei, C.H. and Madu, C.N., 2003. Customer-centric six sigma quality and reliability management. *International Journal of Quality & Reliability Management*, *20*(8), pp.954-964.

- Kumar, S., Satsangi, P.S. and Prajapati, D.R., 2011. Six Sigma an excellent tool for process improvement–a case study. *International Journal of Scientific & Engineering Research*, *2*(9), pp.1-10.
- Li, S.H., Wu, C.C., Yen, D.C. and Lee, M.C., 2011. Improving the efficiency of IT help-desk service by Six Sigma management methodology (DMAIC)–a case study of C company. *Production Planning & Control*, *22*(7), pp.612-627.
- Linderman, K., Schroeder, R.G., Zaheer, S. and Choo, A.S., 2003. Six Sigma: a goal-theoretic perspective. *Journal of Operations management*,*21*(2), pp.193-203.
- Maleyeff, J. and Kaminsky, F.C., 2002. Six Sigma and introductory statistics education. *Education+ Training*, *44*(2), pp.82-89.
- Narula, V. and Grover, S., 2015. Six Sigma: Literature Review and Implications for Future Research. *International Journal of Industrial Engineering*, *26*(1), pp. 13-26.
- Pearn, W.L. and Chen, K.S., 1999. Making decisions in assessing process capability index C-pk. *Quality and reliability engineering international*, *15*(4), pp.321-326.
- Rajvanshi, P.K. and Belokar, D.R., 2012. Improving the process capability of a boring operation by the application of statistical techniques. *International Journal of Scientific & Engineering Research*, *3*(5), pp. 2229-5518.
- Rohini, R. and Mallikarjun, J., 2011. Six sigma: Improving the quality of operation theatre. *Procedia-Social and Behavioral Sciences*, *25*, pp.273-280.
- Roth, N. and Franchetti, M., 2010. Process improvement for printing operations through the DMAIC Lean Six Sigma approach: a case study from Northwest Ohio, USA. *International Journal of Lean Six Sigma*, *1*(2), pp.119-133.
- Sahno, J. and Shevtshenko, E., 2014. Quality improvement methodologies for continuous improvement of production processes and product quality and their evolution. In *9th International DAAAM Baltic Conference "Industrial Engineering"* (pp. 181-186).
- SINGHAL, S.C., 1991. Multiprocess performance analysis chart (MPPAC) with capability zones. *Quality Engineering*, *4*(1), pp.75-81.
- Soković, M., Jovanović, J., Krivokapić, Z. and Vujović, A., 2009. Basic quality tools in continuous improvement process. *Strojniški vestnik-Journal of Mechanical Engineering*, *55*(5), pp.333-341.
- Sokovic, M., Pavletic, D. and Pipan, K.K., 2010. Quality improvement methodologies–PDCA cycle, RADAR matrix, DMAIC and DFSS. *Journal of Achievements in Materials and Manufacturing Engineering*, *43*(1), pp.476-483.

- Srinivasan, K., Muthu, S., Devadasan, S.R. and Sugumaran, C., 2014. Enhancing effectiveness of Shell and Tube Heat Exchanger through Six Sigma DMAIC phases. *Procedia Engineering*, *97*, pp.2064-2071.
- Srinivasan, K., Muthu, S., Prasad, N.K. and Satheesh, G., 2014. Reduction of paint line defects in shock absorber through Six Sigma DMAIC phases. *Procedia Engineering*, *97*, pp.1755-1764.
- Tong, J.P.C., Tsung, F. and Yen, B.P.C., 2004. A DMAIC approach to printed circuit board quality improvement. *The International Journal of Advanced Manufacturing Technology*, *23*(7-8), pp.523-531.
- Valles, A., Sanchez, J., Noriega, S. and Nuñez, B.G., 2009. Implementation of Six Sigma in a Manufacturing Process: a case study. *International Journal of Industrial Engineering: Theory, Applications and Practice*, *16*(3), pp.171-181.
- Vijay, S.A., 2014. Reducing and optimizing the cycle time of patients discharge process in a hospital using six sigma DMAIC approach. *International Journal for Quality Research*, *8*(2), pp.169-82.
- Wooluru, Y., Swamy, D.R. and Nagesh, P., 2014. The Process Capability Analysis-A Tool for Process Performance Measures and Metrics–A Case Study. *International Journal for Quality Research*, *8*(3), pp.399-416.
- Wu, C.W., Pearn, W.L. and Kotz, S., 2009. An overview of theory and practice on process capability indices for quality assurance. *International journal of production economics*, *117*(2), pp.338-359.