Statistical Process Control of an Automobile Parts Manufacturing Company Using Six Sigma

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Declaration

I certify that this research work titled as "Statistical Process Control of an Automobile Parts Manufacturing Company using Six Sigma" is my own work which has been done under the supervision of Dr. Shahid Ikramullah Butt. This research work has not been copied unlawfully from any source. The materials used in this research work has been properly acknowledged / referred.

Dedication

This research work is dedicated to my family whose support, prayers and encouragement gave me strength and made me able to carry out this research**.**

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Abstract

The need for quality has been longer recognized in business environment so that we obtain or manufacture top quality products. In a production environment, quality boosts reliability, increases efficiency and client satisfaction. Practices of Statistical Process Control (SPC) are required in the Quality Manufacturing. For the improvement of manufacturing performances in manufacturing companies, practices of Statistical process Control is much needed. The main focus of this ongoing work is to determine the major reasons of breakdowns affecting productivity and how to improve the company manufacturing ability by reducing those breakdowns using Six Sigma.

Total quality management (TQM) was basically introduced to enhance regularly the product or services to raise the customer's satisfaction level. SPC is a very significant and important tool of TQM. In normal apply; SPC is employed as quality control tool. However in this comprehensive research SPS is employed to increase the total output distinguishing major losses using Six Sigma. Successful implementation of the recommendations of this paper will significantly improve the manufacturing performance of company manufacturing environment.

Six Sigma is being Implemented all over the world as successful Quality Improvement Strategy. This thesis is conducted at an Automobile Parts Manufacturing company to decrease the defect rate of different manufacturing processes used in various Projects of the Production Facility. The Industry selected is Rastgar Engineering Company which is Islamabad Based Automobile parts manufacturing Industry equipped with modern manufacturing and testing Equipments.

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Chapter – I Introduction

1.1 Motivation

In this period of strains on the assets and growing costs of manufacturing it becomes progressively obvious that decision should be made on facts, not simply opinions. Consequently data and information should be gathered and then analyzed. That's where statistical process control will come in. For more than 60 years, the tools of SPC have given benefit to manufacturing Arena by helping through the decision making process. Specifically Control chart has helped a lot in determining the variation which exists in a process implying that a proper action must be taken in order to remove that reason which has a damaging effect on the process or even to make it a standard operating process if that cause includes a helpful effect on the procedure. If there is no special-cause variation available, SPC helps in defining the ability of the stable procedure to judge whether it's operating at a satisfactory level. The effectiveness of SPC is that it is very simple and by using computer to help in making calculations and plotting different kind of chats, its simplicity becomes complete. Now the question is that what is Statistical Process Control? The answer to this question is very simple. Statistical Process Control is an Analytical decision making technique that allows us to see whenever a process is working appropriately and when it isn't. Different kinds of variations are present in every process determining that when those variations are natural and when those variations needs correction is the main key to top quality control. The idea of Statistical Process Control was originated by Dr. Walter Shewart who was working in Bell telephone laboratories during 1920's. He was performing research on different for the improvement of quality and for the reduction of costs. During his that work Dr.

Walter developed the concept of control in regards to variation and developed Statistical Process control charts which gives a simple approach to determine if a particular process is in control or not. Dr. W Edwards Deming further carried on the Shewart's work and took the ideas to Japan pursuing World War II. There the Japanese Companies and different industries liked those ideas very much and they adopted those ideas whole-heartedly. This led the Japanese products to a very top quality. Today Japanese products are worldly famous. For his working in the quality field, Dr Deming is famous all over in Japan. Now a day's Statistical Process Control is used in different manufacturing facilities all over the world [1].

As in this Research work we are also using Six Sigma as a Statistical Process Control technique so here we shall also give a brief introduction about Six Sigma.

Six Sigma is a set of different tools and techniques which leads to the process improvement. What Six Sigma does is it seeks to improve the quality of a process output by finding out and eliminating the sources of defects and reducing the variability in production, manufacturing and business processes. A set is employed by it of quality management methods mostly empirical, statistical methods and creates a particular infrastructure of people inside the organization who are experts and professionals in all these methods. Every Project of Six Sigma carried out in an organization follows a precise sequence of actions, techniques and has a specific worth targets like to reduce the period of a process cycle, to reduce pollution, to minimize costs, to enhance and increase the customer satisfaction, and increase profits. A successful and efficient manufacturing process can be best explained by a sigma rating which shows its yield or show the defect free product percentage it generates. A Six Sigma Process is that one where 99.99966%

of almost all opportunities to create some features of a component are statistically likely to be free from defects i-e (3.4 defective features per million opportunities) [2].

Six Sigma is a centered, rigorous and extremely effective implementation of verified and established quality principles and highly techniques. What Six Sigma wants is that it aims for almost error free business performance virtually. Sigma, δ, is a Greek alphabet letter which is employed by statisticians to gauge or measure the variability in virtually any process. A company's overall performance and efficiency is normally measured by the sigma level of their business methods and processes. The outstanding standard of Six Sigma which is 3.4 problems per million opportunities is a good response and reply to the customers increasing expectations and the also the increasing complexity of modern good merchandise and processes. By the count of an expert, there have been more than 400 TQM tools and techniques. A few of the proven and verified methods is taken by Six Sigma and trains a small group of in-house technical leaders referred to as Six Sigma Black Belts. Those Six Sigma black belts are trained to a very high level of proficiency in the use of these techniques and methods. It is certain that maximum methods which Black Belts make use of and work with are highly advanced, together with up-to-date computer technology, However the equipments and tools are applied within a simple, easy and straightforward performance improvement model referred to as Define-Measure-Analyze-Improve-Control shortly denoted by DMAIC.

A short History of the Six Sigma is that when a Japanese company took over a Motorola factory that used to make Quasar television sets within United States in the 1970's, they promptly set about creating forceful and drastic changes in the manner the factory operated. Soon enough the factory started producing Television sets under Japanese

Management with $1/20^{th}$ as much defects as they had produced under the Motorola's management. They performed this employing the same technology, workforce, and patterns and achieved it while lowering the costs and thus made it clear that the main problem was Motorola's management. It was then admitted by Motorola's personal executives that "Our Quality Stinks". In 1980's Motorola determined that what to try and do regarding it [3] ·Bill Smith was a senior Engineer and scientist at Motorola in 1986. Bill Smith introduces the concept of Sigma in Motorola in order to find out the defects and minimize it, hence standardizing those defects. After that Motorola was provided the main key to address quality concerns in the organization by Six Sigma. Due to the application of Six Sigma , Motorola won the Malcolm Baldrige national Quality award in 1988. After the successful implementation of Six Sigma by Motorola, the Impact of Six Sigma Processes was welcomed by other leading global organizations for the improvement of their business performances. Those organizations include General Electric, Allied Signal, and Citibank. For the better quality Products and customer satisfaction it is increasingly considered as the best practice by investing in Sex Sigma even among mid-sized and smaller companies. In Today's time Motorola still implements Six Sigma in it's business and also gives the benefits of its Six Sigma to different organization throughout the world through Motorola University [4].

1.2 Background of Study

The automotive parts manufacturing industries have always invariably set an example within the Project Management Field and also in the Leadership and in many ways to which quality is always put on top and concerned in effective ways. There is always followed a longtime and established methodology from manufacturing and product development through production. As the world is becoming competitive day by day so from the past decade it has been observed that the world increasing competition has forced different automobile parts manufacturing companies to improve its quality and also to improve its efficiency. The quality of the product can be seen in different ways. What effects the quality and on what base it is evaluated is always decisive, but the bottom line is mostly, in fact always seen and determine according to the customer's requirements [5] .As there are too many management tools, so choosing and applying the best one among those tools can leads a company profile to the top and can improve the performance of the company and If the performance of the company is improved so it will increase the customer satisfaction and will also gain lots of market shares. To improve the product quality, to reduce cost and to improve the efficiency of company, many new techniques have been developed. To bring itself in the competition of business in the modern world, many companies have developed frameworks and quality practices. Total Quality Management, Benchmarking, Business Excellence models, KAIZEN, Statistical Process Control, Theory of constraints and many more improvement programs have been adopted by various companies and have also implemented those programs. Apart from all these programs, Six Sigma (6δ) is a quality improvement technique which was developed by Motorola for the improvement of its product quality. Six Sigma is a best approach to improve quality by statistical measurements [6].

Rastgar Engineering Company is an Automobile parts manufacturing company that is receiving rejection of some of its Automobile parts which are used by different Automobile Industries. This leads to very high economic losses. Its manufacturing facility is in fact a very good one and it has well established manufacturing, machining, and testing section which are equipped with modern machines, manufacturing and testing facilities. Quality management principles and techniques are used in manufacturing processes and quality of product is checked at different stages of manufacturing processes.

1.3 Methodology

In the above discussion it has been said that the company is facing some economic losses just because of defects that occur in manufacturing, machining and molding processes. Just because of those defects lots of products comes out to be defective in the end of the process or in the middle and also lots of products are rejected and send back to company due to which time is wasted and also defective products leads to a bad impression of the company and a huge loss of the company. Hence in order to reduce that rejection and non conformance rate of different parts, the company needs to study comprehensively its manufacturing, machining and molding processes. For that comprehensive study the company must use Statistical Process Control and different Analysis techniques which will help in finding the most critical factors which are affecting the quality of products. As the company is already performing statistical process control techniques like control charts and fishbone diagrams which has helped a lot in reducing the defect rates in product quality. But to reduce those defects further and refine the product quality to a very high level, implementation of Six Sigma is the solution to this problem. Now the question here arises that what difference of Six Sigma Implementation will have on the product quality and how will it bring that difference. So this research will include Statistical Process Control in this company using Six Sigma of all the Foundry processes and efforts will be done to solve the Basic Quality Problems related to different processes which will reduce errors in all the processes and will take the product quality to a very high level and the defect rate will be reduced to 3.4parts per million opportunities. DMAIC is the Six Sigma methodology which will be adopted here in this research.

DMAIC stands for Define, Measure, Analysis, Improve, and Control [7].

1.4 Scope of the project

Scope of this Research is to implement Statistical Process Control techniques. To bring the use of Six Sigma in this company which is a Quality Improvement methodology? Why the use of Six Sigma in this company is necessary? The answer to this question is that Six Sigma will reduce errors that occur in different manufacturing, machining and molding process due to which the rejection rate of this company products will reduce which will give lots of benefits to company. Those benefits include that a huge amount of money wastage will be minimized, and there will be a much competitive environment in this company which is must in nowadays. The Product quality will be much improved and hence all quality standards will be met by this company.

1.5 Objectives of Study

- The most important and main objective of this study is to conduct Statistical Process Control of different automobile manufacturing parts using Six Sigma in Rastgar Engineering Company.
- To reduce the rejection rate of the parts and to make product quality better.
- To reduce the operational costs.

The methodology of Six Sigma which is used here is DMAIC (Define Measure Analysis Improve Control). Further this research is followed by the following milestones.

- Melting Processes Study of Manufacturing Facility
- Statistical Quality Analysis of Melting Processes
- Molding Processes Study
- Statistical Quality Analysis of Molding Processes
- Machining Processes Study in Manufacturing Facility
- Statistical Quality Analysis of Machining Processes
- Testing Processes Study
- Quality Analysis of Testing Processes
- Testing Equipments Checking
- Identification of all those errors which are effecting the quality
- Identifying the defects and implementation of a control plan to minimize those defects
- Controlling and Monitoring all the processes

1.6 Research Benefits

The most important and major benefit of this research is that it will improve the product quality. It will bring quality improvement in the all the manufacturing, machining, molding and testing processes. There will be also other benefits of this research which are listed as follow;

- It will reduce operational costs
- It will bring reduction to scrap, repair, and rework rates

- It will improve effective performance of the company
- It will improve the profit of the company
- It will improve product and system performance
- It will improve satisfaction and motivation of workforce
- It will bring the company to be a better place to respond to external pressures
- It will improve the company image by becoming much more people oriented
- It will define the errors that are affecting different processes
- It will find out the critical factors that are affecting the quality of product and hence those factors will be then eliminated.

1.7 Area of application

The Company which has been chosen for the implementation of Statistical Process Control using Six Sigma is Rastgar Engineering Company. Rastgar Engineering Company is equipped with latest and up-to date machining technologies. The testing equipment of Rastgar Engineering Company has both destructive and non destructive testing equipments. To properly implement Six Sigma technique in this company, The Company is looking for to add a new department for the experts of Six Sigma where training will be given to the employers according to Statistical Process Control and Six Sigma by some other trained Engineers.

1.8 Profile of the Company

Rastgar is a trusted name in many end components like truck and trailer wheel. Rastgar manufacture different types of Products which includes medium and Heavy-Duty truck and trailer wheel hubs and Brake drum assemblies for the OEM's customers and aftermarket. Rastgar have a hundreds and even more than hundreds of parts numbers that are either stock item which is stored in stock or also produced according to the customer needs and requirements. Customers mostly prefer Rastgar because of its vertically integrated processes which start from design development, design analysis (FEA), pattern making, foundry, machining, and fatigue testing. Rastgar has adapted itself to the market needs till now. [8] The Global Customer Base of Rastgar is

- NISSAN
- HINO
- TOYOTA
- DAEWOO
- GRANNING AXLES(Engineering transport solution)
- GIGANT
- MITSUBISHI
- ISUZU
- DANA
- SUZUKI
- MASSEY FERGUSON
- DAIHATSU

Figure 1.1

1.9 Products manufactured by the Company

- WHEEL HUBS

    1. BEDFORD
    2. BPW
    3. DAEWOO
    4. DAF
    5. DEXTER
    6. DOOSAN
    7. HINO
    8. IVECO
    9. MAN
    10. MERCEDEZ
    11. MITSUBISHI

12. TRAILER HUBS
13. RENAULT
14. ROR
15. SAF
16. SMB
17. TRAILER HUBS
18. UTILITY TRAILER HUBS
19. VOLVO
20. WEBB
21. ISUZU

- WHEEL HUB BEARINGS
    1. COMPACT BEARING
    2. TAPPERED ROLLER
- WHEEL HUB ASSEMBLIES
- BRACKETS
    1. CAB MOUNTING
    2. ENGINE MOUNTING
    3. STAY FAN HOUSING
    4. STEERING GEAR
    5. TORQUE
- STEERING KNUCKLES

Chapter – II Literature Review

2.1 Implementation of SPC

In this paper the author says all about the implementation of SPC in different manufacturing companies [9]. Here eight manufacturing companies have been selected. The case study of those eight manufacturing companies involves interviews and questionnaire survey in detail from each company representatives. Along with that it also includes observations on the company's environment. What this paper mainly focuses on is the result of the survey which had conducted in those companies and also the principal findings of those surveys. The type of data which had collected from company was background of the company, whole information about SPC in the company, also the type and different characteristics of SPC software. Along with that other information like advantages of SPC software and its disadvantages were also collected. The results which have been achieved from all these information shows that the Implementation of SPC in a company isn't an easy task. It has to go through a lot of barriers which is related to system in different forms like management, machine and equipments, facilities, attitude, cost, different issues about training.

The technique of using control charts and statistical concepts that are applied in the production process was developed by Walter A. Shewart. Statistical Process Control (SPC) has played central part in managing quality of the products. For the management, monitoring and controlling of a production or service process through statistical methods, quality assurance programs and total quality management (TQM) uses SPC. If a company or an organization is aware of such strategies and methodologies that are required for successful application, the implementation of SPC can be made effective. However, the delay by some companies in application of SPC software for ‘saving’ money has caused the lack of development of SPC in Malaysian small and medium-sized enterprises (SMEs). Excluding the training costs, the software and hardware system of a SPC can cost about RM4500 to RM6500 per site.

This study concluded that due to unaffordable technology system (hardware, software, networking and security) and costs for smaller companies, the implementation and application of SPC system is more difficult in SMEs. Beside this manual system and simple control charts method is preferred by companies for simple operation. Additionally, required level of internal expertise and firm source of external advice is needed for any company, for the implementation of a thorough SPC system. There are not much problems in recruiting or educating workers in large companies that uses SPC.

2.2 SPC for Performance Improvement

In order to enhance the manufacturing capability in production companies [10], the practices of Hourly Data System (HDS) and Statistical Process Control (SPC) are put together. Along with acquisition of the frequencies and time duration of machine breakdowns, core of this conduct is the main causes of breakdowns that affect the productivity levels of the firm. For the continuous betterment of products/services and increased customer satisfaction, Total quality management was brought in. SPC which is used as a quality control device is the core tool of TQM. By the use of HDS, the time loss from different machine breakdowns is identified in order to increase total output through SPC. The findings and propositions of this research can incomparably boost the production performance of the production companies and firms.

The main focus and aim of Total quality management (TQM) is the continuous betterment of customer satisfaction levels. It is a people focused management system. SPC helps in the continuous monitoring of a process. To know the functioning level of a process, that whether it is as required or not, is the purpose of control charting. According to the need and requirement, appropriate steps for correction and betterment are to be taken. For the achievement of manufacturing excellence, SPC is used for the perpetual betterment of volume and quality of production. Profit through customer satisfaction is the main goal of any company or firm which can be made possible through application of SPC tools. To increase the total production volume SPC can be implemented as a quality control device.

It makes the production manager able to easily identify the responsible causes for the poor product quality, machine breakdowns and also huge wastage.

To sort out the frequencies and time span of cigarette manufacturing machine breakdowns a well as the main reasons for such causes of breakdowns, a detailed analysis has been carried out. The final outcome indicates that any breakdown can cause a considerable cost and taking precautions is the most definite approach to overcome such breakdowns. Preventive measures, addressing the patterns of such breakdowns are very helpful in revenue generation, from economical perspective. For the minimization or reduction of issues, long term precautions and actions are required. Along with being a quality control device, SPC can also be adapted for the betterment and boosting of a factory's production performance.

2.3 A framework for implementation of SPC

Statistical process control has achieved its place as one of the most significant part of quality control activities [11]. For the triumphant implementation of SPC, methodological as well as organizational aspects are important, both of which are included and discussed in this paper.

SPC is usually associated with control charts, but mere control charts do not qualify as a competent SPC system now days. While from another perspective, SPC is considered as total quality management (TQM). For all the processes like designing and products or services, the notion of SPC can be used if it starts in the manufacturing sector. Hence, the frame work of this research paper predominantly directs towards the production processes. Along with that, it also focuses on how implementation of SPC in a company initiates TQM process.

In the application of SPC, the following organizational problems occur:

- The implementation of SPC throughout the company is a long process and may take years; it requires the investment of time as well as money.
- Continuous attention and full support of higher management is required.
- The delegation of tasks, responsibilities and authority to the lowest possible level are also the demands of SPC.
- The expertise of an SPC consultant is required for the proper implementation of SPC.
- The firm should be well aware of handling problems by the use of data.
- Project management as well as team work are also listed as the basic requirements.

Various firms and companies applied this frame work which resulted in the successful application of SPC. Including both methodological as well as organizational plans, this frame work gives a practical approach for the implementation of SPC in manufacturing. The project approach and workbook method stimulate an organization to get started with SPC.

2.4 SPC techniques in Automotive Industry

SPC is implemented in those companies which offer the most expanded and most up-to-date range of sealing solutions for different uses in the automotive industry, to its customers, in this paper [12]. Using devices that provides objectivity over subjective opinions and numerically analyses the strength of each source, SPC is able to canvass a process and the cause point of variation in that process, which is the main power of SPC. Cause and effect diagram and control charts, that are the two main techniques out of the total seven, are implemented in this industry. The analysis of shortcomings in the shocker seals of an automotive industry is the main focus of this present work. The root causes when removed through implementation of SPC, the percentage rejection is reduced from 9.1% to 5% and process capability of 0.953 is achieved.

Situated in northern India, with the collaboration of three industries, this firm is one of the most recognized and largest firms of the Automobile Rubber Parts industry, with its wide and expanded range of parts. It has also achieved TS-16949:2002, QS-9000 and ISO-9002 standards of quality assurance.

This work focuses on shocker seals. After the analysis of the main needs of the production process, the statistical process control (SPC) of the specific process is found out. By decreasing the sum of malfunctioned products and saving re-doing cost plus time, SPC analysis helps in the betterment of the efficiency of the manufacturing process. Both time and money can be saved by applying the preventions suggested through SPC analysis for each specific product. The rejection level of shocker seals was more than 9.1% due to which they were the main concern, though betterment in the rejection level of all the other products was also evaluated. The functioning of shocker seals was improved to a greater extent than the required after the implementations that were suggested through SPC. Out of 400 observations of outer diameter of Shocker seals, no any observation is falling outside of control limits on both X and R charts.

2.5 Six Sigma for Quality Improvement

In this paper the author has focused a case in an Auto Ancillary unit which consists of about 400 employees [13]. The author has employed different methodologies of Six Sigma to improve the quality and achieve the dream of Six Sigma quality level. The methodology of Six Sigma has been applied to one of the product assembly in order to reduce the defect levels which are very critical for the customers. The implementation of Six Sigma methodology lead to a better improvement and it helped a lot in the financial line of the company. Further the author has explained that in Small and Medium enterprises if one is going to initiate Six Sigma, so the top management of that enterprise should select the best energetic and intelligent person among their enterprises and should properly train at least one person on Green Belt from external organization if they are ready to help and support. After that, the enterprise can think to properly apply the 'Internal Training Methodology' (ITM) for education and training on Six Sigma with the help of those trained persons which have been trained already in a different organization. Now why such type of internal training in an enterprise is needed?

The answer to this question is very simple. Such type of internal training in an enterprise is needed because Small and medium Enterprises can't invest in such a heavy cost for training.

As Six Sigma has always very good result in the improvement of quality and implementing Six Sigma methodology is a financial hit for an enterprise. So for further improvement of Six Sigma results more advanced tools can be used like Design of Experiment and software which is called Minitab.

2.6 Six Sigma DMAIC Methodology

In this Paper the author has done work on Statistical process Control [14]. The author did statistical analysis in order to evaluate and improve different welding processes and its settings. What happens is that performing statistical analysis in this organization will improve the sigma value and also the yield of Welding Process and also of overall facility of Welding. As Six Sigma adapt to different methodologies for the improvement of Processes Quality, but here in this Welding facility the Six Sigma methodology which was selected for the implementation is DMAIC (Define, Measure, Analysis, Improve and Control). The Project scope was to reduce the defect percentage up to 0.25% in the define phase. The second phase which is measure phase will measure the value of every process and will put a base line for that project. That includes that to target the welding process with the least sigma level and also to select that specific target at which the Sigma level has to be obtained. The Sigma process which was selected as the target process was Shield Metal Arc Welding Process with a Sigma Level of 3.3 Sigma. Stainless steel is the base metal which was used. Different Experiments were performed which were mostly Screening experiment. Those Screening experiments were performed to analyze the main source of Variation in that Shield metal Arc Welding Process.

An Improvement Strategy was formulated in the Analyze Phase Findings. In order to bring the Welding Process in a required Sigma Limits so that Improvement Strategy was then implemented. A Control Plan was then established in the Control Phase of the Project. After improvement the Cost of Quality was measured. This showed a huge Cost savings. The Cost savings improvement was because of the improvement in the sigma values of Shield Metal Arc Welding Process from 3.3 to 4.3 Sigma and the overall Welding Facilities Sigma level has increased from 4.0 Sigma to 4.3 Sigma.

2.7 Application of Statistical techniques

In this Paper the author says about Process Capability [15]. What is Process Capability and How Process Capability is implemented. All the steps have been listed in a very simple and easy so that the readers can easily understand it. The answer to that question that what is Process capability is , Process Capability Indices are very helpful and effective tools for the Quality improvement, for the productivity improvement and also very helpful in managerial decisions. In this study and research, an Analysis of Process Capability was done in the medium-sized company. That company Produces Machine and spare parts. In the Company Machining line the Process-Capability Analysis was carried out. Normal Histograms and different types of probability plots were prepared for this Analysis. The Process Capability indices which are C_p and C_{pk} were then calculated. It was found that for the whole process the Process Capability was not adequate. Also the Mass Production was not stable. It was unstable. It is very necessary to improve the level of quality to satisfy the Process Capability measure. That quality level is improved by shifting the mean of Process or Process mean to the target value and then reducing different variations in the whole process.

In order to find whether the process is capable or not capable, for that purpose SPC technique was used so that to evaluate the Machine capability C_p and also C_{pk} of manufacturing process. The parts which were nonconforming were determined in numbers different spans of time like short of long periods of time. When the whole process was monitored so after that a very clear and large improvement was experienced due to increase in Process Capability indices and also in the reductions of defective parts per million.

Process capability indices are calculated to know whether process is capable or not by following formulas.

$$C_p = \frac{USL - LSL}{6\delta} \qquad C_{pk} = Min\left[\frac{USL - \bar{\bar{X}}}{3\delta}, \frac{\bar{\bar{X}} - LSL}{3\delta}\right]$$

Capability index	Estimation of the process
$C_{Pk} = C_P$	Process is placed exactly at the centre of the specification limits.
$C_P < 1$	Process is not adequate.
$1 \leq C_{Pk} < 1.33$	Process is adequate.
$C_P \geq 1.33$	Process is satisfactory enough.
$C_P \geq 1.66$	Process is very satisfactory.
$C_{Pk} \neq C_{Pk}$	Process is inadequate, new process parameters must be chosen.

Table 2.1

2.8 Statistical Analysis of Process Capabilities [16]

In this research paper, the author has written about the statistical tolerance limits methodology and also has described its applicability to estimate the process capability. The company where this case study has been conducted is Kiran Machine Tool Jalgaon. Various cutting parameters like feed rate, speed of machine, depth of cuts are affecting the control valve cylinder head. All the process are in statistical control in this company but to improve the process costs, the capability indices should be improved (nearly to 1.67). With the improvement in process capability, the production rate increases and the amount of scrap becomes less. Hence the Process cost has been enhanced by means of Process Capability Measurement.

There have been a great number of benefits from the Process Capability but one of those benefits is the capability of large processing area which reduces the production cost to a significant amount. The Cp and Cpk which are the measurement of process capability can provide a very useful information and can also be a useful assessment for the process costs to enhance it in a significant way. The Process engineer can assess the potential of a process condition with the help of process capability indices. The process engineer can also compare the process costs with the help of process capability indices such as Cp and Cpk. What’s the effect of improving the value of Process Capability indices near to 1.67? The answer is that when the value of process capability indices is improves near to 1.67 so a large saving will be done in inspection cost, also in labor cost and the tool cost saving will also increase. Hence its overall effect will be that a large amount of saving will occur in the total production cost.

So from all of the above discussion it is concluded that to maintain a high value of process capability indices is not necessary. If we increase and maintain the value of Cpk nearly to 16.7 so the production rate can be much higher.

Chapter – III Research Methodology

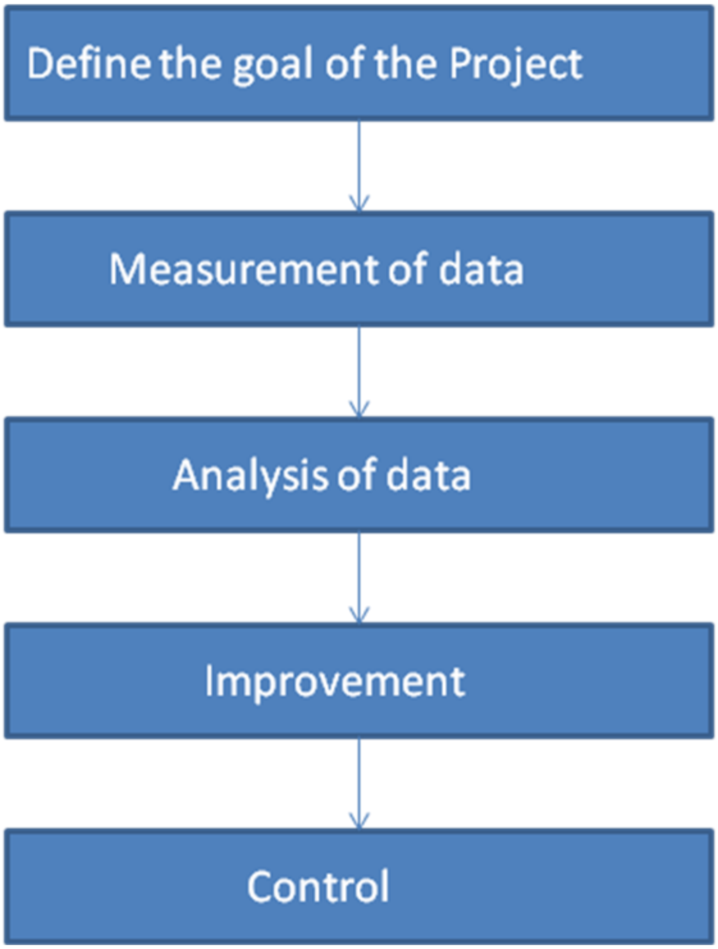
3.1 Introduction to Chapter

In this chapter the Research Methodology will be explained in detail. This chapter in the start will show a flow chart of Research Methodology which will be explained in detail stepwise that

- Which methodology of Six Sigma we are using.
- Why we are using that specific Methodology of Six Sigma.
- What I did in every phase of my research.
- How I did it.
- What were the improvements because of using that Methodology?

But before explaining this methodology in detail, this chapter will give us an idea that what is Statistical Process Control and what are their tools in detail. After having an idea about statistical process control, it will explain Six Sigma and the projects concerned with Six Sigma.

3.2 Flow Chart of Research Methodology



1. Define specific goal which is to reduce the defect rate and operational cost
2. Measure defect rate of parts
3. Analyze problems ,cause and effects must be considered
4. Improve process on bases of measurements and analysis
5. Control process to minimize defects

3.3 Statistical Process Control

In the Modern Era the manufacturing cost is an important part of the profit which is to be keeping in mind always on the top priority. Hence with the rising cost of manufacturing, the decision must always be made based upon facts and not just observations. For that the data must be gathered and then that data must be analyzed. Hence for the collection of data and then analyzing that data, Statistical process Control is the best tool. From the last 65 to 70 years the Statistical Process Control tools has benefited a lot different processes and have helped them in every possible way due to which the manufacturing cost was minimized. In Statistical process Control, Control charts has has helped a lot to find a defective process or any cause during a process which has detrimental effect on the whole process. Hence an action must be taken to eliminate that cause. Hence Statistical Process Control helps to define the stability and operation of a process that whether that particular process is at its acceptable level or not.

In order to define Statistical Process Control in a simple way,

Statistical Process Control is an important monitoring tool which uses different statistical methods to analyze a process that whether a process is correctly working or not. It manages, monitor and control a process. SPC is such a tool which can be applied to any process that needs to improve and control its variations.

3.3.1 History of SPC

The idea of Statistical Process Control was founded by Dr. Walter Shewart. In 1920,s Dr. Walter Shewart was an employ in the Bell Telephone Laboratories who was working on the task of to lower cost. Dr. Shewart was conducting research to lower the cost of the process and improve the quality. Dr. Shewart hence developed the control concept concerned with variation. During that research Dr. Shewart discovered Statistical Process Control charts and came up with its idea which provided a very simple way that whether a particular process is operating in a good way or not, whether that process is in control or not [17].

Dr. W. Edwards Deming carried on the Shewart's Work on Statistical Process Control and he took that concept of control charts to Japan following WWII. In Japan, The Japanese Industries took that concept and adopted it. After adopting the concept of SPC and Control charts, the quality of Japanese Industry became very high and it also lowered the cost of manufacturing. Hence Dr. Deming became very popular in Japan regarding the Product Quality.

3.3.2 Application of SPC

The applications of SPC are

1. To Understand a Specific Process and it's Specification limits
2. To Eliminate the special cause of variations in order to make the process stable
3. To monitor the current and ongoing manufacturing and production process by using control chats, to detect any significant changes of variation.

3.3.3 Control Charts

Control charts are very important tool regarding the Quality Control. Control charts work in a simple way. They monitor different operating processes to show that whether a process is performing in a correct way or wrong way. Control charts easily determine any defective cause which is affecting the process badly and gives low quality product. So when Control charts identify those causes then those causes are eliminated which results into a better quality. Control charts can identify that whether a process is stable or not.

Stable process is the one which has no defect and the control chart detection rules is not triggered by it. [18]

Control charts are not different from what a simple connected point charts is. All the points there on the charts are plotted on x/y axis. X-axis represents the time. The Plotted point on the chart normally represents the average of subgroups or sometimes ranges of variation between subgroups. A few horizontal lines are also drawn across the charts which show the average measurement and control limits.

3.3.4 Types of Control Charts

Below are the different types of control charts. It has also been explained with every control charts that what is its centerline and also the symbol for that control chart type.

For example the first Row in the following figure says that that the control charts type is Individual. Now the Centerline for Individual chart type is the average of the individual single data values for that baseline chart. The symbol for that individual chart type is X bar.

Control Chart Type	Centerline	Symbol
Individual	The average of the single (individual) data values for the baseline chart	$\bar{x}$ (x bar)
Moving Range	The average of the moving (or rolling) ranges calculated from the chart data	$\overline{MR}$
X-bar	The average of the subgroup averages calculated from the baseline chart data	$\bar{\bar{x}}$ (x double bar)
Range	The average of the subgroup ranges calculated from the baseline chart data	
np	The average of the np's (number good/bad) in each sample group collected for the chart	$\overline{np}$ (np bar)
p	The average of the p's (proportion good/bad) calculated for each sample group in the chart	$\bar{p}$ (p bar)
c	The average of the c's (total number of flaws, defects, occurrences, etc.) in each sample group collected for the chart	$\bar{c}$ (c bar)
u	The average of the u's (average number of flaws, defects, occurrences, etc., per unit) calculated for each sample group	$\bar{u}$ (u bar)

Table 3.1

Below is the xbar chart for quality characteristic in which it is clearly shown that what is Upper limit and what is lower limit. Centerline has also been shown and the outside limits have also been shown here.

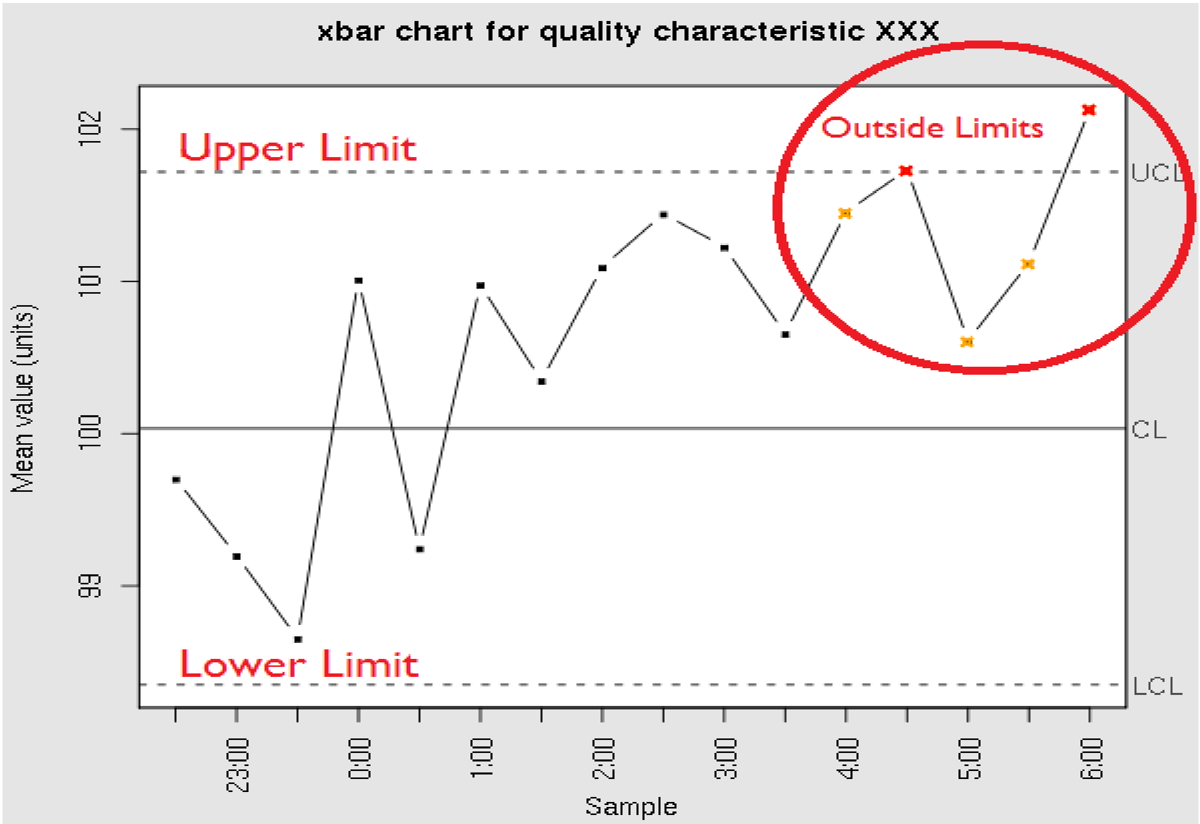


Figure 3.1

Following are different control charts from which we will get a better idea about control charts and its limits, centerline etc.

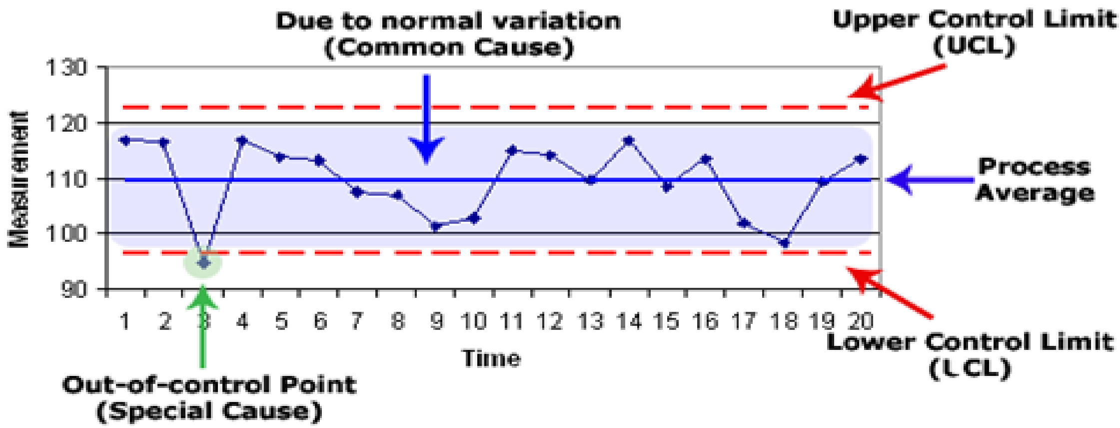


Figure 3.2

Below is the control chart for the threading operation performed in an Industry

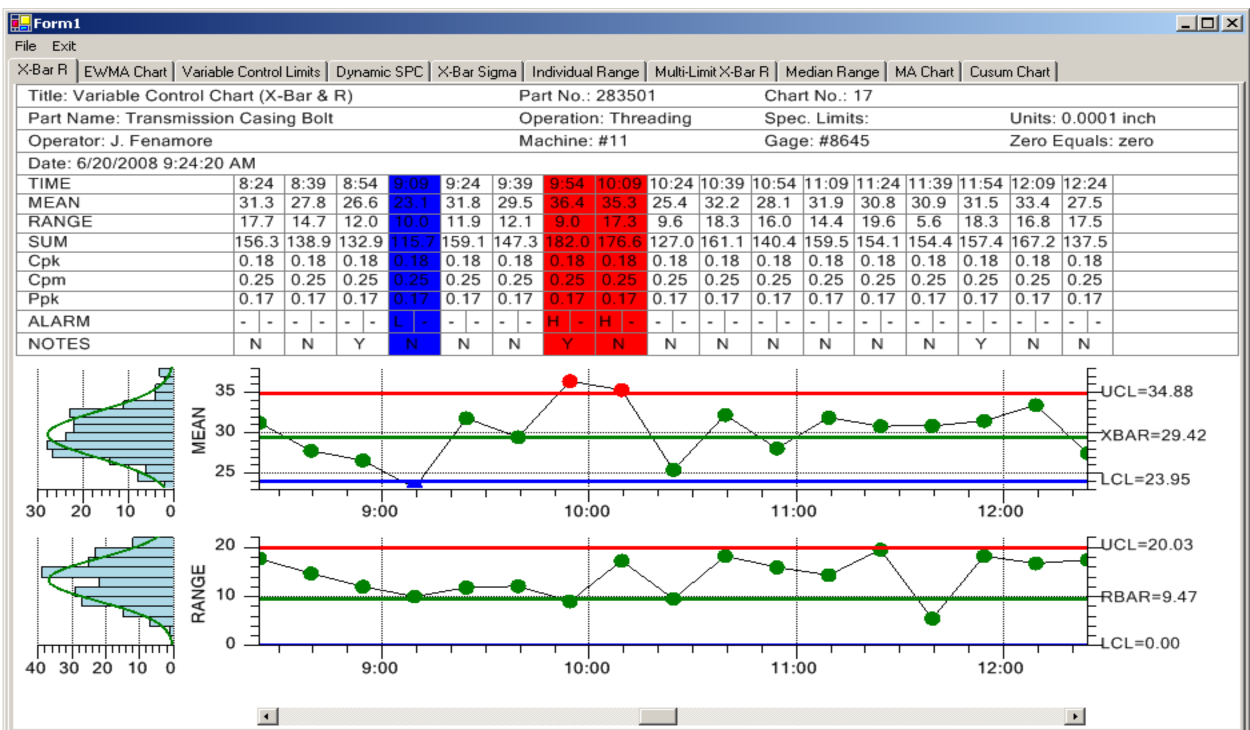


Figure 3.3

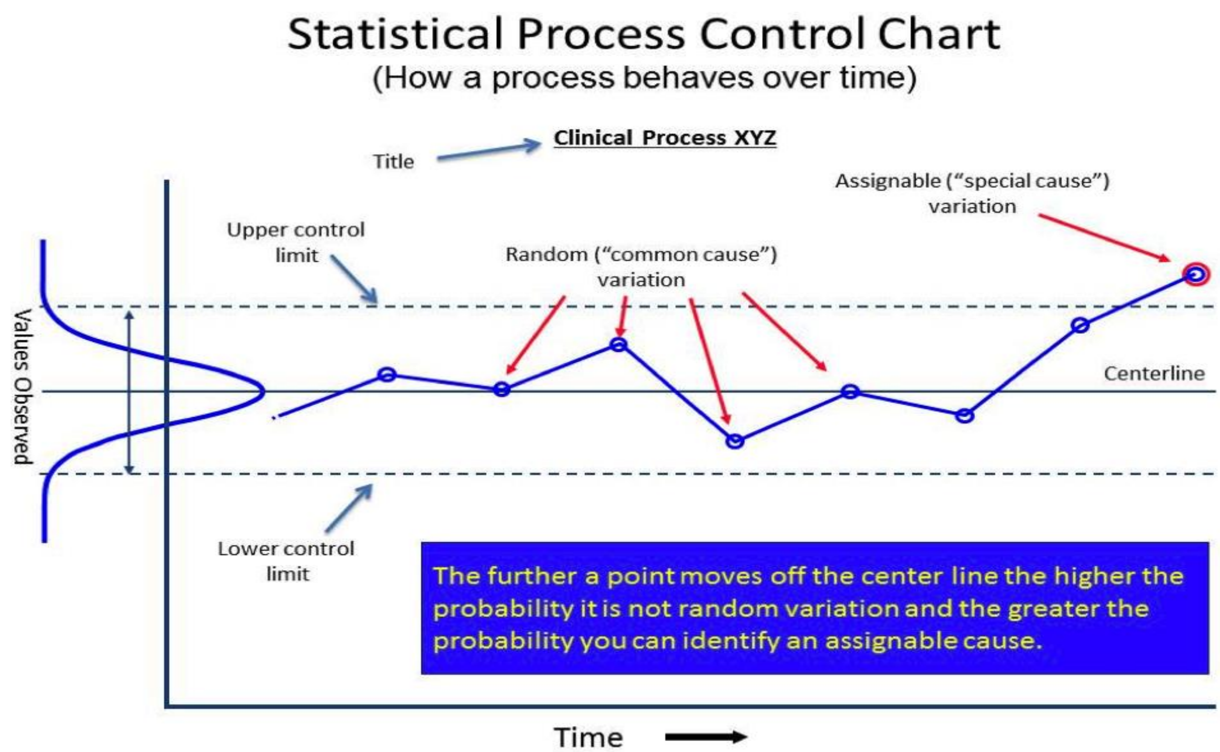


Figure 3.4

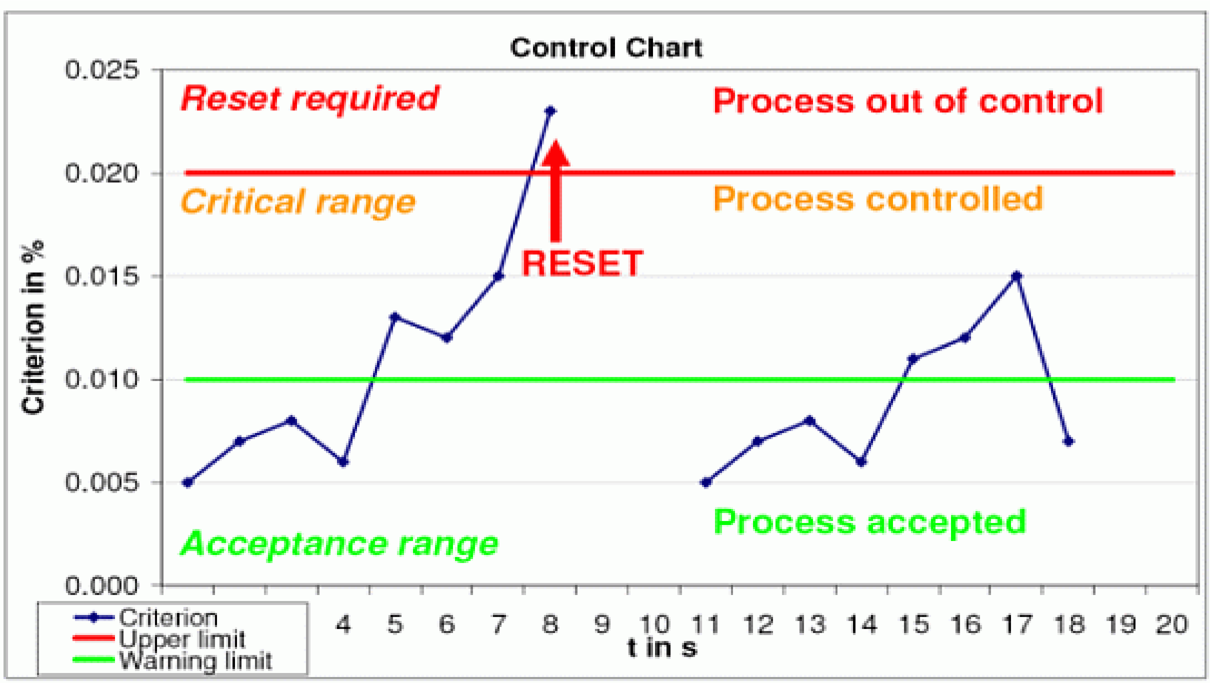


Figure 3.5

There are four steps involved in statistical Process control techniques

1) Plan
2) Do
3) Study
4) Act

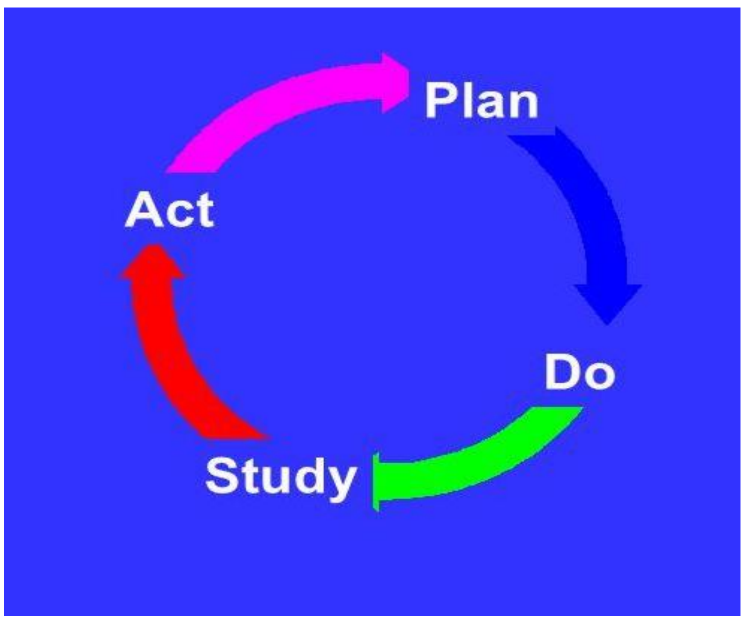


Figure 3.6

There are eight different Specific Statistical Process Control techniques which are used in different organizations to understand better and to help in the improvement of processes. Those eight SPC tools are

1) Check Sheet
2) Cause and Effect Sheet
3) Flow Chart
4) Pareto Chart
5) Scatter Diagram
6) Probability Plot
7) Histogram
8) Control Charts

3.4 Six Sigma

Six Sigma is a long term good business strategy whose main purpose is to reduce the cost by reducing the variability in products and different processes. Six Sigma measures that how much a process has been deviated from perfection. The target of Six Sigma is such that there will be only 3.4 million defects per million opportunities. Six Sigma is a very effective, focused and rigorous technique. The aim of Six Sigma is such that it virtually provides a business which is error free. As the Six Sigma standard is such that it allows only 3.4 defects among 1 million opportunities, hence the customers like it very much. The demands and expectations of customers are increasing for Six Sigma due to its aim of providing error free business. [19]

Six Sigma Projects follow two Project methodologies.

1) DMAIC (Define Measure Analyze Improve Control)
2) DMADV (Define Measure Analyze Design Verify)

- DMAIC is used for such kind of Projects whose main purpose is to improve an existing business Processes.
- DMADV is used for such kind of Projects whose aim is to create new products and to create new process designs.

The proposed project for Six Sigma which we will use here is DMAIC. DMAIC stands for five key Areas. Those five areas on which this Data collection of DMAIC is comprised of are

1. Define
2. Measure
3. Analyze
4. Improve
5. Control

3.4.1 History of Six Sigma

Six Sigma was first approached in the late 1980's in Motorola Company. It was introduced in the Mass Manufacturing environment in that company. It was introduced by Engineer Bill Smith. [20]

The main reason because of which Six Sigma was introduced was that Motorola was struggling to meet the customer demands by manufacturing best quality products. After Bill Smith introduced it in Motorola then Jack Welch took it to General Electric in 1995. GE adopted it whole heartedly and hence it gave better results to GE. Hence the Quality Products of Both Companies i-e Motorola and General Electric was improved a lot and gave much better results in the reduction of cost and also benefited the companies a lot. Both the Companies still consider Six Sigma as the base for their strategic improvement in quality.

Since 1990 Six Sigma has been widely used by different industries for the improvement of their product quality and reducing the cost level. A few companies which use Six Sigma as a strategy for quality improvements are (Allied Signal, Kodak, Honeywell, Sony, Toshiba, Texas Instruments). Other benefits which have been observed for Six Sigma includes improved Processes, quality improvement, short cycle times, increased Stock Price. In the past five years hundreds of different companies and organizations have adopted Six Sigma for their Business Strategy. Apart from that hundreds of companies have shown their interest in adopting Six Sigma.

3.4.2 Why Six Sigma?

Six Sigma has been adopted by hundred of organizations as their Business Strategy. Now the reason behind that Why those organizations have adopted Six Sigma can be summarized as follow in a few points.

1) Six Sigma is adopted by a company to improve its financial performance and to increase the profitability.
2) Six Sigma is adopted by a company to reduce the cost of Poor quality.
3) Six Sigma reduce the amount of wastes which also results in reducing cost.
4) Six Sigma improve Product and Service Performance
5) Six Sigma is adopted so that to be Focused on, To be responsive to, Customers

3.4.3 DMAIC

Those Projects where the processes are needed to be improved and the product quality is to be enhanced so that to satisfy the customers and eliminate the defects which are adversely affecting the quality. In such Projects DMAIC sequence is to be followed.

What is DMAIC sequence?

The Answer to this question is given below by explaining DMAIC a little bit.

1) Define

This step of the DMAIC sequence identify and point out the main steps that are to be much improved. It will also investigate about the needs of customers and their demands for good quality and also will enlighten us about the customer expectations. Along with these it will also specify the project objectives and the time measure for those specific objectives.

2) Measure

This stage gathers and collects information about the existing processes that how well they can achieve those measures which were identified and selected in the define stage.

The issues which have been identified, so this stage also measure the extent of those issues and gather all information about those issues.

3) Analyze

This stage of DMAIC identify or point out those factors which are affecting the process and which have a hand in those problems that were identified and selected in the define stage. This step involves testing and also analysis if it is necessary.

4) Improve

This stage of the DMAIC optimizes the current ongoing process. The factors that were identified in the analyze stage are studied and for the improvement of process those factors are to understand in a better way. It also involves systematic testing like poka yoka or design of experiments so that to bring improvement in the process and eliminate the factors which are affecting the process.

5) Control

This step of DMAIC is used to control the process so that it may not slip back. It ensures that all the factors which are adversely affecting the process have been eliminated or corrected and the process is in control now. It also ensures that the performance of the process will not decrease again and hence it locks in the improvements that have been brought in the process. Any deviations from the target have been corrected and further deviation will not occur again.

Figure 3.7

Five steps in DMAIC Sequence of Six Sigma

3.4.4 Implementation Roles of Six Sigma

For the Successful implementation of Six Sigma, Six Sigma follows few basic key roles which have been described below. [21]

1) Executive Leadership

   Executive Leadership is very essential for the successful implementation of Six Sigma. It involves the CEO and other top management members. Executive's oversight and represent the Six Sigma.

2) Champion

   Champion in Six Sigma is actually the Senior Executive who has the responsibility of implementing Six Sigma in the organization. Champion supports and tries to find resources for the progress of Six Sigma implementation in a best possible way. Champions also mentor the black belts and hence they work as a mentor to black belts. [20]

3) Master Black Belt

   Master Black Belt is the one who is very expert in Six Sigma. There is hardly one Master Black Belt for every thousand employees in a Six Sigma Organization. Champions are the one who identify Master Black Belt. Master Black Belts takes coaching from Champions and then they further guide Black Belts. Master Black Belt has the responsibility of mentoring Six Sigma and also training and other technical processes in Six Sigma. They are fully aware of statistical methods and are excellent in those skills. Master Black Belt must have ASQ Six Sigma Black Belt Certification.

4) Black Belt

Black Belts are the one who are experts in Six Sigma. They manage and operate Six Sigma Projects. Black Belts work under Master Black Belts. Black Belts work to apply Six Sigma methodology and statistical methods to the desired projects. In a Six Sigma organization or company, for every hundred employees there is hardly one black belt. Black Belt course from a good organization is must for the Black Belts to complete that course. Black Belts must always continue their work under the guidance of Master Black belts and they must work hard to get the ASQ Six Sigma Black Belt Certification.

5) Green Belt

Green Belts are the ones who are less qualified than Black Belts. They have less knowledge of Statistical methods than Black Belts. Green Belts work under Black Belts in smaller Projects and when there is a large project then they work along with Black Belts. Green belts must get Green belt course which is ten days training. Green Belts must have or should work hard to get ASQ Six Sigma Green Belt Certification.

6) Process Owner

The Process Owner is the person who works as a Manager of a specific section in the Project. Once the Six Sigma Project is completed then the Process Owner will be responsible for that Process.

7) Six Sigma Team

Six Sigma team consists of the people who work under the supervision of Black Belts in the Six Sigma Project. Six Sigma team is mostly kept small. It hardly consists of six members. Those Six members are selected on the basis of their devotion to work and their statistical knowledge.

Below are a figure and a table from which we can have a much better idea of Six Sigma.

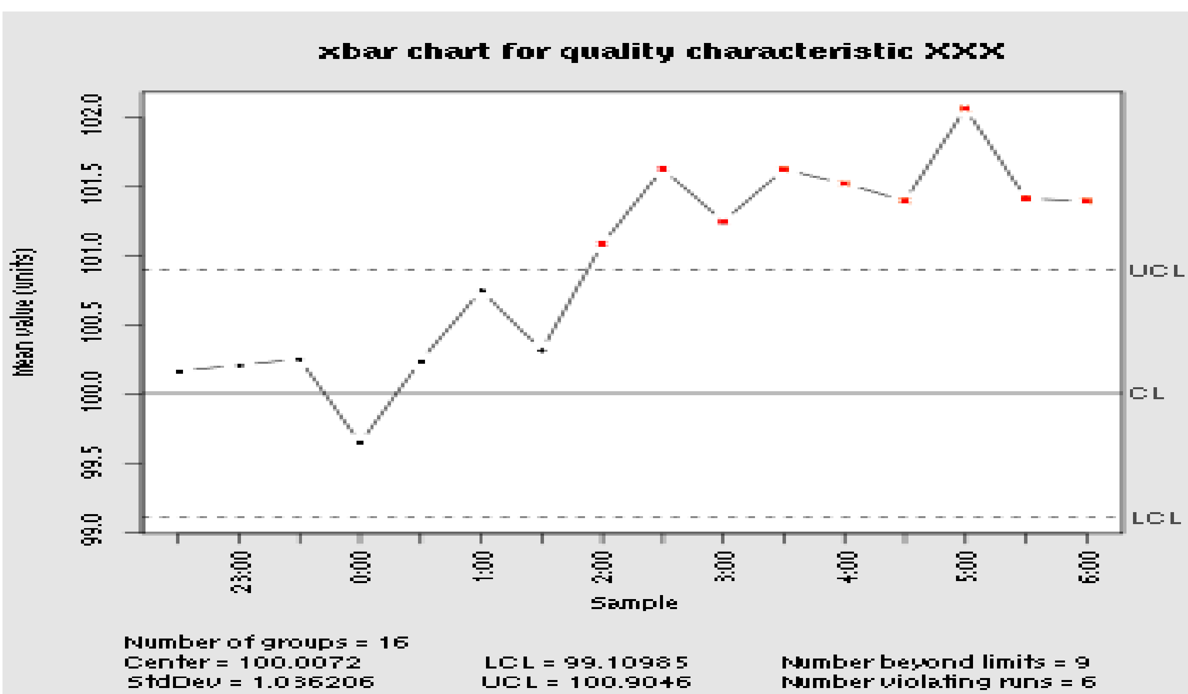


Figure 3.8

This is a control chart which shows a process having 1.5 Sigma drift toward the Upper Specification limit. Control charts are mostly used to give and maintain Six Sigma Quality.

Sigma level	Sigma (with 1.5σ shift)	DPMO	Percent defective	Percentage yield	Short-term C_{pk}	Long-term C_{pk}
1	−0.5	691,462	69%	31%	0.33	−0.17
2	0.5	308,538	31%	69%	0.67	0.17
3	1.5	66,807	6.7%	93.3%	1.00	0.5
4	2.5	6,210	0.62%	99.38%	1.33	0.83
5	3.5	233	0.023%	99.977%	1.67	1.17
6	**4.5**	**3.4**	**0.00034%**	**99.99966%**	**2.00**	**1.5**
7	5.5	0.019	0.0000019%	99.9999981%	2.33	1.83

Table 3.2

3.5 Process Capability

The ability of a process to fulfill the criteria of meeting the required product design or its technical specifications is called Process Capability. In order to conduct the Process Capability it is necessary that process must be normally distributed.

3.5.1 Process Capability Indices

There are two Process Capability indices which give us detail about a process that whether that process is capable or not.

a) **Cp** : Cp is that Process Capability index which tells us about the curve that how smart the curve is

b) **Cpk**: Cpk is that Process Capability Index which tells us about the location and Positioning of a curve.

3.5.2 How to measure Cp and Cpk?

a) Cp

Formula for finding Cp is

$$Cp = \frac{USL - LSL}{6\delta} \qquad (1)$$

USL = Upper Specification Limit

LSL = Lower Specification Limit

6δ = Six Sigma

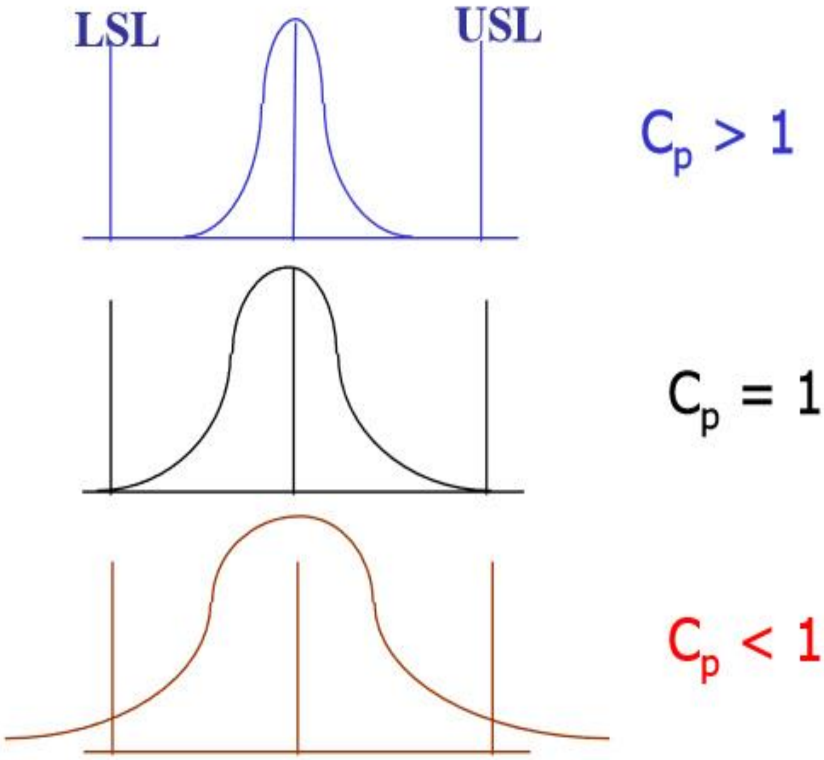


Figure 3.9

Now the question here is that what value of Cp is acceptable?

The answer to this question is given below

If

Cp < 1.0	The Process is Poor
Cp = 1.0	The Process is SO Ok
Cp = 1.3-1.5	The Process is good
Cp = 2.0	The Process is Excellent, that is 6 Sigma

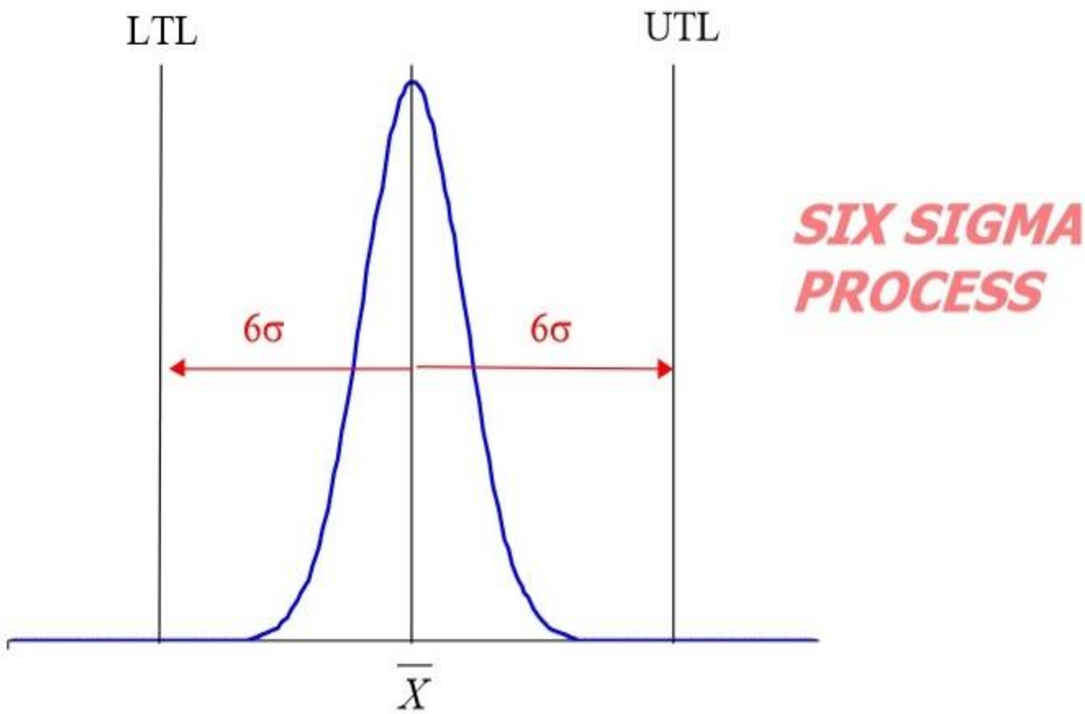


Figure 3.10

$$Cp = \frac{12\sigma}{6\sigma} = 2$$

To have a much better idea about Cp so let us discuss an example studied in the said Industry about Cp from which we will come to know that whether that process is capable or not.

The company is carrying out a manufacturing process which produces a certain part of automobile with a mean diameter of 3 inches and with a standard deviation of 0.04 inches. The upper and lower Engineering specification limits are 2.07 inches and 1.92 inches.

Find out whether the process is capable or not.

The formula which we will use is

$$Cp = \frac{USL - LSL}{6\delta}$$

$$Cp = \frac{2.07 - 1.92}{6(0.03)}$$

$$Cp = \frac{0.15}{0.18} = 0.833$$

As Cp < 1, Hence Process is not a capable Process

b) Cpk

Formula for finding Cpk is

$$Cpk = \min\left[\frac{\bar{X} - LSL}{3\sigma}, \frac{USL - \bar{X}}{3\sigma}\right] \quad (2)$$

$\bar{X}$ = Mean diameter of the specific part

LSL = Lower Specification Limit

USL = Upper Specification Limit

σ = Standard deviation of the process

As we had told earlier that Cpk tells us about the position or location of curve, so the following chart will explain the above sentence in detail.

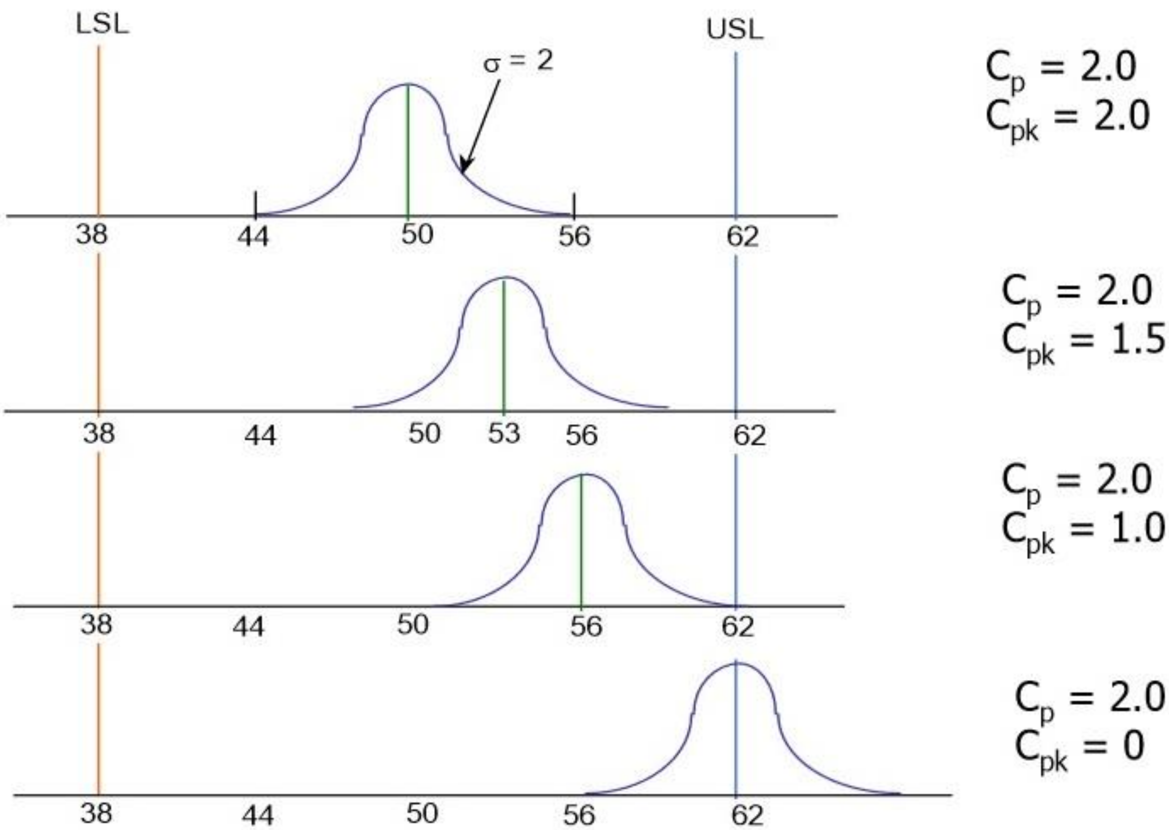


Figure 3.11

In the above chart the process is Six Sigma as we can see that Cp = 2. And whenever Cp =2 so that process will be Six Sigma.

In the First chart the value of Cpk is 2.0 which is equal to Cp. We can see the location of curve that where it is.

- When Cp = Cpk so that Process is centred.
- When Cpk < Cp so that Process is Off-Centred which can be seen in above chart.

In the Second chart the value of Cpk is 1.5 which is less than 2.0, Hence the curve location has changed a bit and has shifted towards right a bit.

In the Third chart the value of Cpk is 1.0, hence the curve position has changed again and shifted towards right a bit more.

In the Fourth Chart the value of Cpk is 0, hence curve position has changed and further shifted towards the right.

To have a clear idea about the value of Cpk, let us explain an example again in term of Cpk.

- The company is carrying out a manufacturing process which produces a certain part of automobile with a mean diameter of 2 inches and with a standard deviation of 0.04 inches. The upper and lower Engineering specification limits are 2.07 inches and 1.92 inches.

Find out whether the process is capable or not. Also find out the position of Curve.

The Formula for finding Cpk which we will use here is

$$\text{Cpk} = \min\left[\frac{\bar{X}-LSL}{3\sigma}, \frac{USL-\bar{X}}{3\sigma}\right]$$

$$\text{Cpk} = \min\left[\frac{2-1.92}{3(0.04)}, \frac{2.07-2}{3(0.04)}\right]$$

Cpk = min [0.08/0.12, 0.07/0.12]

Cpk = min [0.667, 0.58]

Cpk = 0.58

Hence the process is not capable. Also the value of Cpk shows that the Process mean is not on target.

Both Cp and Cpk indexes together provides us information about the process that how it is performing with respect to the specification limits.

In the above formulas Specification limits such as LCL and UCL have been used.

If we don't have any idea that what's the value of UCL and LCL so we can use different formulas to find UCL and LCL. Those formulas are given below

To find Upper Specification Limit (UCL)

$$UCL = \bar{\bar{X}} + Z\,\delta_x \qquad (3)$$

To find Lower Specification Limit (LCL)

$$LCL = \bar{\bar{X}} - Z\,\delta_x \qquad (4)$$

Where

Z= Standard Normal Variable (which is 2 if the confidence is 95.44%, 3 if the confidence is 99.74%)

δ_x= It is the standard deviation of the sample means distribution which is computed as $\delta/\sqrt{n}$

δ= It is the Process standard deviation

n= Sample size

We can also use the following formulas to find UCL and LCL [22]

$$UCL = \bar{\bar{X}} + A_2 \bar{R} \qquad (5)$$

$$LCL = \bar{\bar{X}} - A_2 \bar{R} \qquad (6)$$

Where

- $\bar{\bar{X}}$ = Average of the sample means
- $\bar{R}$ = Average range of the samples
- A_2 = Factor which can be obtained from the following table

UCL and LCL for Range R chart can also be find out by using following formulas

$$UCL_R = D_4 \times \bar{R} \qquad (7)$$

$$LCL_R = D_3 \times \bar{R} \qquad (8)$$

In the above formulas A_2, D_3, D_4 depends on sample size n.

A_2, D_3, D_4 will be given in the following table from where we can write down its value

Sample Size n	Factor for $\bar{x}$-Chart	Factors for R-Chart	
	A_2	D_3	D_4
2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78
11	0.29	0.26	1.74
12	0.27	0.28	1.72
13	0.25	0.31	1.69
14	0.24	0.33	1.67
15	0.22	0.35	1.65
16	0.21	0.36	1.64
17	0.20	0.38	1.62
18	0.19	0.39	1.61
19	0.19	0.40	1.60
20	0.18	0.41	1.59
21	0.17	0.43	1.58
22	0.17	0.43	1.57
23	0.16	0.44	1.56
24	0.16	0.45	1.55
25	0.15	0.46	1.54

Table 3.3

Hence from the above table we can easily have sample size n, A_2, $D_{3,}$ D_4

UCL and LCL can also be find out by the following formulas

$$UCL = \bar{\bar{X}} + A_2 R \qquad (9)$$

$$LCL = \bar{\bar{X}} - A_2 R \qquad (10)$$

- $\bar{X}$ is the average or mean of a sample
- R is the Range

In order to find out $\bar{X}$, $\bar{\bar{X}}$, $\bar{R}$ we use the following formulas

$$\overline{X} = \frac{X1 + X2 + X3 + X4}{4} \qquad (11)$$

Where n is the sample size which is 4 in this case

Similarly for Mean or Average of samples that is $\overline{\overline{X}}$

$$\overline{\overline{X}} = \sum \frac{\overline{x_1 + ---------- + x_k}}{K} \qquad (12)$$

Where K is the number of total subgroups

Average Range that is $\overline{R}$ can be calculated as

$$\overline{R} = \sum \frac{R_1 ----------- R_k}{K} \qquad (13)$$

$$\text{Range} = X_{max} - X_{min} \qquad (14)$$

Chapter – IV Data and Analysis

4.1 Introduction to Chapter

In this chapter all the Industrial work which is done will be explained in detail. The data which has been collected from the Industry will be written in detail here in this chapter. This chapter will explain in detail that how the data was collected and what type of data was collected from the Industry. Further this chapter will explain that how that collectable data was brought into use and how the results were manipulated in enhancing the quality improvement by using the Six Sigma as a tool of Statistical Process Control.

As the methodology which I am using is DMAIC which is shown as

1) Define
2) Measure
3) Analyze
4) Improve
5) Control

So according to DMAIC methodology a complete detail about my work is shown below but before that a detail about different sections of the Industry is necessary so that to understand the methodology better after that.

4.2 Sections in Industry

There are three sections of the industry

1) Foundry
2) Machining
3) Production

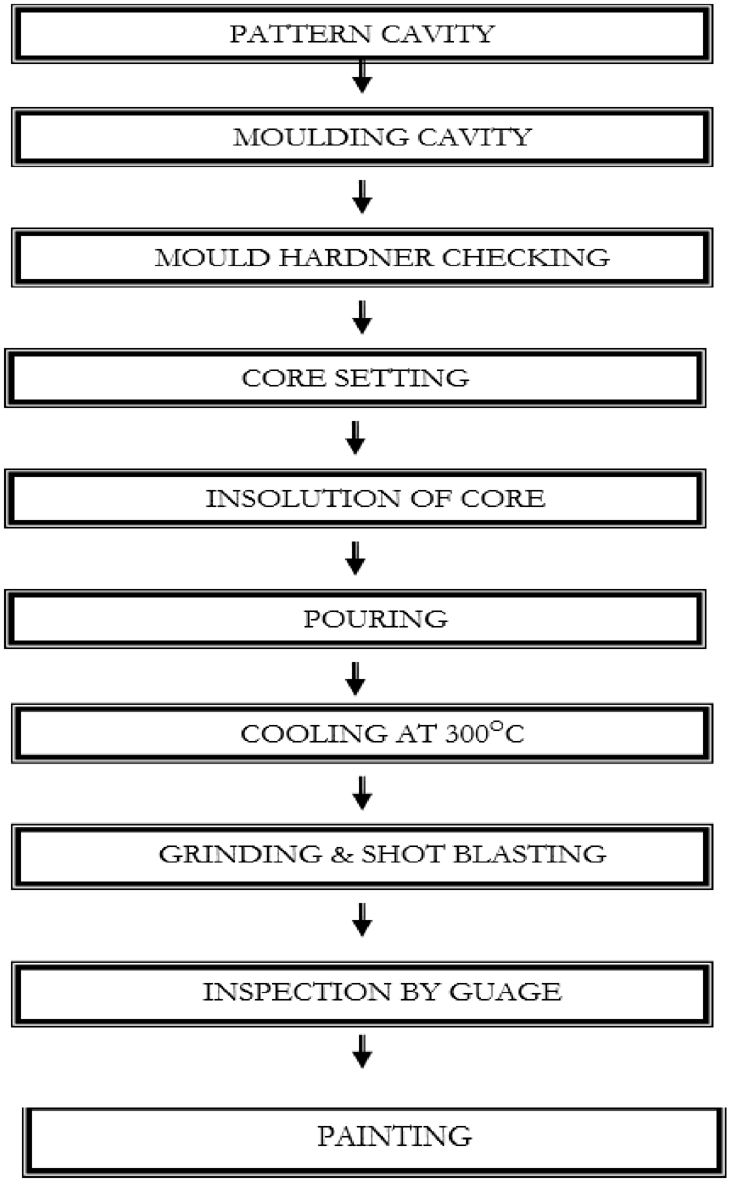
4.2.1 Foundry [23]

Foundry is that section of the industry where the metals for different parts are cast into shapes. Now how this casting is done here. First the metals are melted into liquid form and after that they are poured into a mold. Once it cools and the metal get solidified so then the mold material is removed. Parts of different shapes and of a desired frame are formed here.

The whole casting process which occurs in Foundry shop consists of following steps.

1) Melting
2) Furnace
3) Degassing
4) Mold Making
5) Pouring
6) Shakeout
7) Debating
8) Heat treating
9) Surface Cleaning
10) Finishing

Process flow:



1. Melting

2. Pouring

3. Molding

4. Knockout

Salient Features

- **Steel Scrap**
- Foundry Return
- Ferro Alloys
- Thermal Analysis
- **Spectro Analysis**
- Wedge Control
- Temperature Measurement

Salient Features

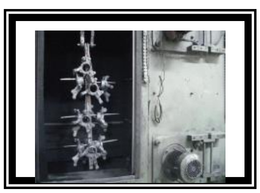
- Time Control
- **Spectro Analysis**
- Impact & UTS sample casting
- Pouring through MAGMA Software calculated gating system

Salient Features

- Sand control
  - Compactibility
  - Permeability
  - Moisture
  - Compression Strength
  - Splitting Strength
- Mould Hardness
- Visual Inspection

Salient Features

- Punch Out
- De-gating



5. Shot Blasting

6. Grinding

7. Painting

8. Testing

Salient Features

- Sand Removal
- Time Control
- Visual Inspection

Salient Features

- Visual Inspection

Salient Features

- Visual Inspection

Salient Features

- UTS & Elongation
- **Micro Structure**
- **Impact at -30C**
- Nodularity
- Hardness
- Ultra Sonic
- Destructive Testing

Figure 4.1

For a wheel Hub a whole Casting Process has been shown below in a Flow Chart

FOUNDRY PROCESS CHART HIGH PRESSURE MOULDING LINE HEINRICH WAGNER SINTO (H.W.S)-Wheel Hub

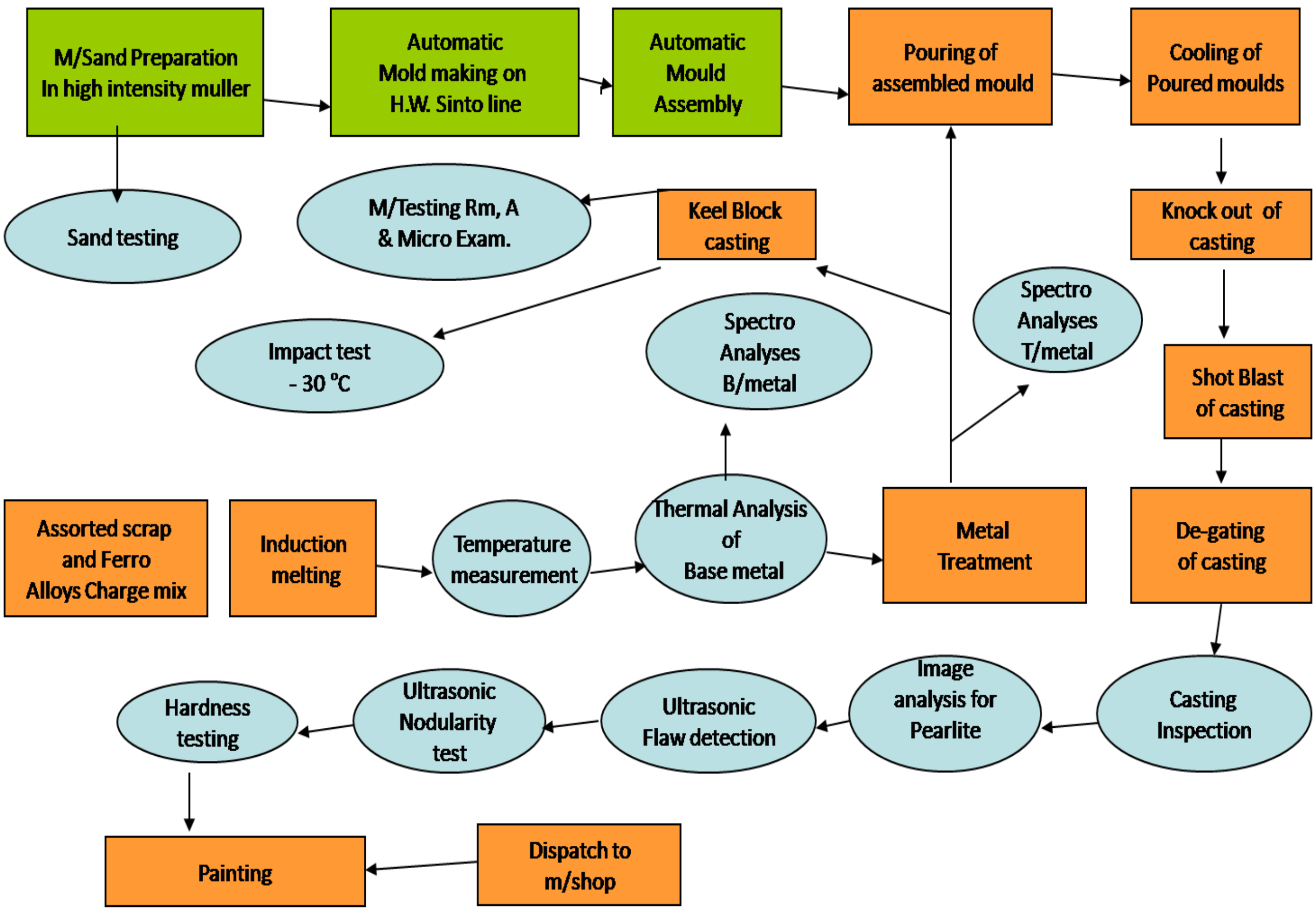


Figure 4.2

4.2.2 Machining [24]

Machine shop in industry is like a building. Here machining of different parts is done. Expert in Machining are there in Machine shop which use different cutting tools and machine tools to make parts. The parts which are produced here are the end product. It means that those parts are almost ready to be shift or to be sold to customers. Different machine tools which are used in machine shop are

1) Lathe Machines
2) Milling Machines
3) Drill Presses
4) Grinding Machines

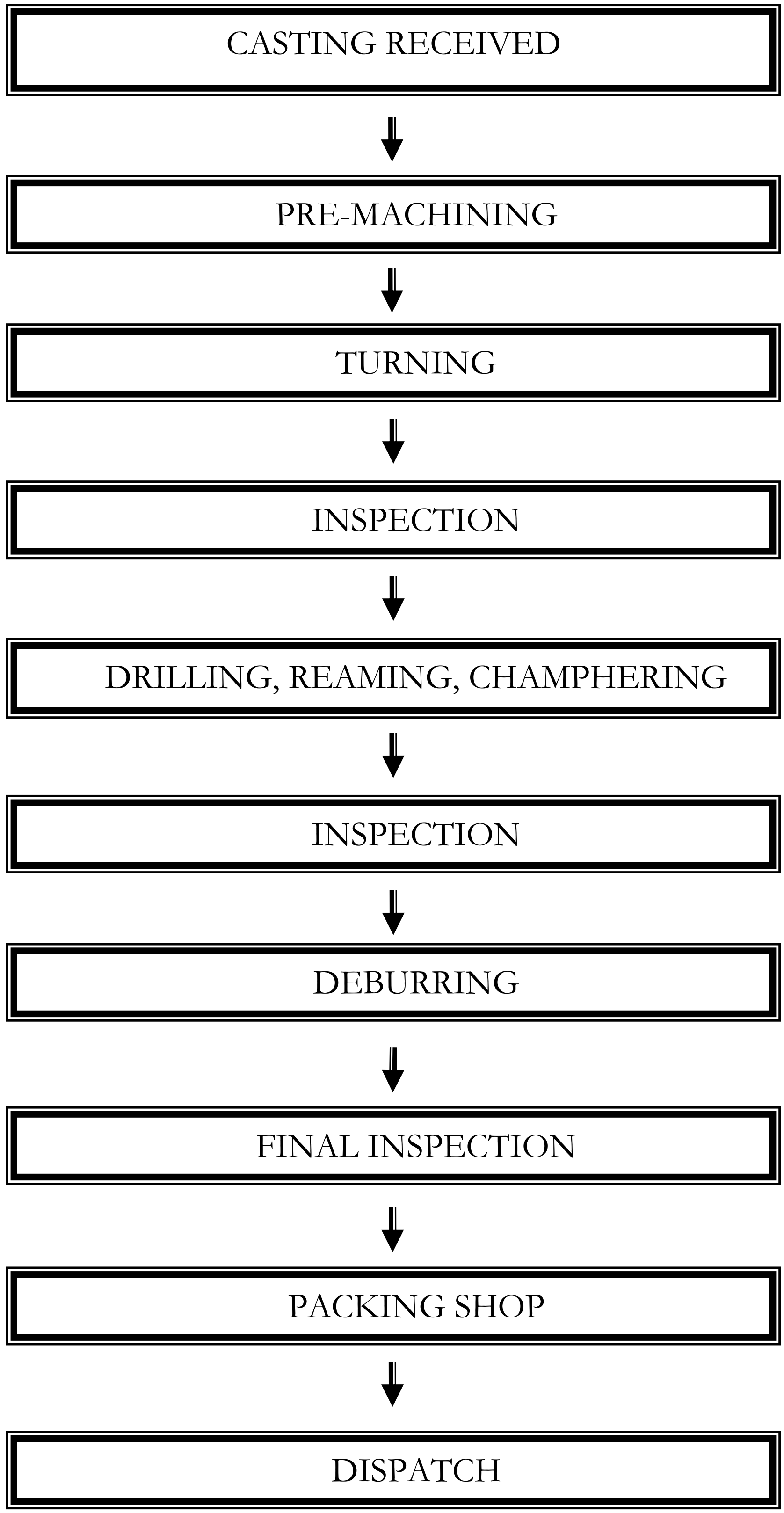
Etc

Similarly the types of Processes which occur in a machine shop are

1) Cutting
2) Boring
3) Milling
4) Drilling
5) Shearing
6) Binding
7) Grinding

Etc

Process Flow of Machining Process:



S. NO	Process	Salient Features	Work Element	Machine Parameters
1	Premachining 1st operation	Rough Facing & Turning	Lathe Machine	Feed Rate 0.2mm & 1.5mm Cutting Speed 260 RPM Sharp Tool Tip
2	Premachining 2nd operation	Back side turning & Rough Facing	Lathe Machine	Feed rate 0.2mm Cutting speed 260 RPM Sharp Cutting Tool Tip
3	Turning 1st operation	Final facing Turning Boring	Puma 550 ECO	Feed Rate 0.3mm Spindle Speed 500 RPM Sharp Cutting Tool Tip
4	Turning 2nd operation	Final slot Turning	Puma 550 ECO	Feed Rate 0.3mm Spindle Speed 500 RPM Sharp Cutting Tool Tip
5	Inspection	Inspect the size of Turning operations	Calibrated Measuring Instruments	
6	Drilling, Reaming, Champhering	Drilling, Reaming, Champhering & Taping	V 430 FV 001	Feed Rate 0.3mm Spindle Speed 500 RPM Sharp Cutting Tool Tip
7	Inspection	Inspect the size of Drilling Inspection	Calibrated Measuring Instruments	Calibration 360 Mandrel Zero Position Weight 10 g/cm checked
8	Debarring	Remove the sharp edges	Debarring Tools	Drilled Balancing Dia
9	Final Inspection	Inspection of all sizes mention in drawing	Calibrated Measuring Instruments	

4.2.3 Production [25]

Production is that section of the industry where Planning of Production is carried out.

Production planning is like a plan for the upcoming or future production. For that future production the facilities which are needed are pointed out and are arranged as soon as possible by the staff. What actually is done in a planning Horizon? It is shown as below.

- To determine the required product mix
- To determine the factory load so that to satisfy the needs of customers
- To match for the existing customers the required level of production
- To schedule that when the actual work is going to start in the manufacturing facility
- To choose which type of work is going be carried out first
- Completing and then delivering different production orders to the production facilities

There are different types of production such as Batch Production, Single item manufacturing, continuous production, Mass production; all these have different production planning.

Production control is also combined with production panning sometimes and together they are called as Production planning and control.

Production planning staff must work closely with marketing staff to develop production plans because marketing department can provide them the sales forecast and also the list of customer orders. And Production planning is different for different types of productions.

So above was a bit introduction about different sections of the Industry so that to understand the methodology better.

Now after writing about different sections of the industry we'll write down in complete about the Methodology in step wise that what we needed to find and what we did to achieve our Goal.

4.3 Methodology

4.3.1 Define Phase

In define phase we'll write about the Goal of the project that actually what's our main goal. What we have to achieve in our research.

The goal of the project has been defined in bullet form to understand it easily as

- To reduce the defect rate of the parts manufactured in Foundry and Machining department
- To reduce the operational cost in Foundry department because of those parts
- To take preventive actions to reduce the defect rate of the parts in Machining department

4.3.2 Measure Phase

After defining the Goal of Project, We started to collect data of the Foundry and Machining Processes in detail So that to measure the Rejection rate that how much parts are being rejected monthly and how much is the Rejection cost because of those Parts.

But to measure the rejection rate first we need to discuss about Foundry and Machining sections of the Industry in detail that what type of processes are performed there and how it works in making a specific part.

Now we will write down the part wise rejection report of foundry. This Report is from the month of March to April and then we will carry out its cost analysis using Excel.

For the Month of March the Part wise Rejection report is

Part-Wise Rejection Report for the Month of March 2014

Serial No	Label -- Part Name	Units Checked	Units Passed	Units Rejected	Rejection %	Unit weight Kg	Total Passed Casting Weight Kgs	Total Rejected Casting Wieght Kgs	Cost of Rejection @ Rs. 120 per kg
1	D--Wheel Hub-9348PA	9017	8892	125	1.39%	22.26	99999.99	2782.5	333,900
2	U--Wheel Hub Bedford 4725	1164	1060	104	8.93%	18.22	19313.2	1894.88	227,386
3	Q--Hitch Plate 8867 -- Body	4030	3610	420	10.42%	3.66	13212.6	1537.2	184,464
4	a--Steering Knuckle(Right) 43211	4645	4379	266	5.73%	4.62	20230.98	1228.92	147,470
5	E--Wheel Hub-AP286	183	153	30	16.39%	31.18	4770.54	935.4	112,248
6	M--Planetary Carrier-PMT586	1794	1739	55	3.07%	16.55	28780.45	910.25	109,230
7	b--Steering Knuckle(Left) 43212-	5392	5256	136	2.52%	4.62	24282.72	628.32	75,398
8	S--ABS rings	3321	3260	61	1.84%	6.5	21190	396.5	47,580
9	m--Brake Drum 37101	145	131	14	9.66%	27.4	3589.4	383.6	46,032
10	A--Wheel Hub-HP2830	108	94	14	12.96%	27.1	2547.4	379.4	45,528
11	k--Body Hydraulic Pump	1281	1212	69	5.39%	4.78	5793.36	329.82	39,578
12	i--Piston Hyd.Pump(192-269HB)	1671	1301	370	22.14%	0.87	1131.87	321.9	38,628
13	j--1868736M1 Valve Chamber	1836	1678	158	8.61%	1.91	3204.98	301.78	36,214
14	F--Wheel Hub-AP051	33	25	8	24.24%	32.5	812.5	260	31,200
15	I--Brake Drum-PEAK-8805	559	529	30	5.37%	8.63	4565.27	258.9	31,068
16	K--Brake Drum-PEAK-8858	672	631	41	6.10%	5.9	3722.9	241.9	29,028
17	B--Wheel Hub-ISU128Z	169	161	8	4.73%	26.13	4206.93	209.04	25,085
18	O--Planetary Carrier-PMT404	1223	1171	52	4.25%	3.63	4250.73	188.76	22,651
19	n--Wheel Hub 89139-835-0	277	272	5	1.81%	32	8704	160	19,200
20	C--Wheel Hub-ISU1040	100	95	5	5.00%	30.85	2930.75	154.25	18,510
21	l--Body Hyd Pump 1665500M1-F	1254	1199	55	4.39%	2.58	3093.42	141.9	17,028
22	o--WH1-42312-143-1	220	215	5	2.27%	27	5805	135	16,200
23	V--Wheel Hub-HP2231	72	68	4	5.56%	33.43	2273.24	133.72	16,046
24	H--Wheel Hub-PEAK-TR-505	1183	1081	102	8.62%	1.3	1405.3	132.6	15,912
25	T--Hitch Plate 8867 -- Handle	3812	3512	300	7.87%	0.4	1404.8	120	14,400
26	c--Brake Drum-HP37130	175	170	5	2.86%	23.84	4052.8	119.2	14,304
27	N--Planetary Carrier-PMT587	887	864	23	2.59%	4.35	3758.4	100.05	12,006
28	X--Wheel Hub - HP 37170	140	134	6	4.29%	15.16	2031.44	90.96	10,915
29	J--Brake Drum-PEAK-8823	78	72	6	7.69%	12.1	871.2	72.6	8,712
30	Z--Wheel Hub-1631PA	263	260	3	1.14%	23.9	6214	71.7	8,604
31	W--Wheel Hub - HP 37040	150	148	2	1.33%	20	2960	40	4,800
32	f--BKT CAB HINGE RH 51701-3	243	235	8	3.29%	4.6	1081	36.8	4,416
33	Y--WH-3453-1201	116	115	1	0.86%	36.54	4202.1	36.54	4,385
34	G--Wheel Hub-AP052	4	3	1	25.00%	29.5	88.5	29.5	3,540
35	e--BKT CAB HINGE LH 51702-3	217	214	3	1.38%	5.2	1112.8	15.6	1,872
36	h--Stay Fan Housing 11356-1120	151	148	3	1.99%	4.6	680.8	13.8	1,656
37	d--Wheel Hub-F55604	298	297	1	0.34%	7.96	2364.12	7.96	955
38	R--Hitch Plate 8867 -- Plunger	4121	4116	5	0.12%	0.2	823.2	1	120
39	g--Stay Fan Housing 11356-1110	153	153	0	0.00%	4.4	673.2	0	-
40	L--Brake Drum-PEAK-8888	8	8	0	0.00%	8.4	67.2	0	-
41	P--Wheel Hub-AP857	2	2	0	0.00%	26.9	53.8	0	-
42	p--Wheel -Hub Richard-935K	12	12	0	0.00%	27.63	331.56	0	-
								Total	1,776,270.00

Table 4.1

We have focussed on the Part Wheel Hub Bedford-4725 which is a wheel hub of a Mini Truck.

- Complete detail of the Part Wheel Hub Bedford 4725 for the month of March 2014

Units Checked = 1164

Figure 4.3

Units Passed = 1060

Unites Rejected = 104

Rejection % = 8.93%

Cost of Rejection = 227,386 PKR

From the Foundry Shop the number of Parts which came to Machine shop are = 1060

Process function	Defect Mode	Effect of defect	Detection
Turning Ist Operation	Bore Over Size	Reject	2
	Bore Under size	Reject	2
	Outer Dia undersize	Reject	2
	Outer Dia oversize	Reject	3
Turning 2nd Operation	Thickness undersize	Reject	1
	Hole Oversize	Reject	1
	Hole Undersize	Reject	2
Drilling Full Operation	Thickness undersize	Reject	3
	Tap oversize	Reject	2
	Tap Broken	Reject	1
	Hole over size	Reject	2
	Pad(land) tear out	Reject	2
	Hole wall fractures	Reject	1
Debarring	Edges sharp	Reject	1
			Total = 25

Hence total number of parts which rejected in machine shop out of 1060 was 25

Six Sigma Level For the month of March in Foundry:

The formula to find Six Sigma level is [26]

$$\text{DPMO} = \frac{(\text{Number of Defects X 1,000,000})}{((\text{Number of Defect Opportunities/Unit}) \times \text{Number of Units})}$$

- For the month of March the number of Wheel Hub parts which was produced in the Foundry shop was 1164. 8 individual checks were performed to test quality of the parts. During testing 104 parts were rejected.

Defects: 104

Opportunities: 1164

Defect opportunities per unit: 8

Putting the values in above formula we get

DPMO = 11,168

Sigma Level = 3.78

4.3.3 Analyze Phase

In Analyze phase we will write down about all the problems because of which the rejection of the parts occurred.

The Problems because of which the rejection of the part occurred are

1) Sand inclusion

2) Cold shut

3) Mold shift

4) Porosity

5) Core blow

6) |===Other===|

7) Mould broken

8) Core shift

9) Short poured

10) Rough surface

11) Fettling Fault

12) Blow hole

13) Mould leak

14) Core broken

15) Out Casting

16) Casting short

17) Hard

1. **Sand Inclusion:**

Also called Sand hole which form irregularly close to the casting surface.

Figure 4.4

Causes:

Betonite content low (7.5%)

Pouring time too long

Core mismatching

Movement of Mould not smooth

2. **Cold Shut**

The freezing of liquid metal surface during the pouring of casting due to improper pouring

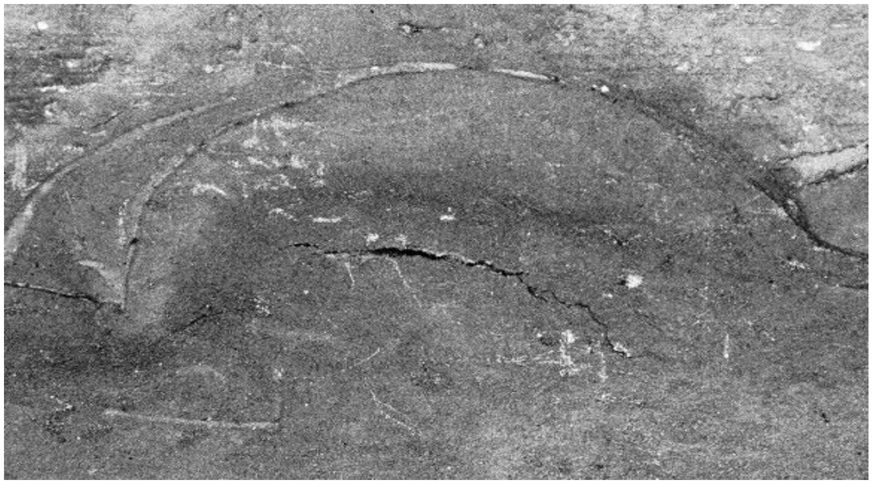


Figure 4.5

Causes:

Lack of Fluidity in molten metal

Faulty design

3. **Mold Shift**

It results in a mismatching of the top and bottom parts of the casting usually at parting line

Figure 4.6

Causes:

Carelessness of the operators

Cope and Drag not in proper

Position

Loose box pins

4. **Porosity**

Formation of bubbles within the casting after it has cooled.

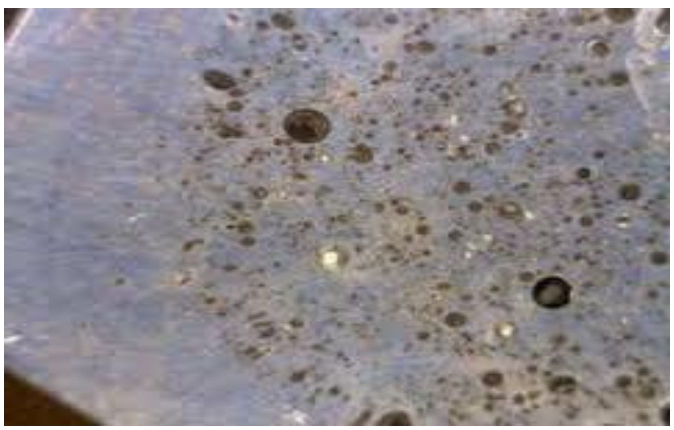


Figure 4.7

5. **Other:**

Hammering by mistake

In gate broken by mistake

6. **Out Casting:**

Mismatch of the pattern

Causes: Loose Box Pins, Carelessness

7. **Core Broken**

Cavity not properly generated due to which core break

8. **Shot Poured:**

The upper portion of the casting is missing

Cause:

Insufficient quantity of liquid metal in the ladle

Figure 4.8

9. **Fettling fault :**

Proper Removal of Unwanted metal not done

Cause:

Grinding not occurred properly

Figure 4.9

10. **Blow Holes:**

A group of cavities which is mostly large in size

Causes:

Moisture content too high

Betonite too high

Compaction of the mould too high

Figure 4.10

Now the number of parts rejected because of each defect along with percentage has written below in the form of a table which will give us a clear picture about the number of parts rejected.

S#	Defect	No. of Parts	Percentage %
1	Sand inclusion	29	2.52%
2	Cold shut	25	2.12%
3	Mold shift	9	0.73%
4	Porosity	8	0.68%
5	Core blow	7	0.61%
6	|===Other===|	6	0.51%
7	Mould broken	5	0.49%
8	Core shift	4	0.37%
9	Short poured	4	0.30%
10	Rough surface	3	0.28%
11	Fetling Fault	1	0.11%
12	Blow hole	1	0.10%
13	Mould leak	1	0.05%
14	Core broken	1	0.05%
15	Out Casting		0.02%
16	Casting short		0.00%
17	Hard		0.00%
	Totals	**104**	**8.93%**

Table 4.2

Pareto Chart Analysis for the Month of March according to this table is drawn which is shown below

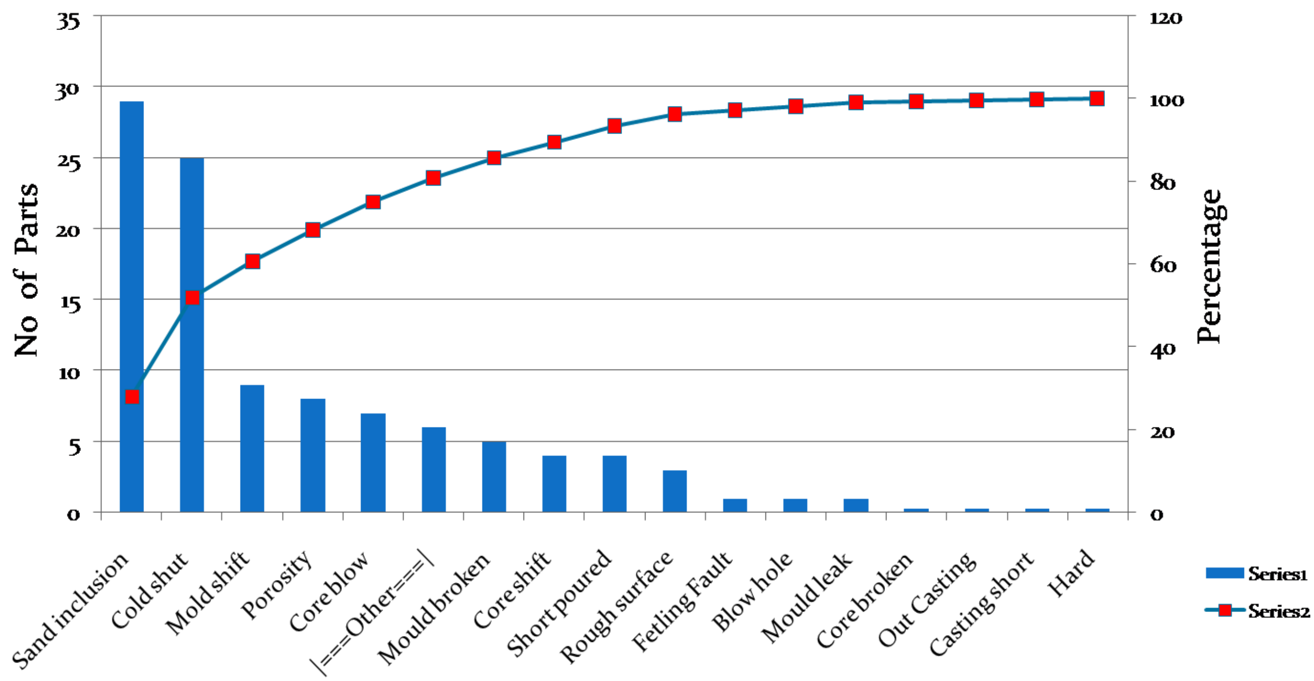


Figure 4.11

Figure 4.12

Defective Wheel Hubs which have been rejected

Rejection Report for Wheel Hub in Machining Process:

From the Foundry Shop the number of Parts which came to Machine shop are = 1060

Machining Process which were performed on these 1060 parts are

1) Pre-Machining
2) Turning 1st Operation
3) Turning 2nd Operation
4) Drilling Full Operation
5) Deburring

The problems because of which the rejection of the parts has been occurred in machine shop are written below in the form of a chart so that to understand that which problem occurred in which process.

Process function	Defect Mode	Effect of defect	Cause of Defect	Detection
Turning Ist Operation	Bore Over Size	Reject	Inserts Broken	2
	Bore Under size	Reject	Operator Mistake	2
	Outer Dia undersize	Reject	Operator Mistake	2
	Outer Dia oversize	Reject	Operator Mistake	3
Turning 2nd Operation	Thickness undersize	Reject	Tool problem	1
	Hole Oversize	Reject	Insert Broken	1
	Hole Undersize	Reject	Tool Problem	2
Drilling Full Operation	Thickness undersize	Reject	loose insert	3
	Tap oversize	Reject	Tool holder problem	2
	Tap Broken	Reject	Machine problem	1
	Hole over size	Reject	Incorrect Spindle RPM	2
	Pad(land) tear out	Reject	Excessive Head during drilling process	2
	Hole wall fractures	Reject	Excessive heat and Mechanical stress created	1
Debarring	Edges sharp	Reject	Operator Mistake	1
			Total Rejections	25

4.3.4 Improvement Phase

In Improvement Phase it is written that what necessary actions were carried out in order to remove the defects and reduce the rejection rate of the parts.

So the Necessary actions which were carried out to bring improvement in the product quality and reduce the rejection rate of the parts are

1) Sand Inclusion and Blow Holes [27]

a) Control Sand Properties (2-5 % water,5% carbonaceous coal, 85-90 % silica)

b) Adjust Betonite as 8-10 %

c) Instruction to the operators to properly clean mould

d) Movement of mould should be smooth

e) Compaction of mold should be done at 210 bar

2) Cold Shut [28]

Adjust proper pouring temperature (1450-1510 °c)

3) Mold Shift

a) Check pattern mounting on match plate

b) Use proper molding box and closing pins

4) Porosity

1) Increase metal pouring temperature (1450-1510 °c)

2) Pour metal as rapidly as possible (2-3 mins)

3) Remove slag from metal surface

5) Poured Short

Have sufficient metal in the ladle to fill the mould so that to avoid the poured short defect

6) Fettling Fault:

Smooth grinding must be performed so that to remove the unwanted metal properly because of which the fettling fault occur

7) Other:

Instruction to the operators were given to be careful with the parts so that hammering or in gate broken mistakes doesn't occur

8) Out Casting

a) Box Pins Should be tight properly

a) Use proper molding box

After taking the preventive actions in Improvement phase, the effect of those preventive actions on the rejection of the parts has been noticed which is written below so that we get to know that what the Rejection report of the parts was before taking preventive actions and after taking preventive actions?

For the month of April the Rejection report is

Part-Wise Rejection Report for the Month of April 2014

Serial No	Label -- Part Name	Units Checked	Units Passed	Units Rejected	Rejection %	Unit weight Kg	Total Passed Casting Weight	Total Rejected Casting Wieght	Cost of Rejection @ Rs. 120 per kg
1	G--Wheel Hub-9348PA	6724	6548	176	2.62%	22.26	99999.99	3917.76	470,131
2	P--Hitch Plate 8867 -- Body	3495	3028	467	13.36%	3.66	11082.48	1709.22	205,106
3	c--Steering Knuckle(Right) 43211-	3936	3748	188	4.78%	4.62	17315.76	868.56	104,227
4	V--Wheel Hub Bedford 4725	599	565	34	5.68%	18.22	10294.3	619.48	74,338
5	N--Brake Drum-PEAK-8863	444	396	48	10.81%	10.1	3999.6	484.8	58,176
6	d--Steering Knuckle(Left) 43212-0	4323	4235	88	2.04%	4.62	19565.7	406.56	48,787
7	T--ABS rings	2133	2081	52	2.44%	6.5	13526.5	338	40,560
8	R--Wheel Hub-Samko-501130	227	215	12	5.29%	25	5375	300	36,000
9	f--Wheel Hub-Samko-21204562	115	107	8	6.96%	31.18	3336.26	249.44	29,933
10	S--Wheel Hub-Samko-500349	195	187	8	4.10%	29	5423	232	27,840
11	J--Wheel Hub-PEAK-TR-505	2255	2097	158	7.01%	1.3	2726.1	205.4	24,648
12	C--Wheel Hub-HP2841	207	200	7	3.38%	28.5	5700	199.5	23,940
13	O--Planetary Carrier-PMT586	370	358	12	3.24%	16.55	5924.9	198.6	23,832
14	k--Bearing Housing FPW LB12P9004-	622	527	95	15.27%	1.85	974.95	175.75	21,090
15	W--Wheel Hub-HP2231	129	124	5	3.88%	33.43	4145.32	167.15	20,058
16	g--Wheel Hub-Samko-500671	80	75	5	6.25%	31.17	2337.75	155.85	18,702
17	M--Brake Drum-PEAK-8858	87	61	26	29.89%	5.9	359.9	153.4	18,408
18	I--Wheel Hub-AP052	124	119	5	4.03%	29.5	3510.5	147.5	17,700
19	Z--Wheel Hub-Samko-1060	92	88	4	4.35%	31	2728	124	14,880
20	U--Hitch Plate 8867 -- Handle	4539	4236	303	6.68%	0.4	1694.4	121.2	14,544
21	A--Wheel Hub-HP1930	226	222	4	1.77%	26.9	5971.8	107.6	12,912
22	h--Body Hydraulic Pump	434	413	21	4.84%	4.78	1974.14	100.38	12,046
23	e--Wheel Hub-Samko-501186	60	57	3	5.00%	29.9	1704.3	89.7	10,764
24	Q--Hitch Plate 8867 -- Plunger	3495	3278	217	6.21%	0.2	655.6	43.4	5,208
25	a--WH-3453-1201	78	77	1	1.28%	36.54	2813.58	36.54	4,385
26	l--Wheel -Hub 00Z01	77	76	1	1.30%	35.3	2682.8	35.3	4,236
27	F--Wheel Hub-ISU1040	61	60	1	1.64%	30.85	1851	30.85	3,702
28	b--Wheel Hub-Samko-500350	77	76	1	1.30%	28.19	2142.44	28.19	3,383
29	B--Wheel Hub-HP2830	66	65	1	1.52%	27.1	1761.5	27.1	3,252
30	E--Wheel Hub-ISU128Z	45	44	1	2.22%	26.13	1149.72	26.13	3,136
31	i--Body Hyd Pump 1665500M1-FR	318	312	6	1.89%	2.58	804.96	15.48	1,858
32	Y--Wheel Hub - HP 37170	1	1	0	0.00%	15.16	15.16	0	-
33	m--Wheel -Hub NA001	175	175	0	0.00%	24	4200	0	-
34	j--Brake Drum 37101	2	2	0	0.00%	27.4	54.8	0	-
35	D--Wheel Hub-GNDL90176	99	99	0	0.00%	30.94	3063.06	0	-
36	H--Wheel Hub-AP286	62	62	0	0.00%	31.18	1933.16	0	-
37	K--Brake Drum-PEAK-8805	1	1	0	0.00%	8.63	8.63	0	-
38	L--Brake Drum-PEAK-8823	2	2	0	0.00%	12.1	24.2	0	-
39	X--Wheel Hub - HP 37040	2	2	0	0.00%	20	40	0	-
40	n--Weel-Hub FPW-F44304	11	11	0	0.00%	6.55	72.05	0	-
								Total	1,357,780.80

Table 4.3

After writing down all these results in excels so we did its cost analysis which is given as below.

Month	Rejection Cost
Mar-14	1,776,270
Apr-14	1,357,781

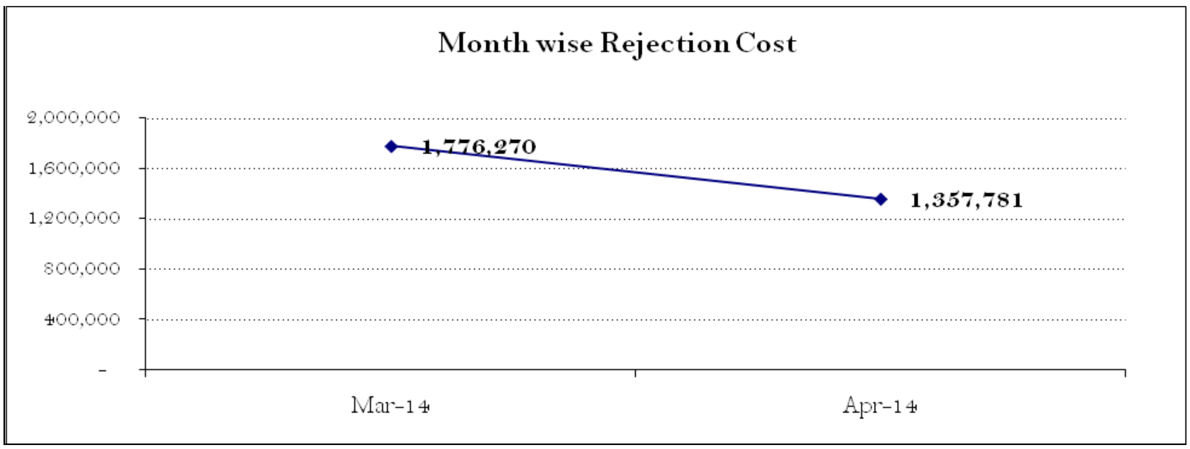


Figure 4.13

Complete detail of the Part Wheel Hub Bedford 4725 in Foundry for the month of April 2014

Units Checked = 599
Units Passed = 565
Unites Rejected = 34
Rejection % = 5.68%
Cost of Rejection = 74,338 PKR

Defect wise the number of parts rejected are

S#	Defect	No. of Parts	Percentage %
1	Sand inclusion	10	1.13%
2	Cold shut	6	1.00%
3	Mold shift	5	0.64%
4	Core blow	2	0.42%
5	Porosity	2	0.41%
6	Mould broken	2	0.41%
7	Rough surface	1	0.39%
8	|===Other===|	1	0.40%
9	Core shift	1	0.40%
10	Mould leak	1	0.23%
11	Short poured	1	0.20%
12	Fetling Fault	1	0.02%
13	Core broken		0.01%
14	Casting short		0.00%
15	Hard	1	0.00%
16	D.Testing		0.00%
17	Blow hole		0.00%
	Totals	34	5.68%

Table 4.4

Pareto Analysis for the month of April is

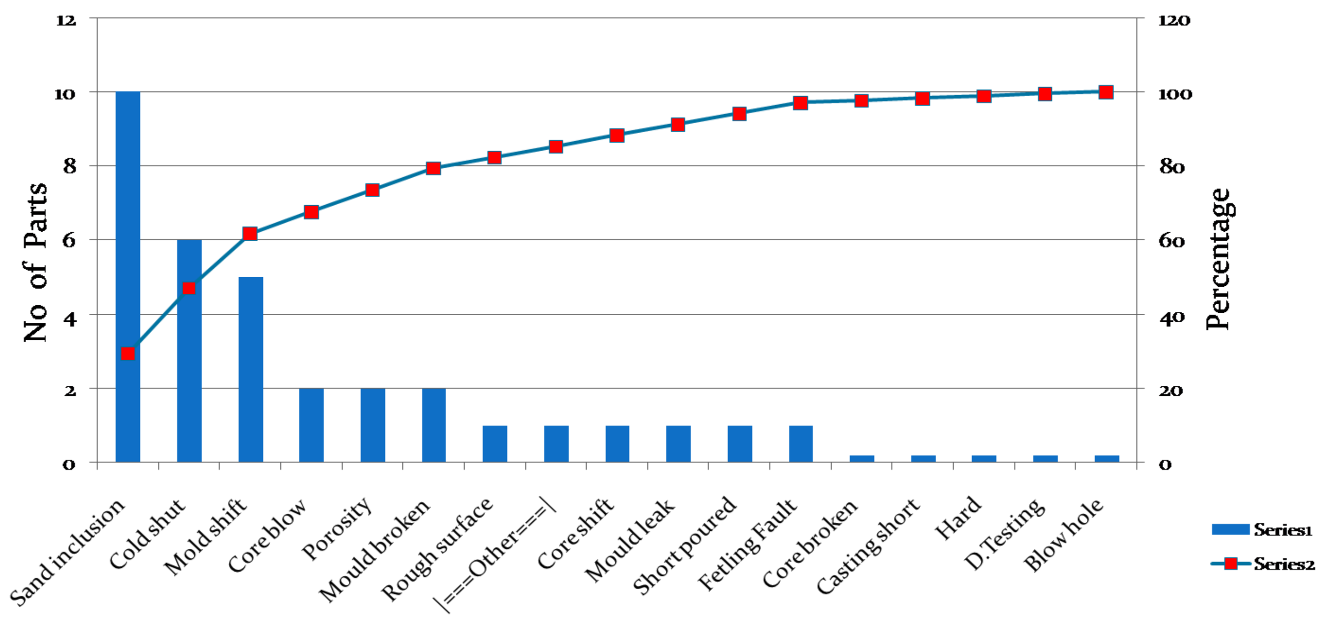


Figure 4.14

Rejection Report for Wheel Hub in Machining Process:

From the Foundry Shop the number of Parts which came to Machine shop are = 565

Machining Process performed

1) Pre-Machining
2) Turning 1st Operation
3) Turning 2nd Operation
4) Drilling Full Operation
5) Deburring

Process function	Defect Mode	Effect of defect	Cause of Defect	Detection
Turning Ist Operation	Bore Under size	Reject	Operator Mistake	1
	Outer Dia oversize	Reject	Operator Mistake	1
Turning 2nd Operation	Hole Undersize	Reject	Tool Problem	2
	Hole Oversize	Reject	Insert Broken	1
Drilling Full Operation	Hole wall fractures	Reject	Excessive heat and Mechanical stress created	1
Debarring	Edges sharp	Reject	Operator Mistake	2
			Total Rejections	08

Six Sigma Level For the month of April in Foundry:

- For the month of April the number of Wheel Hub parts which were produced in the Foundry shop was 599. 8 individual checks were performed to test quality of the parts. During testing 34 parts were rejected.

Defects: 34

Opportunities: 599

Defect opportunities per unit: 8

Putting the values in formula we get

DPMO = 7095

Sigma Level = 3.95

4.3.5 Control Phase

Now we will write about the control plan that What should we do to control the amount of rejection and to make the product quality better so that we increase the sigma level and try to make a setup according to the Six Sigma requirement.

The company is trying to control its rejection of the parts and to make its quality better. The steps which have been taken for prevention of defects reduced the rejection rate of the parts and increased the sigma level. Templates have been made by the company for Six Sigma which are given below. The Six Sigma preventative Maintenance plan is shown below

Six Sigma Preventative Maintenance Plan

Process Name: ______________________		Prepared by: ______________________	Page: _____ of _____
Customer ______________________	Int/Ext _____	Approved by: ______________________	Document No: __________
Location: ______________________		Approved by: ______________________	Revision Date: __________
Area: ______________________		Approved by: ______________________	Supercedes: __________

System	Failure Mode	CTQ		Predictor	Predictor Level	Measurement Method	Sample Size	Frequency	Who Measures	Where Recorded	Decision Rule/ Corrective Action	SOP Reference
		KPOV	KPIV		USL LSL							

Table 4.5

Along with that Six Sigma Process Control Plan template was also made so to control the defects and hence minimize the rejection cost by following that Process Control Plan

Six Sigma Process Control Plan

Process Name: ______________________ **Prepared by:** ______________________ **Page:** ______

Customer ______________________ **Int/Ext** ______ **Approved by:** ______________________ **Document No:** ______

Location: ______________________ **Approved by:** ______________________ **Revision Date:** ______

Area: ______________________ **Approved by:** ______________________ **Supercedes:** ______

Sub Process	Sub Process Step	CTQ		Specification Characteristic	Specification/ Requirement		Measurement Method	Sample Size	Who Measures	Where Recorded	Corrective Action
		KPOV	KPIV		USL	LSL					

Table 4.6

4.4 Future Recommendations

As from the improvement phase of Six Sigma methodology it is clear that there has been a decrease in the rejection of parts in foundry department and also in machining department. This decrease in rejection rate occurred because of the preventive actions taken to control the rejection cost of the foundry department. From only one type of part producing in foundry we see that a huge amount of cost rejection has been occurred because of Six Sigma methodology. Hence in the future, Six Sigma technique should be properly implemented for all the parts casting in the foundry shop of the industry from which the rejection cost will reduce to a very huge amount and the company can get rid of a huge loss which occurs because of the rejection of parts. The rejection cost of machining department has also to be found so that to observe the reduction in rejection rate of parts in machining shop and also the cost rejection percentage in machining processes will be reduced with it. Along with that Six Sigma technique should be properly implemented in every process which is taking place in industry whether that is in foundry department or machining department or production department but with implementing Six Sigma technique in the whole industry will minimize the rejection percentage of the parts and the company product quality will become outstanding and with that the company will have an increasing demand among its customers. The company must give special training to its workers and Engineers by Six Sigma experts who better know about the Six Sigma Process control plan and can give a very huge benefit to the company by giving training to the company engineers and workers.

Chapter – V Conclusion

From this Project it was concluded that Six Sigma can make the future performance of the said industry very good. It has already brought a bit improvement in the product quality and has reduced the rejection rate. After implementing it as a whole like training their workers by Master Black Belts, It will bring improvement in the quality and will increase the customers for the industry.

The improvements which occurred because of using Six Sigma to reduce the rejection rate and operational cost are

- Parts Rejection Percentage decreased in Foundry from 8.93% to 5.68%
- Sigma level increased from 3.78 to 3.95
- Cost of Rejection decreased in Foundry from 227,386 PKR to 74,338 PKR
- Rejection Percentage decreased in Machining from 25 parts to 8 parts

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