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[ICAME-2018]

ISSN 2348 – 8034
Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

# ENHANCING PRODUCTIVITY THROUGH SIX SIGMA IN MANUFACTURING INDUSTRIES

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## ABSTRACT

Over the last several months, the effort to become lean and lower the cost has echoed all the way from the halls of government to the smallest company's back room. In times of severe economic challenge, the natural reaction is to take decisions that can make an organization become as lean and focused to the extent possible. This paper discusses the benefits and pitfalls associated with lean manufacturing management starting from the idea that pleasing the customer should be at the root of all effort leading through the ravages of overzealous application of lean to the maximum. Elements of lean discussed in this paper address organizational waste, human resources, distributed design, supply chain management, customer management, and the financial system. This paper also discusses about the popular lean manufacturing environment and makes practical recommendations to new adopters to avoid failures due to the improper application of "lean" in their organization. It also aims to report the results of a study on the implementation of Lean Six Sigma (LSS) in a developing country. An effort is also made to report about the implementation of LSS to reduce the defects in casting, welding and grinding processes used in various manufacturing industries.

***Keywords***: *Productivity, six sigma, lean, DAMIC, DMADV, DPMO.*

## I. INTRODUCTION

Six sigma is set of techniques and tools for improvement. It was developed by Motorola in 1986.Sir bill smith "the father of six sigma "introduced this quality improvement methodology to Motorola. Six sigma is now an enormous 'brand' in the worlds of cooperate development. A six sigma process is one in which 99.9999% of the products manufactured are statistically expected to be defect free i.e. 3 to 4 defects per million.

**History**

Since the 1920's the word sigma has been used by mathematicians and engineers as a symbol for a unit of measurement in product variation. In mid-1980's engineers in Motorola in USA used six sigma an informal name for an in house initiative forreducing defects in production processes, because it represented suitably high level of quality.In late 1980's Motorola extended the six sigma methods to critical business processes and six sigma became a formalized in-house branded name for performance improvement methodology i.e., beyond purely "defect reduction."In1991 Motorola certified its first black belt six sigma experts, which indicates the beginnings of formalization of the accredited training of six sigma methods. In 1995, six sigma became well known after Mr.Jack welch made in a central focus of his business strategy at general electric and today it is different sectors of industry. By the year 2000, six sigma was effectively established as industry in its own right, involving the training, consultancy and implementation of six sigma methodology.

**Objectives of sixsigma:**

- Overall bussiness improvement
- Remedy defects/varability
- Reduce costs
- Reduce cycle time
- Improve customer satisfaction

ISSN 2348 – 8034
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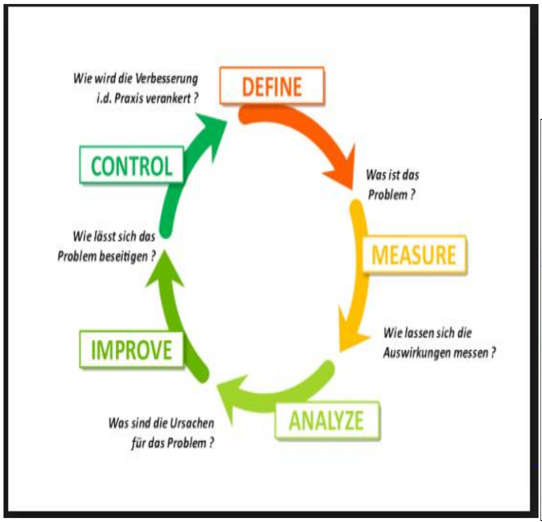
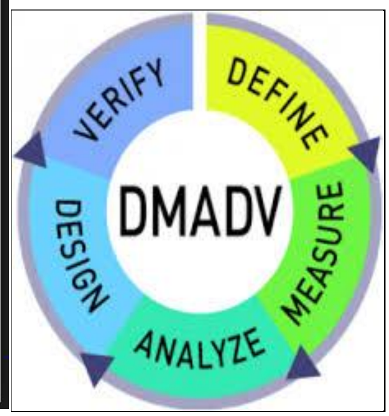
**Methodology:** The techniques used for implementation of six sigma are DAMIC and DMADV. DAMIC is used for projects aimed at improving an existing business process. It has 5phases viz. define, measure, analyse, improve, control. DMADV is used for projects aimed at creating new product or process designs.It consists of 5 steps viz define,measure, analyse, design,and verify.




## II. SOFTWARESUSED

The soft wares used areArena, Airs six sigma,Bonita open solution BPMN2 standard and kPI's for statistic monitoring, Jmp, Mat lab or gnu octave, Microsoft Vision, Statetc.

**Case studies considered:** In this work 3 case studies are presented related to manufacturing processes. They are Metal casting, grinding and welding**.**

***Case study***
***casting defects***

The company considered for case study is a south Indian SME which produces many automobile aluminium components for their various clienteles in India and abroad. Among the various components produced in lots, two stroke engine oil pump body is selected for this analysis. The reason for selecting this component is that the oil pump body has more Rejections than the remaining parts. The castings are manufactured in pressure die casting method.Around 90% of the company's output is being supplied within India.some may be Identified after a preliminary machining process. The component selected for this study is one such type being used in two wheeler's engine is lubricating pump. Since it is the Heart of engine assembly, presence of any defect in the casing may lead to severe consequences in operation. At the customer end, the castings are put in heat treatment process for 24 hours before starting the machining operations. During machining, blow holes are noticed particularly at the flange section of the component.Presence of such acasting defect may result in oil seepage when the assembly is put in operation. At this point of rejection, the casing costs is considerable to the client's company. Hence, it becomes imperative to produce porous free castings not only to reduce rejections but also to minimise the cost of rejection.

***Define phase:***

This phase of the DMAIC methodology is aimed at defining the scope and goals of implementing Six Sigma in terms of customer requirements and developing a process that delivers these requirements. This defect control study was most important for top Management of the company as it was known that an effective solution to this problem Would have a significant impact on overall productivity as well as client satisfaction on Product quality. In this project, occurrence of blow holes in the oil pump body is the Prime concern. After performing a number of brainstorming exercises it is arrived at the conclusion that the presence of blow holes was primarily influenced by

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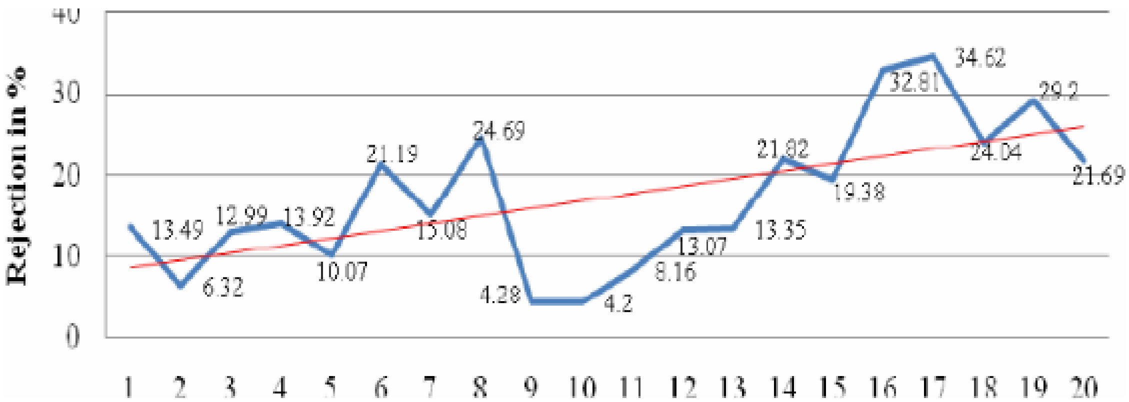
the die casting process. The solution to this problem was unknown and the impact of the problem was very severe as it leads to a low quality and high rejections.

*Measure phase:* This is essentially a data-collection phase. At this phase, the following two importantaspects were addressed. Production and rejection statistics of oil pump body for the completed 20 batches are collected from the company's record and it infers that the rejection was in increasing trend as shown in Figure1.FIG:1 It represents rejection rate before implementation of six sigma




***Analyse phase:***

This phase is intended to analyse the data to determine the direction of process improvement. In thiscase, it is important to identify the possible sources of variation Which lead to blowholes. A cause and effect study is conducted and parameters, thought to contribute to more blowholes are listed as shown in Figure 2 .Among the possible parameters, five (metal temperature, intensifier pressure, metal degassing frequency, 2nd phase turns, and metal mixing ratio) are selected for further analysis.

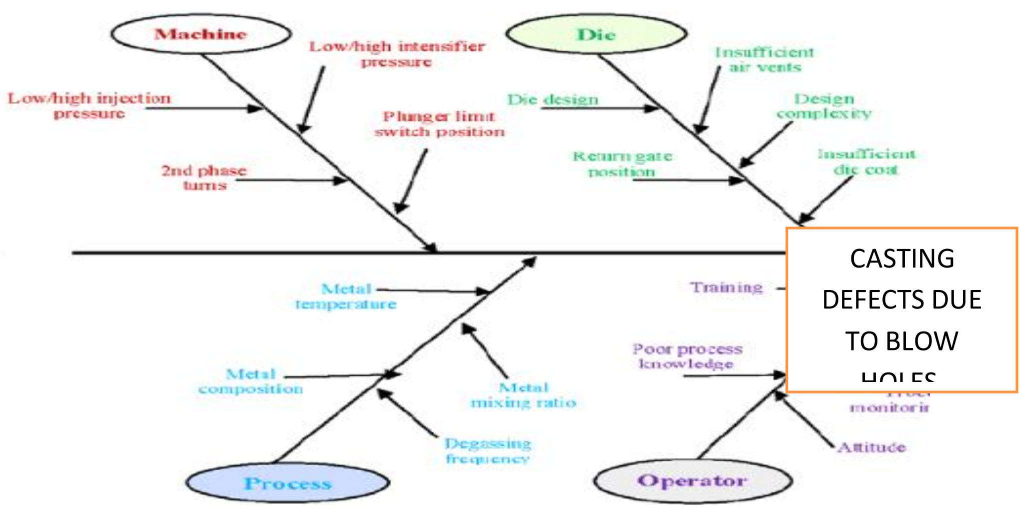



***Fig 2: Cause and effect diagram***

***Improve phase:***

In this phase, Taguchi's DoE is used with the five process parameters identified fromthe analysis phase. Quality and productivity Improvement is achieved using Six Sigma and Taguchi method.

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***Control Phase:***

The real challenge of Six Sigma methodology is not in making improvements to the process but in providing a sustained improvement to the optimisation. This requires standardisation and constant monitoring and control of the optimised process. Metal temperature and degassing frequency were found to be the influencing parameters for casting defect. Interactions of metal temperature with intensifier pressure and degassing frequency were also found critical for blowholes formation. An extensive training program for the personnel affected by the process changes was conducted within the company where the case study was performed. It is well known that real improvement will only come from the shop floor. Process sheets and control charts were made so that the operator can take preventive action before the critical process parameters and critical performance characteristics stray outside of the control limits. A complete database is prepared to maintain the improvement of the result. Implementations of the mentioned suggestions resulted in process improvement of process yield. A conformation test is conducted with batch volume of Quality and productivity Improvement using Six Sigma and Taguchi methods 1000 pieces at the optimum factor settings. Out of 20,000 components produced in 20 batches, the client report showed that 1,296 components are rejected due to blowholes after machining. The confirmation experiment results inferred that the rejection rate is brought to 4.8% in average as shown in Figure 3.

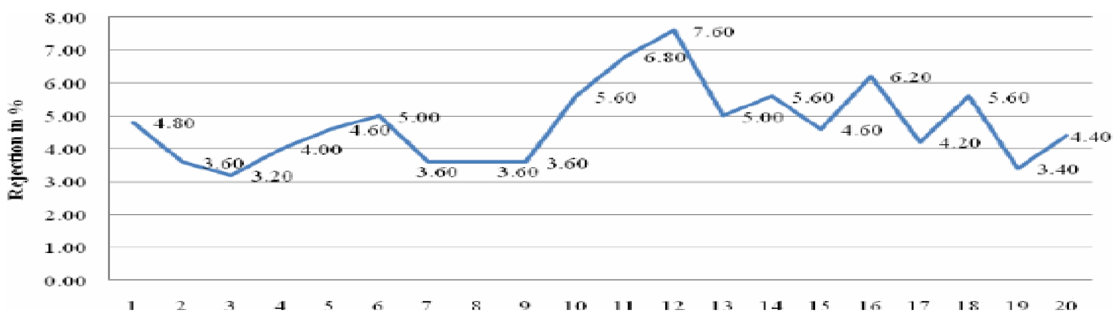



***Fig 3: Rejection rate after implementation of six sigma***

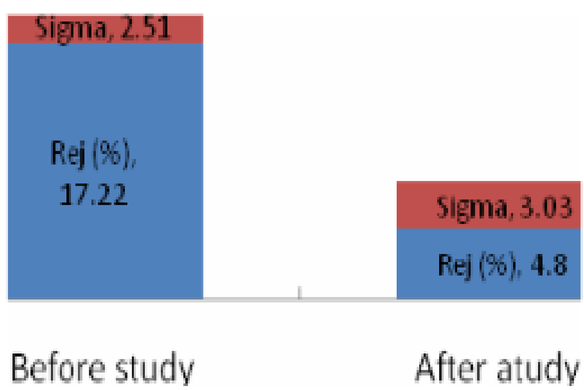
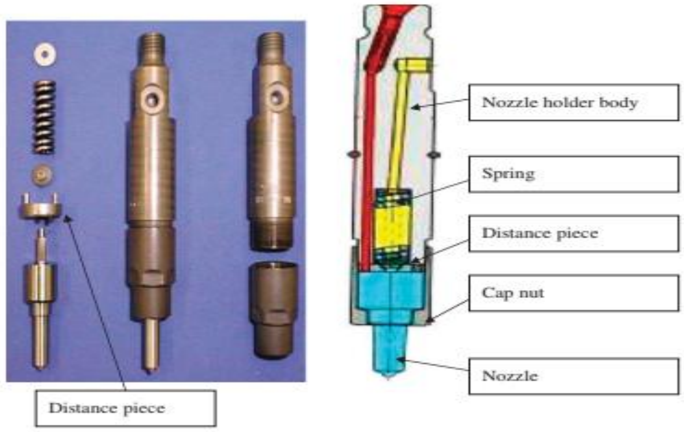



***Fig4: Displays the results of rejection rate in the form of bar graph before and after implementing six sigma.***

## III. CASE STUDY: Grinding defects

This case study deals with the reduction of defects in the fine grinding process in an automobile part manufacturing company in India. The company with manpower of approximately 2550 people is manufacturing common rail direct injection (CRDI) system pumps for vehicles. These pumps were used in cars, trucks and buses throughout the world. An injector primarily consists of nozzle and nozzle holder body.




The components used in fuel injector and their functions are as follows. Distance piece aligns the high-pressure fuel lines of nozzle holder body and nozzle Its both sides are fine ground precisely to ensure sealing of the high-pressure fuel coming from holder body to nozzle. Cap nut retains the nozzle and distance piece with the holder body with sufficient torque to ensure sealing. Spring and pressure bolt ensures the functioning of injector with set opening pressure and timely delivery of fuel. The current project was undertaken in the distance piece fine grinding process, which is done by fine grinding machine. Different types of distance pieces were fine ground in this machine. This is a sophisticated and very expensive CNC fine grinding machine. It finishes both faces of distance pieces in batches precisely with sub-micron flatness values. After fine grinding, distance pieces were inspected visually to find various defects. Since the production of distance pieces were in thousands per shift, it was not practically possible to do 100% inspection of these components by objective methods. Hence visual inspection was carried out for all the components with reference to master pieces and visual limit samples. Since the rejection level of distance pieces after fine grinding process was very high and the function of the component in the product was highly critical, it was essential to do 100% inspection. Hence, it was decided to address this problem through the Six Sigma DMAIC methodology.

***Define phase**:* This phase of the DMAIC methodology aims to define the scope and goals of the improvement project in terms of customer requirements and to develop a process that delivers these requirements. The team had several meetings with the Champion and MBB to discuss various aspects of the problem, including the internal and customer-related issues arising because of this problem. The team decided to consider the rejection percentage of distance pieces after fine grinding process as the Critical to Quality (CTQ) characteristic for this project. The goal statement was defined as the reduction in rejection of distance pieces by 50% from the existing level, which should result in large cost saving for the company in terms of reduction in rework and scrap cost.

**Measure:** The objective of the measure phase is to understand and establish the baseline performance of the process in terms of process capability or sigma rating. The CTQ considered in this case was the rejection percentage of distance pieces after the fine grinding process. These rejections were mainly due to the occurrence of different types of defects, such as burr, shades, deep lines, patches and damage, on the component after machining. The schematic representation of these defects is presented in Figure 5. These defects create an uneven surface in the component that could lead to fuel leakages in pumps. After machining, the components were visually inspected for these defects. Master samples were provided for identifying each of these defects and inspectors did the inspection. Since there was no instrument involved the inspection process and only visual inspection was performed.

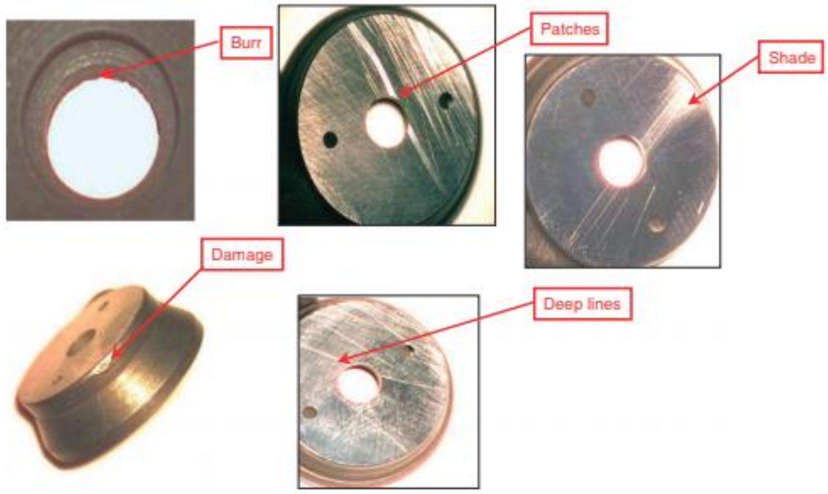



***Fig 5 : Defects in Grinding process.***

***Analyse phase:*** After mapping the process, the team proceeded to analyse the potential causes of defects. A cause and effect diagram was prepared after conducting a brain storming session with all the concerned people from the process along with the project team. The output of the cause and effect diagram depends on a large extent on the quality and creativity of the brain storming session. Figure 6 below illustrates the cause and effect analysis prepared during the brain storming session.The next step in this phase was to gather data from the process in order to obtain a better picture of the potential causes, so that the root cause/s can be identified. The team had detailed discussion with the process personnel to identify the possible data that can be collected on the potential causes in the cause and effect diagram.

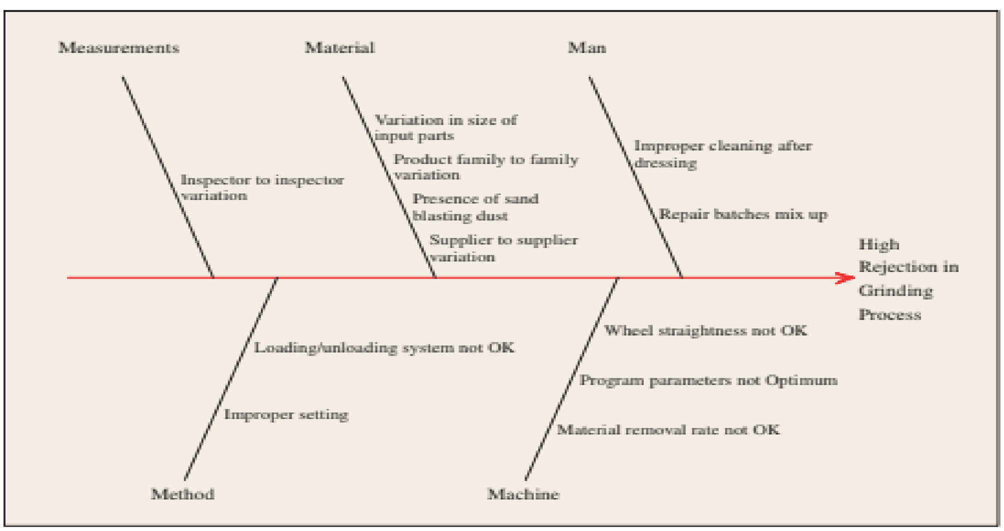



Fig 6 : cause and effect diagram of rejection problem in grinding process.

**Then finally found the root causes:**Repair batch mix up,Product family to family variations, Presence of sand blast dust, Material removal rate not OK, Process parameters not optimum, Improper setting, Loading/unloading system not ok.

***Improve phase:*** *This phase of the Six Sigma project is aimed at identifying solutions for all the root causes identified during the Analyse phase, implementing them after studying the risk involved in implementation and observing the results. At this stage, as decided earlier, a DOE{Design of Experiments} was planned for optimizing the process/machine parameters. The parameters selected through these discussions were load applied, initial load setting, coolant flow rate, upper wheel rpm, lower wheel rpm and cage rpm. Since the relationship between these parameters and MRR was not known, it was decided to experiment all these parameters at three levels. The existing operating level was selected as one level for experimentation. The team based on various operational feasibilities selected the other two levels as shown in table 1.*

***Table1: parameters and levels selected for experimentation***

| Sl. no. | Factor | Levels | | |
|---|---|---|---|---|
| 1 | Load applied | 170 | 200* | 230 |
| 2 | Initial load setting | Minimum | Medium | Maximum* |
| 3 | Coolant flow rate | 8 LPM | 12 LPM | 16 LPM* |
| 4 | Upper wheel RPM | 70* | 90 | 110 |
| 5 | Lower wheel RPM | 50* | 60 | 70 |
| 6 | Cage RPM | 20* | 30 | 40 |

Hence, an implementation plan was prepared for the above solutions with responsibility and target date for completion for each solution. A time frame of two weeks was provided for implementing these solutions. All the solutions were implemented as per the plan and the results were observed in table 2.

***Table2:parametersand optimum working level***

| Sl. no. | Factor | Optimum level |
|---|---|---|
| 1 | Load applied | 170 |
| 2 | Initial load setting | Medium |
| 3 | Coolant flow rate | 12 |
| 4 | Upper wheel RPM | 90 |
| 5 | Lower wheel RPM | 60 |
| 6 | Cage RPM | 30 |

***Control phase:***

As a part of ISO 9001 implementation, once in three months internal audits were carried out in the process. The CTQs of the projects were added to the internal audit checklist so that verifications can be performed during the audits. Control chart is a statistical tool used to monitor a process over time to determine whether special causes of variation occur in the process. Implementing appropriate control chart can do future monitoring of the process for assignable causes. When any signal for assignable cause appears in the control chart, the quality control inspector discusses this issue with the operator and immediate action was initiated on the process. The reaction plan displayed near to the machine gives direction for identifying the action required for addressing the assignable cause. Also, training was provided for the people associated with the process about the improved operational methods so that they are able to manage the process effectively.

***Table 3: causes for defects and solutions***

| Sl. no. | Cause | Solution |
|---|---|---|
| 1 | Repair batches mix up | New storage system for repair parts introduced in the process |
| 2 | Product family to family variation | Process parameters were optimized as per result of DOE |
| 3 | Presence of sand blasting dust | Cleaning method after sand blasting introduced |
| 4 | Material removal rate not OK | Reference table prepared for adjusting load |
| 5 | Process parameters not OK | Optimum factor level combination from DOE |
| 6 | Improper setting | Optimum factor level combination from DOE |
| 7 | Loading/unloading system not OK | Conditioning of grinding wheel-loading table is done. |

After implementation, the data were compiled from the fine grinding process with respect to the defects for one month and the rejection percentage was found to be 1.19. Hence, as a result of this project, the rejection percentage of the distance pieces at the fine grinding process reduced from 16.6 to 1.19%. The corresponding approximate sigma level was estimated as 3.76. Thus, the sigma level of the process has improved from 2.47 to 3.76. This shows significant improvement in terms of sigma rating as well as defect percentage in figure 7.

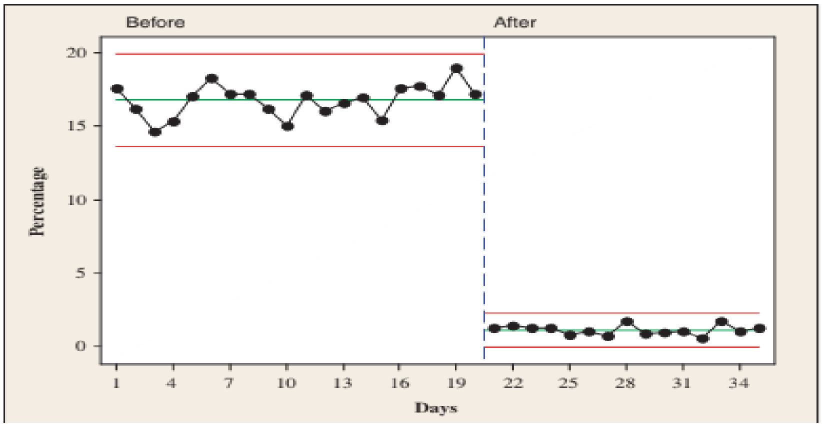



***Fig 7: percentage defect before and after implementation of six sigma***

***CASE STUDY: Welding defects***

This case study deals with rejection reduction in welding defects of different pipes of K2 (Pulsar 180) chassis like main pipe, centre pipe, head pipe are minimized by using six sigma tools in BadveAutocompsPvt Ltd. Five major defects were found in chassis, are Spatter, Weld burn,Incomplete weld ,Welding undercut , Blow holes are shown in figure no 8.


***Fig 8: welding defects***

***Define phase:***

In this phase, define the purpose of project, scope and process background for both internal and external customers.Six sigma is a business improvement strategy which focuses on reducing the defects and/or reducing the cycle time and improving the customer oriented quality. The data of components which was collected initially before implementation of six sigma tool is used to calculate standard deviation and hence process capability.

Quantity of components inspected, for 500 chassis:Main Pipes: 500, Centre Pipes: 1000, Head Pipes: 500

*Table 3: It represents the type of defect and quantity of defects*

| Sr. No. | Defects | Quantity | | |
|---|---|---|---|---|
| | | Main pipe | Centre pipe | Head pipe |
| 1 | Spatter | 76 | 23 | 46 |
| 2 | Weld burn | 57 | 16 | 32 |
| 3 | Welding incomplete | 7 | 4 | 6 |
| 4 | Welding undercut | 5 | 2 | 3 |
| 5 | Blow holes | 3 | 2 | 1 |

***Measure phase:***

Defects per million opportunities (DPMO) is the average number of defects per unit observed during an average production run divided by the number of opportunities to make a defect on the product under study during that run normalized to One million.

*Table 4:*

| Sr. No. | Component | DPMO | Sigma Level |
|---|---|---|---|
| 1 | Main Pipe | 59200 | 3.125 |
| 2 | Centre Pipe | 9400 | 3.947 |
| 3 | Head Pipe | 35600 | 3.515 |
| 4 | Overall | 28400 | 3.63 |

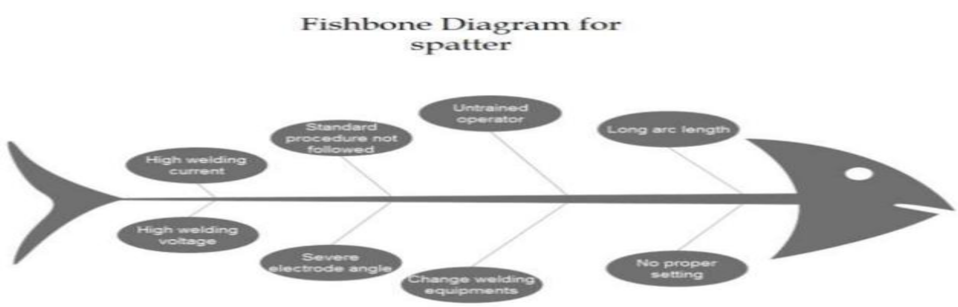
***Analysis phase:***

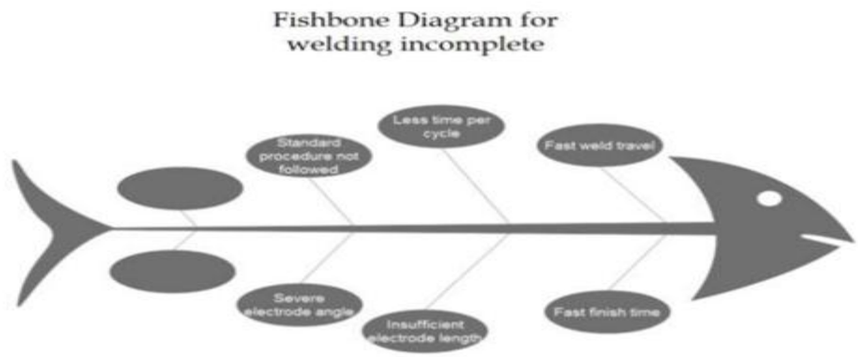
This phase involves detailed examination to identify causes behind the defects. Table no 5 gives the process parameters that affect the occurrence of defects with their observed values.

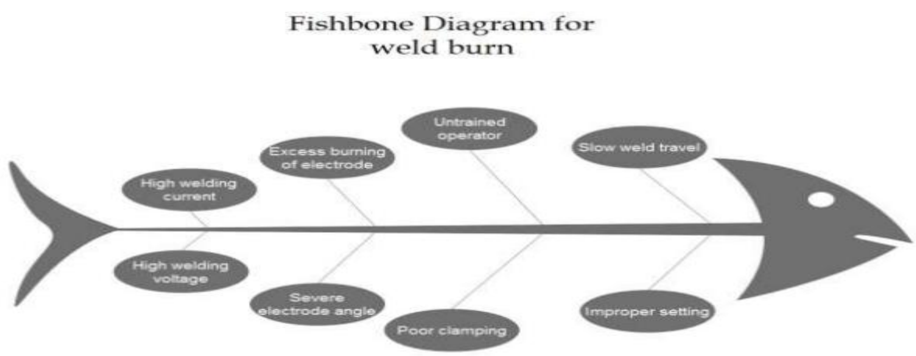
*Table 5:*

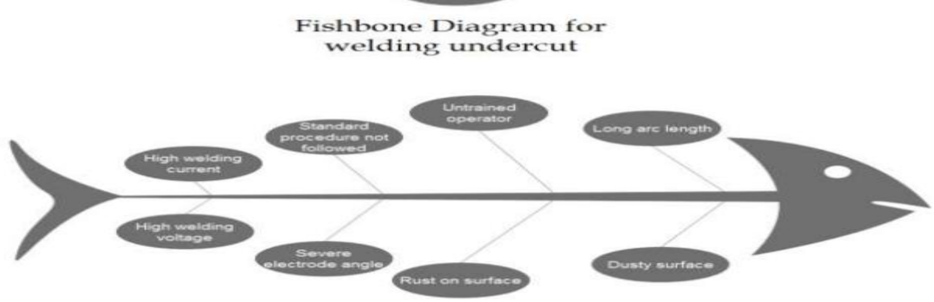
| Parameters | Specifications |
|---|---|
| Current | 200 A |
| Voltage | 25 V |
| Gas flow | 7 lpm |
| Wire speed | 18 m/min |
| Air pressure | 4-5 $Kg/m^2$ |

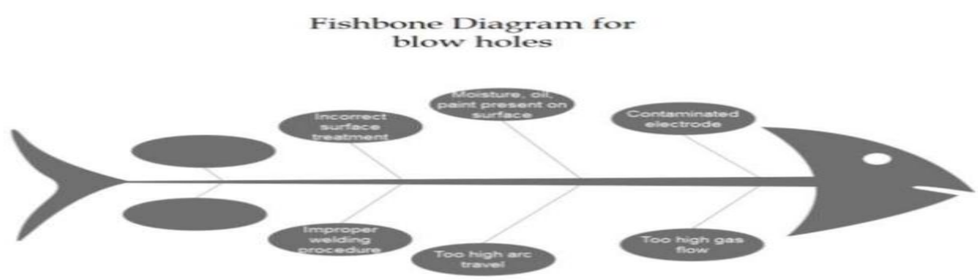
**Based on process observations cause and effect diagrams can be plotted as:**






***Improve phase:***

The observed values of process parameters were found to be improper for the manufacturing process. Further studies about defects revealed that the defects occurring during manufacturing can be minimized by changing the process parameters to some extents. Table no 6. gives the improved values of process parameters.

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*Table 6: Represents improved range of process parameters*

| Parameters | Range |
|---|---|
| Current | 160-180 A |
| Voltage | 18-20 V |
| Gas flow | 10-15 Lpm |
| Wire speed | 9-15 $m/min$ |
| Air pressure | 4-5 $Kg/m^2$ |

***Control phase:***

This phase includes implementation and periodic re-evaluation of changes made in process or process parameters. After changing the process parameters the quantity of defects was reduced considerably as shown in Table 7. The comparison of defects and sigma level i shown in Table 8

*Table 7: Quantity of defects before and after implementation of six sigma*

| Sr. No. | Defects | Quantity | | | | | |
|---|---|---|---|---|---|---|---|
| | | Main pipe | | Centre pipe | | Head pipe | |
| | | Before | After | Before | After | Before | After |
| 1 | Spatter | 76 | 24 | 23 | 6 | 46 | 8 |
| 2 | Weld burn | 57 | 33 | 16 | 10 | 32 | 11 |
| 3 | Welding incomplete | 7 | 0 | 4 | 0 | 6 | 0 |
| 4 | Welding undercut | 5 | 0 | 2 | 0 | 3 | 0 |
| 5 | Blow holes | 3 | 1 | 2 | 2 | 2 | 1 |

*Table 8: it is the comparison between defects and sigma level before and after application six sigma*

| Sr. No. | Component | DPMO | | Sigma Level | |
|---|---|---|---|---|---|
| | | Before | After | Before | After |
| 1 | Main Pipe | 59200 | 24995 | 3.125 | 3.69 |
| 2 | Centre Pipe | 9400 | 3760 | 3.947 | 4.4 |
| 3 | Head Pipe | 35600 | 6150 | 3.515 | 4.01 |
| 4 | Overall | 28400 | 9600 | 3.63 | 3.94 |

## IV. CONCLUSION

- Six Sigma is a disciplined, data-driven approach and methodology for eliminating defects in any process – from manufacturing a to product to services. This paper represents the effective introduction and implementation of a Six Sigma program which can lead to a breakthrough in profitability, bringing with it a cultural change and gaining customer loyalty.

- Six Sigma is most effective when an organisation already has a firm idea of what forms of products and services are in alignment with the organisations goals and customer expectations.
- The rejection rate in defects in casting process is found to be reduced from 17.2% to 4.8%, in grinding process is found to be reduced from 16.6% to 1.19% and in welding is found to be 10.42% to2.9%.
- **On Comparing welding, casting, & grinding processes** it is found that effective implementation of six sigma has lead to substantial reduction in the rejection rate in all the three areas of manufacturing . Hence one can expect similar gains in every field.

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