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A review on casting defects reduction in a foundry shop using DMAIC technique

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ABSTRACT

To become globally compatible and to gain business as well operational excellence industries are implementing various quality improvement initiatives like Lean manufacturing, ISO certification, Total Quality Management, Quality Circle, etc.. But results explored by these initiatives are timely constrained and not that much profitable. So methodology, which can provide breakthrough improvement in a short time, is required to be introduced and implemented. Six Sigma is the same methodology which can provide breakthrough improvements in the short time period, so it is very essential to explore its application for gaining quantum gains and profit in terms of quality, market share and customer satisfaction.

Keywords— *Total Quality Management, Six Sigma, DMAIC*

1. INTRODUCTION

To achieve Six Sigma quality, a process doesn't produce more than 3.4 defects per million opportunities. An 'opportunity' is defined as a chance for non-conformance, or not meeting the required specifications. This means we need to be nearly flawless in executing our key processes.

Strategy:
- Know What's Important to the Customer
- Reduce Defects
- Reduce Variation
- Centre around Target

Key Concepts of Six Sigma:
- At its core, Six Sigma revolves around a few key concepts.
- Critical to Quality: Attributes most important to the customer
- Defect: Failing to deliver what the customer wants
- Process Capability: What your process can deliver
- Variation: What the customer sees and feels

2. METHODOLOGY OF SIX SIGMA

Six Sigma has been defined as the statistical unit of measurement, a sigma that measures the capability of the process to achieve a defect-free performance. Six is the number of sigmas measured in a process when the variation around the target is such that only 3.4 outputs out of one million are defects under the assumption that the process average may drift over the long term by as much as 1.5 standard deviations. The term sigma is used to designate the distribution or the spread about the mean of any process. Sigma measures the capability of the process to perform defect-free work. A defect is anything that results in customer dissatisfaction. For a business process, the sigma value is a metric that indicates how well that process is performing. Higher sigma level indicates less likelihood of producing defects and hence better performance. Six Sigma has two key methodologies: DMAIC Methodology and DMADV Methodology, both inspired by Deming's Plan-Do-Check-Act Cycle.

2.1 DMAIC

The DMAIC means Define, Measure, Analyse, Improve and Control. These all work together to create the DMAIC process. This process is incredibly important in the six sigma process because it is what helps bring a diverse team together. This is what helps them complete a processor model so that they can share their work and get the job done. It is used to improve an existing business process.

DMAIC consists of the following steps:

Step 1: Define process improvement goals that are consistent with customer demands and the enterprise strategy.

Step 2: Measure key aspects of the current process and collect relevant data.

Step 3: Analyze the data to verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered.

Step 4: Improve or optimize the process based upon data analysis using techniques like Design of Experiments.

Step 5: Control to ensure that any deviations from target are corrected before they result in defects. Set up pilot runs to establish process capability, move on to production, set up control mechanisms and continuously monitor the process.

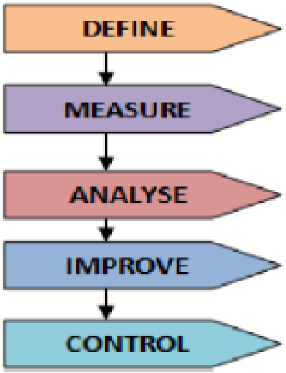

Fig. 1: Five Steps to DMAIC approach

2.2 DMADV

The DMADV means Define, Measure, Analyse, Design and Verify where DMAIC is used to improve the existing business process. DMADV is used to create a new product or process design.

DMADV consists of the following steps:

Step 1: Define design goals that are consistent with customer demands and the enterprise strategy.

Step 2: Measure and identify CTQs (characteristics that are Critical to Quality), product capabilities, production process capability, and risks.

Step 3: Analyze to develop and design alternatives, create a high-level design and evaluate design capability to select the best design.

Step 4: Design details, optimize the design and plan for design verification. This phase may require simulations.

Step 5: Verify the design, set up pilot runs, and implement the production process

In this work, we are going to discuss the DMAIC methodology in detail.

3. DMAIC METHODOLOGY

The DMAIC methodology has a core process: Define-Measure-Analyze-Improve-Control (DMAIC) methodology. The five steps to DMAIC approach are shown in figure 1.

3.1 D: Define

This is the overall problem definition step. This is one of the most critical phases of DMAIC Methodology, if required, maximum time and efforts should be allocated to this phase. This phase identifies critical customer requirements and links them to business needs. The aim of Define phase is to define the project with all details including project title, objective, scope, team composition, expected benefits and schedule for the project in terms of the customer requirements and identify the process delivering these requirements. This phase helps to envisage the scale and complexity of the problem. The first task was to develop a project charter to help team members clearly understand the scope and boundaries of the project, project objectives, project duration, resources, roles of team members, estimated financial gains from the project, etc. This creates a sense of ownership for the project; it also prevents the delivery of mixed messages between project managers and team members. The problem must be selected in such that it is directly linked to an organization's business metrics and bottom line. If the six sigma project is not in link with the organizational goal then it's not possible to get expected results from it.

Following aspects were covered in this phase on the problems selected.

(a) Fixing problem statement to work upon.
(b) Critical to quality (CTQ) tree based on costumer's needs and requirements
(c) Drawing a high-level process map to understand the process

Tools and techniques used in the define phase:

(a) Project charter.
(b) SIPOC model.
(c) Voice of Customer (VOC).
(d) Process flow

3.2 M: Measure

This is essentially a data-collection phase. Once the problem has been defined, it must be decided what additional measurements must be taken to quantify it. This phase is concerned with selecting one or more product characteristics, mapping the respective process, making the necessary measurements, recording the results on process control cards, and establishing a baseline of the process capability or process performance. This is basically a data collection phase wherein present situation data are collected and then the current sigma level is calculated for the process in question. Sigma level can be calculated by different methods, based on the type of data. Wrong or incorrect data collection can sink the complete six sigma process.
At this phase, the following two important aspects were addressed.

(a) Data collection: Accurate and sufficient measurement and data are needed. Data are the essence of the six sigma project
(b) Calculation of present sigma level: Sigma level can be calculated by different methods, based on the type of data. For discrete data defects per million opportunities (DPMO) number is calculated and then sigma level is ascertained from the DPMO-sigma level table.

$$DPMO= (Number of defects × 106)/ (Number of Opportunities × Number of units)$$

Where,
Number of defects = number of rejections (i.e. at least one defect exists to impute the product as defective).
Number of opportunities = number of CTQs.
Number of units = number of units produced

Tools and techniques used in measure phase:
(a) Pareto chart
(b) Process flow chart
(c) Statistical Quality Control (SQC) tools

3.3 A: Analyse

The measurement and data must be analysed to see if they are consistent with the problem definition and also to see if they identify the root cause. A problem solution is then identified. Sometimes, based on the analysis, it is necessary to go back and restate the problem definition and start the process over. The objective of Analyse phase in a Six Sigma project is to identify the root causes that are responsible for high variation in the selected CTQs. The aim of the analyse phase in a Six Sigma project is to identify the potential causes for the process problem being studied and then select the root causes with the help of data and their analysis. Once a list of potential causes has been generated, the next step is to plan for validation of these causes based on the data collected from the process. A lot of innovative thinking and discussions are required to identify the potential causes of a problem. A brainstorming session was planned and conducted by the team with the involvement of all the concerned personnel of the process, and a list of potential causes for variation in CTQ was generated. A cause-and-effect diagram was drawn based on these causes.

Tools and techniques used in the analysis phase:
(a) Pareto Chart
(b) Brainstorming
(c) Root Cause Analysis
(d) Five-Why Analyse Technique
(e) Failure mode and effect analysis
(f) Hypothesis Testing

3.4 I: Improve

During the improve phase of the project, solutions for the selected root causes are to be identified and implemented to observe the results. As per the decision of the team in the analyse phase. After understanding the root cause of the problem and have quantitative data, we identify possible solutions. Tests may be required to understand any interaction between the input variables. Tolerances have to be examined to see if they truly represent need. Once we have tested the possible solutions, we implement the best of those solutions and verify that results we predicted are actually occurring. The improve phase spotlights on developing thoughts to get rid of root causes of variation, testing and standardizing those solutions.
Tools and techniques used in the Improvement phase:
(a) Pareto diagram
(b) Taguchi's Design of experiment
(c) Brainstorming
(d) ANOVA
(e) Analysis of variance

3.5 C: Control

The control phase is where the new system is in place and it is institutionalized by modifying various systems, policies, procedures, budgets, and instructions to make it work for the entire company. If you do not put into control the six sigma gaols, then the previous four stages were worthless. The basic objectives of this phase are to ensure that our processes stay in control after the improvement solution has been implemented and to quickly detect out of control state and determine the associated causes so that actions can be taken to control the problem before non-conformances are produced. Success in this phase depends upon how we did in the previous phases. In the control phase, tools are put in place to ensure that the key variables remain within

acceptable ranges over time so that process improvement is maintained. Depending upon the type of the problem and operating system of the concern, the following control measures were recommended:
(a) Periodic review of the various measures suggested in Improve phase.
(b) Statistical Quality Control (SQC) charts. Thus maintaining targeted sigma level.

4. REVIEW OF PAST STUDIES

T. R. Vijayaram et al (2010) reviewed paper, some of the solutions and quality control aspects are explained in a simplified manner to eliminate the unawareness of the foundry industrial personnel who work in the casting manufacturing quality control departments. This review paper provides very valuable information to the young manufacturing and mechanical engineers who have the interest to start their career in the manufacturing concerns of medium and large scale captive foundries. Raghwendra Banchhor, S.K. Ganguly (2010) reviewed published research on the green sand casting process. The effects of riser design, gating system, moulding sand, oxidation and deformation of casting during heat treatment, machining allowance, etc., on the economical manufacture quality castings, were reviewed. Determining the optimal process parameter setting will significantly improve the mould yield, output ratio of metal, shorten manufacturing period, save energy and resource, reduce pollution, and improve the competitiveness of enterprises. Sushil Kumar et al (2011) analyse casting defects and concluded that the quality can be improved by Six Sigma i.e. (DMAIC) approach of parameters at the lowest possible cost. It is also possible to identify the optimum levels of signal factors at which, the noise factors effect the response parameters is less. The outcome of their case study is to optimize the process parameters of the green sand castings process, which contributes to minimize the casting defects. The optimized parameter levels for green sand casting process are moisture content (4.0%), green strength (1990 g/cm2), pouring temperature (14100C) and mould hardness number vertical & horizontal (72 & 85) respectively. Udhaya Chandran.R.M (2011) focused to minimize the casting Defects such as sand drop, sand blow holes, scabs, pinholes. In that by using Taguchi method is a powerful problem solving for improving the quality of the product. The parameters considered are moisture content (%), Green Strength (g/cm2), mould hardness, sand practical size. The Taguchi approach is used to capture the effect of signal to noise ratio of the experiments Based on the orthogonal array used due to optimum conditions are found. The outcome of this paper that the selected process parameters continuously affect the casting defects in the foundry. The improvement expected in reduction of casting defects is found to be 47.66%.

D.N. Shivappa et al (2012), found the four prominent defects in casting rejections. They noticed that defects such as Sand drop, Blow hole, Mismatch, and Oversize in Trunion Support Bracket (TSB) castings are frequently occurring at particular locations. Prachi K. Tawele, Laukik P. Raut (2012) studied the defect of casting i.e. warpage can be reduced. These will helpful to the quality control department of casting industries for analysis of casting defects. Also, the casting simulation technology has now days become a beneficial powerful tool for casting defect troubleshot. This will reduce the lead time for the sample casting; improved productivity. In general, warpage can be eliminated by iteratively designing (gating) system and by referring methods which help in the analysis of casting defects may minimize the rejection of casting. Uday A. Dabade and Rahul C. Bhedasgaonkar (2013) have put their emphasis on casting defect analysis using Design of Experiments and Computer Aided Casting Simulation Techniques. They work to analyse the sand related defects in green sand casting. They applied Taguchi based orthogonal array for experimental purpose and analysis was carried out using Minitab Software for analysis of variance and analysis of mean plot. Also, they worked for shrinkage porosity analysis using casting simulation technique by the introduction of a new gating system design. So the results obtained to them with new gating and feeding system design are a reduction in shrinkage porosity about 15% and improvement in yield about 5%. From the literature review, it is revealed that the successful application of Pareto analysis and CED can significantly reduce the defects of manual casting operations and increases efficiency. In this paper sand preparation, mould making, pouring and shakeout processes are considered for reducing defects rate. Pranay S. Parmar, Vivek A. Deshpande (2014) reviewed some research papers different results are taken and give the main objective using 7 QC tools is (to reduce rejections) most useful and economical tools. These tools and techniques are simple to implement and it needs the top management involvement and employee support. Although SPC seems to be a collection of statistically based problem-solving tools, there is more to the successful use of SPC than learning and using these tools. SPC is most effective when it is integrated into an overall, companywide quality improvement program. C.B. Patel and Dr H.R. Thakkar (2015) studied the research work made by several researchers for minimizing various defects and to improve productivity. They conclude that quality tools are playing an important role in decision making during the defect analysis. Chintan C. Rao and Darshak A. Desai (2015) reviewed the previously published papers, and give the where the industry has to work, this paper mainly focuses on the general overview of publication and the case industry, this paper gives which methodology adopted by industry, discuss the various tools and techniques used by the company and how much benefits got by the company by using DMAIC methodology.

5. CONCLUSION

Understand the current scenario of the foundry industry. in now a day's foundry industry produce product different types like ferrous and non- ferrous, this case study mainly focuses on steel foundry, present China provides casting product good quality with less time .various types of casting process like melting, moulding, core making, melting, pouring, shake out.

Study about various casting defects occur in foundry industry like shrinkage, blow hole, porosity, pinhole, sand inclusion, cold shut, miss run, surface discontinuity, mould break, flash etc. Give an idea about how to occur defects and which types of precaution taken in future. process mapping means flow process chart – material types in which shows all activity from raw material to finish goods with time, find non-value added activity and remove it.

Tools & technique used in foundry industry based on quality and productivity aspect like 7 QC –tools, DOE, Taguchi method, method study, TQM, TQC, just in time, casting simulation techniques, six sigma – DMAIC method etc. Understand the implementation of this technique in the foundry industry at last which types of benefits occur after implement methodology.

Many researchers have conducted experiments to find the sand process parameters to get better quality castings. They have successfully reduced the casting defects considerably up to 6% by proper selecting sand parameters. DoE is the technique which can be implemented in any processing industry. In India, there is a number of small scale industries which can implement such techniques to improve the yield, give standard process parameter and increase the effective capacity of the unit.

From the study of all the research paper, we conclude that six sigma is a breakthrough improvement methodology with the use of six sigma it is confirmed that we get a min.50% improvement if we work hard and top management involvement is good. It can also be concluded that DMAIC methodology is mostly used by the industries for their performance improvement. This study will help small scale foundry to initiate Six Sigma projects in their organizations and improve their performance in terms of customer satisfaction as well as financial benefits with an increase in competitiveness in the worldwide market of the foundry.

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