ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

A REVIEW ON REDUCING CASTING DEFECTS AND IMPROVING PRODUCTIVITY IN A SMALL SCALE FOUNDRY USING DMAIC APPROACH

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DOI: 10.5281/zenodo.1312726

ABSTRACT

Casting has various processes like Pre casting Processes, pattern making, core making, molding and mold assembly making, Casting Processes, furnace charging, melting, holding and pouring, and Post casting Processes, shakeout, inspection and dispatch etc. In India there are many foundry have followed conventional and manual operations. Mold shifting, Crushing, Lower Surface finish, Shrinkage, Porosity, Cold shut and Extra material are common casting defects due to these manual operations. Improve quality and productivity by apply seven quality control tools technique sum of the known problems which are face in the small scale to top level scale of industries. This review paper presents all data of manual sand casting operations and defects leads to rejection and also represents analysis of these defects with seven quality control tool.

Keywords: Seven quality control tools, Productivity, Casting defects, Cold shut.

I. SIX SIGMA: HISTORICAL BACKGROUND

Six Sigma began in 1986 as a statistically based method to reduce variation in electronic manufacturing processes in Motorola Inc. in the USA. It is developed by Bill Smith at Motorola, later it was adopted by General Electrics and Allied Signals, where it was initiated by Jack Welch. There are two important contributions from GE's way of implementation to the evolution of Six Sigma. First, Jack Welch demonstrated the great paradigm of leadership. Second, he backed the Six Sigma program up with a strong rewards system. GE changed its incentive compensation plan for the entire company so that 60 percent of the bonus was based on financials and 40 percent on Six Sigma results. The new system successfully attracted GE employees' attentions to Six Sigma. Moreover, Six Sigma training had become a prerequisite for advancement up GE's corporate ladder. Welch insisted that no one would be considered for a management job without at least Green Belt training by the end of 1998.

Further, Six Sigma has undergone many changes and improvement with the passage of time, also its implementation from manufacturing industries to service industries as well. Six Sigma can be applicable to any product, process or transactions. It can also be applied business operations such as Research & Development (R&D), sales and marketing, on time delivery process, administration and other areas that directly affects the customers. It is a project-by-project improvement approach, which consists of analysis of quantitative data by using statistical tools and techniques. It is a highly data driven approach. Because breakthrough improvements and profits are associated with it, it has taken an attention from academics and practitioners worldwide.

II. METHODOLOGY OF SIX SIGMA

Six Sigma has been defined as the statistical unit ofmeasurement, a sigma that measures the capability ofthe process to achieve a defect free performance.Six is the number of sigma measured in a process,when the variation around the target is such that only3.4 outputs out of one million are defects under theassumption that the process average may drift overthe long term by as much as 1.5 standarddeviations. The term ―sigma‖ is used todesignate the distribution or the spread about themean of any process. Sigma measures the capabilityof the process to perform defect-free work. A defectis anything that results in customer dissatisfaction.For a business process, the sigma value is a metricthat indicates how well that process is performing. Higher sigma level indicates less likelihood ofproducing defects and hence better performance.

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Six Sigma has two key methodologies:
DMAIC Methodology and DMADV Methodology,both inspired by Deming's Plan-Do-Check-Act Cycle.

- DMAIC
- DMADV

DMAIC:
The DMAIC means Define, Measure, Analyses,Improve and Control. These all works together tocreate the DMAIC process. This process is incrediblyimportant in six sigma process because it is whathelps bring a diverse team together. This is whathelps them complete a process or model so that theycan share their work and get the job done. It is usedto improve an existing business process.

DMAIC consists of following steps:

- Define process improvement goals that are consistent with customer demands and the enterprise strategy.
- Measure key aspects of the current process and collect relevant data.
- Analyze the data to verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered.
- Improve or optimize the process based upon data analysis using techniques like Design of Experiments.
- 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.
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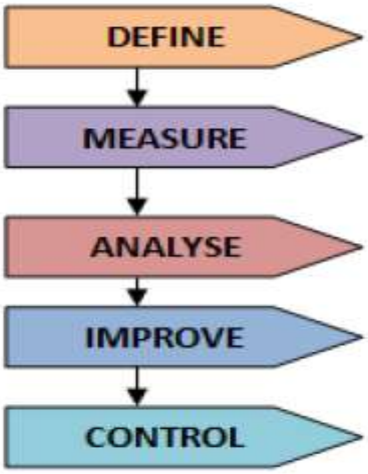

Fig.1.1: Five Steps to DMAIC approach

III. CASTING PROCESS

Production of casting involves various processes such as pattern making, moulding and assembly, sandpreparation, core making and melting, pouring, shakeout etc. The overall casting process becomes very critical forcomplex parts. Based on various researches find best foundry process in which included all the activity.

Casting process is the most widely used process in manufacturing industries. The activities involved in castingprocess are, Pattern making for creation of mould box, Core making for insertion in mould assembly, fitting of pattern,gating system and sand for mould preparation, remove prepared mould and placed for pouring, fill the mould cavity withmolten metal, allow it to solidify and at last, remove the cooled desired casting. These activities are commonly usedbecause of its simplicity in process, economic to operate and easy to produce small size castings.Casting is a process which carries risk of failure occurrence during all the process of accomplishment of thefinished product. Casting process involves complex interactions among various parameters and operations related tometal composition, methods design, moulding, melting, pouring, shake-out, fettling, machining like grinding andinspection etc various operation carried out.

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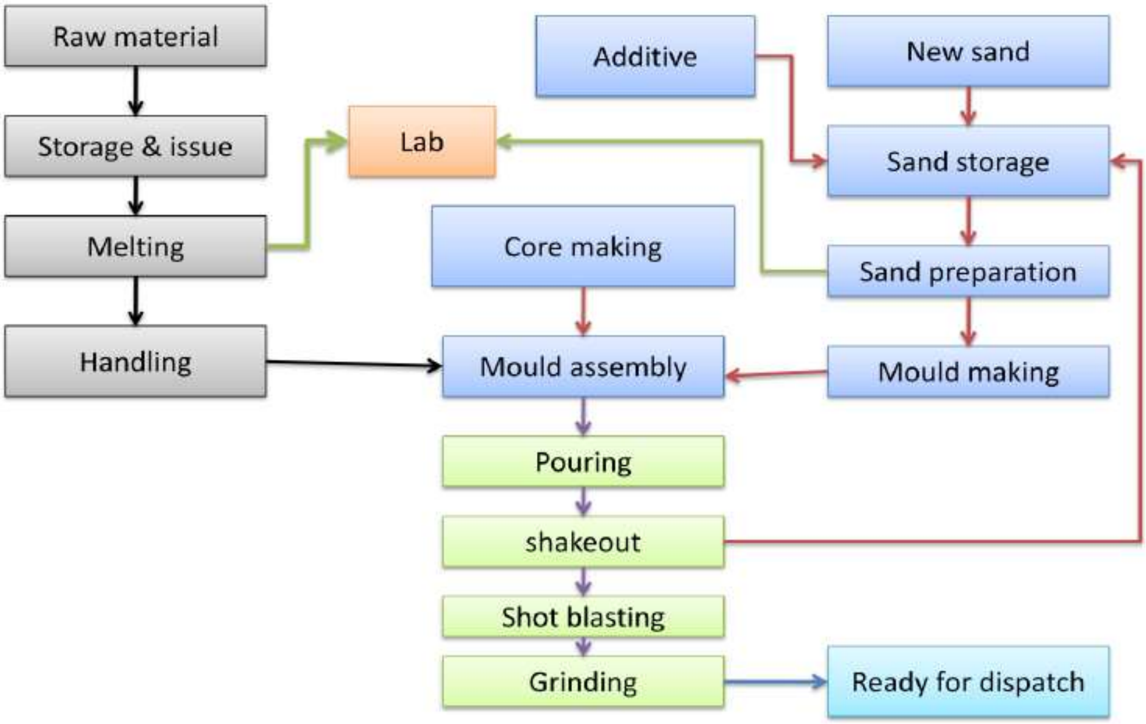

Fig. 1.2: Various casting process from raw material to finish product

IV. SMALL SCALE FOUNDRY-AN OVERVIEW

In the era of globalization, producing good quality castings as per the standards needs multidirectional competitiveness. Indian foundry industries are constantly on the alert to gain a competitive edge. Yet, the Focus is deviating fromoverall operational excellence. To compete globally, foundry men have to move ahead from the slogan of 'satisfyingcustomer' and adopt and rigorously Endeavour for 'customer delight'. Meeting customer demands will not be sufficient,requirements will be to exceeding them through quality and productivity improvement. For global competitiveness,foundry industries are trying many techniques such as quality circles, total quality management (TQM), InternationalOrganization for Standardization certifications, etc. All these techniques are well capable of producing the desiredresults, but the darker side of the coin is the issues related with their implementation and longer time span to realize thebenefits. There are myths that Six Sigma is suitable for large organizations only but, Six Sigma is equally suitablefor Small scale foundry too.

V. CASTING DEFECTS

Casting defects can be classified as follows-

1. Filling related defect
2. Shape related defect
3. Thermal defect
4. Defect by appearance

These defects are explained as follows.

- **Filling related defects**
    1. **Blowhole: -** Blowhole is a kind of cavities defect, which is also divided into pinhole and subsurface blowhole.Pinhole is very tiny hole. Subsurface blowhole only can be seen after machining. Gases entrapped bysolidifying metal on the surface of the casting, which results in a rounded or oval blowhole as a cavity.Frequently associated with slags or oxides the defects are nearly always located in the cope part of the mouldin poorly vented pockets and undercuts.
    2. **Sand burning: -** Burning-on defect is also called as sand burning, which includes chemical burn-on, andmetal penetration. Thin sand crusts firmly adhering to the casting. The defect occurs to a greater extent in thecase of thick-walled castings and at high temperatures. The high temperature to which the sand is subjectedcauses sintering of the bentonite and silicate

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Impact Factor: 5.164
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components. In addition, the always present iron oxides combinewith the low-melting-point silicates to form iron silicates, thereby further reducing the sinter point of the sand.Sintering and melting of the impurities in the moulding sand enable the molten iron to penetrate even faster,these layers then frequently and firmly adhering to the casting surface.

3. **Sand inclusion: -** Sand inclusion and slag inclusion are also called as scab or blacking scab. They areinclusion defects. Looks like there is slag inside of metal castings. Irregularly formed sand inclusions, close tothe casting surface, combined with metallic protuberances at other points. Sand inclusion is one of the mostfrequent causes of casting rejection. It is often difficult to diagnose, as these defects generally occur at widelyvarying positions and are therefore very difficult to attribute to a local cause. Areas of sand are often tornaway by the metal stream and then float to the surface of the casting because they cannot be wetted by themolten metal. Sand inclusions frequently appear in association with CO blowholes and slag particles. Sandinclusions can also be trapped under the casting surface in combination with metal oxides and slag's, and onlybecome visible during machining. If a loose section of sand is washed away from one part of the mould,metallic protuberances will occurhere and have to be removed.
4. **Cold lap or cold shut: -** Cold lap or also called as cold shut. It is a crack with round edges. Cold lap is because of low melting temperature or poor gating system. When the metal is unable to fill the mould cavity completely and thus leaving unfilled portion called misrun. A cold shunt is called when two metal streams do not fuse together properly.
5. **Misrun: -** Misrun defect is a kind of incomplete casting defect, which causes the casting uncompleted. The edge of defect is round and smooth. When the metal is unable to fill the mould cavity completely and thus leaving unfilled portion called misrun. A cold shunt is called when two metal streams do not fuse together properly.
6. **Gas porosity: -** The gas can be from trapped air, hydrogen dissolved in aluminium alloys, moisture from water based die lubricants or steam from cracked cooling lines. Air is present in the cavity before the shot. It can easily be trapped as the metal starts to fill the cavity. The air is then compressed as more and more metal streams into the cavity and the pressure rises. When the cavity is full it becomes dispersed as small spheres of high pressure air. The swirling flow can cause them to become elongated.

- **Shape defects**
  1. **Mismatch defect: -** Mismatch in mould defect is because of the shifting moulding flashes. It will cause the dislocation at the parting line.
  2. **Distortion or warp: -** Warped Casting—Distortion due to warp age is known as warp defect.
  3. **Flash defect: -** Flash can be described as any unwanted, excess metal which comes out of the die attached to the cavity or runner. Typically it forms a thin sheet of metal at the parting faces. There are a number of different causes of flash and the amount and severity can vary from a minor inconvenience to a major quality issue. At the very least, flash is waste material, which mainly turns into dross when re-melted, and therefore is a hidden cost to the business.

- **Thermal defects**
  1. **Cracks or tears: -** Cracks can appear in die castings from a number of causes. Some cracks are very obvious and can easily be seen with the naked eye. Other cracks are very difficult to see without magnification.
  2. **Shrinkage: -** Shrinkage defects occur when feed metal is not available to compensate for shrinkage as themetal solidifies. Shrinkage defects can be split into two different types: open shrinkage defects and closedshrinkage defects. Open shrinkage defects are open to the atmosphere, therefore as the shrinkage cavity formsair compensates. There are two types of open air defects: pipes and caved surfaces. Pipes form at the surfaceof the casting and burrow into the casting, while caved surfaces are shallow cavities that form across thesurface of the casting. Closed shrinkage defects, also known as shrinkage porosity, are defects that formwithin the casting. Isolated pools of liquid form inside solidified metal, which are called hot spots. Theshrinkage defect usually forms at the top of the hot spots. They require a nucleation point, so impurities anddissolved gas can induce closed shrinkage defects. The

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

defects are broken up into macro porosity and microporosity (or micro shrinkage), where macro porosity can be seen by the naked eye.

3. **Sink mark and void: -** Sink marks and voids both result from localized shrinkage of the material at thicksections without sufficient compensation. Sink marks appear as depressions on the surface of a moulded part.These depressions are typically very small; however they are often quite visible, because they reflect light indifferent directions to the part. The visibility of sink marks is a function of the colour of the part as well as itssurface texture so depth is only one criterion. Although sink marks do not affect part strength or function, theyare perceived to be severe quality defects. Voids are holes enclosed inside a part. These can be a single hole ora group of smaller holes. Voids are caused when the outer skin of the part is stiff enough to resist theshrinkage forces thus preventing a surface depression. Instead, the material core will shrink, creating voidsinside the part. Voids may have severe impact on the structural performance of the part.

- **Defects by Appearance**
  1. **Metallic projection Joint flash or fins:-** Flat projection of irregular thickness, often with lacy edges,perpendicular to one of the faces of the casting. It occurs along the joint or parting line of the mould, at a coreprint, or wherever two elements of the mould intersect.
  2. **Cavities: -** Blowholes, pinholes, Smooth-walled cavities, essentially spherical, often not contacting theexternal casting surface (Blowholes). The defect can appear in all regions of the casting.
  3. **Discontinuities: -** A crack often scarcely visible because the casting in general has notseparated into fragments. The fracture surfaces may be discoloured because of oxidation. The design of thecasting is such that the crack would not be expected to result from constraints during cooling.
  4. **Incomplete casting: -** Poured short. The upper portion of the casting is missing. The edges adjacent to themissing section are slightly rounded; all other contours conform to the pattern. The spree, risers and lateralvents are filled only to the same height above the parting line, as is the casting.
  5. **Incorrect dimension or shape: -** Distorted casting. Inadequate thickness, extending over large areas of thecope or drag surfaces at the time the mould is rammed.
  6. **Defective surface Flow marks. : -** On the surfaces of otherwise sound castings, the defect appears as lineswhich trace the flow of the streams of liquid metal.
  7. **Rat Tail and Buckles: -** Rat tails and buckles are caused by the expansion of a thin outer layer of mouldingsand on the surface of the mould cavity due to metal heat.

VI. LITERATURE REVIEW

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 interest to start their career in the manufacturing concerns of medium and large scale captive foundries.

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 on 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.

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.

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Chiragkumar S. Chauhan, sanjay C. Shah, Shrikant P. Bhatagalikar (2013) reviewed paper has been conducted in order to define role and importance of seven basic quality tools (7QC tools) within quality management system. To stay in continuous improvement continuous staff education and training is necessary. Quality tools has important place in data collecting, analysing, visualizing and making sound base for data founded decision making. The paper stresses on the use of the seven basic quality tools to improve processes and to solve problems.

Varsha M. Magar, Dr. Vilas b. Shinde (2014) studied general idea about all 7 QC tools and its importance regarding to minimize the risk of errors in systems. It enhances workers ability to think generate ideas, solve problem and do proper planning. The main aim of this paper is to provide an easy introduction of 7 QC tools and to improve the quality level of manufacturing processes by applying it. QC tools are the means for Collecting data, analysing data, identifying root causes and measuring the results. These tools are related to numerical data processing .All of these tools together can provide great process tracking and analysis that can be very helpful for quality improvements. These tools make quality improvements easier to see, implement and track.

C.B. Patel and Dr. H.R. Thakkar (2015) studied the research work made by several researchers for minimizing various defects and to improve the productivity. They conclude that quality tools are playing an important role in decision making during the defect analysis.

Vivek V. Yadav and Shailesh J. Shaha (2016) presented research work carried out in foundry to minimize casting rejection due to major defect. A problem is facing with the single cylinder head. Study focuses on analysis of Blow hole defect which contributes more in total rejection percentage. Quality analysis is carried out which includes the Root cause analysis to find out actual reasons behind occurring the blow holes. Quality control tools such as Pareto analysis, Cause and Effect (Ishikawa) diagram, and why-why analysis are used for analysis. Accordingly corrective actions and preventive measures are suggested and implemented. Central gas vent cleaning practice is added as a check point in process control check sheet and Pasting of wet green sand on central gas vent during mould box assembly is added as process compliance. Evaluation of effectiveness after implementation of these changes shows significant reduction in rejection due to blow hole as well as in total rejection. Rejection due to blow hole is minimizes from 7.74% to 1.81%. It turns into considerable reduction in total revenue loss as well as productivity improvement by 8.60%.

Anuj kumar et al (2017) studied on local foundry shop in Haryana and objective of my study are: 1. To identify the root factors causing casting defects in Brake drum. 2. To improve the quality by reducing the casting defects in Brake drum. 3. Compare the defects in Brake drum with and without DMAIC.

Jaykar Tailor and KinjalSuthar (2017) presented a review on reducing defects in various areas by Six sigma DMAIC Methodology. In modern era, the Six Sigma tools and techniques have been implemented in various sectors, which strive to ameliorate continuous improvement in achieving less variation, cost and high quality of end products. Six Sigma emerged as a natural evolution in business to increase profit by eliminating defects. Six Sigma is a powerful world class improvement business strategy that enables companies to use simple but powerful statistical methods to define, measure, analyse, improve and control (DMAIC) processes for achieving operational excellence. In this paper, DMAIC approach is carried out that has been reviewed from different research papers.

VII. CONCLUSION

Understand current scenario of 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 provide 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 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.

ISSN: 2277-9655
Impact Factor: 5.164
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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 implementation of this technique in 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 are 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 confirm 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 increase in competitiveness in worldwide market of foundry.

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Ganguly, P., & Rana, R. (2018). A REVIEW ON REDUCING CASTING DEFECTS AND IMPROVING PRODUCTIVITY IN A SMALL SCALE FOUNDRY USING DMAIC APPROACH. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *7*(7), 115-122.