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Quality Improvement Tools for Casting Defects in Foundry

Er.Prajakta P. Desai[1*], Er. Harshwardhan C.Pandit[2]
[1] *Assistant Professor, Department of Mechanical Engineering, Sanjay Ghodawat University, Kolhapur, Maharashtra. India.*
[2] *Assistant Professor, Mechanical Engineering, Department of Technology, Shivaji University, Kolhapur, Maharashtra. India.*
[*] *Corresponding author - patil.pr@sginstitute.in*

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Abstract
Quality Management and related enhancements have become a critical management component for many small and large businesses. This study focuses on enhancing specific production processes in the foundry's finishing operations and resolving a particular problem regarding the bottleneck in the blasting region. This paper reviews the quality improvement tools for casting defects in the foundry. In the application section, the current status of the finishing operation is determined using process analysis, and an improvement strategy is given. Industrial practices such as brainstorming and workshops were utilized in the project part.

I. Introduction:

Quality improvement is a continuous activity performed throughout an organization to increase the effectiveness of individual activities and processes that benefit the organization and customers. Quality improvement is a continuous process of improving the activities and maintaining the standards. Defect reduction is the main requirement in the industry. In the foundry, the sand casting processes are critical to reducing the defects. 5 to 10 % of a foundry's entire income is allocated to internal and external defects [1]. Reducing faults in sand casting foundries necessitates an initial comprehension of process factors, process parameters, and their influence on the quality of the final cast [2].

The reduction of casting defects and productivity improvement depend upon the casting process. Six Sigma methodologies provide systematic and structured quality improvement methods of the processes and products [3]. Six Sigma is the method that translates information into possibilities for business success, and it is based on defect reduction through methods that stress process understanding, measuring, and process upgrades [4]. The DMAIC is a well-known process improvement six sigma methodologies used in an existing underperforming process [5]. This DMAIC framework applies to a wide range of operations. It quantifies process variance that results in defect generation. [4, 8].

Montgomery and Woodall (2008)[6,], the Six Sigma technique focuses on reducing variance in product characteristics within the defined objective so that defects are unlikely to occur and, if they do occur, are at 3.4 defects per million opportunities. Six sigma procedures use the fundamental seven quality tools to collect and evaluate data. Six Sigma processes produce 3.4 defects per million non-conforming goods produced in a process. The six Sigma approach reduces faults in a process and influences the generation and application of process knowledge. According to Giannetti et al. (2014)[8,], knowledge creation is the main contributing component to attaining process improvement in the Six Sigma technique. Table 1 shows the entire DMAIC framework, tools, and actions.

Six Sigma step	Activity	Tools
Define	•The key Customer requirement	SIPOC
	•The key process that is affecting the customer requirement	Pareto charts
	• The process parameters to be measured	Scatter Plots
	•The goal of Six Sigma Implementation	XY Matrix
Measure	•Identify the fundamental process measures	Process flow,
	•Measure the process variation	Check sheets
	•Identify the required data to solve the defect	Pareto Chart
	•Design the data collection plan.	Histograms
	•Collect data	
Analyse	•Analyse the collected data.	ANOVA
	•Analyse the process variation	FMEA
	•Find the root causes of the defect	Cause and effect Diagram
Improve	•Make a list of all possible solution to the defect problem	Affinity diagram
	•Examine the possible solutions	Multi-voting
	•Validate the solutions	FMEA
Control	•Control and monitor the process	Control chart
	•Collect process data	TPM
	•Come up with new process control limits of the improved process.	

Table 1: Six Sigma DMAIC framework[4,6,7]

In particular, the surface defect was a significant issue for particular industry. Painted surface defects demanded rework or repair and heavy costs related to "not doing work right the first time". The article discusses the causes of surface defects, defect characteristics, and systematic prevention methods. Those casting surface defects were analyzed in the steel structure part name engine cover. Every foundry industry faces the challenge of producing castings of specified quality and producing on time. Defect-free casting with higher quality provides a competitive advantage for any company. Hence, companies implement various quality standards such as KAIZEN, 7QC TOOLS, and Total predictive maintenance. One case study is referred to here to analyze the painted surface defects [9]. The most common flaws of painted surfaces were insufficient thickness and surface contamination as revealed by the Pareto-Lorenz analysis.

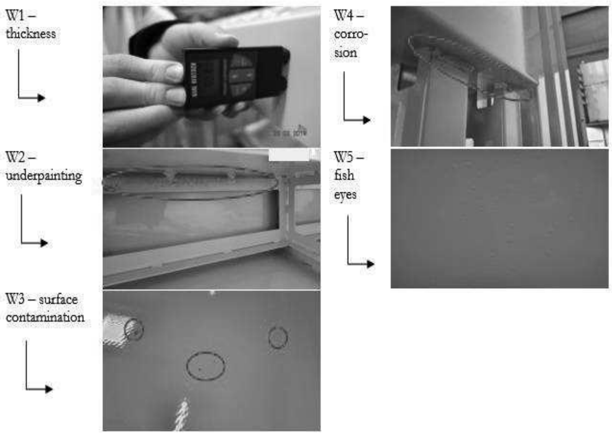

Fig. 1 Examples of occurred defects of the painted surfaces

The following defects were discovered as a result of the investigation conducted on the painted surfaces made in the inspected company:
W1 - thickness, W2 - under painting, W3 – surface contamination, W4 - corrosion, W5 - fish eyes. Fig. 1 demonstrates the defects. Pareto-Lorenz diagram was used for the defect occurrence frequency analysis as shown in Fig.2. The defects were graded with symbols ranging from W1 to W5, and they were arranged in descending order of the frequency with which they occurred, starting with the most common.

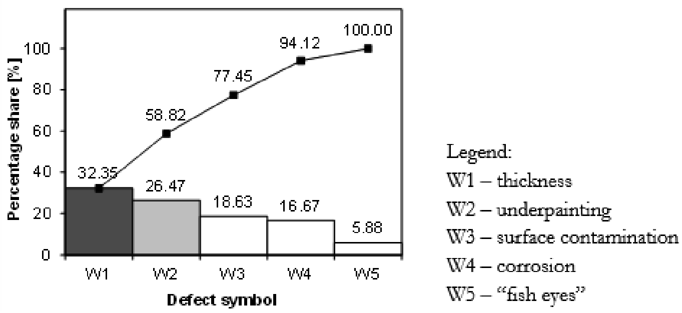

Fig. 2 Frequency occurrence analysis of defects in painted surfaces using the Pareto-Lorenz diagram

This analysis revealed that varnish coatings were caused due to the surface contamination and uneven thickness of the varnish layer caused the defects. The 40% defects caused 58.82% of problems related to varnish coatings.

The quality level was 58.82% after eliminating defects marked as W1 (thickness) and W3 (surface contamination.) The cause of these defects was mainly due to an employee's skill. FMEA analysis confirmed it. PDPC diagram that the surrounding environment should be neat and clean and plays a vital role in reducing surface defects. The Ishikawa diagram was used to examine the causal factors, which revealed that most defects were related to the management, machine and worker. The affinity diagram further confirmed the human factor's unique role in developing faults. The results of the performed study show that the lack of expertise of the varnisher was the essential element influencing the incidence of faults in painted surfaces, which was verified by the results of the matrix diagram and interrelationship diagram analysis Significant flaws were caused by the unskilled employee, who also affected the establishment of other defects-causing reasons. The most frequently suggested approach for preventing faults was training[9].

II. Defect structure

The Integrated Module is not software but a program consisting of a user interface backed up by the interference engine and knowledge base. [11]. Nirav Mehta et al. provided the defect cold shut defect structure. Effective operation of the Integrated Module is primarily dependent on the user interface [10].

III. Defect diagnosis in an integrated module

The integrated module's success relies on the accurate and precise diagnosis of the fault, which yields the correct integrated module. The development of an integrated module aids in detecting casting problems for small and medium-sized companies. In the present research, the investigation of casting defects covers two distinct features. Identifying the casting flaw is the most critical aspect, and rectification is indicated to eradicate the casting problem.

a) **Defect Selection** –suitable for skilled worker

b) **Defect Diagnosis** - helpful step for fresh workers.

The defect identification process is a critical and essential phase executed for defect rectification. The skilled and fresh person operating on an integrated module affects the result of defect analysis. Understanding the nature of casting defect by the skilled person assists select correct defects from the list. The untrained person using casting defect space must undergo the defect diagnosis process. The questionnaire steps on defects; the questions are like the geometry, location and appearance of the defect and geometry. The next step is casting defect analysis. The exact identification of the casting defect is possible in this step. The answers to the frequent questions lead to deciding and finalizing the defect type by the integrated module. Figure 3 represents an overview of integrated module.

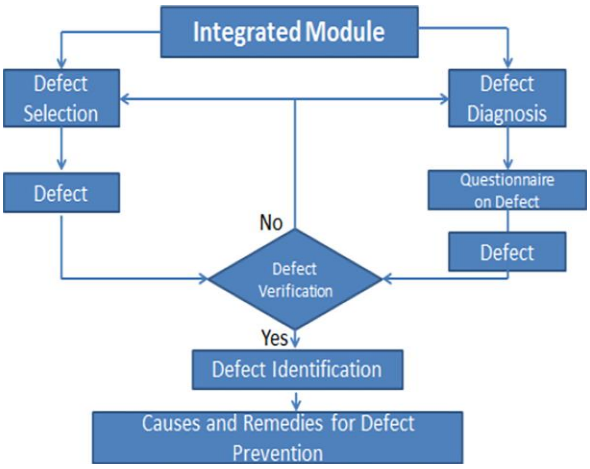

Fig. 3. Overview of the process of the integrated module [10].

As an output, the user gets details on the defect identification, selection, and diagnosis. The result is achieved by processing the database as an integrated module. Present research work was limited to surface defects.

IV. Water analogy

For flow measurement in casting and gating systems, computational modeling and physical experimentation are most utilized. However, actual studies are required to validate the computer model of mould filling. Although numerical models are commonly used in research and production to detect casting problems, their accuracy is questioned due to a lack of validation. To look into the flow characteristics. For analysis, researchers favour physical models and methodologies. Use of the water analogy to analyze basic castings' flow properties or was mainly appropriate for the experimental examination of thin-section cast specimens. The essential advantage is that all aspects of the mould cavity and gating system are visible [12].

P.D. Webster (1967) [13] examined metal flow in runners. Gating ratio of 1:3 to 1:1.5 was validated for aluminium alloys in the first stage. In the second stage, he employed water models and sand moulds with fused silica glass windows to study the flow patterns at the sprue-runner junction. The investigation discovered a significant shrinkage of the metal stream at the connection site, which produces gas suction into the metal stream, resulting in improper casting.

A hydraulically based model was presented by F.J. Bradley et al. (1992) [14] to determine the flow distribution. The gating system performed the analysis of complex three-dimensional topologies using the pipe node path representation. After that, a comparison was carried out with computer simulations for the above system that includes pouring cups, runner and gate. The results of the experiments were found to be in reasonable accord with previously published research on molten steel experiments and were found to be in good agreement with one another.

Bottom filling in a vertical plate cavity with a thin thickness was investigated by researchers Van Der Graaf et al. (2001) [15]. Experiments on the visualization of the process of filling the mould were performed water in a Perspex model and cast iron and aluminum in a sand mould with a glass front. The behavior of the liquid surface and liquid metals was investigated, and an observation was made pertaining to the velocity fields across the cavity and temperature distribution. Quantitative information regarding the surface behaviour and velocity pattern was obtained during the filling phases from both the CFD results and the DPIV.

A case study on the Six Sigma methodology for reduction of green sand casting process defects for a truck transmission part was proposed by Patil et al. [16]. The DMAIC (Define–Measure–Analyze–Improve–Control) approach and the Taguchi method were utilized to reduce the number of flaws present in the Transmission Case. The the cause-and-effect diagram, the process map and the project charter were the three essential tools utilized in their work [16]. The DoE and ANOVA techniques were combined to statistically determine the correlation of defects with the pouring rate, green strength and mould hardness to find optimal levels, which were required to reduce the number of defects. In this study, an attempt was made to compare the current procedure and the one that is being proposed, and the findings of that comparison have been addressed in detail.

The time-temperature dependence of the casting process parameters in green sand moulding was investigated by Pandit and Deshpande [17]. The research provides a fresh viewpoint in the form of a theory called the Theory of Combined Imbalance of Process Parameters. This theory adds a different perspective to comprehending the defect production mechanism that occurs in green sand moulded castings. This study aims to advocate for a methodical approach that can correlate the mould and melting process parameters and defect reduction.

Even though numerous preventative measures are taken before casting, including the design of gating systems, the raw material quality and processes, such as moulding, melting, and pouring are nevertheless rejected because of the development of defects. Pre-process steps are carried out, including casting design simulation, mould filling simulation, and development of gating and risering systems. The steps of analysis of rejection, determining the causes of rejection, and implementing corrective actions are included in the post-process steps. Steps that take place during the process include optimizing and maintaining the parameters of the process at a predetermined level.

Foundry historical data analysis and implementation was studied by Pandit and Dabade [18] to optimize casting process parameters. Pandit et al. [19] created an innovative interactive prototype of system for detecting and analyzing casting defects using a structured procedure.

According to Murguia et al. [20], to reduce the number of castings failing to achieve customer acceptance specifications, it becomes obligatory to correctly identify the process parameter generating a particular defect along with optimized levels.

This is done to reduce the number of castings that do not meet the customer acceptance specifications. Using a method known as Response Surface Methodology (RSM), this research project aimed to investigate how the manufacturing of grey cast pump impellent castings could be improved in a foundry that produces grey cast iron components. It was established that the proportion of clay, the percentage of moisture, and the hardness of the mould were the essential elements for production process control. In the course of the experiment, three distinct levels of each element were studied. Analysis and optimization of the process parameters for confirmatory studies was done using the Statgraphics Centurion Statistical Software. An analysis of variance (ANOVA) test was carried out to determine whether parameters were statistically significant. A significant number of flawless pump impeller castings were produced due to obtaining the ideal parameter settings and having these settings validated by confirmatory trials. According to the study's findings careful selection of casting process parameters is a crucial and significant step in casting defect analysis.

V. Conclusion

Quality improvement is anything that results in a positive change in quality performance. Better control or higher standards can both lead to improvement. Quality can be improved through the use of quality control tools. A proper methodology is developed, including quality control tools such as Pareto analysis, Ishikawa diagram, i.e. cause and effect diagram, brainstorming, and why-why analysis. After implementing this methodology, the organization can have more control over the process. A thorough examination of the root cause can yield a permanent solution. The successful implementation of the remedies results in a lower casting rejection rate and a quality improvement.

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