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Minimization of Rejection Rate and Lead Time in Medium Scale Foundry Industry by using Lean Manufacturing Practices

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Abstract: *In the current globalization, production demand and customer satisfaction have progressively amplified with the development of a new technological process. This research's main objective is to reduce waste by reducing rejection in the manufacturing process and maintaining rejection percentages to meet company standards for specified departments. The industry's current rejection percentage was analyzed based on department wise and investigated the rejection rates for different products. After identifying the various causes of rejection in the current system, various methods are proposed to reduce the rejection level by identifying different defects. Different lean tools like Pareto analysis, cause and effect diagram, and VSM were applied to identify the defects and minimize rejection. The Pareto analysis was carried out to identify the major defects, and a cause and effect diagram was used to identify various methods to reduce the defects. Minitab statistical tool was used for Pareto analysis, and iGrafx is used for cause and effect diagram and also used for VSM to identify value-added, and non-value added activities. From the final results, it was noticed that the lead time was reduced by about 1000 minutes, and the rejection rate was reduced to less than 5%.*

Keywords: *Foundry, Rejection, Lean Practices, Minitab, Productivity*

Introduction

In today's competitive market, planning productivity is one of the main components of successful industrial organizations. An increase in productivity can reduce the cost of production and increase output. Productivity depends on various factors like labor, machinery, raw materials, quality, rejection, etc. In this research, lean manufacturing and other concepts to the foundry industry that manufactures enclosed drive were addressed. Due to the various constraints in its production process, the company cannot meet its customer demands at the right time. Hence, this work aims to increase productivity by implementing some of the lean concepts to minimize the rejection level and reduce the overall lead time, which can satisfy customer demands to a certain extent. With over fifty years of experience, Anala pumps (Pvt) Ltd produces a wide range of water pumps for the agricultural, commercial and domestic sectors. They are an award-winning manufacturer with the captive foundry, motor lamination, and winding wire units. When other companies focus on the global market of demand for customers, Anala groups focus on quality, which can be achieved by reducing rejection rates using various lean methodologies.

In contrast, the rework of rejected products leads to a loss of companies' profit. The company may be mass-producing products for a series of process to come out with final products. Pumps parts manufacturing have a series of process which makes quality control. Being an important part of a foundry, controlling measures are to be sent to quality engineers every day to avoid rejection.

Literature Review

Indian manufacturing industries have become internationally competitive in the vendor's market, owing to elevated demand. Hence, production quantity to be increased by means of reducing the rejection rate and overall lead time. Reviews on different sand casting defects in the foundry industry were studied. The articles showed different types of casting defects and were also given the causes for each defect. Hence, a detailed root cause for each defect was found, which will help the quality department [1-4]. A research article based on sand casting defects using six sigma methodology in a foundry was analyzed. There are about 10 casting defects, and the risk priority for each defect have been found through failure mode effect analysis. After implementing the necessary suggestions, the results show a significant effect in reducing the rejection level and the cost of rejection per unit [5-8]. The defects occurring in the casting process were studied and classified the defects into three types. These three categories are classified based on filling, shape, and thermal. Each defect has been identified, and remedies have been given for quantifying results to be produced inside the industries [9-12]. Different studies on reducing casting defects in a foundry line were reviewed. The studies showed effective use of DMAIC methodology inside the foundry line and found different casting defects. The defects were analyzed, and improvement methods have been made, whereas the results show that the defects have been reduced and increased productivity [13-17].

An overview of implementing lean manufacturing in the foundry industry is studied, and it shows that lean manufacturing has proved itself in economic stability. A case study on the analysis of casting defects in the industrial scenario was discussed, showing nine different casting defects. Appropriate remedial measures to overcome the defects were suggested to improve the overall productivity and quality [18-20]. A diagnostic study on analysis of the casting defects in a foundry was carried out and found defects such as sand drop, blowhole, mismatch and oversize, and suitable remedial measures for each defect. The final result shows that about 65-77% reduction in rejection for each defect [21-23]. The potential benefits are emanating from the application of Value Stream Mapping (VSM) along with assessing its effectiveness in scenarios where it has been implemented already.

Furthermore, challenges faced in the implementation of the VSM tools are collated. Various solutions to address these challenges have been presented in the light of tribulations faced by today's industry [24-27]. VSM is the starting point of lean manufacturing tools. It has three stages; there are current stage, future stage, and implementation. VSM is used to identify the problem. Future stage VSM eliminates non-value-added activities and necessary non-value added activities to enhance productivity and then make the standard operating procedure in the production line by reducing lead time and improving method study. This tool is reducing the bottleneck for making continuous flow [28-30]. Based on the above literature, in this research, a study was taken on foundry division of diffuser housing integral casting component industry to minimize the rejection rate and lead time by implementing the appropriate lean tools.

Problem Definition and **Methodology**

Productivity is reduced due to the occurrence of defects in the foundry. These defects occur in various processes of manufacturing. The rejection percentage is not within the company standards in some places. The higher the components produced, the rejection percentage of the companies' acceptable rejection percentage is 5%, which is the rejection limit. Hence, in this study, more rejection rate was identified and included a simple approach in analyzing the foundry's rejection rate to reduce rejection. Figure 1 represents the study's methodology and the various steps involved in the completion of the study.

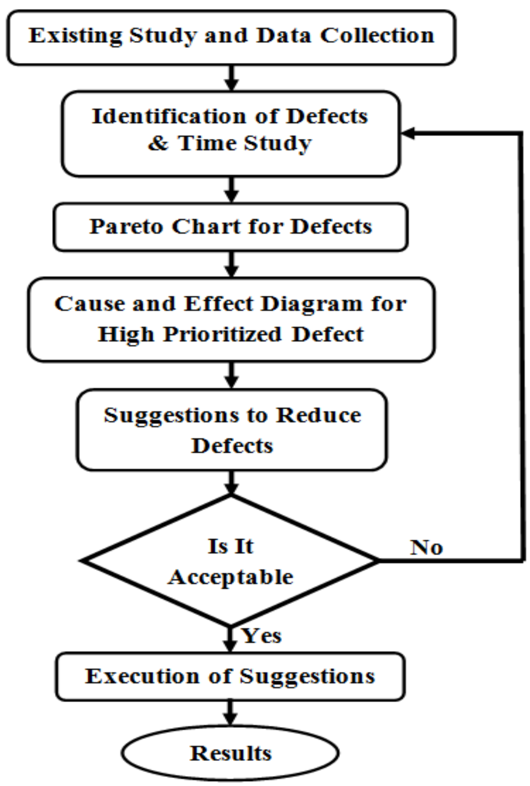

Fig. 1: Methodology Flow Chart

Data Collection and Analysis

The data has been taken for five months in the foundry division's production line from January 2019 to May 2019. Different defects were found, such as sand drop, sand fusion, core crush, blowholes, cold shut, slag, shrinkage, box lift, short poured, and knock off fettling. The major defects found in the foundry, such as sand drop and blowholes, are shown in Figure 2 and Figure 3, respectively.

Fig. 2: Sand Drop

Fig. 3: Blow Holes

The various defects from foundry 1 to unit 2 have been categorized and drawn in a bar chart, as shown in Figure 4, for a better idea of defects. It was observed that the major defects are sand drop and blowholes, which are about 1040 and 900, respectively. Figure 5 shows the various defects from foundry 1 to unit 4 were categorized and were drawn in a bar chart for a clear idea of defects. The results show that the major defects are sand drop and blowholes, which are about 3850 and 730, respectively. Figure 6 shows the different defects from foundry 1 to the machine shop, and each defect has been categorized and drawn in a bar chart. The major defects are sand drop, and blowholes were found as 9395 and 6610, respectively. The various defects from foundry 1 to Anala pump industries have been categorized, and defects were drawn in the bar chart, as shown in Figure 7. The figure shows that the major defects are held on the sand drop and blow holes about 965 and 490. Similarly, the various defects from foundry 1 to Anala sub engineering Building Services (ABS) have been categorized, and defects were drawn in the bar chart, as shown in Figure 8. The major defects are sand drop and blowholes found from the graph, about 376 and 470.

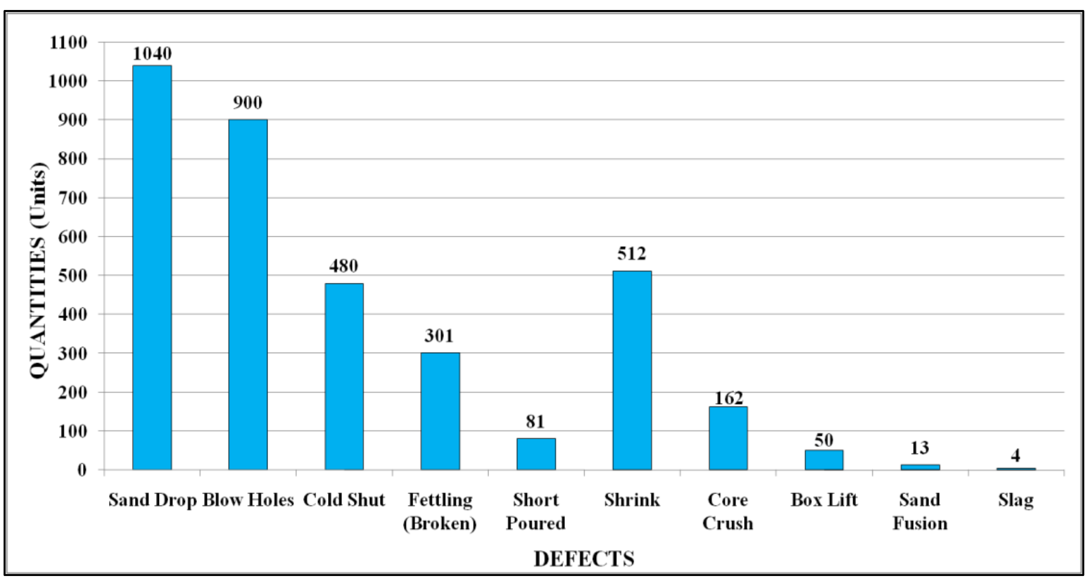

Fig. 4: Results of Defects from Foundry 1 to Unit 2

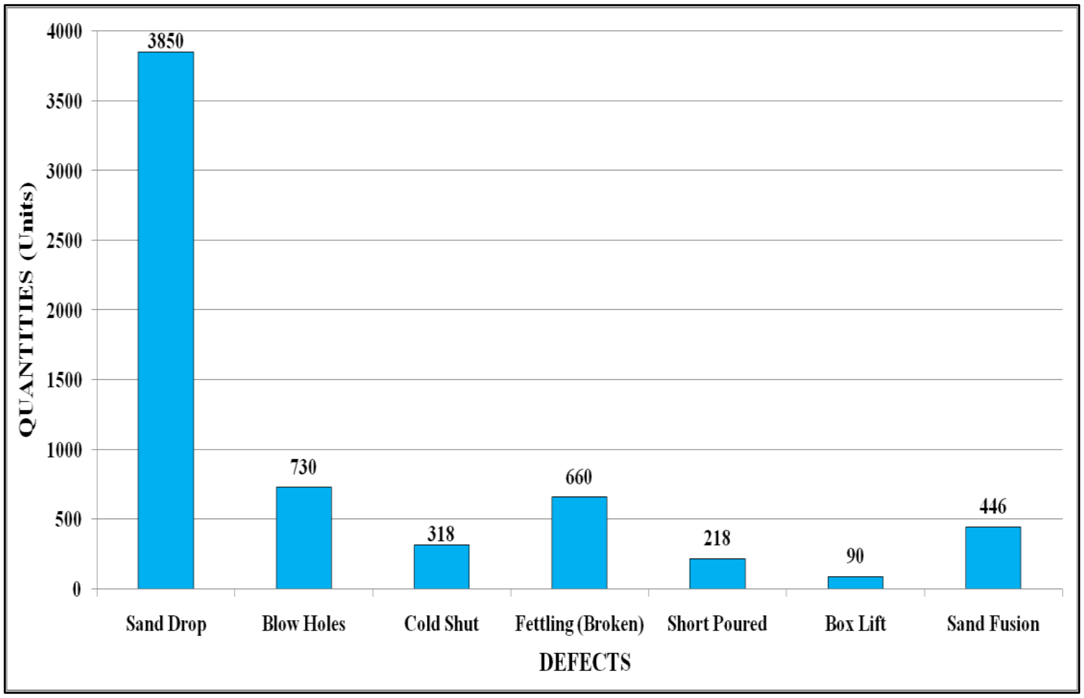

Fig. 5: Results of Defects from Foundry 1 to Unit 4

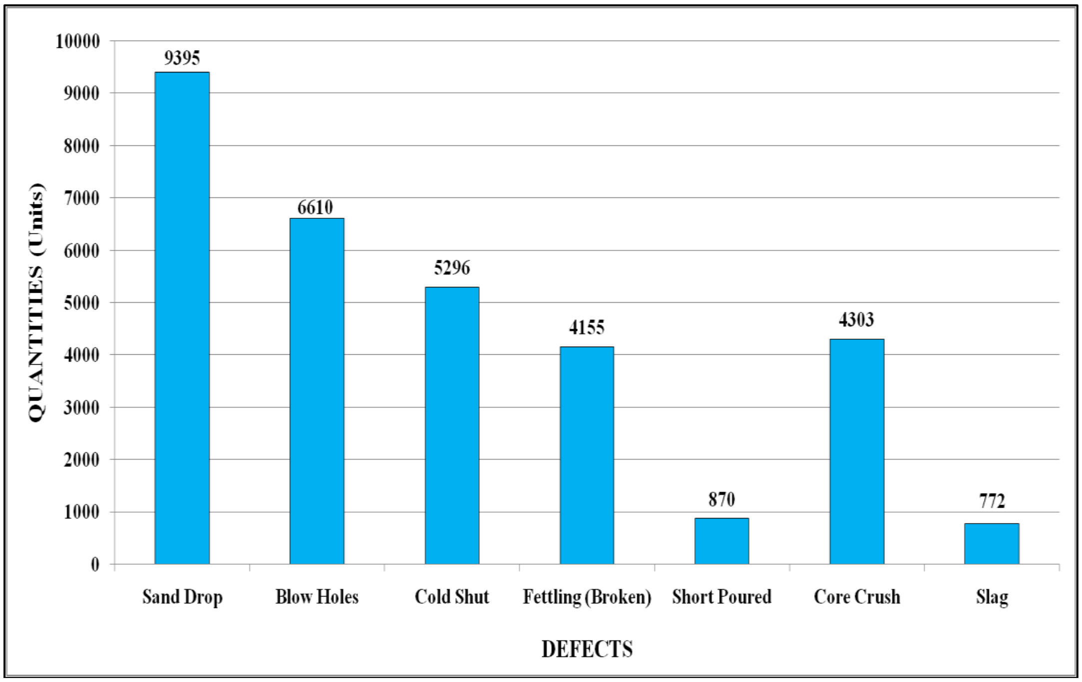

Fig. 6: Results of Defects from Foundry 1 to Machine Shop

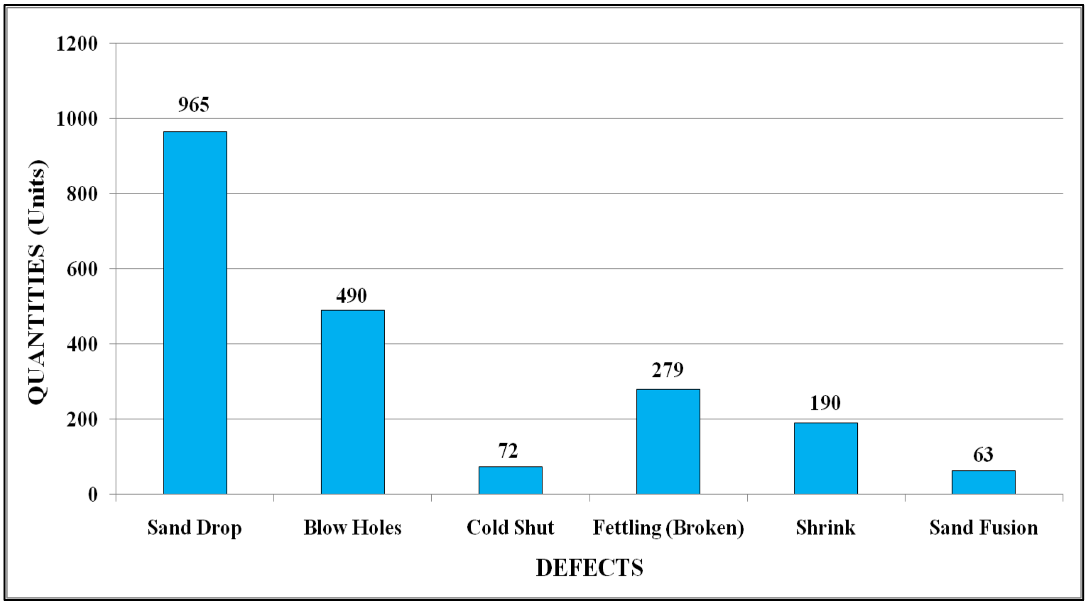

Fig. 7: Results of Defects from Foundry 1 to Anala Pumps Industries

Based on the Pareto analysis, sand drops and blow holes come under the 80/20 line, as shown in Figure 9; hence, these defects are concentrated and studied for rejection analysis. Based on the graph results, it was observed that the failure of sand drop contributes 35.15%, and the blowhole contributes about 20.69%. The percentage of rejection in foundry 1 was calculated for January 2019 and given in Table 1. As per the company standards, only 5% of the rejection rate is tolerable. The results showed that the tolerance limit of the Unit 1 machine shop and ABS are having more than 5% of rejection rates, such as 5.51% and 6.54%, respectively.

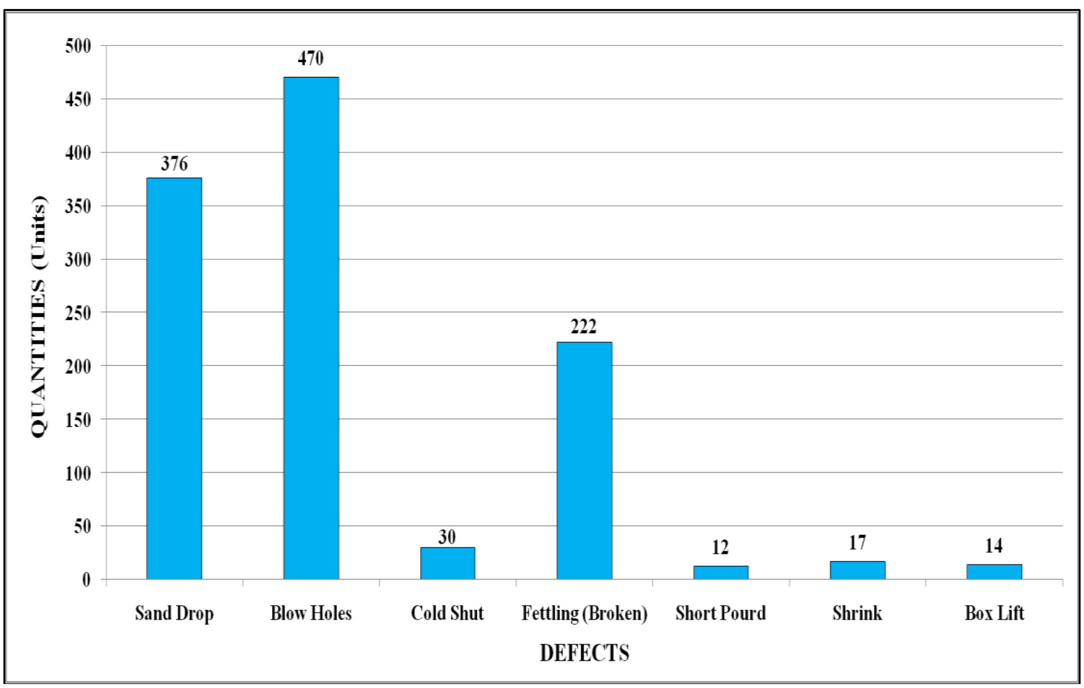

Fig. 8: Results of Defects from Foundry 1 to ABS

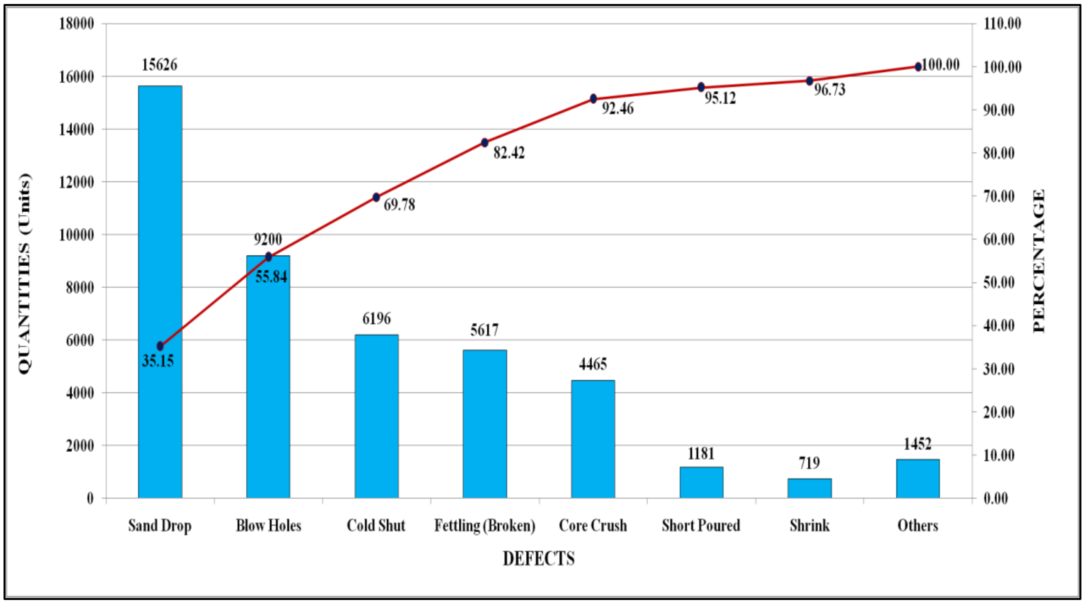

Fig. 9: Pareto Analysis for Overall Defects from Foundry 1

Table 1: Results of Rejection Rate in Foundry 1 for January' 2019

Defects from Foundry 1	Quantity Produced	Quantity Rejected	% of Rejection
UNIT 2	76955	3543	4.60
UNIT 4	158501	6312	3.98
UNIT 1 Machine Shop	**569725**	**31401**	**5.51**
Anala Pump Industries	72951	2059	2.82
ABS	**17445**	**1141**	**6.54**
Overall Defects	895577	44456	23.46

The above table unit 1 machine shop is considered for rejection analysis because they have high rejection quantity. Unit 1 machine shop produces 165 different components in which 51 different components are having a rejection rate of above 5%. Similarly, the overall rejection quantity of the different components (codes) with more than 1000 numbers of rejection for January 2019 were analyzed, and the results are given in Table 2. From the table, the component of diffuser housing integral casting EQRS 42 having code of ASF392 is selected for rejection analysis because it has the highest production quantity compared to other components. Hence, EQRS 42, which is produced, has a production quantity of 103881 and the rejected quantity 10096 with the rejection of 9.72% is > 5%. The various defects that occurred with the number of defects in the selected code are noted and given in Table 3.

Table 2: Results on Components More than 1000 Nos Rejection Quantity for January' 2019

Code	Components	Quantity Produced	Quantity Rejected	% of Rejection
CPC650	Diffuser housing integral casting EQR	10661	1402	13.15
ASF448	Diffuser housing integral casting EQRS 51	11633	1114	9.57
CPC660	Diffuser housing integral casting EQR	17080	1611	9.43
ASF392	**Diffuser housing integral casting EQRS 42**	**103881**	**10096**	**9.72**
ASF360	Diffuser housing integral casting EQRS 49	49135	4332	8.82

Table 3: Defects on ASF392 Code for January' 2019

Defects	Blow Holes	Core Crush	Sand Drop	Cold Shut	Fettling	Others
Quantity	2288	2137	2148	1610	1540	373
% of Rejection	22.66	21.17	21.28	15.95	15.25	3.69

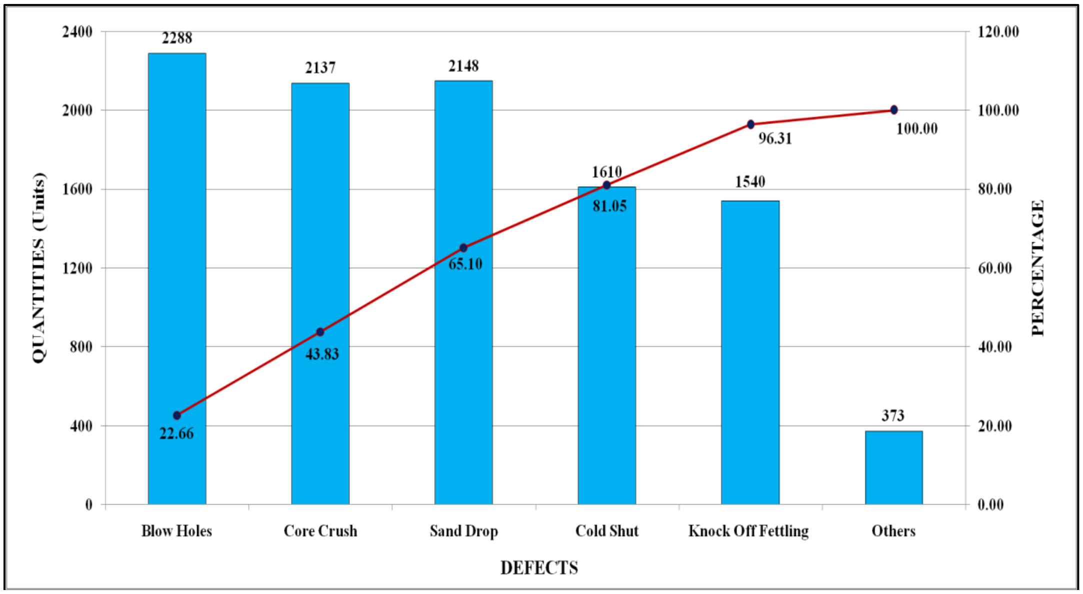

Fig. 10: Pareto Analysis for Diffuser Housing Integral Casting EQRS 42 for January' 2019

Figure 10 of Pareto analysis observed that the defects of blow holes, core crush, and sand drop are contributing major roles with 22.66%, 21.17%, and 21.28%, respectively. Hence, all three major defects should be focused on for analysis to minimize the rejection rate.

Cause and Effect Diagram

The fishbone or cause and effect diagram for the defect of blow holes in integral diffuser housing EQRS 42 is drawn, as shown in Figure 11. The various major causes are identified based on material, design, methods, and machines, and their sub causes are also identified, such as improper ventilation, gating system, ramming, and pouring speed.

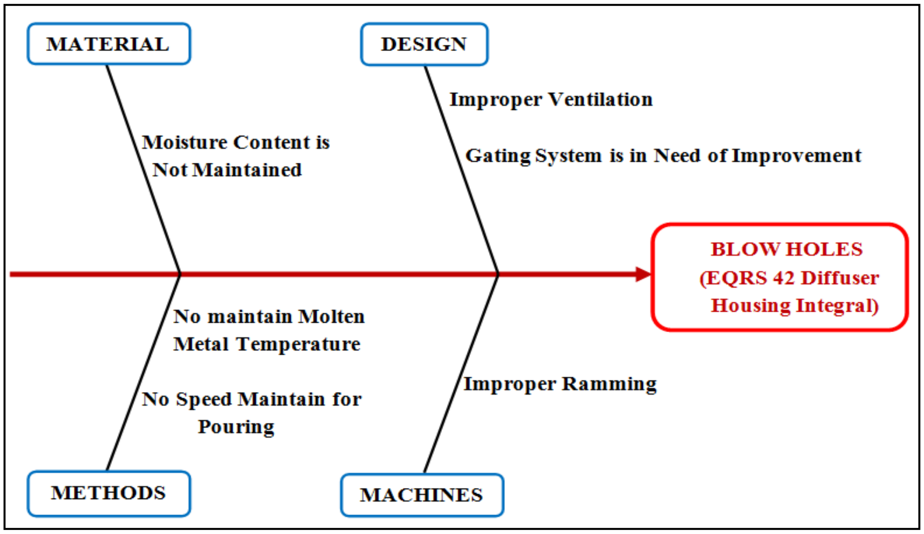

Fig. 11: Fishbone Diagram for Blow Holes in Diffuser Housing Integral Casting EQRS 42

Suggestions: From Figure 11, it was observed that the major cause of design plays an important role in the reduction of defects, whereas the necessary design modifications to be carried out by the department of pattern development in the foundry. Based on the pattern department, gating methods should be improved by increasing the flow of liquid metal and modifying pattern design by introducing a strip of about 0.5mm, which facilitates the flow of gases in pattern and helps in the ventilation of gases.

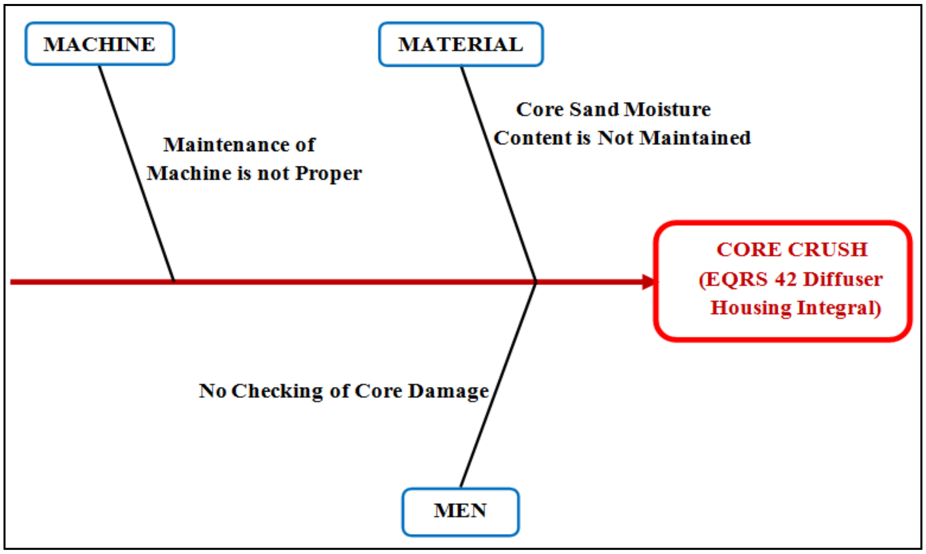

Fig. 12: Fishbone Diagram for Core Crush in Diffuser Housing Integral Casting EQRS 42

The fishbone or cause and effect diagram for the defect of core crush in integral diffuser housing EQRS 42 is drawn, as shown in Figure 12. The various major causes are identified based on Machine, material, and men. Their sub causes are also identified, such as improper maintenance of Machine, core sand moisture content, and core damage checking.

Suggestions: Figure 12 noticed that men's major cause plays an important role in reducing defects when the employee places the core after inspection. This small change in the core process almost removes core crush and reduces defects close to zero.

Current State VSM: The current state value stream mapping was developed based on the existing data and is shown in Figure 13. Each process's cycle time was calculated, and lead time, value-added, non-value-added activities were also calculated. From the current state VSM, it was observed that the total cycle time is 45 hours for each batch production, and the total value-added time is 120 minutes. Based on the current state VSM processes, the future state can be predicted.

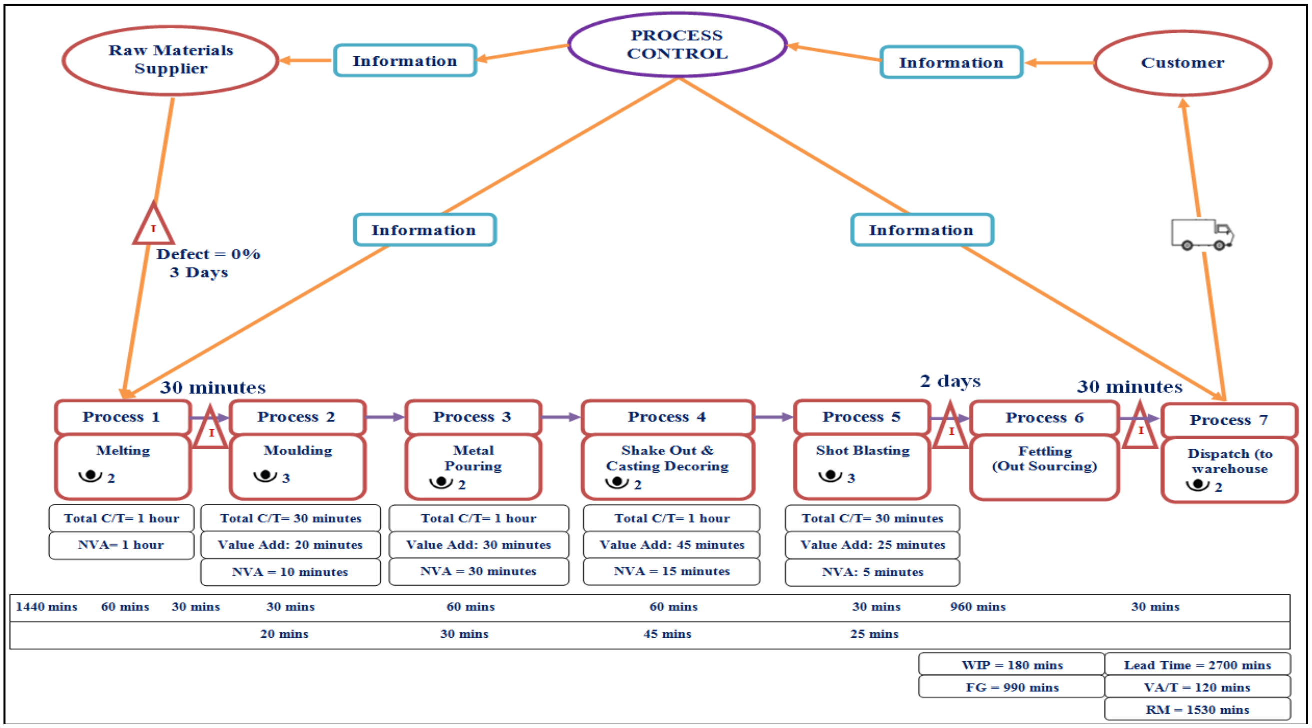

Fig. 13: Current State VSM for Foundry 1 Process

Future State VSM: The future state value stream mapping was constructed based on the suggestions and developed processes shown in Figure 14. Figure 14 observed that the total lead time was reduced about 1000 minutes, and the total time for finished goods was drastically decreased. Initially, the fettling process was outsourced, whereas more defects may occur due to non-control of company jurisdiction. This may be replaced by doing in the house itself with robotic arms recently purchased, as shown in future state VSM. This fettling process does not go beyond the company's jurisdiction, and due to the autonomous fettling process, the defects can be reduced drastically.

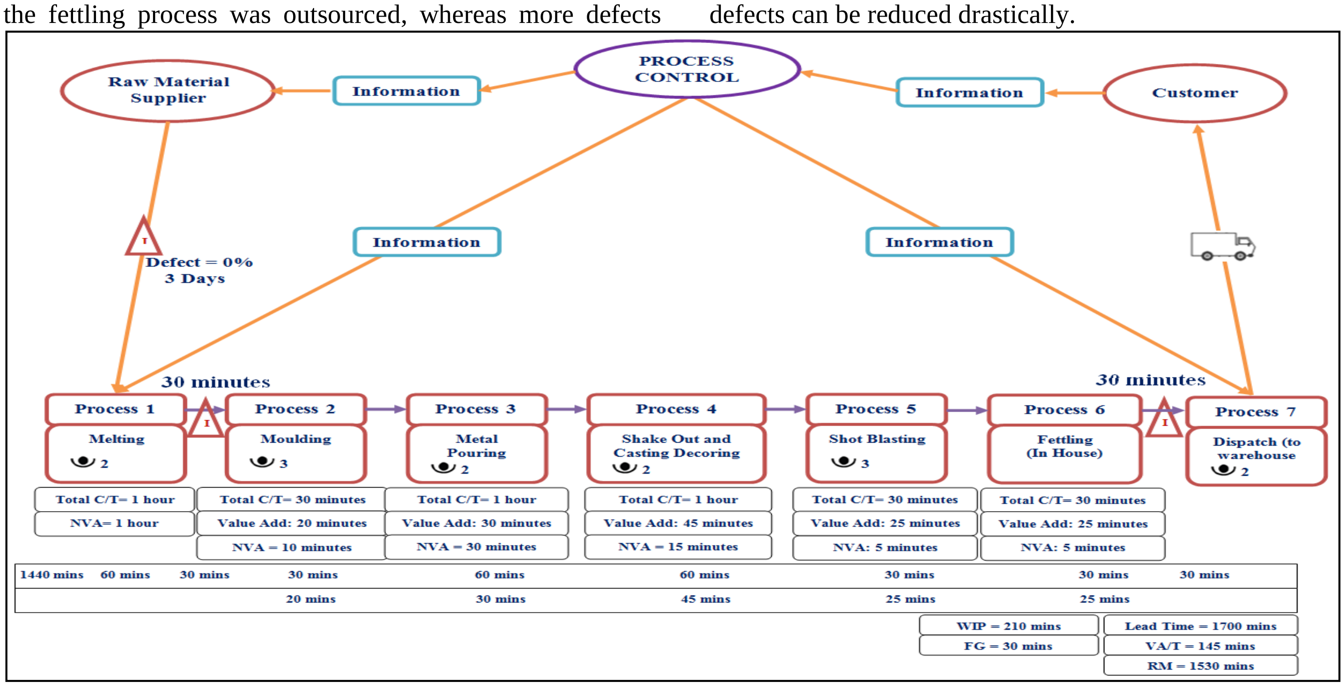

Fig. 14: Future State VSM for Foundry 1 Process

Results and Discussion

After the execution of necessary suggestions and the lean practices in the existing method, the rejection results have been collected for Foundry 1 and defects on ASF392 Code for May 2019. They are given in Table 4 and Table 5 as monthly production and the rejection rate, respectively. The results found that the percentage of rejection for all the units were reduced, particularly unit 1 machine shop, and ABS becomes less than 5%. The overall percentage of rejection is reduced by about 5.56%. The Pareto analysis chart for the result of the rejection rate for the ASF392 Code for May 2019 is shown in Figure 15. The comparative results of the rejection rate for diffuser housing integral casting EQRS 42 for January and May 2019 are given in Table 6. The overall reduction of rejection rate before and after implementing lean execution is shown in Figure 16. The results found that the rejection rate of Diffuser housing integral casting EQRS 42 was reduced from 9.72% to 4.95%, which is about 4.77% after implementing necessary lean practices.

Table 4: Results of Rejection Rate in Foundry 1 for May' 2019

Defects from Foundry 1 to	Quantity Produced	Quantity Rejected	% of Rejection
UNIT 2	76960	2432	3.2
UNIT 4	158510	5210	3.3
UNIT 1 Machine Shop	**569730**	**23304**	**4.1**
Anala Pump Industries	72955	1950	2.7
ABS	**17449**	**810**	**4.6**
Overall Defects	895604	33706	17.9

Table 5: Results of Improved Rejection Rate for May 2019

Defects	Blow Holes	Core Crush	Sand Drop	Cold Shut	Fettling	Others
Quantity	1270	1110	1010	960	710	80
% of Rejection	24.71	21.60	19.65	18.68	13.81	1.56

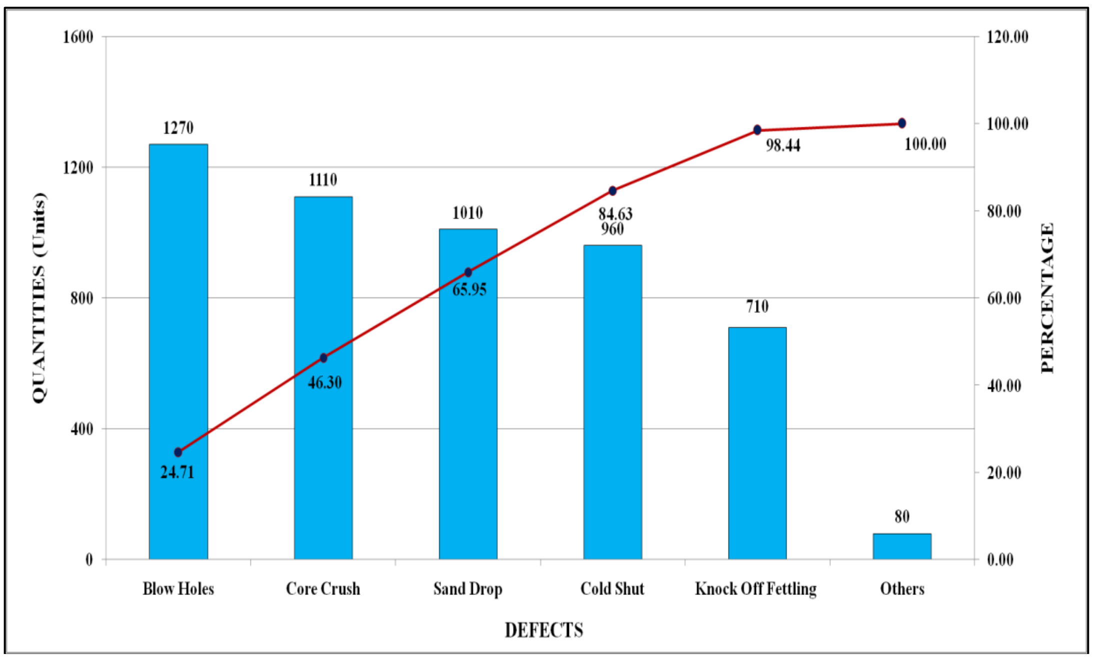

Fig. 15: Pareto Analysis for Diffuser Housing Integral Casting EQRS 42 for May' 2019

Table 6: Comparative Results on Diffuser housing integral casting EQRS 42

Code	Month	Quantity Produced	Quantity Rejected	% of Rejection
ASF392	January	103881	10096	9.72
	May	103885	5140	4.95

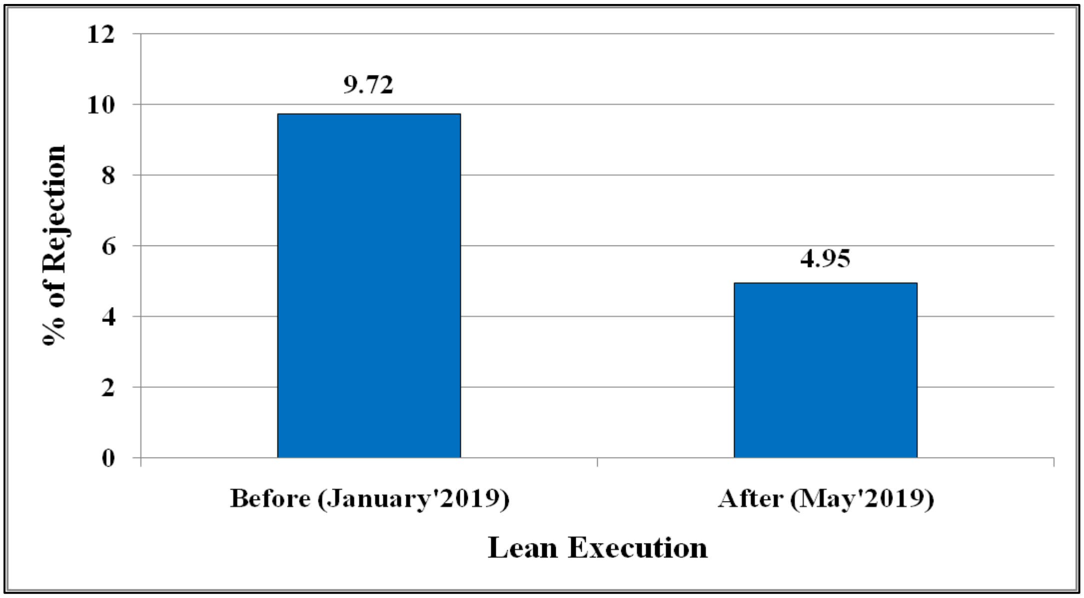

Fig. 16: Percentage of Rejection before and after Lean Execution

Conclusion

Major industries play an important role in manufacturing the good quality of products to attain customer satisfaction. The aim of the depreciation of rejection rate and lead time was carried out in this case study. The above analysis observed that the major defects occur on blow holes, core crush, and sand drop. The defects such as blowholes, core crush, and fettling have been reduced by changing the design pattern for providing proper ventilation, checking core for damage by the workers through visual inspection, and in-house processing. The overall rejection rate of foundry 1 has been reduced by about 5.56% through the proper lean suggestions and executions. The major role of the defect on diffuser housing integral casting EQRS 42 was reduced to 4.95%, which is an acceptable company standard.

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