Application of Quantitative Fishbone Diagram for Investigation of Erosion Defect in CI Casting Produced by Sand Casting Process

Mr. S. M. Ingale[#1], Dr. V. A. Raikar[*2], Mr. S. M. Shinde[#3]
[#1] *Associate professor, Dept. of Mechanical Engg., Sanjay Ghodawat University, Kolhapur, Maharashtra, India*
[*2] *Vice Chancellor, Sanjay Ghodawat University, Kolhapur, Maharashtra, India*
[#3] *Lecturer, Dept. of Mechanical Engg., Jazan University, Jazan, KSA*

Abstract

Sand casting is the most widely used process for manufacturing of CI casting. The castings produced by this process are rejected due to different types of casting defect related to sand pattern, core, mould and or metal. There are various sand related casting defects like sand erosion, blowholes, shift, penetration and sand inclusion etc. Various quality control tools have been used to control the casting defects. However, in this paper an attempt has been made to investigate sand related erosion casting defect by using quantitative fishbone diagram. This technique not only helps us to know sub causes but also helps to know the level of extent of sub causes influencing casting defect. At the end, risk associated with each sub cause will assist in determining which can be neglected and which require immediate treatment.

Keywords - *Casting Defects, Erosion, Quantitative Fish Bone Diagram, Risk, Treatment*

I. INTRODUCTION

There are various clusters of foundries in India at Agra, Ahemdabad, Batala, Belgaum, Chennai, Coimbatore, Faridabad, Gurgaon, Howrah, Hyderabad, Indore, Jalandhar, Kolhapur, Kolkata, Ludhiana, Mumbai, Pune, Sholapur and Rajkot etc. Each foundry cluster is known for catering services to specific end use market. I have taken foundry units from Kolhapur foundry cluster, which is known for providing services to automotive sector. In the selected unit we have first studied various cast parts produced by them and then we have selected component which is having maximum rejection. Further, total rejection is classified into various casting defects based on its source. Quantitative fish bone diagram is helpful for the investigation of root cause of major defect.

II. LITERATURE REVIEW

There are various attempts made to classify the defects. In ASM metals handbook volume 15 different types of casting defects are given. However, an attempt is made to classify the casting defects based on the stages involved in the manufacturing of sand casting.

Harvir Singh et. al. has discussed minimization of the Casting Defects Using Taguchi’s method. However, there is limitation of number in selection of parameter and its levels. It is used after identification of root causes. It is only a partial factorial experiment. It involves lot of time and cost.

SuyashVichare et. al. has mentioned fish bone diagram shrinkage, misrun and inclusion for aluminium casting to control effects. However, CI castings produced by sand casting requires modification before implementation.

Amit Sata has developed three levels of cloud-based casting defects categorization system based on geometry, integrity and property. But it has not covered all casting defects in CI casting. We have considered more defects for the casting as it was present for the selected product.

Vaibhav Ingle has presented review on filling related, shape related and thermal related defects. It gives causes in general. But in order to control it is required to categorise the causes. It is done in this paper for selected defect.

Supriya Priyadarsini et. al. has presented review on analysis of the causes of different types of defects and provided the remedial measures which may be helpful in improving the quality of product along with increase the productivity. The analytical approach of the same is presented in paper.

B. Chokkalingam et. al. has given a systematic procedure to identify the root cause of shrinkage defect in an automobile body casting of SG iron. Quantitative approach helped to reduce shrinkage defect. We have extended the approach with modification for CI casting and sand related erosion defect.

Gheorghe ILIE et. al. made Fishbone diagram become a very useful instrument in risk identification stage. They proposed to extend the applicability of the method by including in the analysis the probabilities and the impact, which allow determining the risk score for each category of causes, but also, of the global risk. This approach is followed to control the rejections of casing due to a defect.

III. METHODOLOGY

Traditionally qualitative approach was used for fish bone diagram. However, we have proposed quantitative approach for the same. Hence, Codification is done for main cause and sub cause. Risk value is calculated for main cause and sub cause. Then the root cause is identified based on highest risk value. Strategy is formed and implemented based on root cause. Results are then confirmed before implementation. If there is an improvement, then process is standardised

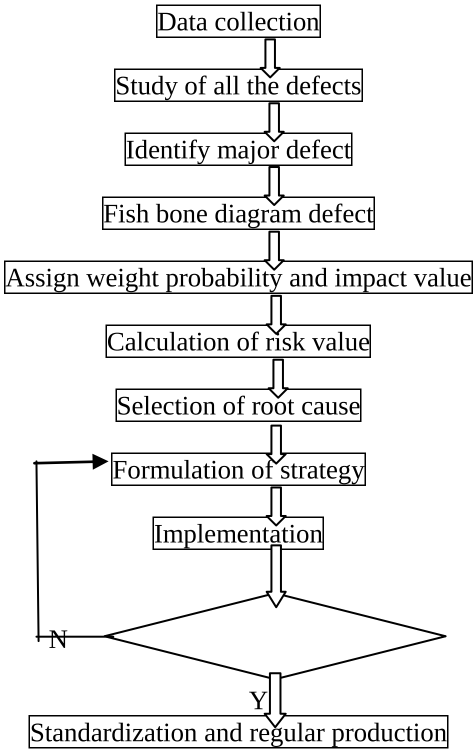
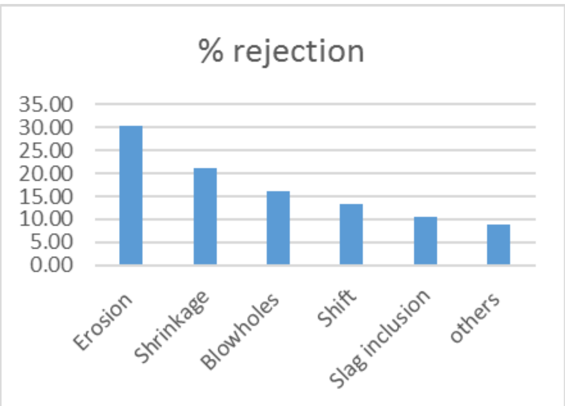


Fig. 1 Methodology for quantitative fish bone diagram

IV. INVESTIGATION OF ROOT CAUSE USING QUANTITAVE FISH BONE DIAGRAM

For the selected component percentage of different defects are as below.



. **Fig. 2 Pareto analysis of casting defects**

The total rejection is 16.68 % for the component.

It is observed that the major defect is erosion, which need to be further investigated to identify root cause. Based on stages in the manufacturing three sources are identified viz. sand, moulding and pouring. For each main cause sub causes are identified which are contributing to main defect. Then Fish bone diagram that is shown in figure below is constructed.

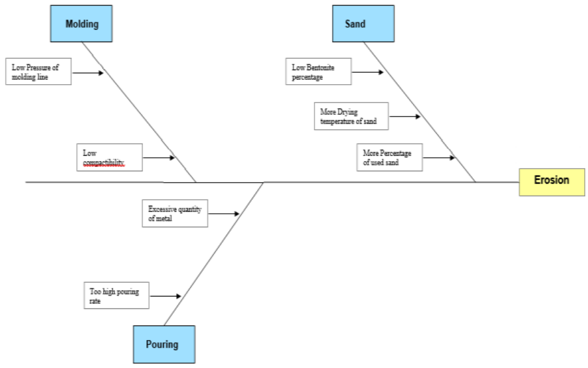


Fig. 3 Fish bone diagram for erosion casting defect

We have proposed quantitative approach for the same. Hence, codification is done for easy identification and calculation in this quantitative approach

TABLE I : Coding of main causes and sub causes

Issue	Cause	Sub cause	Code
1	Sand		S_1
	1.1	Less Bentonite	S_{11}
	1.2	More Drying temperature	S_{12}
	1.3	More Percentage of used sand	S_{13}
2	Moulding		
	2.1	Low compactibility	S_{21}
	2.2	Low pressure of moulding	S_{22}
3	Pouring		
	3.1	Too high pouring rate	S_{31}
	3.2	Excessive quantity of metal	S_{32}

Based on past experience and historical data following weights are attached to each main cause and sub cause

TABLE III: Weightages of main causes and sub causes

Secondary causes	Main Causes			Weight Control
	S_1	S_2	S_3	
S_{11}	0.45			
S_{12}	0.35			
S_{13}	0.2			
Weight Control	1			
S_{21}		0.6		
S_{22}		0.4		

Weight Control		1		
S_{31}			0.7	
S_{32}			0.3	
Weight Control			1	
Weight of Main Cause	0.55	0.25	0.2	1

Risk is then calculated depending upon the impact and probability of sub causes

TABLE IIIII: Risk of sub causes

Issue	Cause	Probability (p)	Impact (I)	Risk (R)
1	S_{11}	0.33	0.8	0.264
2	S_{12}	0.33	0.6	0.198
3	S_{13}	0.33	0.5	0.165
4	S_{21}	0.5	0.8	0.4
5	S_{22}	0.5	0.6	0.3
6	S_{31}	0.5	0.9	0.45
7	S_{32}	0.5	0.5	0.25

If probability is low and impact is low then it is minimum level risk, which can be safely neglected. If probability is high and impact is low, then it is medium level risk and hence attempt must be made to minimize the frequency of occurrence by changing process parameters to minimize the risk. If probability is low and impact is high, then it is medium level risk and hence attempt must be made to reduce the impact by preparing contingency plan. If probability and impact both are high then it is a critical level risk, which requires immediate attention.

Risk value of main causes and sub causes is shown in the table below.

TABLE IVV: Risk value of main causes and sub causes

RS_i	Wsij	Rsij	Risk value
S_{11} S_{12} S_{13}	0.45 0.35 0.2	0.264 0.198 0.165	0.1188 0.0693 0.033
RS_1	0.55		0.2211
S_{21} S_{22}	0.6 0.4	0.4 0.3	0.24 0.12
RS_2	0.25		0.36
S_{31} S_{32}	0.7 0.3	0.45 0.25	0.315 0.075
RS_3	0.2		0.39

Global risk Value (GRV) is calculated from the above table using the following formula.

$$GRV = WS_1 \times RS_1 + WS_2 \times RS_2 + WS_3 \times RS_3$$
$$= 0.55 \times 0.2211 + 0.25 \times 0.3600 + 0.20 \times 0.3900$$
$$= 0.2896$$

It is clear that risk associated with pouring is highest. Risk associated with sand is lowest. Following is the graphical representation of the risk associated with each man cause.

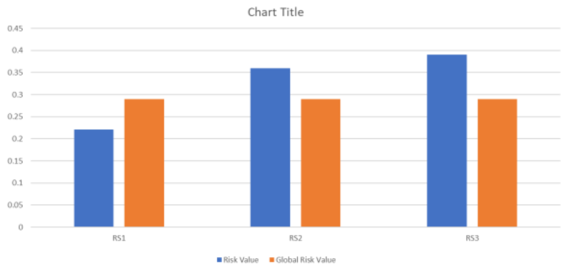


Fig. 4 Comparison of risk value of main cause with global risk value

As pouring is the main cause having highest risk value 0.39compared to global risk value of 0.2896, it is considered for formulation of strategy in order to control the rejection by reducing erosion casting defect. It is clear from the table that sub cause too high pouring rate is having highest risk value of 0.315. Therefore, it is recommended that pouring to be done slowly while filling up the mould cavity. In order to have optimum value of the pouring rate following empirical formula is used.

- Unit casting weight = 14.40 kg
- Total poured weight = 14.4/0.75 = 19 kg
- Composition factor = 3.85
- Fluidity in mm = 721mm
- Pouring time (t) = K (0.95+0.046T) × 1.48 × √W

= 6 sec.

Pouring time was suggested as 8 sec. as against 5 sec as a pouring time currently used. Further it was checked with the AutoCAST to have optimum value of the pouring rate

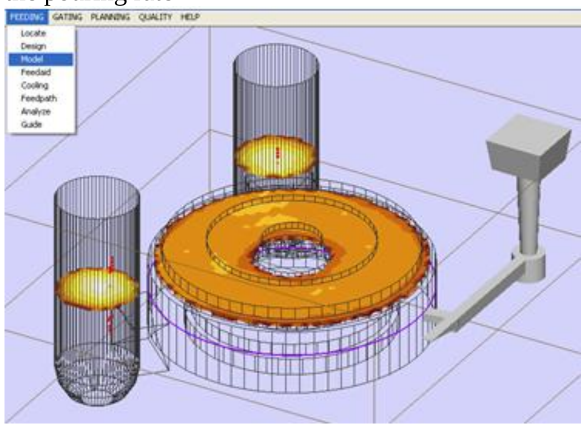


Fig. 5 Mould filling using simulation software

V. CONCLUSION

After implementation of strategy the total rejection is reduced to average 13.12 % from average16.68%. After implementation of strategy, contribution of erosion casting defect to total rejection is reduced from 5.08% to 2.55%.

Quantitative analysis of fish bone diagram helps not only to find the sub causes which needs immediate treatment but also the associated risk value of the same. It also helps us to know the sub causes which don't require immediate attention and its associated risk value.

VI. FUTURE SCOPE

Quantitative fishbone diagram is very useful quality control tool for controlling other defects also. This tool can be extended to any problem for getting the root cause and associated risk value.

Skilled personnel is required for implementation of quantitative analysis of fish bone diagram to identify root cause. Hence, an expert system if designed will make it easy for implementation

ACKNOWLEDGMENT

We herby thankful to the foundry for sharing valuable information for the paper and providing necessary resources and set up for performing necessary research.

REFERENCES

.

[1] 49th Census of World Casting Production, Modern castings, December 2015, pp 26-31

[2] B. Chokkalingam, V. Raja, J. Anburaj, R. Immanual, M. Dhineshkumar, "Investigation of Shrinkage Defect in Castings by Quantitative Ishikawa Diagram", Archives Of Foundry Engineering, ISSN (1897-3310) Volume 17 Issue 1/2017, pp 174 – 178

[3] Amit V. Sata, "Development of Cloud Based Casting Defects Categorization System (CDCS)", Archives Of Foundry Engineering, ISSN (1897-3310) Volume 17 Issue 1/2017, pp 216 – 222

[4] Suyash Vichare, Shubham P Sawant, Pratik Sanas, Ashwin Parmar," Casting Defect Analysis Using SQC Tool", International Journal of Novel Research in Electrical and Mechanical Engineering Vol. 4, Issue 2, May - August 2017, pp 36-42

[5] Supriya Priyadarsini, Sarojrani Pattnaik and Mihir Kumar Sutar, "Defects in Casting, their Causes and Remedial Measures: A Review", International Journal of Computer & Mathematical Sciences IJCMS ISSN 2347 – 8527 Volume 6, Issue 11 November 2017, pp 228-234

[6] Vaibhav Ingle, Madhukar Sorte, "Defects, Root Causes in Casting Process and Their Remedies: Review", Int. Journal of Engineering Research and Application, ISSN: 2248-9622, Vol. 7, Issue 3, (Part -3) March 2017, pp 47-54

[7] G.Ravi, Dr.Pradip Kumar Talapatra "Optimization of gating system Design for Cast Iron & S.G Iron Foundries", International Journal of Engineering Trends and Technology (IJETT), May 2017. ISSN:2231-5381., pp 42-49

[8] C. Narayanaswamy, K. Natarajan, "Optimization of casting defects analysis with supply chain in cast iron foundry process", METALURGIJA 55, 4, 2016, 815-817 815, ISSN 0543-5846

[9] Andreas Felsberger, Bernhard Oberegger, Gerald Reiner, "A Review of Decision Support Systems for Manufacturing Systems", SamI40 workshop at i-KNOW '16, Graz, Austria,2016, pp 1-8

[10] Harvir Singh, Aman Kumar, "Minimization of the Casting Defects Using Taguchi's Method", International Journal of Engineering Science Invention ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726, Volume 5, Issue 12, December 2016, pp 06-10

[11] Gheorghe ILIE, Carmen Nadia CIOCOIU, "Application of fish bone diagram to determine the risk of an event with multiple causes", Management research and Practice, Vol. 2, Issue 1 (2010) eISSN 2067-24620

[12] Dr. B. Ravi &. M. n. Shrinivasan, "Computer aided gating and metal rising simulation" at 40th Annual convention of IIF, Madras, 1992, pp 269 – 283