INVESTIGATION OF SAND INCLUSION CASTING DEFECT USING QUANTITATIVE FISH BONE DIAGRAM

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Abstract: Castings are widely used in all the industries which are metallic, machine components. Production of casting will continue to play an important role in the economic prosperity of a nation. Casting soundness include physical appearance with dimensional accuracy and better surface finish and free from any kind of defects. This is possible with new and better techniques of production, based on stringent control of quality at each stage of casting production and the equipment's used in the processes. In this paper an attempt has been made to control the defects arising due to molding sand. Quantitative approach of fish bone diagram is proposed for controlling of defects. It requires weightage, probability and impact values as input based on experience and historical data. Risk values are the calculated for main causes and sub causes to determine root cause. Based on the root cause strategy is formulated to control the rejection in the proposed method. This method is very useful in identifying critical process parameter which requires immediate attention.

***Index Terms* – Quantitative Fish Bone Diagram, Probability, Impact, Risk Value, Critical Process Parameter**

I. Introduction

The Indian foundry industry manufacturers metal cast components for applications in auto, tractor, railways, machine tools, sanitary, pipe fittings, defence, aerospace, earth moving, textile, cement, electrical, power machinery, pumps, valves, wind turbine generators etc. Most of these products are produced by sand casting processes. There are common defects in all such types of casting. Process parameters during preparation of sand, moulding, core making, melting & pouring and design of gating system are responsible for most of the time for various casting defects. In order to control the rejection, some of the critical parameters responsible for rejections must be controlled. It involves a lot of time and cost in taking such decisions. These parameters can easily be identified by the proposed quantitative fish bone diagram. As a case study, we have selected gear box housing which is having maximum rejection of 20.49%. The rejection in percentage of each of the casting defect for gear box housing is recorded. Instead of qualitative fish bone diagram, quantitative fish bone diagram is proposed for the investigation of major defect.

II. Literature Review

There are different types of defect related to sand, moulding, core making, pouring & melting and gating system. We have made an attempt to identified the root causes of these defects.

Saurav Adhikari et. al. has adopted implementation of quality control tools, fishbone diagram, and pareto chart tools for identification and elimination of the root causes responsible for malfunctioning of the fuel pump. Further 5-why analysis was used to obtain root cause. But I proposed quantitative approach for the same.

Avinash Juriani in his study provided an intense knowledge of critical casting defects and their root cause analysis. They presented technically feasible remedies for minimizing several casting defects and improving the quality of castings which will serve as control measures for quality control. But detailed study for one of the defects is helpful for similar defect in the same group of casting. We have attempted the same in the present paper for sand inclusion.

Asmamaw Tegegne et.al. studied burn on defect and found many reasons for these defects. By doing analysis using fish bone diagram, they found that the use of poorly designed gating system led to turbulence flow, uncontrollable high temperature fused the silica sand and liquid polystyrene penetrated the poorly reclaimed and rammed sand mold as a result of which eroded sand has penetrated the liquid metal deeply and reacted with it. As our defect is related to sand, we have studied similar parameters for our defects.

Aniruddha Joshi et. al. presented manual metal casting operations and rejections due to defects in the foundry. They had selected defects like mold shift, Crush, surface finish, buckling, fins, shrinkage, porosity and cold shut/ Mis run for analysis and used Pareto chart and Cause and Effect diagrams to know correct cause and correct remedial factors to improve quality. We followed similar approach for sand inclusion to begin with. Further we have given weightages to main cause and sub cause to reach at the root cause.

Anil Rathore et. al. had studied cold shut defect in found in the delivery casing which is produced by using gray cast iron. The quality control tools like Check Sheets, Histograms, Pareto Analysis and Fishbone Diagrams were used to analyze the defect and to find the parameters which affect the final quality of casting. Three parameters were selected which affect most to the final quality which is Pouring Temperature, Pouring Time and Gating System. Similarly, we selected few parameters for investigation of sand inclusion defect.

Zanele Mpanza found that most common contributors to these defects were man, methods, control and machinery. Some of the significant root causes identified were the lack of employee training, poor quality control and lack of supervision. The root causes were then analyzed using the 5 Whys method. Once the root causes were analyzed, a corrective action plan was developed. This helped t minimize the scrap. We have added process related Apart from these causes some process related causes are identified which helped us to identify the root cause of sand inclusion defect.

V.V.Mane et. al. had analyzed Defective castings to identify major casting defects such as shrinkage, blowholes and shrinkage by using pareto diagram. Castings rejected due to major casting defects had characterized to determine process parameters responsible causing major defects. The process parameters considered were green compressive strength, permeability, loss on ignition, carbon equivalent, volatile data in return sand, pouring temperature, A.F.S..number, mold hardness, return sand temperature, active clay, dead clay, moisture content and compatibility. We have considered few of these critical parameters for investigation.

B. Chokkalingam et. al. mentioned that a systematic method was required to identify the root cause of the defect among possible causes, consequently specific remedial measures have to be implemented to control them. They presented a systematic procedure to identify the root cause of shrinkage defect in an automobile body casting and control it by the application of Pareto chart and Ishikawa diagram. with quantitative Weightage. We propose a quantitative method of fish bone diagram for investigation of sand inclusion defect.

III. Methodology

Traditionally qualitative approach is used for fish bone diagram. However, in this paper we have proposed quantitative approach of fish bone diagram for obtaining the root cause and associated remedial action for controlling the sand inclusion casting defect. Following is the methodology used for the same

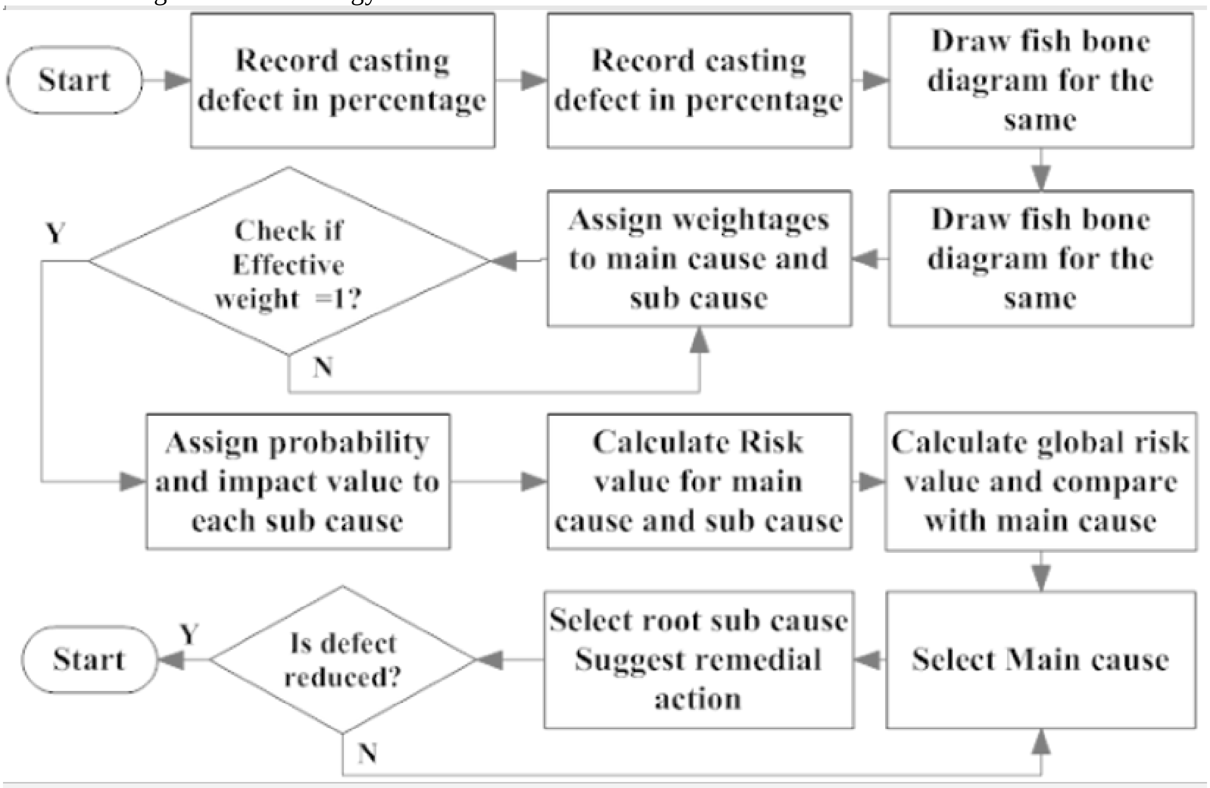

Fig. 1 Methodology for quantitative fish bone diagram

IV. Observations

For gear box housing, we have recorded the rejections for the first three months and have calculated the average rejection for the first three months. The percentage rejection is as shown in the figure below

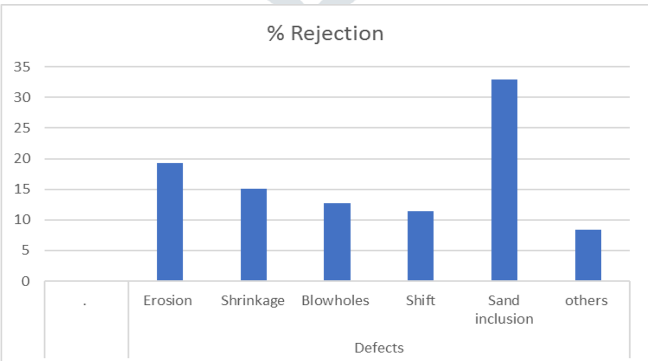

Fig. 2 Average Rejection in Percentage for various casting defects of gear box housing

Pareto chart id constructed from above data in order to identify major defect of the gear box housing. Same pareto chart is shown below in Fig. 3

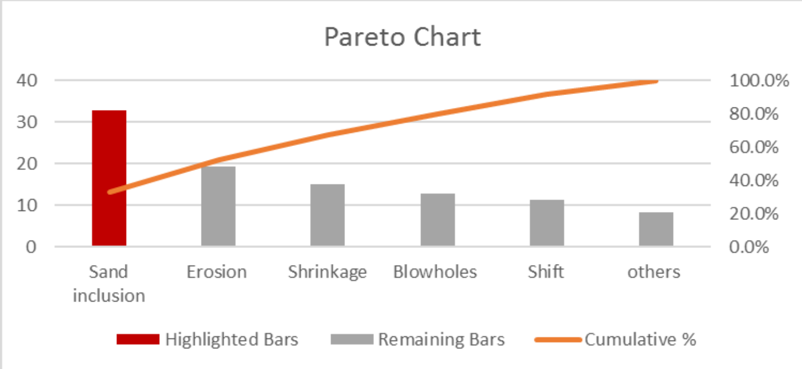

Fig. 3 Pareto chart for various casting defects of gear box housing

V. Results and Discussions

Fish bone diagram is then constructed for gear box housing. Its main causes like M_1, M_2, M_3 and sub causes like S_{11},S_{12}…are identified. These are represented below in Fig. 4

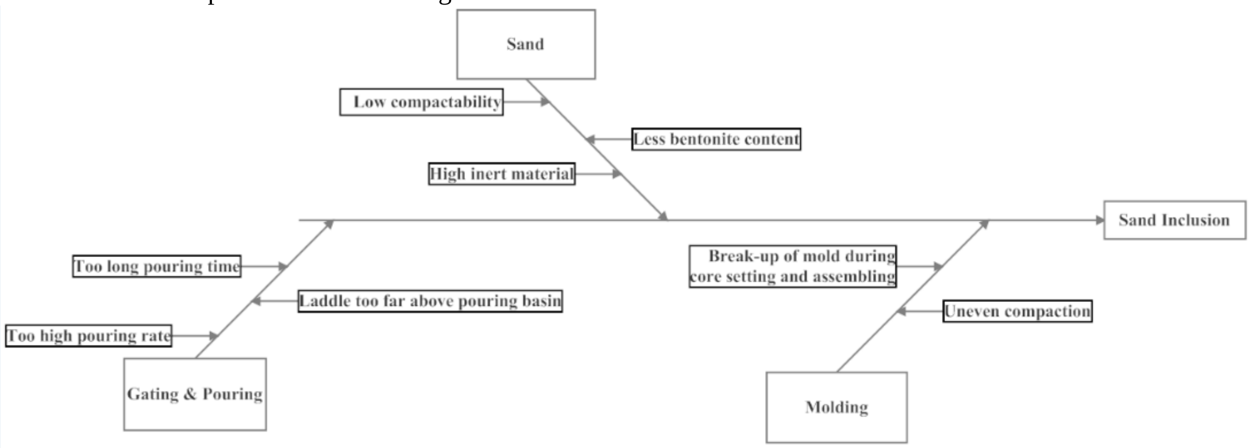

Fig. 4 Fish bone diagram of sand inclusion casting defect.

We have proposed quantitative approach for the same. Hence codification is done for easy identification and calculation in this quantitative approach. Based on past experience and historical data weights are attached to each main cause and sub cause. Weights for the main cause and sub cause is also presented in the same table

Table 1 Codification and assignment of weight to main causes and sub causes.

Issue	Cause	Sub cause	Code	Weight control	
				Main Cause	Sub Cause
1	Sand		S_1	0.45	
	1.1	Low compactability	S_{11}		0.50
	1.2	Less bentonite content	S_{12}		0.40
	1.3	High inert Material	S_{13}		0.10
2	Moulding		S_2	0.25	
	2.1	Uneven compaction	S_{21}		0.55
	2.2	Break-up of mould during core setting and assembling	S_{22}		0.45
3	Pouring		S_3	0.30	
	3.1	Too high pouring rate	S_{31}		0.45
	3.2	Ladle too far above pouring basin	S_{32}		0.40
	3.3	Too long pouring time	S_{33}		0.15

The probability and impact are assigned to each sub cause. Probability is assigned based on frequency of occurrence in the past and impact value is assigned based on severity. Risk is then calculated as a product of probability and impact. If probability is low and impact is low then it is level risk which is 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.

Table 2 Calculation of risk value of main causes and sub causes

Sr. No.	Main Cause	Sub cause	Weight (W)	Probability (P)	Impact (I)	Risk (R)	Risk Value
1		S_{11}	0.5	0.20	0.55	0.110000	0.055000
2		S_{12}	0.4	0.15	0.35	0.052500	0.021000
3		S_{13}	0.1	0.10	0.10	0.010000	0.001000
4	S_1		0.45			0.077000	0.034650
5		S_{21}	0.55	0.10	0.40	0.040000	0.022000
6		S_{22}	0.45	0.15	0.60	0.090000	0.040500
7	S_2		0.25			0.062500	0.015625
8		S_{31}	0.45	0.15	0.45	0.067500	0.030375
9		S_{32}	0.4	0.10	0.45	0.045000	0.018000
10		S_{33}	0.15	0.05	0.10	0.005000	0.000750
11	S_3		0.30			0.049125	0.0147375

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

$$GRV = WS_1 \times RS_1 + WS_2 \times RS_2 + WS_3 \times RS_3$$
$$= 0.45 \times 0.077000 + 0.25 \times 0.062500 + 0.30 \times 0.049125 = 0.0650125$$

It is clear that risk associated with sand (0.3465) is highest. Risk associated with pouring (0.147375) is lowest. Following is the graphical representation of the risk associated with each man cause.

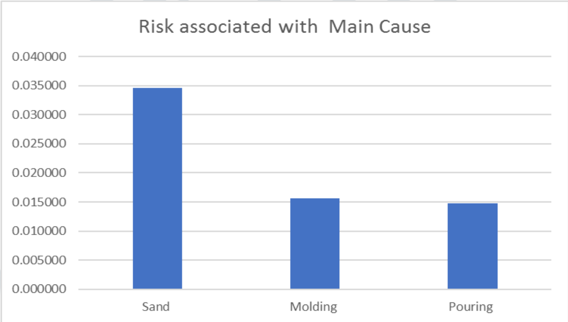

Fig. 4 Comparison of risk value of main causes

If we further analyze, it is found that risk associated with sub cause Low compactability (S_{11}) is highest in the main cause sand (S_1) compared to other sub causes. Hence low compactability is declared as the root cause of the sand inclusion defect using quantitative fish bone diagram. It is recommended to increase the compactability of sand. This higher compactability will in turn will have higher plasticity and will reduce the sand inclusion defect.

There are two main factors affecting compactability are mulling time and evaporation of moisture. The longer the cumulative mulling, lesser the drop. As sand and clay is mulled thoroughly, most of the clay platelets have absorbed water and very little further absorption can take place making compactability more stable after discharge from muller.

As there is more evaporation of moisture, compactability reduces. The amount of evaporation of moisture depends on the amount of clay added at the muller. Increased clay addition increases drop in compactability, Higher is the clay level, higher the loss in compactability. As the temperature gets above 46 ^{0}C due to addition of return sand, moisture evaporates faster and correspondingly compactability decreases. Number of transfer points. As the sand is transported from the muller to the molding machine, it travels through different belt conveyers to hoppers. Every time sand is transferred from one conveyor to another, it is exposed to ambient conditions. This exposure results in more evaporation and loss of moisture. When ambient air is hot and dry, moisture evaporation is increased and there is drop in compactibility. After suggesting these remedial actions again the defects were recorded and it was found that there is considerable drop in the rejection due to sand inclusion.

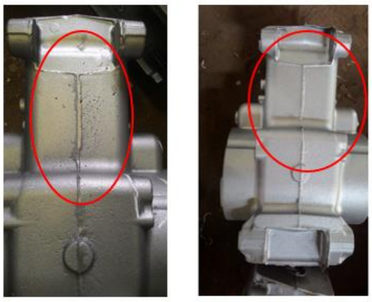

Fig. 5 Before and after implementation of strategy

VI. Conclusion

After implementation of strategy the total rejection is reduced to average 16.61 % from average 20.49% as a reduction in sand inclusion defect.

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.

VII. 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 are 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

Sensors are may be used for data acquisition for the purpose od decision making in order to control compactability.

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