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Investigation of Shrinkage Defect in Castings by Quantitative Ishikawa Diagram

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Abstract

Metal casting process involves processes such as pattern making, moulding and melting etc. Casting defects occur due to combination of various processes even though efforts are taken to control them. The first step in the defect analysis is to identify the major casting defect among the many casting defects. Then the analysis is to be made to find the root cause of the particular defect. Moreover it is especially difficult to identify the root causes of the defect. Therefore, a systematic method is required to identify the root cause of the defect among possible causes, consequently specific remedial measures have to be implemented to control them. This paper presents a systematic procedure to identify the root cause of shrinkage defect in an automobile body casting (SG 500/7) and control it by the application of Pareto chart and Ishikawa diagram. with quantitative Weightage. It was found that the root causes were larger volume section in the cope, insufficient feeding of riser and insufficient poured metal in the riser. The necessary remedial measures were taken and castings were reproduced. The shrinkage defect in the castings was completely eliminated.

Keywords: Casting, Shrinkage defect, Pareto chart, Ishikawa diagram

1. Introduction

Casting defects occur while manufacturing casting due to the involvement of processes like pattern making, core box making, moulding, core making, core setting, mould closing, melting, metal pouring, heat treatment, and fettling. Generally, variations found in these processes make the task especially difficult to control the defects even in a more controlled process. The initial step in the defect analysis is to identify the major casting defect among the many defects. Then the analysis is to be made to find the root cause of the particular defect. Proper care is to be taken to identify the actual root cause among many probable causes in the tools as well as manufacturing processes. In order to minimize the casting defects, It is essential to identify the root causes for each casting defect. Generally casting defects occur in the production areas such as pattern, sand, mould, core, mould closing, melting, pouring, heat treatment and finishing. In this paper, shrinkage casting defect in an automobile body casting (SG 500/7) is discussed.

The shrinkage defect in SG iron casting can be avoided by an external feeding to the casting along with graphitization expansion. These two factors compensate volumetric shrinkage of the spheroidal graphite iron (SG) casting. In general riser feeding was adopted as the main method in foundries to avoid shrinkage in SG iron castings. Even though failures are found in riser feeding method, causes of failures can be found by proper analysis to reduce the shrinkage defect in castings.

This paper identifies and analyzes the major shrinkage casting defect in an automobile body SG Iron body casting (SG 500/7) using the flowchart [1-2] as shown in the Figure 1.

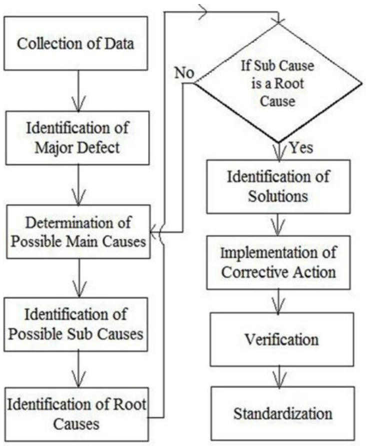

Fig. 1. Defect Investigation Flow Chart

2. Methodology

The production and rejection details for automobile body casting for 4 months period were collected. All the major defects occurred in the casting were studied and is shown as bar chart [3-5] in Fig. 2 (Abbreviations: WT- Wall Thickness Variation, BH- Blow Holes, SH- Shrinkage Defect, SI- Sand Inclusion, MD- Mould Damage).

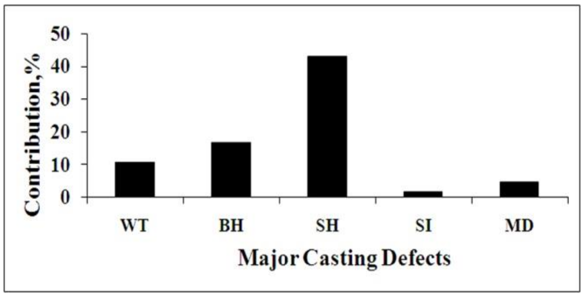

Fig. 2. Bar chart of casting defects

A Pareto chart was drawn for all the defects occurred and the shrinkage defect was found as the major defect among the all the defects as shown in Fig.3.

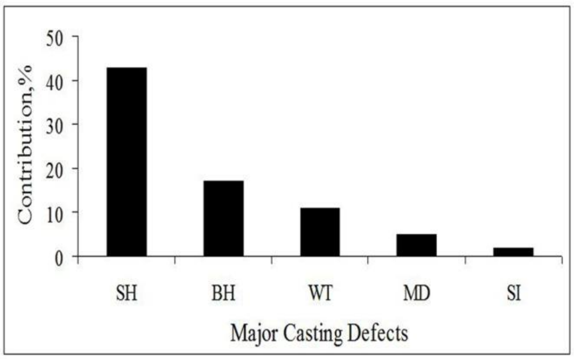

Fig. 3. Pareto chart of casting defects

3. Results and discussion

Shrinkage associated casting defects occur in the heaviest section of the casting that solidify later and do not have liquid metal flow either from the riser or adjoining sections after mould was completely filled. The first step in the defect analysis is to identify the possible key variables that cause the defect. The simple method used to determine the cause is the use of Ishikawa diagram. The strength of this technique is that the collective information related to the tools and processes used to manufacture the casting are available in graphical form. The identified possible main causes for the shrinkage defect for this casting are casting design, pattern, gating, Risering, melting, pouring and moulding. [6-8]. The most effective remedial measures have to be taken only after analyzing the probable sub causes of the defect. Generally, Ishikawa diagram may not have quantitative data for the further analysis [5]. Weights for the each cause in the diagram were added and percentages of influence of each cause for the defect were identified. This cause and effect diagram with Weightage used to find the major influencing causes that lead to the occurrence of the defect. The data for the shrinkage defect was collected and used to make the matrix diagram of the shrinkage defect. Initially the main causes for the shrinkage defect were identified (abbreviations are represented in brackets) and are given in the Table 1. Subsequently the sub-causes were determined using comparison matrix and are given in Table 2 [6-17].

Table1.
Relative weights of main causes

Factor	**1**	**Σn**
Casting Design (CD)	1.75	0.1186
Pattern (PN)	3.0	0.2033
Gating and Risering (GR)	3.5	0.2373
Melting (ME)	2.5	0.1695
Pouring (PG)	2.5	0.1695
Moulding (MO)	1.5	0.1017
Total	14.75	≈1

n- Relative weight

Table 2.
Sub-Causes leading to the defect

	Sub-Causes	**1**	**Σn**
Casting Design	Isolated heavy section	0.25	0.143
	Change in section size	0.5	0.286
	Too small fillets	0.5	0.286
	Lesser area for feeding	0.5	0.286
	Total	1.75	≈1
Pattern	Larger volume section in cope	1.75	0.583
	Use of lesser height cope	1.0	0.333
	Insufficient area of core prints	0.25	0.083
	Total	3.0	≈1
Gating and Risering	**Smaller diameter/height riser**	0.25	0.071
	Improper design of neck	0.25	0.071
	No funnel pipe formed in riser	1.25	0.357
	Improper location of riser	0.5	0.143
	Insufficient feeding	1.25	0.357
	Total	3.5	≈1

Melting	Excessive nodule count	0.75	0.3
	Minimum silicon content	1.0	0.4
	Tapping cold metal	0.25	0.1
	Too high tapping temperature	0.5	0.2
	Total	2.5	≈1
Pouring	Pouring cold metal	0.5	0.2
	Too high pouring temperature	0.75	0.3
	Insufficient metal poured	1.25	0.5
	Total	2.5	≈1
Moulding	Mould dilation/enlarge	0.25	0.166
	Weak soft moulds	0.25	0.166
	Low green compressive strength	1.0	0.666
	Total	1.5	≈1

The main causes as well as their sub-causes were assigned their weight. The weights for each cause were calculated using a pair of comparison method. In this method if one of the factors is the most important than the other it is given as grade 1. whereas the other factors get the grade 0. If the contributions of both the factors are equal they are given 0.5 each. To precisely evaluate the causes. the rating scale can use the values 0. 0.25. 0.5. 0.75 and 1. The values from Table 1 and Table 2 are used to draw the Ishikawa diagram.

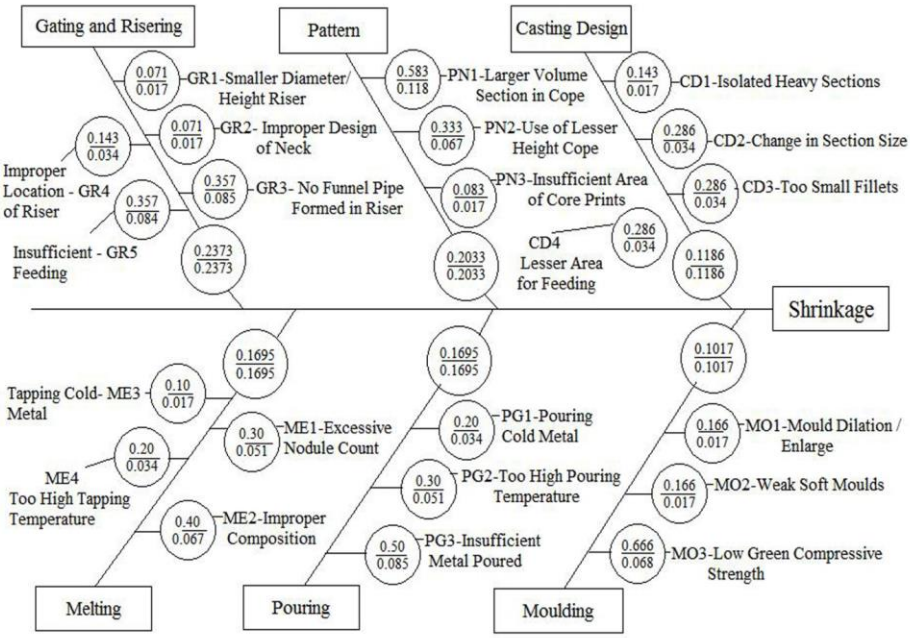

Fig. 4. Ishikawa diagram for shrinkage defect

3.1. Ishikawa diagram

The diagram consists of contribution of main causes and their sub-causes which includes their weights for the occurrence of the shrinkage defect. The standardized weights of the major factors are placed in Ishikawa diagram as shown in Fig.4 in circles under the titles casting design, Pattern, Gating and Risering, Melting, Pouring and Moulding. The upper value in the circle indicates the relative weight referred to a given factor. whereas the lower value indicates the absolute weight referred to the whole group. A comparison matrix was used to determine the sub-causes of the main causes. Their relative weight and absolute weight are indicated in the circles positioned in the Ishikawa diagram. The major causes and their sub-causes contributing to the shrinkage defect in castings with their percentage are given in Table 3.

The major causes of the shrinkage defect identified from the Ishikawa diagram are shown in Fig 5.

3.2 Major causes of shrinkage defect

Gating and Risering as well as pattern were the major factors causing the shrinkage defect. Consequently the sub causes were identified and anaysed for these major causes. The sub causes for the shrinkage defect are shown in the Pareto chart Figure.6. Finally the sub causes causing the shrinkage defect are identified as Larger volume section in cope. No funnel pipe formed in riser. Insufficient feeding, Insufficient metal poured. Low green compressive strength, Use of lesser height copes and Improper composition.

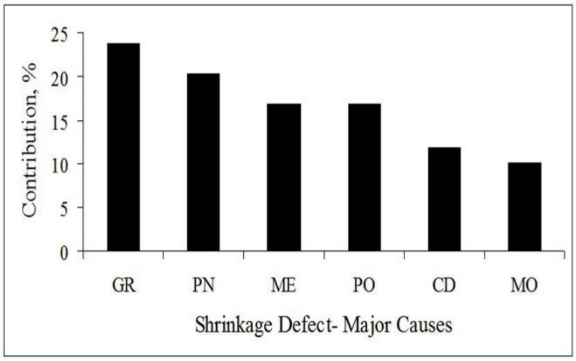

Fig. 5. Major causes of shrinkage defect

3.3 Percentage contribution of major and sub causes

Table 3.
Percentage contribution of major and sub causes

Group	Subgroup	Subgroup (%) in a given group	Subgroup (%) in a given fault
Casting Design	Isolated heavy section	14.2	1.7
	Change in section size	28.6	3.4
	Too small fillets	28.6	3.4
	Lesser area for feeding	28.6	3.4
	Total	100	-
Pattern	Larger volume section in cope	58.3	11.8
	Use of lesser height cope	33.3	6.7
	Insufficient area of core prints	8.4	1.7
	Total	100	-
Melting	Excessive nodule count	30	5.1
	Minimum silicon content	40	6.7
	Tapping cold metal	10	1.7
	Too high tapping temperature	20	3.4
	Total	100	-
Gating and Risering	Smaller diameter/height riser	7.1	1.7
	Improper design of neck	7.1	1.7
	No funnel pipe formed in riser	35.7	8.5
	Improper location of riser	14.4	3.4
	Insufficient feeding	35.7	8.5
	Total	100	-
Pouring	Pouring cold metal	20	3.4
	Too high pouring temperature	30	5.1
	Insufficient metal poured	50	8.5
	Total	100	-
Moulding	Mould dilation/enlarge	16.7	1.7
	Weak soft moulds	16.7	1.7
	Low green compressive strength	66.6	6.8
	Total	100	≈100

The shrinkage defect in the castings can be reduced by implementing the corrective actions. Interchanging of cope and drag patterns were made in the match plates so that larger volume section of the casting was kept in the drag. Subsequently the riser was redesigned and a tall tapered riser was used because no funnel pipe formed in the riser indicates insufficient feeding.

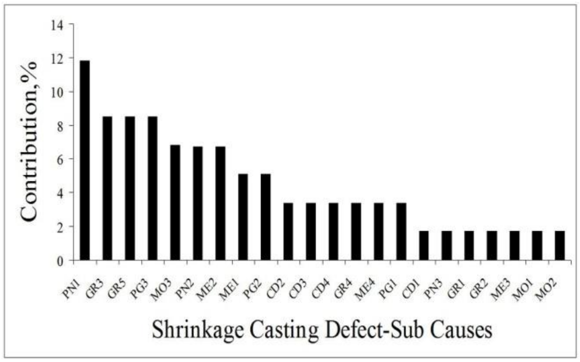

Fig. 6. Sub-causes of shrinkage defect

Metal is to be poured to the full height of the riser as a result of variations of the riser height indicated that insufficient metal was poured in the moulds. The cope and drag pattern with these changes made are shown in Fig 7a and 7b respectively.

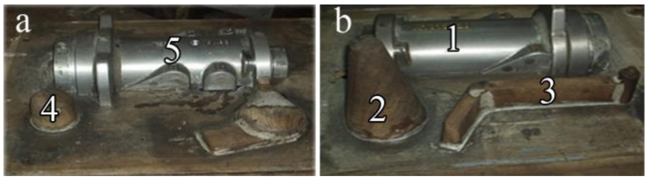

Fig. 7a. Drag pattern. 7b. Cope pattern

The components of gating and feeding systems indicated in fig 7a(larger volume), 7b (smaller volume) and fig 8 (poured casting) are,

1. Pattern (Cope)
2. Riser
3. Runner
4. Well
5. Pattern (Drag)
6. Funnel pipe formation
7. Casting

Moreover metal was poured to the full height of the riser. The metal was poured in the moulds and found that the shrinkage defect was completely eliminated. The poured casting with gating and feeding systems is shown in the Fig 8.

Fig. 8. Casting with redesigned gating and risering systems

4. Conclusions

The identification of the root cause of the casting defect is important to initiate remedial measures to minimize/ eliminate defects. This paper adopts a systematic procedure to find the root cause of the major shrinkage defect occurred in an automobile body casting (SG 500/7) by using bar chart. Pareto chart and Ishikawa diagram with quantitative Weightage. It was found that the root causes were larger volume section in the cope, insufficient feeding of riser and insufficient poured metal in the riser. The necessary remedial measures were taken and castings were reproduced. The shrinkage defect in the castings was completely eliminated.

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